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Importers and exporters in exchange rate pass-through and currency invoicing☆

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ABSTRACT

We explore the role of product market structure on exchange rate pass-through and currency of invoicing in international trade, using very detailed transaction-level data on Canadian imports over a six-year period. A novel feature of the study is the importance of market share on both sides of the importing relationship — that of the exporting and importing firms. We find that exchange rate pass-through and the currency of invoicing are dependent on the size (or market share) of both importers and exporters. Very small or very large exporters have higher rates of pass-through and tend to invoice in the foreign currency, while it is the opposite for exporters in the middle range. By contrast, for larger importers, pass-through is lower and local currency invoicing is more prevalent. These findings are consistent with a simple model of trade pricing under monopolistic competition with endogenous markups and heterogeneity in firm size (on both sides of the transaction).

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1. Introduction

How do exchange rate changes affect economic activity? This is one of the central questions in international trade and macroeconomics. An exchange rate depreciation should raise the price of imported goods, increasing domestic inflation, and leading to adjustments in spending away from imports toward domestic goods. The extent to which exchange rates changes affect domestic prices is an empirical question that has been the subject of significant research effort. While a large literature has advanced the understanding of how exporters adjust prices,[1] one aspect that has received much less attention is the other side of the trading relationship—the role of importing firms in international price setting.[2] Our contribution lies in the joint empirical analysis of importer and exporter behavior. We show that exchange rate pass-through and the likelihood of foreign-currency pricing are a U-shaped function of foreign-supplier (exporter) share of the sectoral import market (hereafter simply referred to as market share). At the same time, the size of importing firm (in terms of market share) is negatively associated with pass-through and positively with local currency pricing (LCP).

Our paper uses a unique micro-data set that allows us to identify individual transactions as well as the identity of importers and exporters in the Canadian import market over a six-year period. In addition, since we observe that transactions are invoiced in different currencies, we are also able to explore the interaction between exchange rate pass-through, market share and the currency invoicing of imports at a highly disaggregated level. Our empirical results

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[1] See Burstein and Gopinath (2013) for an extensive review of this literature.

[2] Goldberg and Tille (2013) consider the role of both the exporter and importer in the determination of currency of invoicing in a theoretical bargaining model. Goldberg and Tille (2016) link the size of trade transactions to the currency of invoicing and find that larger transactions are more likely to be priced in the destination currency. Friberg and Wilander (2008) provide some survey evidence that importers play a role in the determination of the currency of invoicing.

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point to the importance of exporter and importer size (or market shares) in accounting both for exchange rate pass-through and the currency of invoicing.

The presence of a U-shaped relationship between foreign supplier market share and exchange rate pass-through means that both small and very large exporting firms, relative to the market, tend to have higher pass-through than firms with intermediate market shares. The novel finding is that the size of importing firms also plays a key role in exchange rate pass-through. Exchange rate pass-through is negatively (and monotonically) related to the size of importing firms. Moreover, this joint dependence on the market share on both sides of the trade transaction continues to hold when we allow for exchange rate pass-through to depend simultaneously on the market share of exporters and importers.

We further explore the interrelationship between exchange rate pass-through, firm size and the currency of invoicing for imported goods. As in previous studies (e.g. Gopinath et al., 2010), we find that exchange rate pass-through is significantly lower for goods that are invoiced in local (Canadian) currency. This is notable since our measure of pass-through involves exporting firms that have adjusted their nominal prices. We then explore the interaction between firm size and the choice of invoice currency. Estimating an empirical model of invoicing currency, we find that the probability of U.S.-dollar invoicing (as opposed to LCP) is related to the market share of exporting and importing firms in exactly the same pattern as is our estimate of exchange rate pass-through itself. That is, U.S.-dollar invoicing is non-monotonically related to the foreign supplier market share, again in a U-shaped relationship, and monotonically negatively related to the market share of importing firms. Thus, we find that the structural determinants of exchange rate pass-through at the micro-level are the same as the determinants of currency invoicing; the factors related to exporting- or importing-firm size that generate low pass-through tend toward domestic-currency invoicing of imported goods.

Our empirical findings are given an interpretation using a model of trade with monopolistic competition that incorporates the role of both exporters and importers. The model provides a simple framework to illustrate the interrelationship between exchange rate pass-through, market share and the determination of invoicing currency. In the model, exporters differ in cost efficiency (or productivity), which translates into differences in their market shares in equilibrium. Importers also differ in size and, critically, in their demand elasticity. An important building block in our model is that importers with a larger cost advantage, and thus larger market share, have a higher elasticity of demand for the product purchased from each exporter. We justify this assumption with evidence in the data that the elasticity of demand is higher for importers with larger market share.

The model predicts that very small or very large exporters (in terms of their share of the market) have little concern over the impact of increasing their price on their share of the total market, and consequently they will pass through most of any exchange rate movements into their sales price. Exporters in the middle range, however, are more concerned with the effects of price changes on their share of the market, and tend to have lower rates of pass-through.[3] The model also captures the importance of importers for exchange rate pass-through. Given the opportunity to invest (at a cost) in more flexible technologies, high-productivity importers will have a higher elasticity of demand. The result is that exchange rate pass-through is lower for sales to importers with a higher market share (or, equivalently, those with high productivity, low cost structure and hence a higher elasticity of demand for imported goods). The higher the elasticity of demand of the importer, the more an exporter's market share will vary if it changes its price in response to an exchange rate shock. Therefore, conditional on the market share of the exporter, pass-through will be lower for sales to importers with higher market share.

How does this relate to the determination of the invoicing currency? Engel (2006) and Gopinath et al. (2010) construct models where a firm's desired rate of pass-through (in a flexible-price environment) will determine its choice of invoice currency (when price adjustment is sticky). The higher the desired pass-through, the more likely will the exporting firm choose its own currency (or U.S. dollars, in most of our data) for invoicing, while firms desiring low pass-through will be more likely to invoice in the importer's currency (Canadian dollars in our study).[4] Building on this, our model implies that the use of the U.S. dollar in invoicing should be non-monotonic and U-shaped in its relationship to exporter market share, and negatively related to importer market share. As we noted, this is exactly the pattern we find in the data.

Our paper contributes to the extensive literature on the size and determinants of exchange rate pass-through. It is widely recognized that at most levels of aggregation, exchange rate pass-through is less than full. Early studies by Krugman (1987) and Froot and Klemperer (1989) suggested that this was due to the presence of strategic forces leading firms to engage in "pricing-to-market". Later literature proposed that slow nominal price adjustment and local currency pricing may be responsible for partial pass-through both at the import price level and the level of retail prices (see, for example, Devereux et al., 2004). Recently, many studies have made use of more detailed micro-data sets of goods prices. Studies using U.S. micro-data—for example, Gopinath and Rigobon (2008), Gopinath et al. (2010), Auer and Schoenle (2016) and Pennings (2016)—are informative, but the U.S. may be quite a special case, given the central nature of the U.S. dollar in international trade settlement and invoicing (Goldberg and Tille, 2008). There is a growing literature using data for other countries that includes Fitzgerald and Haller (2013) who look at pass-through using Irish data, and Cravino (2014) who uses Chilean data. However, it has been difficult to obtain comprehensive matched data on currency of invoicing, overall market structure and goods prices.

A number of recent empirical papers have linked pass-through with the market share of exporters.[5] Berman et al. (2012) and Amiti et al. (2014) find that under certain conditions, pass-through is declining in exporter market share using French and Belgian firm-level data, respectively. They show that this can be rationalized with different models of endogenous markups. Feenstra et al. (1996) emphasize a U-shaped relationship between exporting country market share and pass-through in the car industry using country level data, while Garetto (2016) finds a similar relationship using firm-level data. Feenstra et al. (1996) base their results on a model of strategic pricing with CES demand, while in Garetto (2016), firms engage in learning their rivals costs over time. Auer and Schoenle (2016) also show that the response of import prices to exchange rate changes is U-shaped in exporter market share using micro-data from the Bureau of Labor Statistics.[6]

Our paper may be distinguished from these recent studies with micro-price data along a number of dimensions. In particular, our

[3] For constant-elasticity-of-substitution preferences, this point was originally made in Feenstra et al. (1996), and more recently by Auer and Schoenle (2016).

[4] Gopinath (2015) also discusses the role of currency invoicing in exchange rate pass-through and shows that there can be important policy implications from asymmetries across countries in the degree of pass-through.

[5] The theoretical link between pass-through and exporter market share was first developed in Dornbusch (1987) and more recently in Atkeson and Burstein (2008).

[6] Since micro-price data from the Bureau of Labor Statistics do not include information on the sales of individual firms, Auer and Schoenle (2016) infer market share indirectly from relative prices.

data set has some unique features, containing information on individual transactions, invoice currency, and importing and exporting firms. In addition, as noted above, we find that the size of exporting *and* importing firms is a crucial feature of the joint determination of exchange rate pass-through *and* the currency of invoicing. Finally, we provide a theoretical interpretation of these findings using a model of monopolistic trade pricing where the actions of both importing and exporting firms determines the degree of exchange rate pass-through.

The paper proceeds as follows. Section 2 develops a simple partial equilibrium model which will provide some guidance for our empirical work. Section 3 describes the data and provides summary statistics. In Section 4, we present the empirical model and results. Section 5 concludes.

2. Theoretical discussion

We explore the determinants of exchange rate pass-through into import prices in a model of monopolistic competition with endogenous markups and heterogenous size of exporting and importing firms. We present the model as a guide to our empirical work, presenting an analytical framework for understanding the relationship between market structure, pass-through and currency of invoicing.

2.1. Pass-through and market shares

Consider an importing country where there are many different sectors (or markets). Within each sector, there are a number of distinct foreign sellers (exporters), and a separate number of distinct buyers (importers). We implicitly take the Armington view that products are differentiated by country, so that the market structure can be adequately described by the sales and purchases of foreign exporters and domestic importers.[7] Each exporter is assumed to produce and sell a unique product, and some of each product is purchased by all the importers. Exporters differ in cost efficiency and in equilibrium this will translate into differences in market share of sales in the sector. Importers are assumed to be intermediaries who purchase a basket of goods from exporters, and with these produce a retail product for domestic final consumers (who are not modeled here). Importers cannot resell products to other importers. Importers also differ in size, again due to differences in cost advantage. This difference in cost also translates into differences in demand elasticity for importing firms.

Our maintained assumption is that importers with larger cost advantage have a higher elasticity of demand for the product of each seller. The theoretical foundations for this assumption are developed in Appendix A, where we construct a simple model of sequential decision-making in which importers can choose from a menu of technologies in advance, with each technology constituting a means of producing the retail good using imported intermediate inputs, and technologies differ in their elasticity of substitution between intermediate inputs. A technology with a higher elasticity of substitution offers higher expected profits to the retailer/importer. But ex ante, it is more costly to choose a technology with a higher elasticity of substitution. Importers with higher exogenous productivity (or lower costs) will choose more-elastic technologies. As a result, larger importers will have a higher ex post elasticity of demand for each product.[8,9]

Assume that in each sector there are N products, each of which is sold by a unique exporter, and M importing firms. Each exporter $i \in N$ sells product i to all M importers. In addition, exporters can perfectly price discriminate, so they set a separate price for each importer. Importers are assumed to be price takers in their input markets. Each importer j has a demand for the imported intermediate good i which satisfies:

$$x_{ij} = p_{ij}^{-\rho_j} p_j^{\rho_j - \eta} X_j, \tag{2.1}$$

where p_{ij} is exporter i's price for importer j, evaluated in importer's currency, and p_j is the sectoral or market price index for importer j.[10] It is assumed that N is small enough that firm i takes into account the impact of its pricing decision on the sectoral price index. In addition, we allow for the inner demand elasticity ρ_j to be specific to the importer, while assuming that the elasticity of demand across sectors η is the same for all importers. As usual, we assume that $\rho_j > 1$, $\eta > 1$ and $\rho_j > \eta$, so that the elasticity of demand for individual goods is greater than the elasticity of demand for the sectoral composite good. Finally, we allow for importers to be different in total size or market share, as reflected in the scale factor X_j.[11]

The sectoral price index for importer j is defined as

$$p_j = \left[\sum_{i=1}^{N} p_{ij}^{1-\rho_j} \right]^{\frac{1}{1-\rho_j}}. \tag{2.2}$$

Exporting firm i's production technology can be represented by a constant returns to scale cost function in terms of the exporter currency:

$$c(y_{ij}, w_i, a_i) = y_{ij} \phi(w_i, a_i), \tag{2.3}$$

where y_{ij} represents sales to importer j, w_i represents a vector of input costs and a_i is a scalar measure of technology. We assume that $\phi(w_i, a_i)$ is increasing in all elements of w_i, and decreasing in a_i.

In terms of the importing firm's currency, the exporter's profit is then defined as

$$\sum_{j}^{M} p_{ij} x_{ij} - \sum_{j}^{M} y_{ij} e_i \phi(w_i, a_i), \tag{2.4}$$

where e_i is the exchange rate for product i (the importer currency price of a unit of exporter currency), and in equilibrium $x_{ij} = y_{ij}$.

[7] We do not have observations on purchases by importing firms from domestic producers. Auer and Schoenle (2016) present empirical support to the Armington view with micro-data. Amiti et al. (2016) offer a recent examination of strategic complementarities in price setting across firms using micro-data in an open economy environment.

[8] Appendix E provides empirical evidence in support of this modeling assumption. There, we show that the estimated elasticity of demand for imports in the data is increasing in importer market share.

[9] One qualification to make concerning this specification is that in many cases, we would expect larger importers to import a wider variety of products, so that market share should in principle encompass both the intensive and extensive margins. Allowing for endogenous variety choice would unnecessarily complicate the pass-through expressions, however, and would not affect the main implications with respect to the relationship between exchange rate pass-through and importer market share, so long as larger importers operated with more flexible substitution technologies.

[10] Here, we maintain the assumption of constant demand elasticity ρ_j. We also explored the exchange rate pass-through implications under alternative specifications where the firm's elasticity of demand was variable. The implications for pass-through and the relationship between pass-through and buyer or seller market share were similar to the results discussed below.

[11] We model importers as price-takers, despite that they may have significant market shares. This may be justified on the grounds that the domestic market (Canada in our data) represents a small fraction of overall world demand for each product. Hence, while a given importer j may have a large share of the total value of Canadian imports of a given sector, its share in the world market may be negligible.

If the exporter sets its price freely, its profit maximizing price is given by

$$p_{ij} = \frac{\epsilon_{ij}}{\epsilon_{ij}-1} e_i \phi(w_i, a_i), \tag{2.5}$$

where ϵ_{ij} is defined as the firm's demand elasticity, given by

$$\epsilon_{ij} = -\frac{d\log(x_{ij})}{d\log(p_{ij})} = \rho_j - (\rho_j - \eta)\left[\frac{p_{ij}}{p_j}\right]^{1-\rho_j}. \tag{2.6}$$

The share of firm i's sales to importer j, relative to all of j's purchases in the sector, is defined as

$$\left[\frac{p_{ij}}{p_j}\right]^{1-\rho_j} = \frac{p_{ij}x_{ij}}{\sum_{i=1}^{N} p_{ij}x_{ij}} \equiv \theta_{ij}(w_i, a_i). \tag{2.7}$$

Firm i's share is negatively related to its price, relative to the price index of importer j. Under an innocuous regularity condition, θ_{ij} is negatively related to the firm's input cost w_i and positively related to the firm's productivity a_i. Given this notation, we can define the elasticity of demand for sales to importer j as $\epsilon(\theta_{ij}) = \rho_j - (\rho_j - \eta)\theta_{ij}$, and this elasticity is decreasing in the firm's market share, given that $\rho_j > \eta$.[12]

If the firm's price is fully flexible, we can obtain the implied pass-through from the exchange rate to its price as follows. Taking a log approximation from Eq. (2.5), we obtain the expression:

$$\frac{d\log p_{ij}}{d\log e_i} = \frac{1}{1+\omega_{ij}} + \frac{\omega_{ij}}{(1+\omega_{ij})}\sum_k \theta_{kj}\frac{d\log p_{kj}}{d\log e_i} + \frac{1}{1+\omega_{ij}}\hat{\phi}\frac{d\log w_i}{d\log e_i}, \tag{2.8}$$

where $\hat{\phi} \equiv \frac{\phi_w w_i}{\phi}$, and $\omega_{ij} = -\frac{d\log(\mu)}{d\log(p_{ij})}$ is the elasticity of the markup to the firm's price, holding the sectoral price p_j constant. We can calculate this elasticity as follows:

$$\omega_{ij} = \frac{(\rho_j - \eta)(\rho_j - 1)\theta_{ij}}{\epsilon(\theta_{ij})(\epsilon(\theta_{ij}) - 1)}. \tag{2.9}$$

The predictions for exchange rate pass-through from Eq. (2.8) depend on the extent to which firm i's competitors for importer j face the same exchange rate as firm i, and the extent to which firm i's domestic cost is affected by changes in the exchange rate. The first term in Eq. (2.8) defines the exchange rate pass-through holding constant both the sectoral price p_j (the second term), and the response of marginal cost in the exporter's currency (the third term). From this term alone, pass-through is less than full because a rise in firm i's price reduces its market share, and this leads to an endogenous fall in the markup. But this is only a partial response, because (a) if the firm has a non-negligible share of the market, its own price rise will lead to a rise in the sectoral price p_j, (b) the change in the exchange rate will lead to direct or indirect effects on competitor prices, which also leads to changes in p_j, and (c) the exchange rate change may affect the firm's marginal cost evaluated in the exporter currency.

Focusing on the last item, we may decompose the term $\hat{\phi}\frac{d\log w_i}{d\log e_i}$ in Eq. (2.8) in the following way. Assume that changes in the exchange rate do not directly affect either the exporter currency prices of inputs in the exporter's country, the prices of local inputs into the good in the importer's currency, or the price of imported intermediate goods that the exporter purchases from third countries. Define the share of local (importing country) inputs in the good as γ_1, the share of third-country intermediate imported inputs as γ_2 and finally, define the sensitivity of the exchange rate of the country where intermediate inputs are purchased relative to the importing country's exchange rate as φ. It follows that $\hat{\phi}\frac{d\log w_i}{d\log e_i} = -(\gamma_1 + \gamma_2\varphi)$. Then from Eq. (2.8), we can define the response of firm i's price to an exchange rate change, holding all other firms' prices as given

$$\frac{d\log p_{ij}}{d\log e_i} = \frac{\hat{mc}_i}{1+\omega_{ij}(1-\theta_{ij})} \tag{2.10}$$

where $\hat{mc}_i \equiv 1-(\gamma_1+\gamma_2\varphi)$ is defined as the full elasticity of marginal cost to the exchange rate.

Condition (2.10) implies that, holding other firm's prices constant, exchange rate pass-through is less than unity. This is first due to the combined presence of 'local' inputs, as measured by γ_1, and intermediate imported goods whose currencies track those of the importing country, captured by the terms $\gamma_2\varphi$. Both of these terms reduce the impact of a depreciation on the firm i's marginal cost. But even for $\hat{mc}_i = 1$, pass-through would be less than unity because the firm's optimal markup depends on its market share, captured by the $\omega_{ij}(1-\theta_{ij})$ term. A rise in the firm's price reduces its market share, leading to an endogenous fall in the optimal markup.

Condition (2.10) does not take account of the endogenous response of all other exporters in the industry equilibrium. But we can incorporate the full industry equilibrium with the following proposition.

Proposition 1. *Assume that exporter $i = 1$ in sector j experiences an exchange rate depreciation, but while all other exporters $i = 2,\ldots,N$ do not, so that $\hat{mc}_1 \geq \hat{mc}_k$ for $k = 2,\ldots,N$. Then (a) pass-through for firm 1 is less than complete, and (b) firm 1's pass-through is non-monotonic and U-shaped in the firm's market share.*

Proof. See Appendix B. ■

Proposition 1 mirrors the results of industry equilibrium developed in Auer and Schoenle (2016), as applied to our model. It can be readily extended to allow for a group of firms within the industry to receive a common exchange rate depreciation. The intuition for the proposition is straightforward. Pass-through for firm 1 in industry equilibrium is written as:

$$\frac{d\log p_{1j}}{d\log e_1} = \frac{\hat{mc}_1}{1+\omega_{1j}} + \frac{\omega_{1j}}{(1+\omega_{1j})}\sum_i \theta_{ij}\frac{d\log p_{ij}}{d\log e_1}. \tag{2.11}$$

For a firm experiencing an exchange rate depreciation, the direct increase in marginal cost exceeds the indirect increase in marginal cost that may be experienced by other firms in the sector. Since Eq. (2.11) makes clear that exchange rate pass-through for any one firm is a unit-weighted sum of the percentage increase in marginal cost and the increase in the sectoral price index, pass-through for the directly affected firm must be less than marginal cost, because the industry price response is a weighted average of the responses in all firms.

Part (b) of the proposition also follows directly. If firm 1 has a negligible market share, then its markup is independent of market share (i.e. $\omega_{1j} \approx 0$), and it will fully adjust price to marginal cost. On the other hand, if the firm has 100 % of the market, then $\frac{d\log p_1}{d\log e_1} = \sum_k \theta_{kj}\frac{d\log p_{kj}}{d\log e_1}$, so pass-through is again complete. Hence, by part (a) it

[12] Note the distinction between the elasticity of demand for any importing firm j, defined as ρ_j, and the elasticity of demand facing an exporter, which depends upon both the primitive parameter ρ_j as well as the firm's market share, which will depend on the firm's costs relative to its competitors. Note also that we are assuming Bertrand competition within any sector. In the case of Cournot competition, the exporter's elasticity would be equal to $\frac{\eta\rho_j}{\eta+(\rho_j-\eta)\theta_{ij}}$. See Auer and Schoenle (2016).

must be the case that pass-through falls and then rises again as θ_{1j} rises from zero to one.[13]

The main novelty of our data and empirical approach is to focus on the role of importer market share. We can summarize the results related to importer market share in the following proposition.

Proposition 2. *For given θ_{ij} such that $0 < \theta_{ij} < 1$, a rise in the importer's elasticity of demand ρ_j reduces exchange rate pass-through for each firm $i = 1, \ldots, N$.*

Proof. Holding $\sum_k^N \theta_{kj} \frac{d \log p_{kj}}{d \log e_i}$ constant, using the definition of ω_{ij}, we can establish that

$$\frac{d\omega_{ij}}{d\rho_j} = \frac{\eta\theta_{ij}(\rho-1)^2}{\epsilon_{ij}^2(\epsilon_{ij}-1)^2}\left(1-\theta_{ij}\frac{(\rho_j-\eta)^2}{(\rho_j-1)^2}\left(1-\theta_{ij}\left(1-\frac{1}{\eta}\right)\right)\right).$$

Since $\eta \geq 1$, the term inside the large parentheses is positive. Hence, a rise in ρ_j raises ω_{ij} and reduces exchange rate pass-through, for firm i, so long as $0 < \theta_{ij} < 1$, holding $\sum_k^N \theta_{kj} \frac{d \log p_{kj}}{d \log e_i}$ constant. But since the rise in ρ_j is common for all firms $i = 1, \ldots, N$, pass-through must fall for all firms, and hence $\sum_k^N \theta_{kj} \frac{d \log p_{kj}}{d \log e_i}$ itself falls, further reducing pass-through for each firm i. ■

The content of Propositions 1 and 2 may be summarized in Fig. 1. The figure illustrates the relationship between the partial equilibrium exchange rate pass-through term $\frac{1}{1+\omega_{ij}(1-\theta_{ij})}$ (for clarity of exposition, we assume that $\gamma_1 = \gamma_2\varphi = 0$) and the firm's share of market j, θ_{ij}, assuming that $\rho_j = 5$ and $\eta = 2$ (this is the low-elasticity scenario). Exchange rate pass-through begins at unity when $\theta_{ij} = 0$, but falls to around 0.7 for intermediate values of θ_{ij}. As $\theta_{ij} \to 1$, pass-through becomes complete again.[14]

Fig. 1 also illustrates the relationship between pass-through and θ_{ij} for a higher elasticity, $\rho_j = 12$. Again, for $\theta_{ij} = 0$ or 1, pass-through is unaffected. But in intermediate ranges of θ_{ij}, pass-through may fall quite dramatically as a result of the higher demand elasticity. In the figure, the lowest value of exchange rate pass-through falls from 0.7 in the initial case of $\rho_j = 5$ to just below 0.4 when $\rho_j = 12$.

Fig. 2 extends Fig. 1 to full industry equilibrium, assuming that there are four firms in the industry, and firm 1 receives the exchange rate shock. The relationship between θ_{1j} and pass-through is qualitatively the same as before, while the relationship between the price response of rival firms and θ_{1j} is hump-shaped, since the spillover from firm 1's shock to those of other firm's will be negligible either when firm 1 has a very small or very large share of the market.[15]

How do these results relate to the measure of exchange rate pass-through that can be obtained from the data? Eq. (2.8) is a comparative static expression from an optimal pricing relationship in a static model. But in repeated observations over a firm's sales to a particular market, the empirical equivalent to measured pass-through

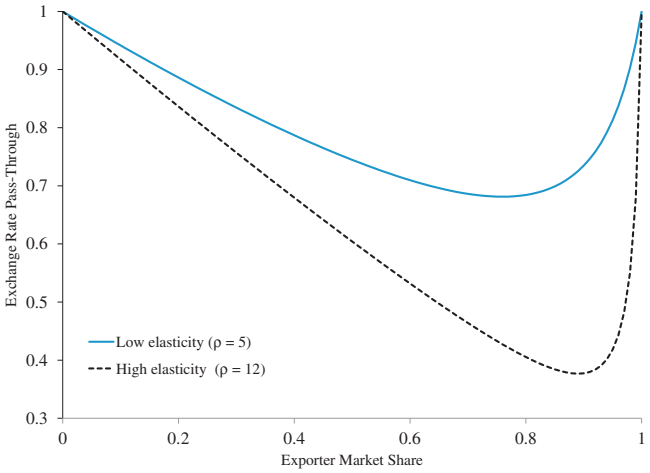

Fig. 1. Exchange rate pass-through and market share.

based on Eq. (2.8) is the regression coefficient of the firm's log price on the log exchange rate. This measures the relationship between the firm's price and the exchange rate, holding all other controls fixed. Thus, we can equate the empirical equivalent of the left-hand side of Eq. (2.8) with

$$\frac{\text{cov}(\Delta \log p_{ijt}, \Delta \log e_{it})}{\text{var}(\Delta \log e_{it})}.$$

2.2. Sticky prices and the choice of invoicing currency

If prices are fully flexible, it should not matter in which currency the transaction is invoiced, since the exporting firm can adjust its price in the importer's currency or in its own currency to achieve its desired markup over costs. With preset prices, however, exchange rate pass-through in the short-run will depend substantially on the currency of invoicing. If prices are set in the producer's currency or another foreign currency, then short-run pass-through is high, since final-goods prices in the importing country will adjust one-for-one with exchange rates. But if prices are set in the local currency (LCP), the pass-through is much lower.

As we make more clear below, our measure of exchange rate pass-through is akin to being conditional on a price change. Hence,

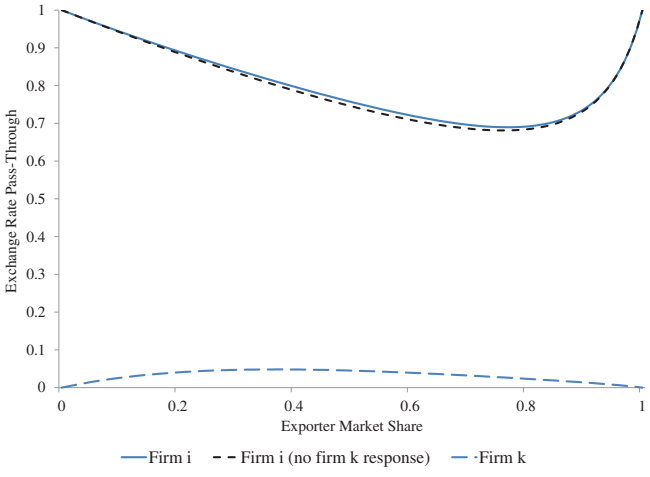

Fig. 2. Exchange rate pass-through and market share with four firms ($N = 4$).

[13] This is not the only model that can rationalize the relationship between exchange rate pass-through and market share. As we pointed out in the introduction, a variety of models, beginning with Dornbusch (1987), imply that firm level pass-through is affected by the size of the firm relative to the market. Our analysis is based on CES demand with strategic pricing. But a negative relationship between market share (on both sides of the market) and pass-through may also be implied by linear demand functions as in the model of Melitz and Ottaviano (2008). Alternatively, the model of Corsetti and Dedola (2005), incorporating local distribution costs that affect exporter pricing, can generate a negative implied relationship between the exporter size and pass-through. Finally, as mentioned above, Garetto (2016) derives a U-shaped pass-through exporter-market share locus in a model with firm level learning.

[14] This Figure assumes $\gamma_1 = \gamma_2\varphi = 0$. However, in reality it is likely that these parameters are greater than 0, and therefore pass-through for extreme values of θ_{ij} will not necessarily be complete.

[15] This result is shown in Proposition 1 of Auer and Schoenle (2016).

by construction, we do not observe pass-through that is triggered purely by exchange rate movements without any price adjustments undertaken by the producing firms. In this case, it might seem that the invoicing currency would be irrelevant to the measured degree of exchange rate pass-through. But if, in fact, sellers are subject to some short-term price rigidity, then the invoicing currency will matter, even for the degree of pass-through that takes place after a price change.

Engel (2006) shows a close relationship between the determinants of pass-through for the firm with flexible prices, and the choice of currency of price setting for the sticky-price firm. In particular, he shows that a firm that would desire a large exchange rate pass-through elasticity under flexible prices is more likely to choose pricing in its own currency (which is termed producer currency pricing or PCP) if it must set the nominal price in advance.[16] Gopinath et al. (2010) extend Engel's result to a model of Calvo staggered pricing. They show that the critical determinant of the currency of pricing is what they define as "medium run pass-through," which measures the pass-through of exchange rate changes to a firm's price after it has an opportunity to adjust its price.

The implication of these theories is that the causality in the empirical relationship between currency of invoicing and exchange rate pass-through should be in the reverse direction. A firm observed to have higher exchange rate pass-through is more likely to invoice transactions in its own currency, while a firm with low pass-through is more likely to invoice in Canadian dollars. Gopinath et al. (2010) show that if a firm's short-run price flexibility is constrained by a Calvo price adjustment process, then it will follow LCP (PCP) when the empirical exchange rate pass-through coefficient is less than (greater than) 0.5. Thus, in terms of our notation, we should anticipate that a given firm will invoice in local currency when

$$\frac{\text{cov}(\Delta \log p_{ijt}, \Delta \log e_{it})}{\text{var}(\Delta \log e_{it})} < 0.5. \tag{2.12}$$

The empirical implication of this condition is that sectors or goods with pass-through below 0.5 should be characterized by Canadian-dollar invoicing, whereas those with pass-through higher than 0.5 should have transactions invoiced in the currency of the exporting country. In general, we find this prediction supported in our data.[17] From a broader perspective, condition (2.12) implies that there should be a significant difference in pass-through measures between Canadian-dollar invoiced goods and non-Canadian-dollar invoiced goods, even conditional on a price change. This prediction is also strongly supported by our estimates.

In Fig. 3, we illustrate how the relationship between pass-through and currency choice will also depend on the market shares of firms involved in trade. We see that for exporters of all market shares trading with low-elasticity importers, transactions will always be priced in the producer's currency (or U.S. dollars). However, for transactions with bigger, more-productive and hence higher-elasticity-of-demand importers, there are exporters with certain market shares that will opt to price their goods in the local currency. That is, their desired pass-through will be low enough that Eq. (2.12) will hold.

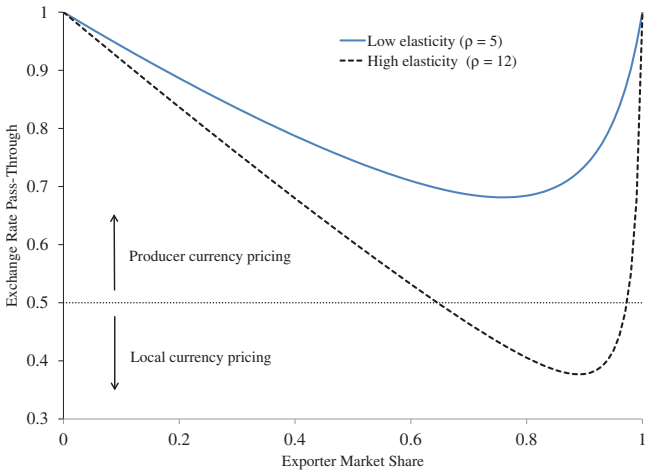

Fig. 3. Exchange rate pass-through, market share and currency choice.

The implication is that there will be a U-shaped relationship between the probability of PCP and exporter market share, and an overall negative relationship between the probability of PCP and importer market share (assuming, in both cases, that at least some importing firms have a high enough ρ_j). Below, we explore these predictions in the data.

3. Data

3.1. Customs data

We use data from the Canadian Border Services Agency (CBSA) that contain information on every commercial import/shipment into Canada from September 2002 to June 2008.[18] The data, collected by the CBSA and housed at Statistics Canada, contain information on the total value of each shipment, the number of units shipped, the 10-digit Harmonized System (HS) product code for the good, an importing firm identifier, an exporting firm/vendor identifier, the country in which the good was produced, the country from which the good was finally exported directly to Canada, and several other pieces of information that are important for the analysis of exchange rate pass-through.

As a proxy for prices, we use unit values defined as total shipment value divided by the number of units.[19] The shipment values are reported in the currency of invoice, and if this is different than Canadian dollars, a Canadian-dollar value is reported using the value of the bilateral exchange rate at the time the good crossed the border. While goods come across the border on a daily basis, we are provided only with the month in which the import entered Canada. In the empirical analysis below, for shipments priced in Canadian dollars, we match the unit values with the monthly bilateral exchange rate between Canada and the country of export. Therefore, for goods priced in non-Canadian dollars, we have a transaction-specific (or

[16] We note that the results of Engel (2006) are quite general in application to the market environment of the price setting firm. In particular, they apply to all cases where the firm has some market power and a well behaved discounted profit function. Thus, the results will apply to the case of strategic price setting and variable markups described above.

[17] While the use of second order approximations lead to expression (2.12), indicating 0.5 as the cut-off threshold for the relationship between pass-through and the currency of invoicing, it is based on an assumption that short-term price stickiness represents the only factor determining the currency of invoice. In reality, there are likely many legal and institutional features of trade relationships that impact on the invoicing decision. As a result, we should not take the 0.5 threshold literally as an exact prediction in the empirical investigation.

[18] This data set is similar to the Argentine import customs data used by Gopinath and Neiman (2014).

[19] There are several issues that arise from using unit values as a proxy for prices, such as the fact that even though the 10-digit HS codes are quite fine, there may still be more than one distinct product in each code, and therefore observed price changes may be due to compositional changes within the 10-digit HS code, rather than changes in the true, underlying prices of individual goods. Moreover, there may be measurement errors in the number of units. These issues are discussed by Berman et al. (2012) and Amiti et al. (2014), who use similar data. In Section 3.2, we provide a very specific definition of a product that can be tracked over time that addresses these issues, to some extent, but the empirical results that we present should be interpreted with the understanding of these possible data limitations.

day-specific) exchange rate, and for those priced in Canadian dollars, we have a monthly bilateral exchange rate. In the next subsection, we explain how we convert these transaction data into monthly data for the analysis of exchange rate pass-through.

As for the importing firm identifier, we are provided with a scrambled business number (for confidentiality reasons) that allows us to track a single Canadian buyer over time. Aside from this, we have limited information about the buyer other than the province in which it is located. On the exporter side, we have a vendor identifier, which allows us to track a single exporter over time. What we do not know is whether this vendor is a producer or an intermediary—the identifier is built from the company name provided on the customs sheet, which refers to the company ultimately responsible for shipping the good to the border.

Along with reporting the number of units shipped, the data reports what the units are for each shipment. Examples of the unit of measurement include "number", "kilograms" and "litres". When tracking a unit price over time, we take into account the unit of measurement.

Finally, the data provides a value for duty code, which, among other things, lets us know whether a reported import represents a transaction among affiliated companies (intrafirm trade). For our analysis, we drop all of these imports, since we want to focus on interfirm trade, and the model presented above reflects this fact.[20] More information on data construction, how importers and exporters are identified, how the country of origin and export are determined, and how the data can be accessed for replication are provided in Appendix C.

3.2. Panel design: defining monthly prices

To measure exchange rate pass-through, it is important that we have a set of goods whose prices we can track over time. In our data, we can observe many imports of the same good in the same month, and these 10-digit HS (HS10) goods can arrive in Canada from different countries and be purchased by different companies in Canada. Therefore, in the raw data there is no way to track the price of a such a single good over time. To create a price that can be followed over time and used to analyze pass-through, we combine price observations in order to define a good price that is specific to an importing firm (f), exporting firm (v), HS10 product (pr), country of origin (o), country of export (ex), currency (c), unit of measurement (u) and time (t). For clarity of exposition, let $s = \{f, v, pr, o, ex, c, u\}$. We define the price of good s in month t as

$$P_{st} = \Sigma_{l=1}^{n}(\alpha_{lst} \cdot P_{lst}), \tag{3.1}$$

where l is an individual transaction (or import) and α_{lst} is a weight, defined as the relative shipment size to total shipments of the good s. That is,

$$\alpha_{lst} = \frac{Shipment_{lst}}{\Sigma_{l=1}^{n} Shipment_{lst}}, \tag{3.2}$$

where $Shipment_{lst}$ is the number of units in each shipment and n is the total number of imports of good s in a single month.

In addition, since we have a transaction-specific exchange rate for those goods priced in currencies other than the Canadian dollar (the exchange rate can vary depending on what day of the month a good crosses the border), we can create a st-specific exchange rate in a manner similar to the way we created a st-specific price. For those goods priced in Canadian dollars, there is no implied exchange rate in the data. We therefore match these observations with the monthly bilateral exchange rate between the Canadian dollar and the currency of the exporting country. With this definition of a st-specific price, we now have "collapsed " or "condensed" data for each product that we use in the empirical analysis of exchange rate pass-through. In what follows, we refer to the raw data as shipment data, and the monthly condensed data as product-level data. We can also use the value of the shipments (in Canadian dollars) to create weighted statistics.

3.3. Summary statistics

In any given month, we observe approximately five million shipments (we have data for 71 months and the total data set has just under 400 million observations). However, for many of these shipments, either the number of units in the shipment or the unit of measurement is not available. Both of these pieces of information are needed to calculate the unit value and create a time series for a single good. For this reason, we select a subset of products representing a wide range of goods that have this information reported for most of the observed shipments.[21]

The nine product groupings or sectors, along with information on the currency of invoice, are presented in Table 1. The products range from commodities (e.g. vegetable products), to light manufacturing goods (e.g. textiles), to heavy manufacturing goods (e.g. industrial machinery).[22] As for the currency of invoice, overall, 88.0% of weighted imports and 86.0% of the shipments are invoiced in U.S. dollars. For Canadian dollars, these numbers are 8 and 4.5%, and they are 2.9 and 5.6% for euro-priced goods, respectively. The high U.S.-dollar share of overall imports is in line with what has been found in other data sets that contain information on the currency of invoice. Across the nine product categories, we see that there is some variation in the currency of invoice. For example, in terms of the total value of imports, at one extreme only 64.6% of food and beverage imports are invoiced in U.S. dollars (with a significant portion, 33.3%, invoiced in euros), while at the other end 93.3% of vegetable product imports are invoiced in U.S. dollars.

The dominant role of U.S. dollars not only reflects the fact that a significant portion of Canadian imports are from the U.S., but also illustrates the role of the U.S. dollar as a vehicle currency in trades with non-U.S. countries. Take the apparel sector, for example, in terms of the total shipments, around 40% of apparel imports are from China (where China is the country of origin) and the vast majority of these shipments (around 95% of these imports) are invoiced in U.S. dollars.[23] Moreover, in terms of shipments, roughly 67% of apparel imports are invoiced in U.S. dollars; while in terms of value, 88% are

[20] See Neiman (2010) for an analysis of pass-through and intrafirm trade. The implications for exchange rate pass-through within affiliated companies cannot be easily encompassed within our model, and would require a more formal analysis of intrafirm bargaining, perhaps along the lines of Goldberg and Tille (2013). Moreover, there is an added difficulty of dealing with the joint presence of market based transactions and within-firm sales. Given this, we postpone an analysis of the role of affiliates for future research.

[21] For most of the product categories, we were able to calculate the unit prices for close to 100% of the shipment observations. The one exception was consumer electronics, where the unit prices were available only for approximately 85% of shipment observations. We decided to included consumer electronics to ensure that there were a broad set of goods in the sample that included heavier manufacturing consumer goods. More details are provided in Appendix C. As a robustness check, we re-estimated our main empirical models either excluding consumer electronics altogether, or excluding some sub-categories where the missing unit values were concentrated, and found that the results did not change.

[22] In Table 1, the products are defined as a range of HS2 codes. However, within these ranges, some specific HS2 and HS4 products are dropped due to too many missing observations.

[23] If we exclude those imports that have the country of origin being China but the country of export being the U.S., the percentage of apparel imports invoiced in U.S. dollars is still 72%.

Table 1
Summary statistics — currency of invoice.

		Currency of invoice (%) (by value)			Currency of invoice (%) (by shipments)			
	HS code	USD	CAD	EUR	USD	CAD	EUR	Obs.
Overall	–	**88.0**	**8.0**	**2.9**	**86.0**	**4.5**	**5.6**	**37,397,388**
Vegetable products	07–14	93.3	6.0	1.1	95.9	2.1	0.8	6,075,397
Food and beverage	16–22	64.6	1.6	33.3	74.6	5.8	13.9	3,091,614
Chemical products	28–35	86.9	9.7	1.6	83.3	12.4	1.5	2,955,658
Textiles	50–60	82.1	12.2	4.5	89.5	3.6	5.6	3,488,820
Apparel	61–62	88.3	6.5	3.6	66.9	6.3	14.8	6,681,865
Footwear	64	83.1	4.4	11.9	78.6	5.8	13.8	856,652
Metal products	72–81	91.1	6.9	1.7	93.2	2.5	2.2	6,093,213
Industrial machinery	84	88.7	6.3	3.9	93.1	3.9	1.9	5,198,218
Consumer electronics	85	86.1	11.2	1.0	93.6	2.1	1.8	2,955,951

invoiced in U.S. dollars, suggesting that large-volume imports tend to use U.S. dollars for invoicing.

Given that we have both importing and exporting firm identifiers in our data, we can calculate market shares for both groups of firms within each import sector. To do this, we must decide the level of aggregation at which we define market share. After experimenting with a number of definitions, we decided that defining market share at the six-digit HS (HS6) level was the suitable level of aggregation. That is, either for exporters or importers, we define import market share as a given firm's share of the import market, in terms of value, within a given HS6 product category. Therefore, a single firm can have multiple import market shares if they export or import multiple products (across the HS6 classifications).[24] Our definition of import market share is also calendar-year specific, and so a firm's import market share can vary over time.

In Table 2, we present the share of overall imports accounted for by firms in different market share quintiles. More specifically, based on each firm's share of the importer market at the HS6 level, we place them into quintile bins (that is, all firms with import market share between 0 and 20% are assigned to the first quintile bin, those with 20 to 40% in the second quintile bin, and so on). We then calculate the total value of imports accounted for by the firms in the different quintile bins. Both in terms of value and number of products imported (product level), importers and exporters in the first quintile of the import market share distribution account for the majority of imports. However, in terms of value, the other quintiles account for a non-negligible portion of imports—for example, importers in the third, fourth and fifth quintiles collectively account for nearly 20% of imports.[25]

Table 2 also reports the currency of invoice by import market share quintile. For exporters, the share of imports in U.S. dollars is fairly constant across the import market share quintiles, falling within 87 and 91%, and the share of Canadian-dollar- and euro-priced goods varies very little, as well. What is interesting is the relationship between the market share of importers and the currency of invoice. In terms of value, only about 6% of imports by importers in the first quintile of market share are priced in Canadian dollars. However, 21% of the value of imports by the third quintile are priced in Canadian dollars, and roughly 20% for the fourth quintile. This number drops to 4% for the fifth quintile. There is a similar pattern for the product-level measures of imports. In the next section, we take these stylized facts into account when exploring the implications of the model.

4. Empirical analysis

4.1. Exchange rate pass-through

We start the empirical analysis by obtaining a measure of overall pass-through, and pass-through estimates for each product/sector. To do so, we use the following micro-price pass-through regression:

$$\triangle_\tau p_{st} = c + \beta_e \triangle_\tau e_{st} + Z'_{st}\gamma + \epsilon_{st}, \tag{4.1}$$

where $\triangle_\tau p_{st} = \ln(P_{st}) - \ln(P_{s\tau})$ is expressed in Canadian dollars and τ represents the last period in which this price is observed (we have a very specific definition of a good price, and a good will not necessarily be imported every period).[26] Similarly, $\triangle_\tau e_{st}$ is the cumulative change in the log of the nominal exchange rate over the duration for which subsequent imports of good s are observed. Z_{st} includes controls for the cumulative change in the foreign consumer price level, the Canadian consumer price level, Canadian GDP, and fixed effects for every s product and month t. Finally, ϵ_{st} is an error term.[27]

Table 3 presents the results for overall pass-through and for each of the nine products/sectors, individually, from the product level data and the value weighted data.[28] The overall estimate of exchange rate pass-through (pooling all products together) is approximately 59%

[24] We considered defining market shares at both the HS8 and HS4 levels. HS8 codes are often country specific and define a very specific product. This could lead to many firms with very high market shares, even though goods are highly substitutable across these HS8 categories. In general, HS4 categories are slightly broader than HS6, but in many cases HS4 and HS6 codes are the same. As a robustness check, we ran all of our main regressions below with HS4 and HS8 market shares instead of HS6 market shares. The results changed very little and our main conclusions hold.

[25] This ordering places the bulk of firms in the lower quintile bins. An alternative decomposition would place an equal number of firms in each quintile bin, with the first bin containing firms in the first 20% of the market share distribution, and so on. In experimentation, however, we found that exchange rate pass-through within the first and second quintiles is robust to different cuts within each quintile. Moreover, the alternative decomposition would involve mixing firms with very different market shares (particularly in the upper bins) and would make it difficult to detect the importance of market share in Table 2.

[26] It is possible that the interval between product observations is affected by exchange rate pass-through. But given the size of the data set, this is unlikely to be an important factor, and in any case, would be likely to impart only a small bias to the estimated mean of pass-through, and not the relationship between pass-through and invoice currency or market share.

[27] Note that in the absence of firm level data on exporter characteristics, we do not have the ability to add more micro-level controls, such as the differences in import intensity across exporters, as in the paper by Amiti et al. (2014).

[28] Table D.1 in Appendix D presents the pass-through estimates for all the products pooled together, along with the coefficients on the other variables.

Table 2
Currency of invoice by import market share.

Import market share quintile	Value weighted				Product level			
	Share of imports (%)	Currency of invoice (%)			Share of imports (%)	Currency of invoice (%)		
		USD	CAD	EUR		USD	CAD	EUR
Importers								
1	66.8	89.6	6.2	2.9	95.8	85.3	6.3	5.9
2	13.6	89.3	7.6	2.5	2.0	85.8	6.9	6.0
3	7.7	71.7	21.0	6.5	1.7	34.0	32.1	29.6
4	4.7	78.5	19.6	1.2	0.3	64.4	27.4	6.0
5	7.3	93.3	4.4	0.5	0.1	87.7	8.3	3.0
Exporters								
1	76.2	87.2	8.1	3.5	98.2	84.2	6.8	6.4
2	12.2	91.4	6.8	1.2	1.2	87.0	10.3	1.9
3	4.5	87.9	9.7	1.2	0.4	85.7	11.7	1.8
4	2.6	90.2	8.8	0.8	0.1	89.8	6.7	2.7
5	4.6	90.4	7.4	0.5	0.0	84.4	11.8	3.0

using value weights, and 48% using shipment weights.[29] These estimates offer valuable insights into the overall degree of pass-through to import prices in Canada. The Canadian aggregate import price index is constructed in such a way that some of the price data are sampled from other countries (mainly the U.S.). The strong assumptions regarding the degree of pass-through made in this process can create a mechanical relationship between aggregate prices and the exchange rate, resulting in an upward bias on any reduced-form pass-through estimates.[30] Our estimates are not subject to such a bias, since we work with transaction-level data.

In addition to the overall pass-through estimates, we also see that there is a significant amount of variation across the products/sectors. At one extreme, in terms of value-weighted results, the pass-through coefficient for apparel is 0.826 and significant at the 1% level. At the other end, the pass-through coefficient for vegetable products is 0.214 (and it is significant at the 5% level). The other pass-through point estimates fall within this range, with pass-through for footwear and industrial machinery exhibiting high pass-through at 0.744 and 0.752, respectively, and metal products at the lower end with a point estimate of 0.422. These results are in line with the finding that for many other countries, pass-through is incomplete.

4.2. Exchange rate pass-through and the currency of invoice

We next explore some of the implications of the model. We start with pass-through and the currency of invoice. As documented in Table 1, there is some variation within products/sectors when it comes to the currency of invoice. The theory discussed above predicts that pass-through rates will be associated with different currency types: exporters that desire lower pass-through to the import price will price in Canadian dollars (CAD); those that desire higher pass-through will price in foreign currency. To test these hypotheses, we use a similar set-up as in Eq. (4.1), but we introduce dummy variables for whether a specific product is priced in Canadian dollars (D_{CAD}), U.S. dollars (D_{USD}), or euros (D_{EUR}), and include a full set of interaction terms with the exchange rate:

$$\triangle_\tau p_{st} = c + \alpha_1 D_{CAD} + \alpha_2 D_{USD} + \alpha_3 D_{EUR} + \beta_1 \triangle_\tau e_{st} + \beta_2[\triangle_\tau e_{st} \cdot D_{CAD}] + \beta_3[\triangle_\tau e_{st} \cdot D_{USD}] + \beta_4[\triangle_\tau e_{st} \cdot D_{EUR}] + Z'_{st}\gamma + \epsilon_{st}. \quad (4.2)$$

The coefficient β_1 will pick up the degree of pass-through for goods priced in currencies other than Canadian and U.S. dollars, and euros (this is understood to be a very small set of goods). Pass-through to Canadian-dollar-priced goods will be $\beta_C = \beta_1 + \beta_2$, to U.S.-dollar-priced goods it will be $\beta_U = \beta_1 + \beta_3$ and to euro-priced goods it will be $\beta_E = \beta_1 + \beta_4$.

Table 4 presents the results of the estimation. Note that these results are from product level regressions, to better reflect the assumptions and mechanisms presented in the model.[31] The first set of columns shows the estimates and the standard errors, while the last three show the difference between the estimates and indicate whether that difference is statistically significant. The results are generally in line with the predictions of the theory. For all products/sectors, pass-through is higher for U.S.-dollar-priced goods than for Canadian-dollar-priced goods, and in all but one case (vegetable products) the difference between the two estimates is both large and statistically significant. The largest difference between the two pass-through rates is for footwear, where the pass-through estimate for U.S.-dollar goods is 0.702 and for Canadian-dollar goods it is 0.078 (and not significant). For most products/sectors the rate of pass-through is also higher for euro-priced goods than for Canadian-dollar-priced goods. For example, for food and beverage products, the pass-through estimate for euro goods is 0.684, which is larger and significantly different from the Canadian-dollar estimate.

Given that the U.S. dollar is the most common currency in Canadian imports, it is not surprising that the coefficient estimates for U.S.-dollar transactions are closest to the overall pass-through estimates presented in Table 3. Nevertheless, there is some variation in currency within products/sectors.

[29] This estimate of unconditional pass-through between 0.5 and 0.6 is comparable to those in the literature when one allows for the different features of currency invoicing. For instance, Gopinath et al. (2010) find an unconditional pass-through estimate for U.S. imports equal to 0.22, but given that a much higher fraction of imports into Canada are invoiced in foreign currency, in contrast to the US market, a significantly higher unconditional pass-through estimate is to be expected.

[30] For details on Statistics Canada assumptions regarding pass-through, see http://www.statcan.gc.ca/pub/13-604-m/13-604-m2009062-eng.htm.

[31] The model outlines the micro-mechanisms that influence firm pricing behavior. The unweighted regressions are better suited to capture these mechanisms, since the estimates reflect the decisions of any given firm, rather than putting extra weight on firms with high values of imports, as does the weighted regression set-up.

Table 3
Exchange rate pass-through estimates.

	Product level		Value weighted		
	$\hat{\beta}_e$	(s.e.)	$\hat{\beta}_e$	(s.e.)	Obs.
Overall	**0.484*****	**(0.010)**	**0.593*****	**(0.030)**	**7,993,402**
Vegetable products	0.298***	(0.033)	0.214**	(0.092)	959,319
Food and beverage	0.454***	(0.023)	0.552***	(0.046)	585,693
Chemical products	0.419***	(0.018)	0.642***	(0.112)	642,768
Textiles	0.546***	(0.017)	0.671***	(0.039)	606,482
Apparel	0.625***	(0.012)	0.826***	(0.027)	1,528,634
Footwear	0.587***	(0.027)	0.744***	(0.048)	175,342
Metal products	0.302***	(0.013)	0.422***	(0.052)	2,090,899
Industrial machinery	0.662***	(0.014)	0.752***	(0.070)	975,483
Consumer electronics	0.653***	(0.025)	0.710***	(0.094)	428,782

Note: The pass-through coefficients for the specific products are obtained using interaction terms, and therefore there is only one set of coefficients for the other explanatory variables. Each regression includes HS10 product and time fixed effects. We restrict the sample to price changes within the −100% to +100% range. The standard errors are clustered at the HS10 level.

4.3. Exchange rate pass-through and market share

We next explore the predictions of a U-shaped relationship between exporter market share and exchange rate pass-through, and a monotonically decreasing relationship for importer market share. To test these hypotheses, we run the following regression:

$$\triangle_\tau p_{st} = c + \alpha MS_{ht} + \beta_0 \triangle_\tau e_{st} + \beta_1 \left[\triangle_\tau e_{st} \cdot MS_{ht}\right] + \beta_2 \left[\triangle_\tau e_{st} \cdot MS_{ht}^2\right] + Z'_{st}\gamma + \epsilon_{st}, \quad (4.3)$$

where MS_{ht} refers to the market share (as defined in Section 3.3) of either an exporter or importer h (i.e. $h \in \{f, v\}$) at time t. This term, along with a squared term, is interacted with the exchange rate to capture the degree of curvature in the pass-through–import market share relationship.

The results are presented in Table 5. The coefficient estimates for β_0, β_1 and β_2 can be used, along with varying market shares, to map out the pass-through–import market share relationship. In this set-up, the coefficient on the cumulative log change in the exchange rate, β_0, represents the degree of pass-through if market share is zero. We start, in column (I), by including only a single interaction term for exporter market share. The coefficient on the exchange rate–market share interaction term is negative but not statistically significant from zero. In column (II), we include an interaction term between the exchange rate and market share squared. The coefficient on the linear interaction terms is negative and significant at the 5% level, while the coefficient on the non-linear interaction term is positive and significant at the 10% level. This provides initial evidence of a U-shaped relationship.[32]

For importers, there is evidence of a negative relationship between pass-through and market share; however, this does not show up in the linear interaction term, but in the squared interaction term, suggesting some curvature in the relationship. In column (III), the coefficient on the linear interaction term is negative but not statistically different from zero. In column (IV), we include the non-linear interaction term for importers and find that while the linear term becomes positive, it remains insignificant. The non-linear term, on the other hand, is negative and significant at the 5% level. We take this as initial evidence that the relationship between importer market share and exchange rate pass-through is negative.

Finally, in column (V) we include both exporter and importer market shares in the same regression and find that the results largely hold. The linear exporter interaction term is negative and significant, while the non-linear interaction term is positive and significant, suggesting a U-shape relationship between exporter market share and pass-through. On the importer side, we see that again the linear interaction term is positive, but not significant, and the non-linear interaction term is negative and statistically significant. Depending on how we view the insignificant coefficient on the linear interaction term, either the relationship between importer market share and pass-through is flat to start with, but largely declining afterwards, or pass-through is monotonically decreasing in importer market share (if we were to assume that the linear interaction term is equal to zero).

To help clarify these issues and to get an idea of the magnitude of the relationships, in Fig. 4, we use the coefficients from column (V) to plot market share against pass-through for importers and exporters. We see in this figure that there is a U-shaped relationship for exporters—and that pass-through is roughly in the 0.4 to 0.8 range depending on exporter import market share. We provide two lines for the importer market share and pass-through relationship. In the first, we assume that the linear interaction term is positive and equal to 0.164. In this case, there is a very slight hump shape, that can also be viewed as a flat spot in the relationship as pass-through increases by less than 1% from a market share of zero to the peak of the hump at roughly 20% market share, after which it decreases from 0.5 to approximately 0.1 for importer market share equal to 1. Alternatively, we could assume that because the linear interaction term is not statistically different from zero, that it can be treated as being equal to zero. In this case, pass-through is monotonically decreasing in importer market share, decreasing from roughly 0.5 for very small market share firms to just below zero for very large importers.[33]

While Fig. 4 is meant to be merely illustrative of the general patterns in the empirical relationship between market share and pass-through, we also note that there is a very wide distribution of market shares in the data. From Table 2, exporting firms with market shares (within HS6 product categories) greater than 60% account for 7.2% of overall imports by value, and on the import side, importing firms with market share in excess of 60% make up 12% of the value of imports. Hence, while very high market share firms on both sides of the trading relationship are uncommon, they are by no means irrelevant as a feature of the data. Consequently, the pass-through patterns illustrated in Fig. 4 are informative across the full distribution of import market shares.

The coefficient estimates presented above are meant to reflect the effect of increasing the market share of either an importer or exporter, holding all else constant, including the market share of their trading partner. However, the coefficients are estimated from information on exporters (importers) trading with importers (exporters) of varying market shares. In Table 6, we present results for when we hold the market share of the trading partner relatively constant. More specifically, we look at pass-through across exporters (importers) of different market shares trading with importers (exporters) within quintiles of the market share distribution. We

[32] To check on the implications of including very large importers and exporters, we re-ran the currency-choice regressions excluding all importers and exporters with greater than 50 % market share. We still find a significant U shape on the exporter market share and a downward sloping relationship on the importer side.

[33] Our use of quadratic interaction terms in linear regressions to pick up non-linearities in pass-through will not accurately capture the exact relationship between market share and pass-through at all points along the market-share distribution. Therefore, the focus should be on the overall shape of the curves rather the implied pass-through rates at exact market shares. This is particularly the case when pass-through drops below zero. Note also that for the exporter pass-through–market share relationship, the fact that the y-axis intercept is less than 1 provides some evidence that either $\gamma_1 > 0$ or $\gamma_2\varphi > 0$, or both.

Table 4
Pass-through and currency choice.

	CA dollar		US dollar		Euro		Difference		
Product	β_C	(s.e.)	β_U	(s.e.)	β_E	(s.e.)	$\beta_C - \beta_U$	$\beta_C - \beta_E$	$\beta_U - \beta_E$
Overall	0.137***	(0.02)	0.502***	(0.01)	0.497***	(0.02)	−0.37***	−0.36***	0.01
Vegetable products	0.300***	(0.08)	0.325***	(0.05)	0.547***	(0.08)	−0.07	−0.25***	−0.22**
Food and beverage	0.020	(0.03)	0.481***	(0.03)	0.684***	(0.04)	−0.46***	−0.66***	−0.20***
Chemical products	0.128**	(0.06)	0.459***	(0.02)	0.521***	(0.07)	−0.32***	−0.39***	0.06
Textiles	0.096*	(0.06)	0.587***	(0.02)	0.484***	(0.04)	−0.49***	−0.39***	0.10**
Apparel	0.123***	(0.03)	0.623***	(0.01)	0.484***	(0.03)	−0.50***	−0.36***	0.14***
Footwear	0.078	(0.09)	0.702***	(0.03)	0.562***	(0.07)	−0.62***	−0.48***	0.14*
Metal products	0.193***	(0.04)	0.451***	(0.02)	0.255***	(0.07)	−0.26***	−0.06	0.20***
Industrial machinery	0.211***	(0.05)	0.597***	(0.02)	0.589***	(0.07)	−0.39***	−0.38***	0.01
Consumer electronics	0.169**	(0.08)	0.620***	(0.03)	0.740***	(0.11)	−0.45***	−0.57***	−0.12

Note: The pass-through coefficients for the different products are obtained using interaction terms, and therefore there is only one set of coefficients for the other explanatory variables. Each regression includes HS10 product and time fixed effects. We restrict the sample to price changes within the −100% to +100% range. The standard errors are clustered at the HS10 level.

Table 5
Market share and pass-through.

	(I)	(II)	(III)	(IV)	(V)
Exchange rate ($\triangle_\tau e_{st}$)	0.486***	0.487***	0.488***	0.486***	0.486***
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
Exporter market share (MS_{vt})	−0.007***	−0.007***			−0.005**
	(0.002)	(0.002)			(0.002)
$\triangle_\tau e_{st} \bullet MS_{vt}$	−0.099	−0.290**			−0.341**
	(0.065)	(0.145)			(0.159)
$\triangle_\tau e_{st} \bullet MS^2_{vt}$		0.402*			0.648***
		(0.216)			(0.223)
Importer market share (MS_{ft})			−0.005***	−0.005***	−0.003*
			(0.002)	(0.002)	(0.002)
$\triangle_\tau e_{st} \bullet MS_{ft}$			−0.122	0.078	0.164
			(0.082)	(0.142)	(0.151)
$\triangle_\tau e_{st} \bullet MS^2_{ft}$				−0.397**	−0.546***
				(0.197)	(0.210)
Constant	0.003*	0.003*	0.003*	0.003**	0.003*
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Obs.	7,993,402	7,993,402	7,993,402	7,993,402	7,993,402
R^2	0.003	0.003	0.003	0.003	0.003

Note: Each regression includes HS10 product and time fixed effects. We restrict the sample to price changes within the −100% to +100% range. The standard errors are clustered at the HS10 level.
Specification: $\triangle_\tau p_{st} = c + \alpha MS_{ht} + \beta_0 \triangle_\tau e_{st} + \beta_1 [\triangle_\tau e_{st} \bullet MS_{ht}] + \beta_2 [\triangle_\tau e_{st} \bullet MS^2_{ht}] + Z'_{st}\gamma + \epsilon_{st}$, and the variables are defined in the text.

focus mainly on the case where the trading partner falls within the first quintile of the market share distribution.

When holding the importer market share quintile constant at the first quintile, we see that as we increase the import market share of the exporter, pass-through at first increases (from 0.486 to 0.582 from the first to second quintile), then drops to 0.438, before eventually increasing to 1.232 for the fifth quintile. While not completely U-shaped, this is generally in line with the predictions of the model. When holding the exporter import market share constant at the first quintile, we see that as we increase importer import market share, exchange rate pass-through generally decreases (there is a slight increase from the first to the second quintile, but these coefficients are not statistically different from each other). This accords with the prediction of the model that the relationship between importer market share and pass-through is negative.[34]

In the illustrative model analyzed above, exchange rate pass-through is negatively related to importer market share because of the assumption that larger importers have a higher elasticity of demand across products. To provide empirical support for this assumption, we exploit the fact that in the data we observe the same importer importing similar goods from different exporters in the same period and over time. This allows us to investigate whether changes in the relative price of these goods over time results in changes in relative quantities (a measure of the elasticity of demand across products), and whether this relationship varies across firms of different sizes in terms of market share. The details regarding the estimation of the elasticities are provided in Appendix E. In the baseline estimates, we find that the elasticity of demand across these product pairings is 24% higher for a firm with 50% market share as compared to a firm with near zero market share, and 50% higher for a firm with near 100% market share. Thus, there is clear evidence of a relationship between importer market share and the elasticity of demand as described in the model.[35]

4.4. Market share and the currency of invoice

Our model makes the further prediction that exporting firms that prefer lower pass-through to import prices will choose to invoice in the currency of the destination country, while those that prefer higher pass-through will choose their own currency or the U.S.

[34] Note that this framework does not completely control for the size of the trade partner. These are relatively large bins and variation in the size of the trade partner within the bins could explain some of these results. Table 6 also touches on the issue of the determination of pass-through when firms of a similar size meet up. However, whether pass-through is higher for two large market share firms interacting versus two small market share firms interacting remains unclear. This could depend on characteristics of the market that we do not observe, which in turn determine the exact shape of the pass-through/market-share curves.

[35] We thank Cédric Tille for suggesting this procedure.

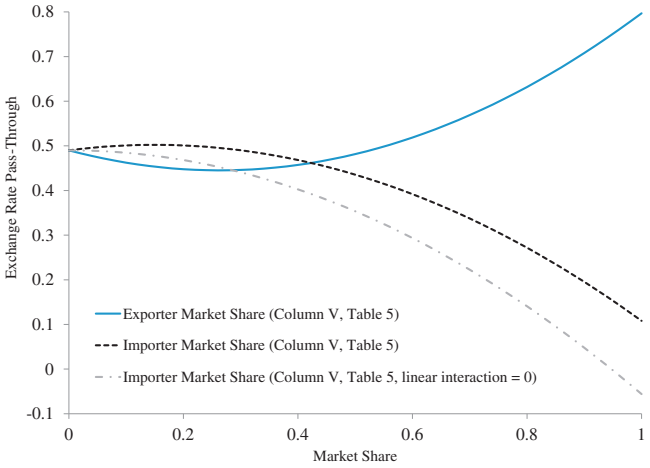

Fig. 4. Exchange rate pass-through and import market share.

dollar. Table 4 above establishes that exchange rate pass-through is systematically higher for U.S. dollar invoicing, across the whole distribution of products in the data. Furthermore, we have shown that exchange rate pass-through is related to the market share of firms.

In this section, we tie these parts of the analysis together to establish a relationship between invoice currency and market share. From the discussion of the theoretical model, it follows that as small exporters increase their market share, they are more likely to price in the destination market currency; but at a certain point, when market share is large enough, an increase in market share makes it more likely for them to price in the producer currency. This is a reflection of the mechanisms that determine the U-shaped pass-through and market share relationship. On the other side, holding the market share of the exporter constant, an increase in importer market share should lower the degree of pass-through and hence increase the chances that imports are invoiced in the local (destination market) currency.

We have some initial evidence, from Table 2, that importers with larger market share are more likely to pay in Canadian dollars (the exception being those firms in the top quintile, where the share of goods priced in Canadian dollars drops). To test these hypotheses more formally, we use a logit model to estimate how import market share affects the probability of invoicing in different currencies. Specifically, we estimate the following equation:

$$\Pr(USD_{st}) = \frac{\exp(v_{st})}{1+\exp(v_{st})}, \tag{4.4}$$

where

$$v_{st} = c + \beta\Delta_\tau e_{st} + \alpha MS_{ht} + Z_{st}'\gamma + \epsilon_{st}.$$

USD_{st} is a variable that is equal to one if a good is invoiced in U.S. dollars, and zero if the price is set in Canadian dollars (because these two currencies account for over 90% of shipments, for clarity we restrict the analysis to them). Again, MS_{ht} refers to the market share of either the exporter or importer at time t. The set of control variables, Z_{st}, is the same as in Eq. (4.1).[36]

Table 7 presents the results from the logit regressions.[37] In columns (I) and (II), we include only exporter market share in the regressions, and find that when only the linear term is included, the estimated coefficient is negative and statistically significant, indicating that the higher the market share of the exporter, the lower the probability of it being priced in U.S. dollars. To test for non-linearity, in column (II), we include a squared exporter market share term. And while the coefficient on the linear term remains negative and statistically significant, the coefficient estimate on the squared term is positive and significant, indicating that the non-linear relationship also applies to currency choice. It suggests that as small market share firms increase their market share, they become more likely to price in Canadian dollars. At a certain point, when market share is large enough, an increase in market share leads to an increase in the probability of pricing in U.S. dollars. This result is consistent with the market share and pass-through results and supports the predictions of the model.

Column (III) presents the results for importer market share and we see that the coefficient on market share is negative and significant. This means that the larger the market share of any given importer, the more likely that importer is to pay in Canadian dollars. This result is consistent with the predictions of the model and is reflected, in part, in Table 2. However, the data presented in Table 2 also suggest that importers with very high import market share (in the fifth quintile) primarily pay in U.S. dollars. In column (IV) of Table 7, we test for any further evidence of this non-linearity by including a squared importer market share term in the regression, but find that the linear and squared terms are both

Table 6
Cross-market shares and pass-through.

		Importer market share quintile				
		1	2	3	4	5
Exporter market share quintile	1	0.486*** (0.010) [7,559,207]	0.489*** (0.038) [132,492]	0.430*** (0.056) [121,261]	0.256*** (0.087) [14,458]	0.282 (0.247) [4817]
	2	0.582*** (0.061) [60,047]	0.514*** (0.077) [35,954]			
	3	0.438*** (0.107) [16,082]		0.649*** (0.155) [10,130]		
	4	0.785*** (0.138) [4955]			0.131 (0.210) [4441]	
	5	1.232*** (0.294) [1500]				0.277 (0.193) [3503]

Note: Off-diagonal (other than when either the exporter or importer market is in the first quintile) estimates are excluded because the regressions have very few observations and therefore the coefficients are insignificant and difficult to interpret. Each regression includes HS10 product and time fixed effects, and the standard errors are clustered at the HS10 level. The number of observations in the regression is provided in the square brackets.

[36] It is possible that the determinants of currency invoicing in U.S. dollars will be different for U.S. exporters and non-U.S. exporters. Goldberg and Tille (2008) define the latter situation as "vehicle currency" invoicing. For simplicity, we abstract from this more general possibility, since it is not part of our model, and as shown in Table 1, besides Canadian dollars, the U.S. dollar represents invoicing currency for the vast majority of shipments in the data.

[37] Because our definition of a product includes the currency in which it is priced, there is no variation in currency over time for individual products. Therefore, we rely primarily on cross-sectional variation to identify the relationship between currency choice and market share. Also, we include the exchange rate as a separate control variable in Table 7, despite that the regressions contain time fixed effects. This is because there is cross-sectional variation in exchange rate changes due both to differences in the timing of the *st* observations in the data and that the exchange rate used for each observation is the weighted average within a month for observed transactions, so that within month variations in exchange rates give rise to differences in the relevant exchange rate across observations.

Table 7
Market share and currency of invoice (logit model).

	(I)	(II)	(III)	(IV)	(V)
Exchange rate ($\triangle_\tau e_{st}$)	−9.502***	−9.503***	−9.481***	−9.485***	−9.506***
	(0.273)	(0.273)	(0.272)	(0.272)	(0.270)
Exporter import market share (MS_{vt})	−1.668***	−4.543***			−5.135***
	(0.253)	(0.877)			(1.162)
(MS_{vt}^2)		5.387***			7.051***
		(1.439)			(1.735)
Importer import market share (MS_{ft})			−0.898***	−0.170	1.352
			(0.301)	(0.620)	(0.873)
(MS_{ft}^2)				−1.241*	−3.005***
				(0.663)	(0.911)
Constant	3.302***	3.345***	3.299***	3.281***	3.325***
	(0.162)	(0.163)	(0.161)	(0.162)	(0.163)
Obs.	7,290,235	7,290,235	7,290,235	7,290,235	7,290,235
Pseudo-R^2	0.103	0.104	0.102	0.102	0.104

Note: The dependent variable, USD_{st}, is equal to one if a good is priced in U.S. dollars and zero if priced in Canadian dollars. Each regression includes HS2 product and time fixed effects. We restrict the sample to price changes within the −100% to +100% range. Standard errors are clustered at the HS10 level.
Specification: $\Pr(USD_{st}) = \exp(v_{st})/(1+\exp(v_{st}))$, where $v_{st} = c+\beta\Delta_\tau e_{st}+\alpha MS_{ht}+Z_{st}'\gamma+\epsilon_{st}$. The variables are defined in the text.

negative, implying a monotonic relationship between importer market share and currency of invoicing.[38]

Finally, in column (V) we include the market share of both exporters and importers in the same regression. We find that the results hold on the exporter side: the coefficient on the linear market share term is negative and significant, and the coefficient on the non-linear term is positive and significant, suggesting a U-shaped relationship between exporter import market share and the probability of pricing in U.S. dollars. On the importer side, the coefficient on the linear term becomes positive, but it is not statistically significant. The coefficient estimate on the non-linear term is negative and statistically significant. Therefore, as in our analysis of the results in column (V) of Table 5, depending on how we treat the insignificant linear term, the relationship between importer import market share and the probability of pricing in U.S. dollars is either very slightly hump shaped, but largely decreasing, or it is strictly decreasing (if we assume the coefficient on the linear term is equal to zero).

5. Conclusions

In this paper, we explore the relationship between import market share, exchange rate pass-through and currency of invoicing in international trade. Our detailed micro-data allow us to measure the import market share, by value of shipment, of all exporters to, and importing firms in Canada over a six-year period, as well as the unit price and currency of invoice for each of these transactions. To provide a framework for thinking about these issues, we develop a model of trade pricing where pass-through of exchange rates to import prices and the choice of currency invoicing depends on the market structure, and in particular the market share of both exporting and importing firms. The model implies that both pass-through and currency of invoicing should be non-monotonically related to exporter market share, in a U-shaped relationship, while pass-through and currency of invoicing should be negatively related to importer market share.

Our empirical work finds evidence in support of the importance of exporters and importers in the joint determination of pass-through and currency invoicing. This finding is new and important to the literature. The implications of our results suggest that industry composition and market structure are critical ingredients in understanding exchange rate pass-through. Moreover, this suggests that changes in the makeup of firms that populate markets over time can lead to change in aggregate pass-through, and therefore the external adjustment process in response to international shocks.[39]

Appendix A. A model of elasticity choice

Here, we sketch out a simple framework to motivate the argument that importing firms may have differences in their technologies for producing retail goods, and can choose among different technologies in advance, subject to a cost. Technologies differ with respect to the elasticity of substitution between imported retail intermediates. We assume that there is uncertainty over intermediate-good prices, so that a greater ability to substitute between intermediates will increase expected profits for retailers. We assume that there are two periods. In period 0, the importer may, at a cost, choose the elasticity of substitution of its technology. In period 1, given the technology, and realized intermediate prices, the importer purchases intermediates, repackages them using its technology, and sells them to retail consumers.

Consider period 1 first. To simplify matters, assume that there are just two inputs into the production of retail goods. Thus an importer purchases from two separate exporters inputs x_1 and x_2, at prices p_1 and p_2. The importer is a price taker in its input market, so takes the prices p_1 and p_2 as given. The importer then packages the intermediate goods into a retail good for final sale according to the technology:

$$y = A\left[v^{\frac{1}{\rho}}x_1^{1-\frac{1}{\rho}} + (1-v)^{\frac{1}{\rho}}x_2^{1-\frac{1}{\rho}}\right]^{\frac{1}{1-\frac{1}{\rho}}}. \tag{A.1}$$

The elasticity of substitution across imported inputs is ρ. The parameter A is a measure of the importer's technology.

[38] It is possible that the very high market share importers are more likely to trade with very high market share exporters, who are at the upper right-hand side of the U-shaped pass-through curve and are more likely to price in U.S. dollars (regardless of the market share of their trading partner). There is evidence of this in Table 6. Looking at the number of observations in the regression results in the vertical column 5 (the fifth quintile of the importer market share), very large importers are almost as likely to transact with an exporter in the fifth quintile (there are 3503 monthly transactions) as they are with small exporters in the first quintile (there are 4817 transactions). Alternatively, we can see that smaller market share importers are much more likely to trade with small market share exporters than with exporters of similar market share.

[39] For example, trends that are visible regarding the concentration of importer size in the Canadian data may have important implications for the sensitivity of domestic prices to exchange rate fluctuations in the future. Some discussion of this possibility is provided in Appendix F.

Given this, the importer's cost function is

$$\left[vp_1^{1-\rho} + (1-v)p_2^{1-\rho}\right]^{\frac{1}{1-\rho}} \frac{y}{A}. \tag{A.2}$$

Assuming that the importer is a monopolist in retail with demand elasticity λ, then the price is a markup $\frac{\lambda}{\lambda-1}$ over marginal costs, and equilibrium profits can be written as

$$\Delta\left(\left[vp_1^{1-\rho} + (1-v)p_2^{1-\rho}\right]^{\frac{1}{1-\rho}} \frac{1}{A}\right)^{1-\lambda}, \tag{A.3}$$

where $\Delta > 0$.

For a given ρ, importers with higher productivity will have lower prices and higher retail sales, which implies that they will have a higher share of the market for the purchase of each imported input.

In period 0, prices p_1 and p_2 are not known, so the importer's expected profit is written as

$$E_0\Pi(\rho, A) = E_0\Delta\left(\left[vp_1^{1-\rho} + (1-v)p_2^{1-\rho}\right]^{\frac{1}{1-\rho}} \frac{1}{A}\right)^{1-\lambda}. \tag{A.4}$$

Here, we explicitly account for the fact that expected profits will depend on the importer's elasticity of substitution across intermediate imports and on its productivity.

Assume that the cost that the importer incurs for choosing an elasticity of substitution ρ is as follows:

$$C(\rho) = \xi\rho^2 + \kappa. \tag{A.5}$$

In period zero, the importing firm will then choose ρ to maximize:

$$\text{Max}_\rho E_0\Pi(\rho, A) - \xi\rho^2 - \kappa, \tag{A.6}$$

where we have assumed there is no discounting.

Using standard theory, we can show that the expected profits function is convex in p_1 and p_2. This is a familiar result from the theory of production—the firm can always adjust inputs in response to variations in input cost in order to do better than responding linearly, so the cost function is concave in the input prices, which implies that the profit function is convex in input prices. But then, as the expected profit function becomes more convex, the higher is the elasticity of substitution. Hence, expected profits are increasing in ρ. Since expected profits are also increasing in A, this leads to the result that the optimal ρ is greater for firms with higher A. The implication is that more-productive firms, or firms that can repackage goods for retail more productively, will have a higher final retail sales level, and therefore a higher import share of any particular intermediate input good. They will also have a more-elastic technology for substitution across different intermediate import goods.

Fig. A.1 gives a simple illustration of the determination of optimal ρ for a high A firm and a low A firm. It is assumed that p_1 is certain, but p_2 is uncertain at period 0. Firms share a similar technology adoption cost given by Eq. (A.5). This is represented by the cost-of-adoption curve. Both firms have expected profit functions

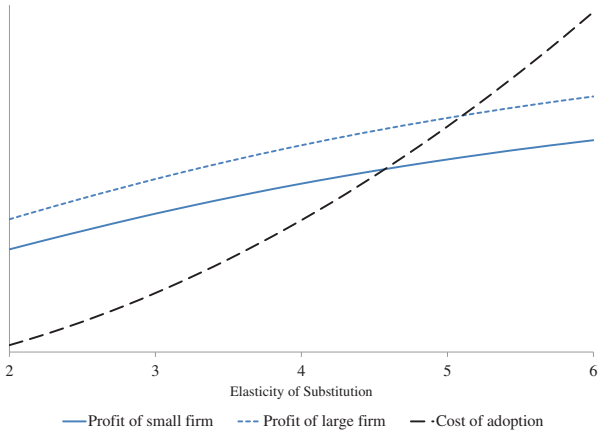

Fig. A.1. Choice of elasticity of substitution.

increasing in ρ, but the more-productive (high A) firm's expected profit always lies above that of the less-productive firm. As a consequence, the optimal ρ is always higher for the more-productive firm. In this environment, we would then expect that firms with a higher market share should have a higher elasticity of substitution across intermediate inputs.

Appendix B. Proof of Proposition 1

Proof. To economize on notation, we omit the market j subscript. First, assume firm $i = 1$ experiences a direct exchange rate depreciation, while all other firms $i = 2, \ldots, N$ experience cost changes only indirectly. Hence, for firm 1 the direct change in marginal cost is defined as:

$$\hat{mc}_1 = 1 - (\gamma_1 + \gamma_2\varphi),$$

while for firms $i = 2, \ldots, N$ the indirect effect is given by:

$$\hat{mc}_i = (1 - (\gamma_1 + \gamma_2\varphi))\frac{d\log e_i}{d\log e_1} < \hat{mc}_1,$$

Then, pass-through for firm 1 may be written as:

$$\frac{d\log p_1}{d\log e_1} = \frac{\hat{mc}_1}{1+\omega_1} + \frac{\omega_1}{(1+\omega_1)}\sum_k \theta_k \frac{d\log p_k}{d\log e_1}, \tag{B.1}$$

while that for firm $i = 2, \ldots, N$ is:

$$\frac{d\log p_i}{d\log e_i} = \frac{\hat{mc}_i}{1+\omega_i} + \frac{\omega_i}{(1+\omega_i)}\sum_k \theta_k \frac{d\log p_k}{d\log e_1}, \tag{B.2}$$

To show part (a) of the proposition, assume contrary to the proposition that pass-through is more than complete, so that $\frac{d\log p_1}{d\log e_1} > \hat{mc}_i$. Then from Eq. (B.1), it must be that

$$\sum_k \theta_k \frac{d\log p_k}{d\log e_1} > \hat{mc}_1$$

which implies that

$$\sum_k \theta_k \frac{d\log p_k}{d\log e_1} > \frac{d\log p_1}{d\log e_1}.$$

In words, the sectoral price index must rise by more than proportionally to the country 1 exchange rate depreciation. Since the sectoral price index is a weighted sum of each firm's pass-through, it must then be the case that the indirect exchange rate pass-through for at least one firm $z \in \{2,\ldots,N\}$ exceeds the direct exchange rate pass-through for country 1. Let z represent the firm in $\{2,\ldots,N\}$ which has the highest exchange rate pass-through. Then it must be that

$$\frac{d\log p_z}{d\log e_1} > \sum_k \theta_k \frac{d\log p_k}{d\log e_1}.$$

But also, by the definition of pass-through for firm z, we have

$$\frac{d\log p_z}{d\log e_1} = \frac{\hat{mc}_z}{1+\omega_z} + \frac{\omega_z}{(1+\omega_z)} \sum_k \theta_k \frac{d\log p_k}{d\log e_1} < \sum_k \theta_k \frac{d\log p_k}{d\log e_1} \quad \text{(B.3)}$$

where the right hand side inequality follows because by assumption $\hat{mc}_z < \hat{mc}_1 < \sum_k \theta_k \frac{d\log p_k}{d\log e_1}$. Thus we have a contradiction, so pass-through for firm 1 must be less than complete. Moreover, since we have assumed that $\frac{d\log p_z}{d\log e_1} \geq \frac{d\log p_j}{d\log e_1}$ for all $j \neq z \in \{2,\ldots,N\}$, the same conclusion must hold for all other firms in $\{2,\ldots,N\}$.

To show part (b) of the Proposition, note that for $\theta_1 = 0$, we have $\omega_1 = 0$ so from Eq. (B.1) we have

$$\frac{d\log p_1}{d\log e_1} = \hat{mc}_1,$$

while for $\theta_1 = 1$, we have

$$\sum_k \theta_k \frac{d\log p_k}{d\log e_1} = \frac{d\log p_1}{d\log e_1},$$

and so again

$$\frac{d\log p_1}{d\log e_1} = \hat{mc}_1.$$

Thus, pass-through is complete for zero market share and 100% market share, while pass-through is incomplete for intermediate market shares $0 < \theta_1 < 1$. Thus, pass-through is U shaped in firm market share. ■

Appendix C. Data details

The trade transaction data from the Canadian Border Services (CBSA) is confidential data housed at Statistics Canada. This means that the data can only be accessed at the Statistics Canada head offices in Ottawa, and all statistics and results derived from the data must be screened before release. The data is provided in monthly files that cover all commercial imports into Canada within that month. Each monthly file has over five million observations, and with 72 months of data, we have just under 400 million observations.

As mentioned, the data set provides information on the number of units in a shipment of a given 10-digit HS code product (as well as the unit of measurement) and the total value of the shipment (in the currency of invoice, as well as in Canadian dollars, if this is not the currency of invoice), which allows us to back out a unit price. However, for many shipments the number of units (or to a lesser extent, the value of the shipment) are not reported, which precludes the calculation of a unit price. In some months, up to 50% of observations do not have the number of units reported.

In examining the data, we found that these missing values for the number of units were generally concentrated in certain products types rather than being spread evenly across products. We therefore wrote a program that keeps only those 4-digit HS products for which at least 85% of the observations had unit prices that could be calculated. For most products, the percentage of observations that had associated unit prices was close to 100%. It was primarily in the consumer electronics category where the percentage of reported number of units was a bit lower. We include the consumer electronics product category to ensure that we have a broad set of products that includes heavier manufacturing consumer goods.

Note that due to the size of the full data set, we were unable to simply stack the monthly observations to undertake analysis with the full data set. Therefore, we worked with the monthly data sets to identify candidate product classes, and then pulled these products from the monthly data sets and stacked the monthly observations. At that point we double checked to ensure that unit prices could be calculated for at least 85% of the product observations.

After cleaning the data set in this way, we were left with nine 2-digit HS product categories and just over 37 million observations. These nine product categories account for roughly 40% of the total value of Canadian imports in any given year, and represent a wide range of product types—non-durables (i.e. vegetable products) and durables (i.e. consumer electronics), consumer goods (i.e. apparel and footwear) and intermediate goods (i.e. metal products), and light manufacturing (i.e. textiles) and heavy manufacturing (i.e. industrial machinery).

The next step was to convert these data into data that could be used for the analysis of exchange rate pass-through. Within a given month, shipments of the same product can enter into Canada multiple times. It is therefore difficult to track the price of a single good over time. Moreover, even though the 10-digit HS code identifies a fairly specific product, there can still be variation in product characteristics within these 10-digit codes (i.e. quality, color, size). For this reason, we decided to define a product based on a number of other criteria. That is, we define a product s as being specific to an exporting firm, importing firm, ten-digit HS code, country of origin, country of export, currency, and unit of measurement. With this definition of a product, we then combined all unit price observations of a product within a month into a single price. This provides us with monthly data that can be used to construct price changes for the estimation of exchange rate pass-through.

C.1. Importer and exporter identifiers

Importantly, the data set provides firm identifiers for the exporting firm and the importing firm. Importing firms are identified off of their importer identification numbers (we do not actually observe these numbers, but are provided with a scrambled identifier that can be used to track a single importer over time). For exporters, the companies names provided on the import documentation have been used by researchers at Statistics Canada to create firm identifiers. These identifiers refer to the firm responsible for the final shipment of the good to the Canadian border. Therefore

these firms are not necessarily the producer of the good and may be intermediaries. For all exporters, a name-matching algorithm was used, and for U.S. based exporters, this was cross referenced with the state of export (a variable available in the data). Because the exporter is only identified off of the company name listed on the import form, there could be some measurement error associated with firms that list substantially different company names on different forms.

C.2. Country of origin and export

In the identification of a product s, we distinguish between the country of origin and the country of export of a good. The country of origin is determined based on the World Trade Organization rules of origin. The exact rules for determining the country of export are complicated, but can generally be understood as follows (this information is based on discussions with officials at the CBSA). If a good is shipped directly from the country of origin to Canada, the country of export will be the same as the country of origin. This will also be true if the good is shipped to Canada via a third country, but the good does not enter the economy of the third country in any way. More specifically, this means that the good does not clear customs in the intermediary country — i.e. it stays in bond as it passes through the intermediary. Even if a firm located in the intermediary is responsible for the transport of in-bond goods, the country of export will not be the intermediary country (nor will the transport company be the exporter). The country of export will be different from the country of origin if the good clears customs in the intermediary country and therefore enters the intermediary economy. The exporter will always be located in the country of export.

C.3. Data availability for replication

The CBSA data is confidential data and must be accessed at the Statistics Canada head office in Ottawa. For access to the data for replication purposes, proposals can be made to the Canadian Data and Economic Research (CDER) center at Statistics Canada (cder@statcan.gc.ca). Anyone working with the data will have to pass a reliability check to become a deemed employee of Statistics Canada.

Appendix D. Overall pass-through estimates

Table D.1 presents all the coefficient estimates from the overall pass-through regressions. The coefficient estimates on the cumulative changes in exporter CPI, Canadian CPI and GDP are positive, which is as expected.

Table D.1
Overall exchange rate pass-through.

	Value-weighted		Product level	
	Estimate	(s.e.)	Estimate	(s.e.)
Exchange rate (β)	0.592***	(0.030)	0.484***	(0.010)
Exporter CPI	0.038	(0.082)	0.073***	(0.022)
Canadian CPI	1.233***	(0.369)	0.311***	(0.062)
Canadian GDP	0.641**	(0.290)	0.735***	(0.061)
Obs.	7,993,402		7,993,402	
R^2	0.017		0.003	

Note: Each regression includes product and time fixed effects. We restrict the sample to price changes within the −100% to +100% range.

Appendix E. The relationship between elasticity of substitution and importer size

In this section, we use the unique features of our data to test the assumption of our model that larger importers have a higher elasticity of substitution across products. To do so, we exploit the fact that we often observe the same importer importing similar goods from different exporters within the same period. Therefore, variations in the relative prices of these goods over time should lead to changes in the relative quantities imported. Moreover, the larger the importing firm, the more sensitive would be the demand for the substitutable goods in response to changes in relative prices — i.e. these firms have a higher elasticity of substitution.

To test this, consider the following empirical framework. Assume that a given importer, f, in time t, imports similar goods (where a good here is HS10 product (pr), country of origin (o), country of export (ex), currency (c) and unit of measurement (u) specific) from two exporters, $v = \{1,2\}$. In this circumstance, if we let $s = \{pr, o, ex, c, u\}$, then we will observe the unit prices for the two goods, P_{f1st} and P_{f2st}, and the related quantities, Q_{f1st} and Q_{f2st}. If this is not the first time that these products have been imported by this importer, we can then identify the growth rates of prices and quantities for each good as follows:

$$\Delta_\tau p_{fvst} = \ln(P_{fvst}) - \ln(P_{fvs\tau}) \tag{E.1}$$

and

$$\Delta_\tau q_{fvst} = \ln(Q_{fvst}) - \ln(Q_{fvs\tau}) \tag{E.2}$$

where τ is the last period in which good s was imported by firm f from exporter $v = \{1,2\}$. Note that τ may differ for the two exporters (in the data, it would be very difficult—and would severely limit the sample size—if we only match goods with the same τ).

If we then take the difference between the price and quantity changes, we will be able to estimate the relationship between changes in relative prices and relative quantities. We can then define the difference between the price changes and quantities across the two exporters as:

$$\Delta_{e\tau} p_{fvst} = \Delta_\tau p_{f1st} - \Delta_\tau p_{f2st} \tag{E.3}$$

and

$$\Delta_{e\tau} q_{fvst} = \Delta_\tau q_{f1st} - \Delta_\tau q_{f2st}. \tag{E.4}$$

With this, one way to test whether the elasticity of substitution of higher for larger importers is to run the following regression:

$$\Delta_{e\tau} q_{fvst} = \alpha + \beta_1 \Delta_{e\tau} p_{fvst} + \beta_2 MS_{ft} + \beta_3 \left[\Delta_{e\tau} p_{st} \cdot MS_{ft}\right] + \Delta Z'_{st}\gamma + \epsilon_{st} \tag{E.5}$$

where MS_f is the import market share of the importing firm (defined in the same way as in the empirical work in Section 4), Z_{st} is the same set of controls as in Eq. (4.1), and ΔZ_{st} is the relative change in the growth rate of these variables as in Eqs. (E.3) and E.4, except for the product fixed effects, which remain unchanged from Eq. (4.1). The idea here is that the larger the import market share of the importer, the more sensitive relative quantity will be to changes in the relative price. So, we would expect $\beta_1 < 0$ (if we are in fact estimating a demand-side elasticity — more on this below), which means that when the price of one good increases relative to another, firms will reduce the quantity demanded of that good relative to the other. Moreover, if $\beta_3 < 0$, this suggests that larger firms (in terms of import market share) have a higher elasticity of substitution.

In practice, some firms will import more than two similar products from multiple exporters. In this case, we create all pairwise matches between the goods from different exporters for a single importer. For example, if an importer imports three similar goods from three exporters (let the number of exporters of one product to one importer be n_v, so in this case $n_v = 3$), in period t there will be three price and quantities values, like in Eqs. (E.3) and E.4, associated with this importer for this good. If $n_v = 4$, there will be six pairwise matches and observations, if $n_v = 5$, there will be ten matches, and so on.

Most of the time, when we observe an importer importing similar goods from multiple exporters, it is the case that $n_v = 2$, which results in a single matched observation for those two imports. However, if $n_v > 2$, there will be an increasing number of matched observations for the same importer importing similar products. To account for the fact that a single importer with many trade partners could make up a disproportionate number of observations, we assign each importer–product–time triplet an equal weight and then divide that weight by the number of resulting matched observations. In practice, we assign each triplet a weight of one, and if, for example, $n_v = 5$ and there are ten matches, each match receives a $1/10^{\text{th}}$ weight. This will limit the influence of a small number of firms with many trade partners on the overall estimates.

It will be important to think about firms that are simply distributors in this analysis (that is, firms that act only as intermediaries between exporters and importers), as their quantity demanded in response to changes in prices may differ from other importing firms. Factors such as maintaining product diversity and demand of specific buyers may affect the relationship between demand elasticities and observed firm size. Unfortunately, the data does not allow us to identify importing firms' characteristics. To address this issue, we carry out our estimation on various samples based on the number of trade partners. We do this because firms with many trade partners for similar products at the same time are more likely to be distributors and are therefore less likely to have a meaningful relationship between market share and the elasticity of substitution.

The estimation results are presented in Table E.1. We estimate Eq. (E.5) by restricting the sample based on the number of trade partners. In column (I), we restrict the sample to those firms that have only two trade partners for a similar good at the same time ($n_{\max} = 2$). In columns (II), (III) and (IV), we include firms with up to five ($n_{\max} = 5$), ten ($n_{\max} = 10$) and thirty ($n_{\max} = 30$) trade partners, respectively. All estimates include time and product fixed effects, and the errors are clustered at the HS10 level.

In column (I), we can see that both the estimates of β_1 and β_3 are negative and statistically significant at the 1% level. This suggests that when the relative price of one good increases, the relative demand for that good decreases, and, moreover, that this elasticity is larger (in absolute value) the higher the market share of the firm. To put this in perspective, the demand elasticity is 24% higher for a firm with 50% import market share versus a firm with near zero import market share; a firm with 100% import market share with have a demand elasticity 50% higher that a firm with near zero import market share.

In column (II), we include all observations of those importers that import a similar product from up to five exporters. The results here are similar: the estimates of both β_1 and β_3 are negative, but the significance level on β_3 is now lower at 10%. Once we allow $n_{\max}$ to equal 10 and 30 (columns III and IV), both estimates remain negative, but the estimate of β_3 become smaller and statistically insignificant. Because of the concern mentioned above that we are capturing more the behavior of distributors when we include increasing number of trade transactions of similar products (as in columns III and IV), we believe that most emphasis should be put on the results in columns(I) and (II). In particular, the results in column (I) provide us with the cleanest test of our hypothesis concerning the relationship between the elasticity of substitution and import market share.[40]

There are two important caveats that should be considered when interpreting these results. First, small firms are less likely to import similar products from different exporters in a single month. In constructing the data to estimate Eq. (E.5), we drop observations of those firms that do not import similar products from multiple exporters in the same period, and therefore we are more likely to drop smaller firms than larger firms. However, we still have many very small firms in the regression sample and the distribution of firm sizes covers the same range of values as the full sample. Second, we are only tracking quantity adjustment on the intensive margin—i.e. an increase in the relative price of one good leads to a reduction in quantity demanded for that product, but demand remains positive—and do not track adjustment on the extensive margin—i.e. an increase in the relative price drives the importing firm demand for that good to zero. Our data do not allow us to track adjustment on the extensive margin in any consistent way.

Finally, our methodology for identifying differences in the elasticity of demand across firms of different sizes resembles the methodologies outlined in Feenstra (1994), Leamer (1981), and Broda and Weinstein (2006), but differs in several keys ways. Because our aim is to identify differences only in the elasticity on the demand side, we do not run the full "two-sided" models of Feenstra and Broda and Weinstein that allow for estimates of the elasticity of demand and supply. In this way, our methodology is closer to Leamer's in that we regress quantity imported on prices and since $\hat{\beta}_1$ is negative, we assume this can be thought of as an *attenuated* estimate of the import demand elasticity. We then use the interaction between import market share and prices to detect differences in the demand elasticity across importers. Unlike Leamer, we do not run the reverse regression (prices on quantity) in an attempt to create bounds on the set of potential values of the elasticity of demand, but rather rely on non-linearities in the *attenuated* demand elasticity estimate with respect to market share to identify differences in elasticity based on the import market share of the importer. As in Feenstra (1994) and Broda and Weinstein (2006), we rely on variation across time and across goods to eliminate good- and time-specific unobservables. Implementing the full Feenstra or Broda and Weinstein procedures

Table E.1
Import market share and the elasticity of substitution.

	(I) $n_{\max} = 2$	(II) $n_{\max} = 5$	(III) $n_{\max} = 10$	(IV) $n_{\max} = 30$
$\Delta_{e\tau} p_{fvst}$	−0.687***	−0.694***	−0.696***	−0.696***
	(0.014)	(0.013)	(0.013)	(0.013)
Importer import	−0.008	0.001	0.002	0.001
market share	(0.041)	(0.029)	(0.026)	(0.025)
$\Delta_{e\tau} p_{fvst}$ • (Importer MS)	−0.332***	−0.214*	−0.142	−0.052
	(0.120)	(0.129)	(0.137)	(0.158)
Constant	−0.010	−0.010	−0.007	-0.007
	(0.030)	(0.022)	(0.021)	(0.021)
Controls	Yes	Yes	Yes	Yes
Product fixed effects	Yes	Yes	Yes	Yes
Obs.	496,903	1,535,025	2,485,613	3,875,855
R^2	0.032	0.033	0.034	0.034

Note: Each regression includes HS10 product and time fixed effects. We restrict the sample to price changes within the −100% to +100% range. The standard errors are clustered at the HS10 level.

[40] We also allowed for higher order terms in the interaction between the exchange rate and market share in these regressions. While we find some significance in higher order interaction terms, we find that there is still a positive relationship between the importing firms market share and the (absolute) elasticity of demand. Since we have no theoretical argument governing the curvature of this relationship besides the prediction that the relationship itself is positive, we rely on the first order terms in order to support our hypothesis.

would be very difficult given the our definition of a good, since for many *st* observations we do not have a long time-series. Finally, our theoretical model described above characterizes Canadian importing firms as price takers. To the extent that this assumption is justified, it lessens the need to use an instrumental variables strategy for price variation in these regressions.

Appendix F. Import market share and pass-through over time

There is a literature on the evolution of exchange rate pass-through to prices. In particular, several studies have looked into whether exchange rate pass-through to import prices may have declined in recent years in industrialized countries (Bouakez and Rebei, 2008; Dong, 2012; Marazzi and Sheets, 2007). In this section, we explore how changes in import market shares over time may be related to changes in aggregate pass-through over time. We start by running weighted rolling regressions to get an estimate of pass-through over time. Specifically, we run the regression Eq. (4.1) on 12-month windows, moving up one month at a time. Our price-change data set covers 70 months; therefore, the rolling-window method allows us to derive 58 pass-through estimates. We present the value-weighted pass-through estimates in Fig. F.1, with the dates on the horizontal axis referring to the point at which the start of the rolling window is January of the given year. The large swings in pass-through over a relatively short period of time are striking. At the start of the sample period, pass-through is just over 50%. By around 2004, pass-through has increased to just under 80%. Pass-through then declines and hovers around 50% from 2006 onwards.

Also in Fig. F.1, we present the share of the total value of imports accounted for by importers and exporters that fall within the third to fifth quintiles of the import market share distribution. Again, for comparison purposes, these numbers are calculated by applying the same rolling windows used in the pass-through regressions. The third to fifth quintiles were selected for the importers to reflect the point at which there is strong evidence that pass-through is lower for larger importers. We can see that the share of imports accounted for by larger importers increased from about 16% at the start of the sample to almost 21% by 2005, before decreasing slightly at the end of the sample to 19%. While there is not a perfect coincidence of the increase in import market share of large importers and the decrease in measured pass-through, the general trends suggest that the larger the import market share of large importers, the lower is overall pass-through.

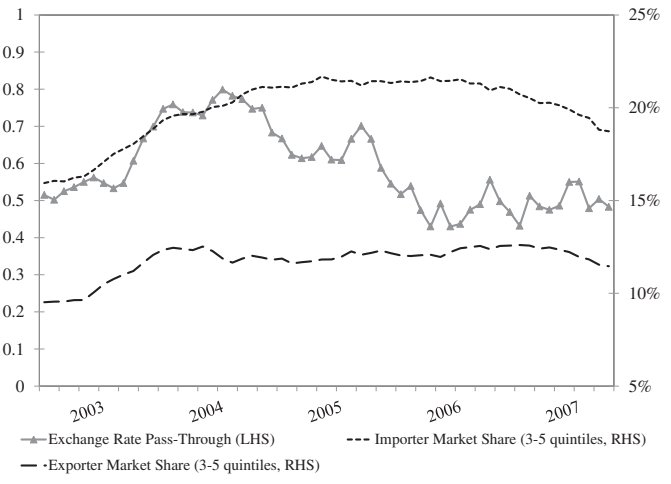

Fig. F.1. Exchange rate pass-through and import market share over time.

As for exporters, given the fact that there is a U-shaped relationship between pass-through and import market share, it is unclear how to best group exporters. Nevertheless, we add together the market share quintiles three through five to be consistent with what we have done on the importer side. Fig. F.1 shows that the share of imports accounted for by larger exporters (in terms of import market share) increased slightly in about the first year of the sample—from roughly 10 to 12%—but then stayed relatively flat. The increase at the start of the sample could be associated with the initial increase in overall pass-through if import market share is shifting toward larger exporters that are located on the upward-sloping section of the U-shaped relationship between pass-through and market share.

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