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Imported Inputs and Invoicing Currency Choice: Theory and Evidence from UK Transaction Data*

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Abstract

A significant proportion of international trade is in intermediate goods. This paper considers theoretically and empirically how exporters' dependence on imported inputs affects their choice of invoicing currency. The model predicts that exporters that depend more on foreign currency-denominated inputs are less likely to price in their home currency. I test this and other theoretical results using a novel dataset that covers UK trade transactions with non-EU countries. I find considerable support for the model's predictions. A 10 percentage point higher share of foreign currency-denominated inputs is associated with a 20 percentage point higher probability of pricing in the same foreign currency relative to the producer's currency.

JEL Classification: F1, F31, F41.
Keywords: Currency of Invoicing; Imported Inputs; UK Trade.

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1 Introduction

The currency denomination of international trade has real effects on the macroeconomy. When prices are sticky, the currency in which goods are priced determines how trade balances and domestic prices respond to changes in exchange rates. Whether prices are set in the exporter's currency (producer currency pricing, PCP) or the importer's currency (local currency pricing, LCP) has been a long-debated issue for modelling in the open economy macroeconomics literature. Early work has also documented the far-ranging policy implications of the choice of invoicing currency for the international transmission of macroeconomic shocks, the effectiveness of monetary policy, and the choice of exchange rate regimes.[1]

However, it is only recently that firms' invoicing currency choice has been considered endogenous in theory and linked to endogenous exchange rate pass-through (e.g., Devereux et al., 2004; Engel, 2006; Gopinath et al., 2010). A fundamental question, then, is what determines the invoicing currency choice. This paper addresses the question and, in particular, theoretically and empirically examines whether exporters' dependence on imported inputs determines their invoicing currency choice.

To guide the empirical strategy, I develop a theoretical framework that features firm heterogeneity in the degree of dependence on imported inputs together with endogenous invoicing currency choice. In a two-country setting with exchange rate uncertainty, the profit-maximizing exporter is assumed to optimally preset prices in a chosen invoicing currency, taking foreign input prices (denominated in the foreign currency) as given. The theoretical results formulate two testable hypotheses that relate imported inputs to firms' choice of invoicing currency. First, exporters that depend more on imported inputs are less likely to use their home currency. This result is consistent with the intuition that exporters using foreign currency-denominated inputs have a hedging incentive to set prices in the same foreign currency to minimize exchange rate risks. However, note that firms are assumed to be risk-neutral in the model.[2] The second prediction is that firms that do not depend on imported inputs are more likely to use their home currency, everything else being equal.

Further, I test the theory's predictions using a novel and rich dataset of the UK's non-EU trade statistics, recorded by Her Majesty's Revenue and Customs (HMRC). The dataset contains 2.54 million export transactions and 7.31 million import transactions

[1] Betts and Devereux (1996) are the first to introduce LCP, as opposed to the assumption of PCP in the Redux model (Obstfeld and Rogoff, 1995) in the new open economy macroeconomics (NOEM) literature. Devereux and Engel (2003) allow prices to be exogenously set in both. See, among others, Corsetti and Pesenti (2005) and Devereux and Engel (2002) for the implications for monetary and exchange rate policies.

[2] Technically, this result comes from the curvatures of the revenue and cost functions. Also, see previous studies such as Baron (1976), Giovannini (1988), Donnenfeld and Zilcha (1991), and Friberg (1998).

in 2011. A distinctive feature of the data is that for each transaction, both invoicing currency and firm identity are recorded, along with the country of dispatch or destination, product and industry codes, statistical values, and other custom variables. Thus, I can match import and export data to identify each exporter's dependence on imported inputs together with the currency denomination of these inputs.[3]

I start the empirical analysis by documenting a large variation in invoicing currency choice across destinations and industries. For example, the share of exports priced in British pounds is approximately 55 percent for the manufacturing industry, whereas the share is close to 70 percent for the food industry. Additionally, exports to the US have the highest share of LCP (47 percent in dollars) among all destinations. Next, I review the stylized facts about the different patterns of invoicing currency choice between importing exporters and non-importing exporters. In particular, three quarters of non-importing exporters (26,618 firms in total) use only the pound as an invoicing currency, whereas the fraction declines to only half for importing exporters (32,289 firms in total). These findings point to firm characteristics as the main explanation for such discrepancies in invoicing currency choice because these two groups do not differ systematically in industry presence, export destination, and the type of goods.

As suggested by the theory, the main empirical specification relates invoicing currency choice to firms' import behavior and the currency denomination of their inputs. The results provide strong support for the theory that importing exporters are less likely to use PCP compared with non-importing exporters after controlling for firm size, destination, and industry effects. Specifically, a 10 percentage point higher share of foreign currency-denominated inputs is associated with a 20 percentage point higher probability of LCP relative to PCP. Furthermore, among importing exporters, a firm with a share of pound-denominated inputs at the 75^{th} percentile is approximately 40 percent less likely to use LCP relative to PCP compared with a firm whose imported inputs are all priced in foreign currencies. The findings also relate currency choice to other firm characteristics. For instance, larger exporters are less inclined to use PCP, a finding that supports the argument that larger firms are more likely to hedge using financial instruments.[4]

In practice, goods may be priced in a third currency other than the exporter's and the importer's currency. This option—namely, vehicle currency pricing (VCP)—is indeed present in the UK trade data and it accounts for 56 percent of imports and 28 percent

[3] The categorization of goods is based on the Broad Economic Categories (BEC) which decomposes goods into three end-use categories: consumption (final), intermediate, and capital goods. I treat both intermediate and capital goods as industrial inputs. Trade in intermediate goods is also related to the following terms: vertical specialization, outsourcing, and fragmentation. See, e.g., Hummels et al. (2001) for definitions.

[4] This argument states that hedging incurs a fixed cost that large firms are more able to afford. See, for instance, Martin and Méjean (2012) for the survey results of 3,013 exporting firms located in five Economic and Monetary Union (EMU) countries.

of exports (primarily in dollars). In a separate section of extensions, I first extend the two-country model to allow for the option of VCP and the use of VCP inputs. As in the two-country framework, the model identifies a similar channel through which input currency denomination affects invoicing currency choice. It predicts that VCP is more likely for exporters with a higher share of VCP inputs, a result strongly supported by the UK trade data.[5]

To complement the main analysis, I review the 2011 currency denomination of UK imports and examine whether the use of imported inputs determines currency denomination at the country level. I use a systematic measure of value added to gross exports (VAX ratios)—computed by Johnson and Noguera (2012)—as a proxy for a country's dependence on imported inputs. If a country heavily relies on imported inputs, the value added to gross exports should be lower by definition. Hence, VAX ratios are inversely related to the dependence on imported inputs. I find that countries that depend more on foreign inputs systematically use less of their home currencies for exports.[6]

This paper is complementary to existing theoretical studies on the determinants of invoicing currency. My theoretical framework is closely related to Engel (2006), who provides the insight that a higher share of costs incurred in the foreign currency is associated with more LCP and a lower exchange rate pass-through via an equivalence result. This result also offers an alternative intuition other than firms' hedging incentives for explaining the deviation from PCP. When a firm would prefer a low pass-through were it to adjust prices freely, it is more likely to use LCP. The main departure I make from this literature is to introduce a specific two-tier production structure that features firm heterogeneity in the degree of dependence on imported inputs.[7] In the robustness check section, I control for a number of other factors discussed in the vast literature on invoicing currency choice: (i) macroeconomic considerations, such as exchange rate volatility (Devereux et al., 2004) and the transaction costs of exchange (Devereux and Shi, 2013); (ii) strategic characteristics, such as bargaining between exporters and importers (Goldberg and Tille, 2008); and (iii) goods characteristics (Bacchetta and van Wincoop, 2003, 2005).

Furthermore, this paper contributes to the empirical literature on the currency denomination of international trade, which is relatively scarce. The lack of empirical evi-

[5] However, other theoretical predictions that relate VCP to exchange rate movements are not supported by the data. These findings may suggest that VCP is due to firms' other considerations such as the transaction costs of exchange (Devereux and Shi, 2013) and an industry coalescing effect (Goldberg and Tille, 2008), rather than firms' profit-maximizing behavior. It may also be the case that the theory introduced is lacking in some way and hence cannot reconcile all pricing strategies.

[6] I also use a further disaggregated VAX ratio at the country-industry level and the results still hold. These ratios are computed by Johnson and Noguera on the basis of the GTAP database and are not published in their paper.

[7] Engel (2006) provides an example of the decision rule that encompasses many other models with the assumption that the cost function is homogeneous of degree one. My model deviates from this assumption and, hence, does not belong to one of these special cases.

dence is in large part due to a lack of disaggregated datasets. For a long time, little was known beyond several stylized facts based primarily on aggregated data.[8] For instance, trade in primary products is mostly denominated in US dollars, whereas trade between developing and industrialized countries is predominantly invoiced in the industrialized country's currency. Also, the fact that inflationary currencies are less likely to be used is documented.[9] Some studies turn to a survey approach, such as Friberg and Wilander (2008) for Swedish exporters and Ito et al. (2010) for Japanese exporters. More recent literature has also seen new evidence from disaggregated data, for instance, Goldberg and Tille (2009) with Canadian import transactions. This paper adds new firm-level evidence to the empirical literature, with a particular focus on imported inputs as a key determinant for invoicing currency choice.

This paper also relates to the growing body of literature on endogenous exchange rate pass-through that examines the role of either imported inputs or invoicing currency choice, or the interaction of both. For example, Amiti et al. (2014) document the direct link between imported inputs and pass-through. In contrast to my focus on currency choice, they highlight the interaction between variable markups and market shares as the underlying channel contributing to the variation in pass-through across firms. Concerning invoicing currency, Gopinath et al. (2010) show a large difference in the pass-through of the average good priced in dollars versus non-dollars.[10] They further consider the cost sensitivity of firms to exchange rate shocks (which directly relates to imported inputs) for determining incomplete pass-through in a calibration exercise, as an empirical implementation of the theoretical result of Engel (2006). Consistent with these implications, my findings provide direct firm-level evidence showing that exporters that depend more on imported inputs are more likely to use LCP.

The paper is structured as follows. The next section presents a simple model to demonstrate how firms' choice of invoicing currency is affected by the presence of imported inputs. Section 3 describes the dataset and documents new stylized patterns of invoicing currency choice in the data. Section 4 presents the main empirical findings. Section 5 first extends the analysis to VCP and then provides country-level evidence of the effect of imported inputs on invoicing currency choice. Section 6 concludes.

[8] One example is Donnenfeld and Haug (2003) who consider country size and exchange rate uncertainty as key determinants for the invoicing currency choice of Canadian imports. Additionally, Wilander (2005) analyzes currency use for Swedish exports using country aggregates such as GDP, distance, and inflation rates as explanatory variables.

[9] See, for example, Grassman (1973), McKinnon (1979) and Tavlas (1997) for the early studies.

[10] See, also, Floden and Wilander (2006) for the theoretical link between firms' price adjustments and invoicing currency choice, and Gopinath and Itskhoki (2010) for the empirical evidence from the US.

2 Theoretical Framework

In this section, I develop a framework that relates invoicing currency choice to firms' dependence on imported inputs, both of which are endogenously determined. The two main ingredients of the framework are the Halpern et al. (in press) model of the firm's choice to import foreign inputs and the Engel (2006) model of endogenous invoicing currency choice under exchange rate uncertainty.[11] Detailed model derivations are shown in Appendix A.

To focus the analysis on the link between imported inputs and invoicing currency choice, I make a number of simplifying assumptions. First, I assume that exporters take the prices and the currency denomination of foreign inputs as given. In fact, some exporters could negotiate with their trading partners for a desirable currency—a practice documented by Friberg and Wilander (2008) and Goldberg and Tille (2009). If exporters are allowed to decide on the currency in which their imported inputs are denominated, how would they choose, taking the currency denomination of exports as given? An intuitive guess is that the currency used for exports is more likely to be selected for imports. However, given any price quotes for the foreign inputs (for example, a payment of USD 100 or GBP 65), cost minimization ensures that the firm always selects the cheaper deal based on its own (known) expected value of the exchange rate, regardless of its quantity demanded and import intensity. Thus, exchange rate uncertainty plays no role in the input currency choice for price takers. From a modelling perspective, this could be easily incorporated into the model.[12]

Second, I assume that all imported inputs are denominated in the foreign currency. The model could be extended to allow for a fraction of the imported inputs to be denominated in the home currency. This extension reduces the degree of input price uncertainty but does not qualitatively change the model's predictions. In the empirical analysis, I take into account each firm's share of imported inputs denominated in the home currency.

Lastly, the two-country framework excludes the possibility of VCP. The framework can also be extended to allow for imported inputs from a third country and the option of VCP. In this case, the firm's decision rule also depends on the covariance between the two exchange rates vis-à-vis the vehicle currency. This model extension and the empirical evidence of VCP are discussed in Section 5.1.

[11] Halpern et al. (in press) focus on the relationship between firms' choice of import varieties and productivity.

[12] Note that under monopolistic competition exporters choose their own invoicing currency for exports. Following a similar logic, their trading partners (foreign importers) could also negotiate for a desirable currency. In the robustness section of the empirical analysis, I control for the bargaining power of importers and exporters.

2.1 Demand

Consider a risk-neutral firm i that sells a differentiated good to a foreign country and faces a CES demand function:

$$D\left(p_i\right) = \left(\frac{p_i}{P^*_{hf}}\right)^{-\lambda} \left(\frac{P^*_{hf}}{P^*}\right)^{-\delta} D^*, \tag{1}$$

where D is the quantity demanded, p_i is the firm's price, P^*_{hf} is the price index for all domestic goods sold in the foreign country, and P^* is the foreign consumer price index (all denominated in the foreign currency). D^* is the foreign demand shifter that is independent of prices. The parameter λ is the elasticity of substitution across varieties with $\lambda > 1$. The parameter δ is the foreign elasticity of demand for domestic goods.

2.2 Production and Import Intensity

The firm uses labor L_i and intermediate goods X_i to produce, following a Cobb-Douglas production function with constant returns to scale given by

$$Y_i = A_i X_i^{\gamma} L_i^{1-\gamma}, \tag{2}$$

where A_i is the firm's productivity and $\gamma \in [0, 1]$ measures the expenditure share on intermediate inputs. The cost of labor is the wage rate W.

Intermediate goods comprise two varieties—domestic and foreign—that are imperfect substitutes:

$$X_i = \left[Z_i^{\frac{\theta}{1+\theta}} + \left(a_i M_i\right)^{\frac{\theta}{1+\theta}} \right]^{\frac{1+\theta}{\theta}}, \tag{3}$$

where Z_i and M_i are the quantities of domestic and imported inputs, respectively. The elasticity of substitution between domestic and foreign varieties is $(1+\theta) > 1$.[13] I assume that the price of the domestic input Z_i is Q, denominated in the home currency. The price of the foreign input M_i is SQ^*, S being the exchange rate (defined as the domestic price of foreign currency), and Q^* being the price denominated in the foreign currency.

The parameter a_i captures the productivity of firm i in using foreign inputs, which in this model varies across firms and directly determines the degree of dependence on imported inputs. A high a_i represents a high productivity advantage for firm i in using foreign inputs, and vice versa.[14]

[13] As domestic and foreign inputs are imperfect substitutes, production is possible without the use of imported inputs. Note that the model also accommodates the cases of perfect substitutes (when $\theta \to \infty$) and perfect complements (when $\theta \to 0$). In the Appendix, I discuss firms' use of imported inputs and their decision rules in these cases.

[14] When $a_i > 1$, using foreign inputs brings productivity advantages. In contrast, $a_i < 1$ implies

The firm pays a sunk cost f_i in terms of labor for importing foreign inputs.[15] Given any output level, the firm first chooses the amount of inputs to minimize its total cost subject to the production technology. The total cost of the firm is given by $WL_i + QZ_i + SQ^*M_i + Wf_i$, which can be written as the sum of a variable cost plus a fixed cost:

$$TC_i = \mu_i Y + Wf_i.$$

The marginal cost μ_i can be derived as

$$\mu_i = \frac{C}{A_i b_i^{\gamma}}, \tag{4}$$

where $C = (Q/\gamma)^{\gamma} [W/(1-\gamma)]^{1-\gamma}$ is a cost index and $b_i \equiv \left[1 + \left(\frac{a_i}{SQ^*/Q}\right)^{\theta}\right]^{1/\theta}$ is the productivity-enhancing effect from using imported inputs. The productivity-enhancing effect is increasing in the productivity parameter a_i.

Using this cost structure, I define ψ_i as the share of costs spent on imported inputs in the total costs of intermediate goods:

$$\psi_i \equiv \frac{SQ^*M_i}{SQ^*M_i + QZ_i}.$$

The parameter ψ_i directly captures the firm's degree of dependence on foreign inputs. The home share of inputs $(1 - \psi_i)$ can be shown as

$$1 - \psi_i = \left[1 + \left(\frac{a_i}{SQ^*/Q}\right)^{\theta}\right]^{-1} = b_i^{-\theta}. \tag{5}$$

The home share of inputs depends on the productivity parameter a_i. A firm with a higher productivity gain from using imported inputs (higher a_i and, accordingly, higher b_i) has a stronger dependence on imported inputs and a lower home share of inputs.

2.3 PCP versus LCP

After deciding on the amount of inputs, the firm is then assumed to preset the prices and invoicing currency one period ahead by maximizing its expected profits with a discount

productivity disadvantages. The price-adjusted productivity, $a_i/(SQ^*/Q)$, captures the advantage of a unit of home currency spent on the foreign variety relative to the home variety. This term also relates to the definition of quality by Grossman and Helpman (1993) as the advantage in services provided by a good relative to its cost.

[15] Fixed costs can explain the fact that some firms do not import foreign inputs. The model can be extended to incorporate a set of differentiated intermediate goods, such that fixed costs play a role in determining the optimal choice of the cut-off set. This extension does not change the model's predictions on currency choice.

factor κ.[16] If the firm sets its price in the home currency (i.e., PCP), then the expected discounted profits are

$$E\Pi_i^{PCP}(p_i) = E\left[\kappa\left(p_i - \mu_i\right)\left(\frac{p_i}{SP_{hf}^*}\right)^{-\lambda}\left(\frac{P_{hf}^*}{P^*}\right)^{-\delta} D^*\right]. \tag{6}$$

If the firm sets its price in the foreign currency (i.e., LCP), then the expected discounted profits are

$$E\Pi_i^{LCP}(p_i^*) = E\left[\kappa\left(Sp_i^* - \mu_i\right)\left(\frac{p_i^*}{P_{hf}^*}\right)^{-\lambda}\left(\frac{P_{hf}^*}{P^*}\right)^{-\delta} D^*\right]. \tag{7}$$

The profit-maximizing prices under PCP and LCP, respectively, are

$$p_i = \frac{\lambda}{\lambda - 1} \cdot \frac{E\left(\mu_i \cdot S^{\lambda}\Omega\right)}{E\left(S^{\lambda}\Omega\right)}, \tag{8}$$

$$p_i^* = \frac{\lambda}{\lambda - 1} \cdot \frac{E\left(\mu_i \cdot \Omega\right)}{E\left(S\Omega\right)}, \tag{9}$$

where $\Omega = \kappa P_{hf}^{*(\lambda-\delta)} P^{*\delta} D^*$. By substituting these optimal prices into the two expected profit functions and taking a second-order approximation, I obtain the firm's decision rule for invoicing currency choice. A domestic firm using foreign inputs sets its price for the foreign market in PCP if

$$\frac{1}{2} var\left(\ln S\right) > \frac{\gamma}{\theta} cov\left[\ln\left(1 - \psi_i\right), \ln S\right], \tag{10}$$

and in LCP if vice versa. This decision rule states that all else being equal, exchange rate volatility makes the firm prefer PCP. In contrast, the covariance between exchange rates and the home share of inputs $(1-\psi_i)$ makes the firm prefer LCP. The former effect captures the firm's consideration of expected revenues, whereas the latter captures the consideration of expected costs. I discuss the two effects in turn.

Exchange rate volatility on the left-hand side of (10) enters the decision rule through the firm's consideration of expected revenues. When the firm chooses PCP, the price is certain, and the quantity (foreign demand) is subject to exchange rate uncertainty. In contrast, when the firm chooses LCP, the quantity is certain, and the price is subject to exchange rate uncertainty. Hence, the firm faces a trade-off between stabilizing price and stabilizing quantity. In this case, the curvature of the revenue functions matters for the optimal currency choice. Technically, the expected revenue function under PCP

[16] Note that the expectation occurs in period $t-1$ when the firm sets its price for period t. The time subscripts are omitted for simplicity.

is convex in the exchange rate and linear under LCP.[17] Therefore, the model predicts that an increase in the exchange rate variance increases the expected revenues under PCP relative to LCP, a finding that is consistent with Devereux et al. (2004) and Engel (2006).

The covariance between exchange rates and the home share of inputs on the right-hand side of (10) enters the decision rule through the firm's consideration of expected costs. For example, if the home currency depreciates (higher S), foreign inputs become more expensive, leading to a higher marginal cost. In this case, the firm incurs a cost from switching from imported inputs to domestic inputs (higher $1-\psi_i$). The covariance term is positive and captures the firm's responsiveness to input price uncertainty. All else being equal, a more responsive firm has a stronger incentive to choose LCP. Additionally, this effect is stronger if the domestic and foreign inputs are less substitutable (with a lower elasticity of substitution θ).

To determine the link between the degree of dependence on imported inputs and invoicing currency choice, I rewrite the right-hand side of (10) in terms of the productivity-enhancing effect b_i using equation (5): $R.H.S = -\gamma cov\left(\ln b_i, \ln S\right)$. Next, I prove that this term is positive and increasing in the degree of dependence on imported inputs ψ_i because $\partial \ln b_i / \partial \ln S = -\psi_i < 0$. These results suggest that a firm with a higher ψ_i is more responsive to exchange rate uncertainty and, hence, more likely to use LCP. Intuitively, when costs are incurred in the foreign currency, choosing LCP provides a natural hedge for the firm. However, note that the result holds for risk-neutral firms in the model.

Through these discussions, I summarize the theoretical results in Proposition 1 and formulate its corollary as follows.

Proposition 1 *A domestic firm that depends more on foreign currency-denominated inputs is more likely to use LCP (relative to PCP) for exports.*

Corollary (to Proposition **1**) *A domestic firm with a higher share of imported inputs denominated in the home currency is less likely to use LCP (relative to PCP) for exports.*

Note that in the model, exchange rates only affect the firm's total costs through using imported inputs denominated in the foreign currency. Therefore, for firms that do not use imported inputs ($\psi_i = 0$), the decision rule for PCP in equation (10) now reads $var\left(\ln S\right) > 0$. This result implies a dominant PCP for firms that do not use imported inputs, a pattern that I document in the descriptive statistics in Section 3. This model prediction is summarized as Proposition 2.

[17] The expected revenue functions are $E\left[p_i \left(p_i / S P^*_{hf}\right)^{-\lambda} \left(P^*_{hf}/P^*\right)^{-\delta} D^*\right]$ under PCP and $E\left[S p^*_i \left(p^*_i / P^*_{hf}\right)^{-\lambda} \left(P^*_{hf}/P^*\right)^{-\delta} D^*\right]$ under LCP.

Proposition 2 *Given any exchange rate volatility, firms that do not use imported inputs are more likely to use PCP for exports, everything else being equal.*

3 Data and Stylized Facts

In this section, I start by describing the dataset used for the empirical analysis. Next, I provide a broad assessment of the currency denomination of UK trade, followed by the stylized facts about importing exporters (i.e., firms that use imported inputs) and non-importing exporters.

The main data source is a highly disaggregated dataset of UK trade from HMRC, which is only available to approved projects. The sample used in this paper includes all UK trade transactions outside the euro zone in 2011.[18] For each trade transaction, I observe a unique trader identifier, the country of dispatch (for imports) or destination (for exports), product code, industry code, statistical value, and the invoicing currency of the transaction. After dropping observations with no information on invoicing currency, the remaining sample accounts for 95.1 percent of total imports (7.31 million observations) and 86.3 percent of total exports (2.54 million observations).

Arguably, one advantage of the UK trade data is the diversity in trading partners. In 2011, the total number of trading partners was approximately 190 for both imports and exports. The main partners are the US—which represents 16 percent of imports and 29 percent of exports—and China—which accounts for 15 percent of imports and 6 percent of exports.[19] This dataset ensures that the analysis in this paper fairly represents a small open economy in international trade rather than a special case with only a few trading partners.

3.1 A Broad Assessment of the Currency Denomination of UK Trade

Interestingly, the number of currencies used in UK trade is quite high, with 76 currencies used for exports and 103 for imports. However, when considering trade value, major currencies such as the pound sterling and the US dollar still dominate as an invoicing currency. Table 1 displays these trade shares and the shares in terms of pricing strategies (PCP, LCP, and VCP). I first observe an asymmetry in the currency denomination of exports and imports: the dominant currency for imports is the US dollar (64.7 percent),

[18] The full HMRC dataset covers complete UK trade transactions between 1996 and 2013. Declaring the invoicing currency became a requirement after 2010 for non-EU imports and after 2011 for exports (for transaction value greater than £100,000). In 2011, non-EU imports accounted for 49.5 percent of the total UK imports and non-EU exports accounted for 46.5 percent of the total UK exports.

[19] These 190 trading partners include countries and autonomous areas, such as Hong Kong. Other main partners are East and Southeast Asia (25 percent of imports and 21 percent of exports) and Europe excluding EU countries (21 percent of imports and 26 percent of exports).

Table 1: Currency of Invoicing in UK Trade with non-EU Countries

	Imports	Exports
Shares of Currency Choice (percent)		
Pound Sterling (£)	24.5	57.4
US dollar ($)	64.7	37.1
Euro (€)	5.3	2.8
Others	5.5	2.7
Sum	100.0	100.0
Shares of Pricing Strategy (percent)		
Producer Currency Pricing (PCP)	18.8	57.4(£)
Local Currency Pricing (LCP)	24.5(£)	14.0
Vehicle Currency Pricing (VCP)	56.7	28.6
Sum	100.0	100.0

whereas exports are primarily priced in pounds (57.4 percent).[20] The euro accounts for a small share because the data do not include trade with EU countries. I also report that VCP is the main strategy for imports, whereas the dominant one for exports is PCP. As previously discussed, the US represents only a small share of UK trade; hence, the US dollar is clearly used extensively as a vehicle currency.

As reported in Table 2, the data further reveal that the asymmetry in the currency denomination of exports and imports holds for all industries, trading partners, and the categories of goods.[21] For both exports and imports, I also observe a significant variation in invoicing currency across industries, trading partners, and the categories of goods. For example, in Panel A of Table 2, it can be seen that the share of exports priced in pounds is approximately 55 percent for the manufacturing industry (SITC 6), whereas the share is nearly 70 percent for the food industry (SITC 0). Panel B of Table 2 displays a comparison between trading partners, and shows that almost all imports from the US are priced in dollars (82.6 percent). Additionally, imports from East and Southeast Asia have the highest trade share priced in pounds (42.3 percent) compared with other destinations. Regarding exports, half of the exports to the US are priced in dollars (47.2 percent), whereas exports to other destinations are primarily priced in pounds.

Next, I categorize goods into final, intermediate, and capital goods according to the Broad Economic Categories (BEC) classification.[22] As shown in Panel C of Table 2, LCP

[20] This pattern is at odds with the Swedish evidence reported in Friberg and Wilander (2008) that exporters primarily use their customers' currencies.

[21] The classifications used are the Standard International Trade Classification (SITC) and the Broad Economic Categories (BEC).

[22] The trade shares of final, intermediate, and capital goods for imports in 2011 are 24, 58, and 14

Table 2: Currency of Invoicing by Industry, Destination, and Category of Goods

	Imports			Exports		
	PCP	LCP(£)	VCP	PCP(£)	LCP	VCP
Panel A: By 1-digit SITC Industry (percent)						
0:Food & live animals	10.5	37.7	51.8	68.0	10.4	21.5
1:Beverages & tobacco	19.0	68.0	12.9	48.4	33.6	18.1
2:Crude materials	30.5	30.9	38.5	65.5	2.4	32.0
3:Mineral fuels	2.7	9.7	87.6	65.0	19.3	15.7
4:Animal & veg. oils	10.6	3.6	85.8	77.9	6.6	15.5
5:Chemicals	32.0	33.8	34.2	54.7	28.8	16.5
6:Manufactured goods	10.2	20.5	69.3	54.8	8.6	36.6
7:Machinery	24.8	29.6	45.6	58.6	14.1	27.4
8:Miscellaneous	14.8	36.5	48.7	65.5	15.5	19.0
9:Unclassified	37.3	0.7	62.0	50.7	0.5	48.8
Panel B: By Trading Partners (percent)						
US	82.6	15.6	1.8	50.2	47.2	2.7
China	0.3	26.0	73.8	62.4	0.1	37.5
East/Southeast Asia	6.4	42.3	51.2	57.3	5.9	36.8
Europe exc. EU	4.6	21.8	73.6	75.5	2.8	21.6
Other Americas	10.9	24.9	64.2	53.4	7.8	38.8
All Others	3.7	21.9	74.4	63.5	1.9	34.6
Panel C: By The BEC Category (percent)						
Final Goods	10.7	41.2	48.1	56.3	27.2	16.5
Intermediate Goods	18.6	20.1	61.3	56.6	15.8	27.6
Capital Goods	21.4	25.2	53.4	59.3	13.2	27.5

Notes: The classifications used are the Standard International Trade Classification (SITC) and the Broad Economic Categories (BEC).

is used more extensively for final goods relative to intermediate and capital goods (in value), particularly for imports. This finding is consistent with the theoretical argument in Bacchetta and van Wincoop (2003) that final goods producers are more prone to use LCP given local competition compared with intermediate goods exporters.[23]

3.2 Stylized Facts About Importing and Non-importing Exporters

In the following discussion, I categorize UK exporters into two groups according to their import behavior: importing exporters use imported inputs and non-importing exporters do not.[24] Out of all 58,907 firms in the exports dataset, 32,289 firms (55 percent) are importing exporters and 26,618 (45 percent) are non-importing exporters. As reported in Table 3, importing exporters account for a much larger share of export value (89.5

percent, respectively. The figures are 18, 57, and 16 percent for exports. Some goods are not classified by the BEC and account for only 3.7 percent of imports and 9 percent of exports.

[23] In their model, all exports are intermediate goods sold to domestic final goods producers.

[24] Foreign inputs imported by importing exporters account for 63.4 percent of all the UK imported inputs. The remainder is imported by firms that sell to only domestic markets.

Table 3: Importing versus Non-importing Exporters

	Importing	Non-importing
Share in export value (percent)	89.5	10.5
Number of firms	32,289	26,618
Fraction of firms (percent)	55.0	45.0
Number of firms with export value in the top 5^{th} percentile	2,568	377
Fraction of firms by pricing strategy (percent)		
All PCP (£)	49.9	75.4
All LCP	2.2	2.5
All VCP	3.5	8.0
Mix of two or more strategies	44.4	14.0
Sum	100.0	100.0

percent) compared with non-importing exporters (10.5 percent). Although importing exporters are on average larger exporters, note that very large exporters are also found in the non-importing group. Within this group, the number of exporters with export shares in the upper 5^{th} percentile is 377 (1.4 percent of non-importing exporters), whereas the importing group has 2,568 very large exporters (8 percent of importing exporters).

A salient and new stylized fact in the UK data is that importing exporters and non-importing exporters exhibit very different patterns of invoicing currency choice. Table 3 indicates that a large share of non-importing exporters (75.4 percent) only use PCP, whereas this figure is only 49.9 percent for importing exporters, a pattern consistent with the theoretical prediction that non-importing firms are more likely to use PCP (see Proposition 2). Additionally, a larger share of non-importing exporters (8 percent) uses only VCP, as opposed to 3.5 percent for importing exporters. More interestingly, only 14 percent of non-importing exporters use a combination of two or three strategies, as opposed to 44 percent for importing exporters.[25]

A natural question is whether the difference in invoicing currency choice between the two groups is primarily driven by firm characteristics, such as import behavior—as suggested by the theory—or by other fundamental differences at more aggregated levels. Table 4 presents these two groups' export shares (in value) by industry presence, destination, and the category of goods. That no substantial heterogeneity in export sectors and destinations between importing and non-importing exporters exists is somehow surprising and highlights that the variation in invoicing currency choice is more likely to come from firm characteristics. Furthermore, a comparison between the shares of different goods shows that importing exporters have a higher share of intermediate goods, which suggests the evidence of their engagement in vertical specialization in global production

[25] Within the mixed group, the average value shares of PCP, LCP, and VCP are 60, 16, and 24 percent for importing firms and 59, 15, and 26 percent for non-importing firms.

Table 4: Importing versus Non-importing Exporters by Industry, Destination, and Category of Goods

	Importing	Non-importing
Shares of exports by 1-digit SITC Industry (percent)		
0:Food & live animals	1.2	5.7
1:Beverages & tobacco	2.8	1.9
2:Crude materials	2.9	6.2
3:Mineral fuels	7.4	1.8
4:Animal & veg. oils	0.1	0.04
5:Chemicals	17.6	21.5
6:Manufactured goods	12.2	8.6
7:Machinery	41.6	40.4
8:Miscellaneous	12.1	13.1
9:Unclassified	2.1	0.8
Sum	100.0	100.0
Shares of Exports by Destination (percent)		
US	28.6	31.1
China	6.3	7.2
East/Southeast Asia	22.5	27.8
Europe exc. EU	16.4	14.1
Other Americas	9.0	5.1
All Others	17.2	14.7
Sum	100.0	100.0
Shares of Exports by the BEC Category (percent)		
Final Goods	17.6	25.0
Intermediate Goods	58.6	41.7
Capital Goods	16.0	13.2
N/A	7.8	20.2
Sum	100.0	100.0

chains.

To summarize, I provide the descriptive statistics of the currency denomination of UK trade and document substantial variations in invoicing currency choice between importing and non-importing exporters. Next, guided by the theory, I formally examine the role of imported inputs in determining exporters' invoicing currency choice.

4 Empirical Evidence

In this section, I first introduce the main empirical specification and the construction of variables that are linked to the propositions developed in Section 2. Next, I present the main empirical results. I conclude this section with a series of robustness tests.

4.1 Empirical Specification and Construction of Variables

I take the entire sample of UK exports to non-EU countries (2.54 million transactions) and reduce it to the firm-product-destination level (0.65 million observations). The dimension that is eliminated is the frequency of shipping for each exporter (at the product-destination level) within a year.[26]

The categorical dependent variables take into account all pricing strategies, including PCP (the default option), LCP, and VCP. The regressions are estimated using a multinomial logit (MNL) procedure that imposes the constraint that the three invoicing alternatives are mutually exclusive and exhaustive (for each firm-product-destination observation). Thus, the MNL estimations yield two sets of results: LCP versus PCP and VCP versus PCP. Statistical significance in these estimations shows the direction in which the explanatory variables shift the likelihood of LCP (VCP) away from the default option of PCP. The main estimating specification is

$$\Pi^{i,j,c}(PCP) = \text{MNL}\left(InputPCP^{i,c},\ InputLCP^{i},\ Import^{i},\ ratio^{i,k},\ \delta_c,\ \delta_k\right),$$

where the superscripts i, j, c and k denote firm, product, destination (country), and industry, respectively.

The first explanatory variable $InputPCP^{i,c}$ measures the share of firm $i's$ imported inputs from country c priced in country c's currency (i.e., PCP from the perspective of the exporter). This variable can be interpreted as firm i's 'effective' dependence on imported inputs from country c. A higher ratio of $InputPCP^{i,c}$ is expected to increase the likelihood of LCP relative to PCP, as predicted by Proposition 1.[27]

Furthermore, I consider a firm-level measure $InputLCP^{i}$ that captures the total share of firm i's pound-denominated imported inputs. This variable is a systematic measure of the overall degree of input price uncertainty facing exporters. For example, suppose an exporter uses inputs from both the US (denominated in dollars) and Japan (denominated in yen) and then produces a final good that it sells to the US. The variable $InputPCP^{i,c}$ only captures the dollar-denominated inputs, whereas the variable $InputLCP^{i}$ takes into account all other input sources. A higher $InputLCP^{i}$ is expected to decrease the likelihood of LCP relative to PCP, as predicted by the corollary of Proposition 1.

[26] On average, firms ship four times a year. The reason for collapsing the data is to avoid assigning more weights to firms that ship more regularly.

[27] Note that Proposition 1 is built on equation (10) where ψ captures imported inputs as a share of total costs. Total costs may be measured as total wage bill plus total material cost, as used in Amiti et al. (2014). When data on costs are not available, sales may serve as a good proxy. However, the UK dataset used in this paper is limited in the available firm characteristics and hence the variable $InputPCP^{i,c}$ does not fully correspond to the theory. Instead, it distinguishes the exporter's dependence on imported inputs from a particular trading partner in an environment of multiple export destinations, an aspect not explored in the theory.

To distinguish between importing and non-importing exporters, I use a dummy variable $Import^i$, which takes the value of one if a firm uses imported inputs and zero otherwise. The use of imported inputs is expected to increase the likelihood of LCP relative to PCP, as predicted by Proposition 2.

Guided by the stylized fact documented in Section 3 that importing firms account for a large export share, I further control for relative firm size proxied by $ratio^{i,k}$, the export share of firm i in an HS-4-digit industry.[28] I start the estimations with destination fixed effects δ_c (at the area level) and industry fixed effects δ_k (at the SITC-1-digit level) and later replace them with destination-industry effects $\delta_{c,k}$.[29]

4.2 Main Empirical Findings

To focus on testing the theoretical predictions, I only report the estimation results for the pair of LCP versus PCP in Table 5, but note that the choice of VCP is also taken into account in the MNL regressions.[30] In columns 1 to 4 of Table 5, the estimates from the MNL regressions are odd ratios rather than marginal effects; therefore, I first interpret the estimated coefficients in terms of the direction of predictions. The magnitudes of these effects are then discussed, with column 5 and column 6 showing the consistent pairwise estimates.

Column 1 reports an unexplained prominence in PCP relative to LCP for UK exports, as the negative coefficient implies. In column 2, I include the main variables related to firms' use of imported inputs. The positive and significant coefficient of $InputPCP^{i,c}$ implies that a higher share of imported inputs denominated in the trading partner's currency makes it more likely that firms use the same currency for exports (i.e., LCP is more likely), which supports Proposition 1. The estimated coefficient of $InputLCP^i$ is significantly negative, which suggests that firms with a higher share of inputs denominated in pounds are more likely to shift from LCP to PCP (see the corollary of Proposition 1). Lastly, the effect of the dummy variable $Import^i$ is also significant. As documented in the descriptive statistics section (see Table 3), firms using imported inputs are less likely to use PCP, which supports Proposition 2. Overall, these results strongly support the model's predictions.

In column 3, I add an extra control for firm size in terms of export share. The positive and significant coefficient of $ratio^{i,k}$ suggests that larger exporters are more likely to price in their trading partners' currencies. One possible explanation is that

[28] HS code stands for the Harmonized Commodity Description and Coding System. Other proxies such as export shares at the SITC-1-digit level and total export shares yield the same predictions.

[29] Destinations at the area level include the US, China, East/Southeast Asia, Europe (excluding the EU), other American countries and all other countries. Using more disaggregated levels of industry effects (at the SITC-5-digit) or destination effects (at the country level) does not change the results.

[30] Full regression results including the pair of VCP versus PCP are reported in Table A1 in the Online Appendix. Also, see Table A2 for the results without fixed effects.

Table 5: Imported Inputs and Invoicing Currency Choice for UK Exporters

Dependent Variable: LCP vs. PCP	(1)	(2)	(3)	(4)	(5) Binomial logit	(6) Binomial logit (ME)
$InputPCP^{i,c}$		0.25***	0.27***	0.88***	0.29***	0.02***
		(0.03)	(0.03)	(0.00)	(0.03)	(0.03)
$InputLCP^{i}$		-0.40***	-0.42***	-0.35***	-0.42***	-0.03***
		(0.04)	(0.05)	(0.00)	(0.07)	(0.07)
$Import^{i}$		0.78***	0.75***	0.59***	0.74***	0.05***
		(0.04)	(0.04)	(0.00)	(0.04)	(0.04)
$ratio^{i,k}$			1.33***		1.34***	0.09***
			(0.14)		(0.13)	(0.13)
Constant	-0.93***	-1.60***	-1.64***	-1.46***	-1.72***	0.09***
	(0.15)	(0.17)	(0.19)	(0.00)	(0.17)	(0.17)
Fixed effects:						
$\delta_c + \delta_k$	Yes	Yes	Yes	No	Yes	Yes
$\delta_{c,k}$	No	No	No	Yes	No	No
Observations	644,704	644,704	644,704	644,704	507,723	507,723
AIC	-	832,915	830,029	969,895	-	-
Pseudo-R^2	-	0.16	0.16	0.02	0.31	0.31

Notes: Observations are at the firm-product-destination level. Columns 1 to 4 present the results in terms of odds ratios from the main multinomial logit specification. The default option is PCP and only estimates of LCP versus PCP are reported. Column 5 shows pairwise estimates from a binomial logit regression. Column 6 reports the average of the individual marginal effects from the pairwise regression. Fixed effects: δ_c are destinations at the area level include the US, China, East/Southeast Asia, Europe (excluding the EU), other American countries, and all other countries; δ_k are industries defined at the SITC-1-digit level; $\delta_{c,k}$ are industry-destination effects at the SITC-2-digit-area level. Standard errors are clustered at the HS4 level (1,191 clusters) and are reported in parentheses. Alternative clustering at the SITC-5-digit level, at the firm level and at the country level yield the same conclusions.

*** Significant at the 1 percent level; ** Significant at the 5 percent level; * Significant at the 10 percent level.

larger firms highly involved in international trade have more incentives and resources to hedge against exchange rate uncertainty using financial instruments; hence, they are more likely to deviate from PCP.[31] The coefficients of the key variables are almost identical to those in column 2.

Next, in column 4, I report the results of the same specification as in column 2 but replace the industry- and destination-specific effects with industry-destination fixed effects (defined at the SITC-2-digit-area level) to explore different levels of variation. Comparing column 4 with column 2, I show that the coefficient of $InputPCP^{i,c}$ more than triples and remains strongly significant. All the other estimates do not change much in size and also remain strongly significant. However, a much lower pseudo R-square in this specification indicates that it does not fit the data as well as the main specification.

[31] Another proxy for firms' engagement in international trade is the number of exporting destinations. In the robustness section, I further split the sample by the number of destinations and discuss the effects of the key variables for each group.

Column 5 reports the pairwise logit estimates for the pair of LCP versus PCP, dropping the observations of VCP. If the implicit assumption of the independence of irrelevant alternatives (IIA) in the MNL procedure holds, estimating a pairwise logit model should yield the same results as estimating a multinomial logit model.[32] A comparison of column 5 with column 3 indicates that the coefficients are almost identical, suggesting consistent MNL estimates in the main specification.

Column 6 quantifies the main results by reporting the average marginal effects of the key variables (as in column 5). Specifically, a 10 percentage point higher $InputPCP^{i,c}$ is associated with a 20 percentage point higher probability of LCP. Furthermore, a firm with the share of pound-denominated inputs at the 75^{th} percentile (or the upper quartile where $InputLCP^{i} = 13.17$ percent) is approximately 40 percent ($= -0.03 \cdot 13.17$) less likely to use LCP relative to PCP, compared with a firm whose imported inputs are all priced in foreign currencies ($InputLCP^{i} = 0$). Finally, the predicted probability of LCP relative to PCP for importing exporters is 5 percent higher than non-importing exporters.[33]

Overall, the main empirical findings in Table 5 provide strong support for the theoretical predictions developed in Section 2. However, I want to ensure that these results are not driven by outliers or specific to firms facing a particular range of input price uncertainty. I re-estimate the (pairwise) binomial logit specification in columns 5 and 6 of Table 5 for importing exporters by splitting the ratio $InputLCP^{i}$ into quartiles. Specifically, importing exporters are further divided into three groups: high InputLCP (with the ratio in the upper quartile), medium InputLCP (below the upper quartile and above the median) and low InputLCP (at the median).[34] With this split, the high group accounts for 31.4 percent of the export share of all importing firms, the medium group accounts for 50.5 percent, and the low group accounts for only 18.1 percent. I report the average marginal effects in columns 1 to 3 of Table 6. These estimated coefficients confirm that the main findings remain valid for all three groups.

Finally, I close this section with an extra exercise to link the empirical analysis to the theoretical assumption in Section 2 that all imported inputs are denominated in the foreign currency (i.e., PCP from the perspective of exporters). To see whether the results from the main specification respond well to this assumption, in column 4 of Table 6 I consider only observations with exporters whose imported inputs are all priced in PCP.[35] For instance, exports to Japan from firm i are included if firm i's imported

[32] This is a test first proposed by Hausman and McFadden (1984).

[33] Note that these results apply to the pairwise comparison of PCP versus LCP. For more quantitative interpretations with different specifications see Section 4.3.3.

[34] Note that the lower two quartiles are grouped together because the median level is at zero. Hence, for the low group the variable $InputLCP^{i}$ is dropped.

[35] This sample contains exports from 10,914 firms that account for approximately 9.1 percent of the total export share.

Table 6: Invoicing Currency Choice by Input Currency Denomination

Dependent Variable: LCP vs. PCP	(1) High InputLCP	(2) Medium InputLCP	(3) Low InputLCP	(4) PCP Inputs Only	(5) LCP Inputs Only
$InputPCP^{i,c}$	0.02***	0.04***	0.01***	—	—
	(0.08)	(0.08)	(0.04)		
$InputLCP^{i}$	-0.03***	-0.15***	—	-0.05***	-0.02***
	(0.09)	(0.09)		(0.09)	(0.21)
$ratio^{i,k}$	0.07***	0.08***	0.09***	0.23***	0.07***
	(0.24)	(0.20)	(0.28)	(0.17)	(0.56)
Constant	0.08***	0.13***	0.11***	0.36***	0.03***
	(0.56)	(0.18)	(0.18)	(0.29)	(0.63)
Fixed effects: $\delta_c + \delta_k$	Yes	Yes	Yes	Yes	Yes
Observations	149,278	135,782	123,335	48,572	18,144
Pseudo-R^2	0.28	0.32	0.32	0.05	0.15

Notes: In columns 1 to 3, firms are sorted by the ratio $InputLCP^{i}$ into above the 75th percentile (or the upper quartile of 13.17 percent), between the upper quartile and above the median level at zero, and at the median level. Column 4 uses a subsample with exporters whose imported inputs (from the trading partner to whom they export) are all priced in PCP. Column 5 considers exporters whose imported inputs (from the trading partner to whom they export) are all priced in LCP. Other details of clustered standard errors and fixed effects are as in Table 5.

inputs from Japan are all priced in Japanese yen. The variable $InputPCP^{i,c}$ is dropped because it no longer captures input currency denomination but the trade share of a trading partner c. The coefficient of $InputLCP^{i}$ reported in column 4 shows that the probability of LCP significantly decreases with the share of pound-denominated inputs, thus again consistent with the theoretical prediction (see the corollary of Proposition 1). Similarly, in column 5, I consider only observations with exporters whose imported inputs are all priced in LCP, and the effect of input currency denomination remains strongly significant.[36]

To summarize, I find that the effects of input currency denomination on invoicing currency choice are significant across firms facing different degrees of (bilateral) input price uncertainty. Even for exporters that use all PCP inputs or all LCP inputs (at the firm-country level), the overall currency exposure in the portfolios matters for their invoicing currency choice.

4.3 Robustness

I consider three sets of robustness tests: including other theoretical determinants as additional controls, considering an alternative proxy for firm size, and using alternative specifications and samples.

[36] This sample contains exports from 3,810 firms that account for approximately 3 percent of the total export share. Note that some firms may appear in both subsamples discussed in this exercise, because the observations are at the level of firm-country pairs.

4.3.1 Additional Controls

In Table 7, I check whether the main results are robust to adding a number of other theoretical determinants for invoicing currency choice. These include a set of macroeconomic factors, a set of strategic factors, and several controls for goods characteristics.

The results reported in column 1 of Table 7 show that the estimated coefficients of the main variables are virtually the same as in Table 5 after the inclusion of several *macroeconomic factors*. First, exchange rate volatility is proxied by the coefficients of variation of the importer's currency value relative to the pound and the US dollar during 2006-2009.[37] As the value of the pound was highly volatile during this period, it is expected that the coefficients of variation of exchange rates against the dollar better capture the volatility of a currency's value. The negative coefficient of $cvUSD^c$ indicates that exporters are more likely to use PCP when selling to a country with a more volatile currency value against the dollar, a finding consistent with the theory of Devereux et al. (2004) and Engel (2006). Further, I add two dummy variables to capture exchange rate pegs with respect to the dollar and the euro, denoted by $Dpeg^c$ and $Epeg^c$, respectively.[38] Exporters are more likely to use PCP relative to LCP when exporting to countries with exchange rate pegs. The last factor included is the transaction costs of exchange, proxied by the variable FX^c, which captures the share of a country's currency in the daily global foreign exchange market turnover.[39] A higher turnover implies lower transaction costs. The findings reveal that a higher share of market turnover increases the probability of LCP. This result implies that a currency that is traded extensively with lower transaction costs is more likely to be used as an invoicing currency, thus consistent with the theory of Devereux and Shi (2013).[40]

Column 2 verifies that the coefficients of the main variables are hardly affected after controlling for firms' *strategic considerations*, specifically, firms' bargaining power as emphasized by Goldberg and Tille (2008). I consider firm experience using the variable $fiveyrold^i$ to capture whether an exporter has more than five years of experience in exporting. Although the coefficient for the pair of VCP versus PCP (not reported) is significant, no significance exists for the pair of LCP versus PCP. On the importer's side, Goldberg and Tille (2009) suggest transaction size as a proxy for the importer's bargaining power, because importer characteristics are not normally observed in trade statistics. I use a dummy variable $Top10^{i,j,c}$ to capture whether a transaction is in the

[37] The variables are computed with the IMF's monthly exchange rates data from the International Financial Statistics series rf.

[38] The definitions follow the IMF's classification in 2007. The various types of pegs include: (a) no separate legal tender; (b) pre announced peg or currency board arrangement; (c) pre announced horizontal band narrower than or equal to 2 percent; and (d) de facto peg.

[39] The data are reported in the BIS Triennial Central Bank Survey, including 35 major currencies in 2007. Currencies not listed in the survey are assigned a zero share.

[40] Also see, among others, Swoboda (1968) and Rey (2001) for previous research on the role of currencies as a medium of exchange.

Table 7: Robustness with Additional Controls

Dependent Variable: LCP vs. PCP	(1) Macro Factors	(2) Strategic Factors	(3) Macro & Strategic	(4) Homogene -ous Goods	(5) Differentiat -ed Goods	(6) All Controls
$InputPCP^{i,c}$	0.24***	0.26***	0.26***	-0.17	0.26***	0.24***
	(0.03)	(0.03)	(0.03)	(0.19)	(0.03)	(0.03)
$InputLCP^{i}$	-0.40***	-0.43***	-0.39***	-0.22	-0.42***	-0.40***
	(0.05)	(0.04)	(0.05)	(0.21)	(0.05)	(0.04)
$Import^{i}$	0.78***	0.75***	0.74***	0.31**	0.77***	0.72***
	(0.04)	(0.03)	(0.04)	(0.15)	(0.04)	(0.03)
$ratio^{i,k}$			1.00***	0.23	1.47***	1.00***
			(0.15)	(0.24)	(0.22)	(0.15)
—Macroeconomic Factors—						
$cvGBP^{c}$	6.25***		6.38***	7.38***	6.73***	6.41***
	(0.50)		(0.41)	(0.48)	(0.41)	(0.49)
$cvUSD^{c}$	-1.64***		-1.70***	0.48	-1.97***	-1.67***
	(0.43)		(0.41)	(0.84)	(0.42)	(0.12)
$Dpeg^{c}$	-0.63***		-0.65***	-0.92***	-0.61***	-0.64***
	(0.06)		(0.06)	(0.81)	(0.06)	(0.06)
$Epeg^{c}$	-1.96***		-1.98***	-1.28***	-1.79***	-1.98***
	(0.34)		(0.34)	(0.37)	(0.33)	(0.34)
FX^{c}	0.04***		0.04***	0.04***	0.03***	0.04***
	(0.00)		(0.00)	(0.01)	(0.00)	(0.00)
—Strategic Factors—						
$fiveyrold^{i}$		0.00	0.12	0.06	0.00	0.00
		(0.02)	(0.02)	(0.13)	(0.03)	(0.02)
$Top10^{i,j,c}$		0.38***	0.36***	0.15	0.35***	0.36***
		(0.02)	(0.03)	(0.13)	(0.03)	(0.02)
—Goods Characteristics—						
Differentiated vs. Heterogeneous						-0.14*
						(0.02)
Final vs. Intermediate						-0.09
						(0.09)
Constant	-5.47***	-1.63***	-5.57***	-5.35***	-5.24***	-5.51***
	(0.19)	(0.16)	(0.21)	(0.52)	(0.10)	(0.18)
Fixed effects: $\delta_c + \delta_k$	Yes	Yes	Yes	Yes	Yes	Yes
Observations	644,704	644,704	644,704	12,207	555,336	644,704
AIC	822,098	838,358	821,296	-	-	819,164
Pseudo-R2	0.16	0.15	0.17	0.18	0.17	0.17

Notes: Columns 1 to 3 add additional controls. Columns 4 and 5 use subsamples of different types of goods, as defined in the Rauch (1999) product classification. Column 6 includes all controls. Other details of clustered standard errors and fixed effects are as in Table 5.

top 10^{th} percentile in value within an HS-4-digit industry. The findings support the theory of Goldberg and Tille (2008) that larger transactions are more likely to be priced in the importer's currency.

Arguably, firm size is also an indicator of exporters' bargaining power, which is

controlled for in the main analysis. Column 3 augments the specifications in columns 1 and 2 together with the firm size variable $ratio^{i,k}$. Overall, all these additional controls have essentially no effect on the estimated coefficients of the main variables.

In columns 4 and 5, I examine the role of *goods characteristics*, particularly the substitutability of goods.[41] I run separate regressions for both homogeneous goods (reported in column 4) and heterogeneous goods (reported in column 5). With this split, I observe that the effects of input currency denomination (the coefficients of $InputPCP^{i,c}$ and $InputLCP^{i}$) stop having any predictive power and disappear completely for homogeneous goods. This finding is somehow intuitive. As these goods are highly substitutable, firms may simply follow what their competitors do or what their trading partners request. The coefficient of firms' import status is halved but remains strongly significant. The results reported in column 5 confirm that the main empirical findings primarily apply to heterogeneous goods.

In column 6, all additional controls previously discussed are included, and I further add a Rauch variable (Differentiated vs. Heterogeneous goods) and a variable that captures the categories of goods (Final vs. Intermediate goods) to examine the effects across different types of goods. I first verify that the effects of the imported inputs variables remain unchanged. The results also suggest that differentiated goods are more likely to be priced in PCP compared with homogeneous goods. This finding is consistent with the theory of Bacchetta and van Wincoop (2005) that LCP is more likely for homogeneous goods because exporters have a stronger incentive to stabilize prices in the currency of their customers when demand is highly elastic. Furthermore, no evidence exists that final goods are more likely to be priced in LCP compared with intermediate goods, as predicted by the model in Bacchetta and van Wincoop (2003). However, note that this result is at odds with the evidence shown in Section 3. A possible explanation for not finding the same result is that final goods transactions are, on average, larger in value than intermediate goods transactions. Another possible explanation is that final goods are shipped more frequently, a dimension that is eliminated when data are collapsed.

4.3.2 Alternative Proxy for Firm Size

As highlighted in the data section, importing exporters are also large exporters, and they exhibit very different patterns of invoicing currency choice compared with non-importing exporters. The main empirical specification considers firm size in terms of trade share and the results confirm that larger firms are less likely to use PCP.

To ensure that the main results do hold after controlling for the firm size effect, in

[41] The classification is based on Rauch (1999), who categorizes three types of goods: Walrasian or homogeneous, reference-priced, and differentiated.

this exercise I use the number of export destinations as an alternative proxy for firm size. I sort all exporters by the number of export destinations into quartiles and re-estimate the main specification for each of the four bins. With this split, exporters in Bin 1 export to more than four destinations (above the upper quartile); the number of destinations in Bin 2 is either three or four (between the upper quartile and the median); firms in Bin 3 export to two destinations (between the median and the lower quartile), and firms in Bin 4 only export to one destination (at the lower quartile).[42] The regression results are reported in Table A3 in the online Appendix.

In all cases, the main results are essentially unchanged, except that the effect of overall currency exposure ($InputLCP^i$) slightly loses its significance in Bin 3 and disappears in Bin 4. However, note that the overall currency exposure coincides with the bilateral input denomination for exporters in Bin 4 because they have only one trading partner. A comparison across columns also shows that the within-group effect of bilateral input denomination ($InputPCP^{i,c}$) on exporters' invoicing currency choice is stronger when the number of destination is lower. These findings further suggest that the effect of import status remains relatively symmetric across bins except for the last one, which has a third of the magnitude (with the odds ratio of 0.2 as opposed to 0.6).

To summarize, I verify that the main results are not specific to exporters' activeness in the export markets. However, for very large firms exporting to multiple markets, the (within-group) effect of the overall currency exposure is stronger. In contrast, exporters with only a few trading partners largely consider the bilateral exchange rate uncertainty against their trading partners' currencies.

4.3.3 Alternative Samples and Specifications

I further check the robustness of the main results within alternative subsamples of the dataset. Overall, these results—reported in Table A4 in the online Appendix—reveal the same qualitative patterns as the main findings in Table 5.

As discussed in the data section, the US is a special case in which LCP (the US dollar) is used extensively compared with other destinations. To address this concern, in column 1 of Table A4, I exclude exports to the US from the sample. A comparison with the main results indicates that, for this subsample, the effect of $InputPCP^{i,c}$ is significantly stronger, whereas the effect of $InputLCP^i$ is reduced by almost one-half. In other words, the bilateral input currency denomination matters for firms' currency choice, particularly when trading with countries other than the US.

Next, I show in column 2 that dropping non-importing exporters has little effect on the estimated coefficients in the main specification. Similarly, in column 3, I evaluate the

[42] The mean of the number of destinations is 3.97; the upper quartile, median quartile and lower quartile are 4, 2, and 1, respectively. Export shares for the four bins are 0.89, 0.05, 0.03, and 0.03, respectively.

effects for firms that use only imported inputs denominated in their trading partner's currency. Given that all observations with $InputPCP^{i,c} = 0$ are dropped, I expect the estimated coefficient to decline in size and this is indeed confirmed by the results. Column 4 considers only the manufacturing sector (SITC 6-8), and the effects of the main variables remain strongly significant.[43] Lastly, another concern is that the main results are driven by firms with very large trade shares. In column 5, I exclude firms with export shares in the top 5^{th} percentile. Excluding large firms from the sample slightly reduces the magnitude of the coefficient of $InputPCP^{i,c}$, consistent with the findings in the previous subsection with the number of export destinations as a proxy for firm size. However, the predictions remain robust and strongly significant.

Another set of robustness checks is to consider alternative specifications and regression models. In the main analysis, the regression model is an MNL procedure that includes VCP as a dependent variable. However, certain policy interests may focus only on the prevalence of invoicing in the home currency. To this end, I further consider alternative regression models and specifications using a dichotomous dependent variable that captures whether a transaction is priced in pounds ($nPCP = 0$) or not ($nPCP = 1$). These results are reported in Table A5 in the online Appendix.

The estimated (average) marginal effects from a binomial logit regression are reported in column 1 of Table A5. Column 2 reports the results from the same specification, but with a linear probability model instead. Overall, the qualitative predictions are consistent with the results from the MNL specification. However, note that the interpretations of these results are quite different from the main analysis because of the dichotomous dependent variable. The findings reported in columns 1 and 2 suggest that importing exporters are approximately 8 to 14 percent more likely to use a foreign currency (either LCP or VCP relative to PCP), compared with their non-importing counterparts. Moreover, a one percent increase in a firm's effective dependence on foreign currency-denominated inputs ($InputPCP^{i,c}$) increases the probability of switching to a foreign currency from PCP by 9 to 12 percent. Finally, with a one percent increase in a firm's total share of inputs priced in pounds ($InputLCP^{i}$), the predicted probability of PCP relative to a foreign currency increases by approximately 18 percent.

Finally, column 3 uses a linear probability model with the full export dataset (2.54 million observations). The full dataset has many identical transactions at the firm-product-destination level in different times of the year, which represent the dimension of shipment frequency. Using the full dataset, I show that except for a downsized and less significant effect of $InputPCP^{i,c}$, all the main predictions remain unchanged.

[43] In 2011, the UK manufactured goods accounted for approximately 56 percent of the total (non-EU) exports.

5 Extensions

In this section, I provide two extensions to the main analysis. The first extension theoretically and empirically considers the case of VCP. The second extension examines the currency denomination of UK imports and provides country-level evidence of the effect of imported inputs on invoicing currency choice.

5.1 Imported Inputs and Vehicle Currency Pricing

5.1.1 Theory: Decision Rule for VCP

I first extend the model presented in Section 2 to allow for the use of VCP inputs and the choice of VCP for exports. I consider a three-country environment in which country V's currency is used as a vehicle currency. Firm i in country H (Home) sells a differentiated good to country F (Foreign). The CES demand curve and production functions are as in Section 2. The only difference is that firm $i's$ imported inputs are all denominated in VCP. Thus, the parameter ψ_i captures the firm's dependence on VCP inputs.

The firm presets the prices and the invoicing currency one period in advance to maximize the expected discounted profits under PCP, LCP, and VCP:

$$E\Pi_i^{PCP} = E\left[\kappa\left(p_i^{PCP} - \mu_i\right)\left(\frac{p_i^{PCP}}{S_{hv}P_{hf}^*}\right)^{-\lambda}\left(\frac{P_{hf}^*}{P^*}\right)^{-\delta}D^*\right], \tag{11}$$

$$E\Pi_i^{LCP} = E\left[\kappa\left(S_{hf}p_i^{LCP} - \mu_i\right)\left(\frac{p_i^{LCP}}{S_{fv}P_{hf}^*}\right)^{-\lambda}\left(\frac{P_{hf}^*}{P^*}\right)^{-\delta}D^*\right], \tag{12}$$

$$E\Pi_i^{VCP} = E\left[\kappa\left(S_{hv}p_i^{VCP} - \mu_i\right)\left(\frac{p_i^{VCP}}{P_{hf}^*}\right)^{-\lambda}\left(\frac{P_{hf}^*}{P^*}\right)^{-\delta}D^*\right], \tag{13}$$

where μ is the marginal cost denominated in the home currency, S_{hv} is the exchange rate between currencies H and V (home currency price of the vehicle currency), S_{fv} is the exchange rate between currency F and V (foreign currency price of the vehicle currency), and p_i is the firm's price set in different currencies. All price indexes are denominated in the vehicle currency. Other variables are as in Section 2.

Following the solution technique in Section 2, the firm sets its price in VCP if and only if

$$\frac{1}{2}var\left(s_{fv}\right) > cov\left(s_{hv}, s_{fv}\right), \text{ and} \tag{14}$$

$$\frac{-\gamma}{\theta}cov\left(s_{hv}, \ln\left(1-\psi_i\right)\right) > \frac{1}{2}var\left(s_{hv}\right), \tag{15}$$

where lower case s denotes the log of exchange rates. From conditions (14) and (15), I develop the following proposition.[44] The detailed proof is shown in Appendix B.

Proposition 3 *A domestic firm is more likely to use VCP for exports with: (i) a higher exchange rate volatility between the destination and vehicle currency, var* (s_{fv}) *; (ii) a lower covariance between two exchange rates cov* (s_{hv}, s_{fv}) *; (iii) a higher share of VCP inputs.*[45]

5.1.2 Empirical Evidence of VCP

Now, I turn to provide the empirical evidence of VCP in the UK trade data. As in the main analysis in Section 4, the estimating specification uses a multinomial logit model with a categorical dependent variable that considers PCP, LCP, and VCP (the default option). The full regression results are reported in Table 8, with each column reporting two sets of results: PCP versus VCP and LCP versus VCP. Column 1 reports the benchmark results. Columns 2 and 3 add additional controls, and the benchmark results remain robust. Therefore, the following discussion focuses on the estimates in column 1.

First, Proposition 3(i) predicts that a higher degree of exchange rate volatility between the destination and the vehicle currency increases the probability of VCP. However, I do not find evidence supporting this model prediction because the coefficients of the variable $cvUSD^c$, representing the coefficients of variation of the exchange rates between the importer's currency and the dollar, appear insignificant.

Proposition 3(ii) suggests that a lower covariance between the two exchange rates (pound/dollar and importer's currency/dollar) increases the probability of VCP. However, the empirical evidence reported in column 1 points to the opposite result. The negative estimated coefficients of $cov\left(e_{£\$}, e_{c\$}\right)^c$ imply that a higher covariance between the two exchange rates shifts the firm's choice toward VCP and away from both PCP and LCP.

Proposition 3(iii) links input currency denomination with VCP choice. Similar to the strategy used in the main analysis, I consider the variable $InputVCP^{i,c}$, which measures firm $i's$ share of inputs from country c priced in VCP. The negative coefficients show that a higher share of VCP inputs significantly increases the probability of VCP. Furthermore, I consider a firm-level measure $InputUSD^i$, which captures the total share of firm i's dollar-denominated inputs. A higher share of dollar-denominated inputs also

[44] Note that all domestic firms face the same exchange rate volatility between the home currency and the third country regardless of their trading partners; therefore, the term $var\left(s_{hv}\right)$ does not appear in the proposition.

[45] Similar to Proposition 1, this is because the covariance term $cov\left(s_{hv}, \ln\left(1-\psi_i\right)\right)$ is positive and increasing in the degree of dependence on VCP inputs ψ_i.

Table 8: Imported Inputs and Vehicle Currency Pricing

Dependent Variables	(1)		(2)		(3)	
	PCP	LCP	PCP	LCP	PCP	LCP
$cvUSD^c$	0.12	-0.24	0.15	-0.29	0.73	-1.84***
	(0.12)	(0.41)	(0.12)	(0.40)	(0.12)	(0.38)
$Cov\ (e_{£\$}, e_{c\$})^c$	-0.06***	-0.29***	-0.06***	-0.29***	-0.07***	-0.26***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
$InputVCP^{i,c}$	-0.47***	-0.47***	-0.41***	-0.75***	-0.46***	-0.42***
	(0.04)	(0.10)	(0.04)	(0.11)	(0.04)	(0.10)
$InputUSD^i$	-0.84***	-0.25**	-0.49***	-0.58**	-0.84***	-0.27**
	(0.03)	(0.03)	(0.01)	(0.04)	(0.01)	(0.04)
$Import^i$			-0.34***	0.61***		
			(0.05)	(0.04)		
$ratio^{i,k}$			-0.87***	0.45***		
			(0.13)	(0.16)		
Constant	4.20***	2.95***	4.30***	2.68***	0.48	-5.01***
	(0.25)	(0.24)	(0.32)	(0.27)	(0.32)	(0.31)
Other Controls:						
Macroeconomic Factors	No		No		Yes	
Strategic Factors	No		No		Yes	
Goods characteristics	No		No		Yes	
Fixed Effects: $\delta_c + \delta_k$	Yes		Yes		Yes	
Observations	642,334		642,334		642,334	
Pseudo-R^2	0.15		0.16		0.16	

Notes: The default option is VCP. Other details are as in Table 5.

significantly increases the probability of VCP.[46] Overall, the findings are consistent with Proposition 3(iii).

To summarize, although evidence exists that the use of VCP inputs make VCP more likely, the empirical results do not fully support the theoretical predictions derived from a three-country framework. One possible explanation is that in practice VCP may be the result of industry-specific or destination-specific considerations, rather than firms' profit-maximizing choice.[47] It may also be the case that the theory introduced is lacking in some way and hence cannot reconcile all pricing strategies. This remains a challenge for future research.

[46] Note that although the dependent variable VCP does not distinguish the US dollar from other currencies, the majority of VCP is with the dollar. An alternative measure of $InputVCP^i$ (at the firm level) yields the same results.

[47] For example, the BIS report of Kenen (2011) finds that more than 70 percent of Asian exports to Japan in 2007 were invoiced in dollars. Other determinants of VCP in this aspect, such as the transaction costs of exchange and a simple industry coalescing effect, have been highlighted in the empirical studies on the role of a vehicle currency in international trade. These determinants have been discussed and controlled for in the empirical analysis.

5.2 Imported Inputs and Invoicing Currency Choice: Country-level Evidence

In this extension, I review the currency denomination of UK imports and examine the effect of imported inputs on currency denomination at a more aggregated level. The main challenge of doing so is to systematically distinguish the degree of dependence on imported inputs across different exporting countries. I use a measure of value added to gross exports (VAX ratio)—computed by Johnson and Noguera (2012)—as a proxy for a country's (or an industry's) dependence on imported inputs. The concept of this measure is that countries or industries with higher value added to gross exports are less dependent on imported inputs. Therefore, higher VAX ratios are associated with lower dependence on foreign inputs.

I take the full sample of the 2011 UK imports from non-EU countries (with 7.31 million transactions). As in the main analysis in Section 4, I use an MNL specification and take PCP as the default option. The regression results are reported in Table 9. The first column includes only constant terms. The positive and significant coefficients show an unexplained prominent use of LCP and VCP (relative to PCP) in UK imports.

In column 2, I add the VAX ratios at the country level, ranging from 0 to 1, to capture the share of value-added exports in total exports.[48] A higher VAX ratio (lower dependence on imported inputs) is associated with lower probability of using PCP. This result implies that countries that engage more in trade in intermediate goods use less of their home currencies for exports. When I use further disaggregated VAX ratios at the country-industry level, the result still holds.[49]

In column 3, I include several controls for macroeconomic factors and goods characteristics. Although these results suggest lower predicted coefficients of the VAX ratios, they remain qualitatively robust and significant. Further, I show that exchange rate volatility—proxied by the coefficients of variation of the exporter's currency value relative to the pound ($cvGBP^c$)—increases the probability of PCP relative to both LCP and VCP. This result is consistent with the theoretical predictions of Devereux et al. (2004) and Engel (2006). Imports from countries with exchange rate pegs ($Dpeg^c$ and $Epeg^c$) are more likely to be priced in LCP or VCP rather than the exporter's currency. The effects of transaction costs in foreign exchange markets are also highly significant, implying that an exporter's currency with lower transaction costs of exchange (higher FX^c) has a higher presence (i.e., PCP is more likely). Finally, final goods in UK imports are more likely to be priced in LCP relative to PCP compared with intermediate

[48] Johnson and Noguera (2012) calculate the VAX ratios for 94 countries and 57 sectors in 2004. Countries not included in the list are assigned the regional average.

[49] These results are not reported. The VAX ratios at the country-industry level are computed by Johnson and Noguera (2012), including 93 countries, 19 regions, and 57 sectors in the GSC codes. These ratios are not published in their paper.

Table 9: Imported Inputs and the Currency Denomination of UK Imports

Dependent Variables	(1)		(2)		(3)		(4)	
	LCP(£)	VCP	LCP(£)	VCP	LCP(£)	VCP	LCP(£)	VCP
VAX^c			-8.65***	-12.91***	-1.68**	-3.30***	-1.62**	-3.44***
			(0.72)	(0.52)	(0.73)	(0.15)	(0.71)	(0.60)
—Macroeconomic Factors—								
cvGBP^c					-5.36***	-8.12***	-6.89***	-8.33***
					(1.76)	(1.33)	(1.63)	(1.33)
Dpeg^c					0.98***	1.86***	0.60***	1.66***
					(0.23)	(0.27)	(0.23)	(0.27)
Epeg^c					1.11***	0.70**	1.31***	0.72**
					(0.35)	(0.30)	(0.34)	(0.29)
FX^c					-0.05***	-0.07***	-0.05***	-0.07***
					(0.00)	(0.00)	(0.00)	(0.00)
—Goods Characteristics—								
Final vs. Intermediate					0.49***	-0.37	0.60***	-0.10
					(0.20)	(0.15)	(0.19)	(0.16)
—Industry Characteristics—								
Mktshare^{k,c}							1.68***	0.68
							(0.39)	(0.42)
Top5^k							-0.22***	0.30***
							(0.08)	(0.08)
Constant	0.66***	0.62***	7.04***	9.89***	3.91***	5.60***	1.89***	4.62***
	(0.13)	(0.09)	(0.52)	(0.37)	(0.70)	(0.54)	(0.68)	(0.74)
Industry effects	No		No		No		Yes	
Observations (millions)	7.31		7.31		7.31		7.31	
AIC	15,507,253		14,238,974		10,437,866		10,275,217	
Pseudo-R^2	-		0.082		0.327		0.340	

Notes: Observations are at the transaction level. The default option is PCP. Fixed effects: industries are defined at the SITC-1-digit level. Alternative fixed industry effects at the SITC-5-digit level yield the same conclusions. Standard errors are clustered at the HS-4-digit level (1,206 clusters) and are reported in parentheses.

goods, a finding that supports the theoretical predictions of Bacchetta and van Wincoop (2003).

In column 4, the main results for VAX ratios remain virtually unchanged, after controlling for two extra industry characteristics. The first factor is the market share of exporters ($Mktshare^{k,c}$), which is the market share of country c in UK imports in an HS-4-digit industry. This variable captures whether exporters from country c are the main trading partners for UK importers. I find evidence that the main trading partners are more likely to use the pound (LCP) relative to their home currency (PCP). The second variable added is a dummy for large transactions ($Top5^k$), which takes the value of one if a transaction falls in the top 5^{th} percentile of transaction value in an HS-4-digit industry. Interestingly, LCP is less likely than PCP, whereas VCP is more

likely than PCP for larger transactions. These findings indicate that transaction size masks a significant degree of heterogeneity in what it represents. For instance, larger transaction size may indicate a larger exporter with stronger bargaining power, which leads to more PCP. However, this effect can be in the opposite direction and indicates a larger importer.[50] In addition, large firms may be more active in trading different currencies in the financial markets, which makes VCP more likely.

To summarize, by examining the currency denomination of UK imports, I document a systematic finding that countries more involved in the global production chains are more likely to deviate from using their home currencies for exports. The data strongly support the theoretical prediction at a more aggregated level (see Proposition 1). Further, the findings suggest the importance of looking into firm characteristics rather than using aggregated proxies so as to uncover the underlying determinants for the currency denomination of international trade.

6 Concluding Remarks

Invoicing currency choice is an example of how micro-heterogeneity can influence aggregate outcomes. The paper documents firm-level variations in invoicing currency choice using a detailed transaction-level dataset and relates firms' invoicing currency choice to their import behavior. The stylized facts documented in Section 3 are completely new, and I view this as an important contribution to the vast literature on the currency denomination of international trade.

Further, the paper develops firms' decision rule for invoicing currency choice that specifically depends on the degree of import intensity. The firm-level and country-level evidence from the UK data strongly supports the theoretical prediction that a higher degree of dependence on imported inputs is associated with a deviation from using the home currency.

The findings in this paper have strong policy implications for the effects of exchange rates on trade prices. The recent exchange rate pass-through literature has identified the link between import intensity and firm-level pass-through via the interactions with markup adjustments. Large firms with higher import intensities tend to absorb more exchange rate variations in their markups, resulting in lower pass-through into destination prices (Amiti et al., 2014). The findings in this paper suggest another underlying mechanism, namely exporters' endogenous choice of invoicing currency according to the degree of their import intensiveness. Large exporters with higher import intensities are more likely to price their goods in a foreign currency (either LCP or VCP). As emphasized by Gopinath et al. (2010), in an environment of endogenous currency choice,

[50] In Goldberg and Tille (2008, 2009), a larger transaction size is used as a proxy for stronger bargaining power of the importers, which makes LCP more likely.

the ideal test is to relate firm-level characteristics that shape both markup variability and cost sensitivity to invoicing currency decisions. A better understanding of these variations is crucial to the development of the pass-through literature.

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References

Amiti, M., Itskhoki, O., Konings, J., 2014. Importers, exporters, and exchange rate disconnect. American Economic Review 104(7), 1942–78.

Bacchetta, P., van Wincoop, E., 2003. Why do consumer prices react less than import prices to exchange rates? Journal of the European Economic Association 1, 662–670.

Bacchetta, P., van Wincoop, E., 2005. A theory of the currency denomination of international trade. Journal of International Economics 67(2), 295–319.

Baron, D. P., 1976. Fluctuating exchange rates and the pricing of exports. Economic Inquiry 14, 425–438.

Betts, C., Devereux, M., 1996. The exchange rate in a model of pricing-to-market. European Economic Review 40, 1007–1021.

Corsetti, G., Pesenti, P., 2005. International dimensions of optimal monetary policy. Journal of Monetary Economics 52, 281–305.

Devereux, M. B., Engel, C., 2002. Exchange rate pass-through, exchange rate volatility, and exchange rate disconnect. Journal of Monetary Economics 49(5), 913–940.

Devereux, M. B., Engel, C., 2003. Monetary policy in the open economy revisited: price setting and exchange-rate flexibility. The Review of Economic Studies 70(4), 765–783.

Devereux, M. B., Engel, C., Storgaard, P., 2004. Endogenous exchange rate pass-through when nominal prices are set in advance. Journal of International Economics 63, 263–291.

Devereux, M. B., Shi, S., 2013. Vehicle currency. International Economic Review 54(1), 97–133.

Donnenfeld, S., Haug, A., 2003. Currency invoicing in international trade: An empirical investigation. Review of International Economics 11, 332–345.

Donnenfeld, S., Zilcha, I., 1991. Pricing of exports and exchange rate uncertainty. International Economic Review 32, 1099–1022.

Engel, C., 2006. Equivalence results for optimal pass-through, optimal indexing to exchange rates, and optimal choice of currency for export pricing. Journal of the European Economic Association 4(6), 1249–1260.

Floden, M., Wilander, F., 2006. State dependent pricing, invoicing currency, and exchange rate pass-through. Journal of International Economics 70(1), 178–196.

Friberg, R., 1998. In which currency should exporters set their prices? Journal of International Economics 45(1), 59–76.

Friberg, R., Wilander, F., 2008. The currency denomination of exports - A questionnaire study. Journal of International Economics 75(1), 54–69.

Giovannini, A., 1988. Exchange rates and traded goods prices. Journal of International Economics 24, 45–68.

Goldberg, L. S., Tille, C., 2008. Vehicle currency use in international trade. Journal of International Economics 76(2), 177–192.

Goldberg, L. S., Tille, C., 2009. Micro, macro, and strategic forces in international trade invoicing, Working Paper 15470, NBER.

Gopinath, G., Itskhoki, O., 2010. Frequency of price adjustment and pass-through. The Quarterly Journal of Economics 125(2), 675–727.

Gopinath, G., Itskhoki, O., Rigobon, R., 2010. Currency choice and exchange rate pass-through. American Economic Review 100(1), 304–36.

Grassman, S., 1973. Currency distribution and forward cover in foreign trade. Journal of International Economics 6, 215–221.

Grossman, G. M., Helpman, E., 1993. Innovation and growth in the global economy. The MIT Press.

Halpern, L., Koren, M., Szeidl, A., in press. Imported inputs and productivity, American Economic Review.

Hausman, J., McFadden, D., 1984. A specification test for the multinomial logit model. Econometrica 52, 1219–1240.

Hummels, D., Ishii, J., Yi, K. M., 2001. The nature and growth of vertical specialization in world trade. Journal of International Economics 54(1), 75–96.

Ito, T., Koibuchi, S., Sato, K., Shimizu, J., 2010. Why has the yen failed to become a dominant invoicing currency in Asia? A firm-level analysis of Japanese exporters' invoicing behavior, Working Paper 16231, NBER.

Johnson, R. C., Noguera, G., 2012. Accounting for intermediates: Production sharing and trade in value added. Journal of International Economics 86(2), 224–236.

Kenen, P. B., 2011. Currency internationalisation: An overview. BIS Papers 61, 9–18.

Martin, J., Méjean, I., 2012. Invoicing currency, firm size, and hedging, CEPII research center working paper 2012-28.

McKinnon, R., 1979. Money and international exchange: The convertible currency system. Oxford University Press.

Obstfeld, M., Rogoff, K., 1995. Exchange rate dynamics redux. Journal of Political Economy 103(3), 624–660.

Rauch, J. E., 1999. Networks versus markets in international trade. Journal of International Economics 48(1), 7–35.

Rey, H., 2001. International trade and currency exchange. The Review of Economic Studies 3, 133–142.

Swoboda, A., 1968. The euro-dollar market: An interpretation. Princeton University.

Tavlas, G. S., 1997. The international use of the US dollar: An optimum currency area perspective. The World Economy 20(6), 709–747.

Wilander, F., 2005. An empirical analysis of the currency denomination in international trade, Mimeo, Stockholm School of Economics.

Appendix A: Model Solutions

This appendix provides the detailed derivation of the model presented in Section 2. I drop the subscript i for brevity. Given output Y, the firm minimizes its total cost:

$$\min_{L,X,Z,M} \mathrm{TC}(Y) = WL + QZ + SQ^*M + Wf.$$

Denote by μ and χ the Lagrange multipliers on production constraints (2) and (3), respectively. The first-order conditions for cost minimization are as follows:

$$W = \mu(1-\gamma)\frac{Y}{L}, \tag{A1}$$

$$\chi = \mu\gamma\frac{Y}{X}, \tag{A2}$$

$$Q = \chi\left(\frac{X}{Z}\right)^{1/(1+\theta)}, \tag{A3}$$

$$SQ^* = \chi\left(\frac{a^\theta X}{M}\right)^{1/(1+\theta)}. \tag{A4}$$

Rearranging these conditions together with (3) gives

$$QX = \mu\gamma Y\left[1+\left(\frac{a}{SQ^*/Q}\right)^\theta\right]^{1/\theta}. \tag{A5}$$

Substituting (A5) and (A1) into (2), I solve for marginal cost μ:

$$\mu = \frac{C}{Ab^\gamma},$$

where $b \equiv \left[1+(aQ/SQ^*)^\theta\right]^{1/\theta}$ and $C = \gamma^{-\gamma}(1-\gamma)^{\gamma-1}Q^\gamma W^{1-\gamma}$. Substituting (A1)-(A4) into the total cost function yields $TC(Y) = \mu Y + Wf$.

The parameter ψ is defined as the fraction of total costs spent on imported inputs: $\psi = SQ^*M/(SQ^*M + QZ)$. Using (A4), I obtain the share of costs spent on imported inputs as

$$\psi = \left(1 - b^{-\theta}\right).$$

Some rearranging yields the home share of inputs in (5). It can also be shown that the partial elasticity of the marginal cost with respect to the exchange rate equals a share

of import intensity:

$$\begin{aligned}\frac{\partial \ln \mu}{\partial \ln S} &= \frac{\partial \ln \mu}{\partial \ln b} \times \frac{\partial \ln b}{\partial \ln S} \\ &= (-\gamma)\left[-\left(1-b^{-\theta}\right)\right] \\ &= \gamma\psi.\end{aligned}$$

Next, I turn to prove the firm's decision rule in (10) following the solution technique of Devereux et al. (2004) and Engel (2006). Using the optimal price under PCP in equation (8), I rearrange the expected discounted profits in equation (6) as

$$E\Pi^{PCP} = \widetilde{\lambda}\left[E\left(S^{\lambda}\Omega\right)\right]^{\lambda}\left[E\left(\mu \cdot S^{\lambda}\Omega\right)\right]^{1-\lambda},$$

where $\widetilde{\lambda} \equiv \lambda^{-\lambda}(\lambda-1)^{\lambda-1}$ and $\Omega \equiv \kappa P_{hf}^{*(\lambda-\delta)} P^{*\delta} D^{*}$. Note that prices are preset one period in advance, i.e., $E_{t-1}(P_t) = P_t$. By taking a second-order approximation and using $\ln(1+x) \approx x$, the (log) expected discounted profits under PCP can be computed as

$$\begin{aligned}\ln E\Pi^{PCP} \approx \ln \Sigma &+ \frac{\lambda^2}{2} var(\ln S) + \frac{1}{2} var(\ln \Omega) + \frac{1-\lambda}{2} var(\ln \mu) \\ &+ \left[\begin{array}{c} \lambda cov(s,\omega) + \lambda(1-\lambda) cov(\ln \mu, \ln S) \\ +(1-\lambda) cov(\ln \mu, \ln \Omega) \end{array}\right].\end{aligned} \tag{A6}$$

where $\Sigma \equiv \widetilde{\lambda} \exp\left[\lambda E\left(\ln S\right)\right] \exp\left[E\left(\ln \Omega\right)\right] \exp\left[(1-\lambda) E\left(\ln \mu\right)\right]$. Similarly, the expected discounted profits under LCP in equation (9) can be shown as

$$E\Pi^{LCP} = \widetilde{\lambda}\left[E\left(S\Omega\right)\right]^{\lambda}\left[E\left(\mu \cdot \Omega\right)\right]^{1-\lambda}.$$

Using the same approximation technique, the (log) expected discounted profits under LCP can be computed as

$$\begin{aligned}\ln E\Pi^{LCP} \approx \Sigma &+ \frac{\lambda}{2} var(\ln S) + \frac{1}{2} var(\ln \Omega) + \frac{1-\lambda}{2} var(\ln \mu) \\ &+ \left[\lambda cov(\ln S, \ln \Omega) + (1-\lambda) cov(\ln \mu, \ln \Omega)\right].\end{aligned} \tag{A7}$$

Now, comparing (A6) with (A7) yields

$$\begin{aligned}\ln E\Pi^{PCP} - \ln E\Pi^{LCP} &= \frac{1}{2} var(\ln S) - cov(\ln \mu, \ln S) \\ &= \frac{1}{2} var(\ln S) + \gamma cov\left(\ln b, \ln S\right) \\ &= \frac{1}{2} var(\ln S) - \frac{\gamma}{\theta} cov\left(\ln\left(1-\psi\right), \ln S\right),\end{aligned}$$

where the second line comes from the equation of marginal cost in (4) and the third line comes from the home share of inputs in (5). The firm's decision rule follows.

The model also accommodates the cases of perfect substitutes and perfect complements between domestic and foreign inputs. When domestic and foreign inputs are perfect substitutes ($\theta \to \infty$), whether or not firms use imported inputs depends on the price-adjusted productivity term, $a_i/(SQ^*/Q)$. If a firm has an advantage in using imported inputs ($a_i/(SQ^*/Q) > 1$), then it uses only imported inputs. In this case, the right-hand side of the decision rule in (10) becomes $var(\ln S)$ and the firm uses only LCP. On the contrary, if a firm has a disadvantage in using imported inputs ($a_i/(SQ^*/Q) < 1$), then it uses only domestic inputs. In this case, the right-hand side of the decision rule in (10) becomes zero and the firm uses only PCP. If the price-adjusted productivity term is unity, the firm is indifferent between the varieties of inputs and also between invoicing currencies. In the case of perfect complements ($\theta \to 0$), firms use both varieties and are indifferent between currencies.

Appendix B: Proof of Decision Rule under VCP

In this Appendix, I provide the proof to Proposition 3. Again I drop the subscript i for brevity. Given the CES demand in (1), the firm presets its optimal prices to maximize the expected discounted profits under PCP, LCP, and VCP, respectively:

$$\begin{aligned} p^{PCP} &= \frac{\lambda}{\lambda-1} \cdot \frac{E\left(\mu\Omega S_{hv}^{\lambda}\right)}{E\left(\Omega S_{hv}^{\lambda}\right)}, \\ p^{LCP} &= \frac{\lambda}{\lambda-1} \cdot \frac{E\left(\mu\Omega S_{fv}^{\lambda}\right)}{E\left(\Omega S_{hv} S_{fv}^{\lambda-1}\right)}, \\ p^{VCP} &= \frac{\lambda}{\lambda-1} \cdot \frac{E\left(\mu\Omega\right)}{E\left(\Omega S_{hv}\right)}, \end{aligned}$$

where $\Omega \equiv \kappa P_{hf}^{*(\lambda-\delta)} P^{*\delta} D^*$. Using these optimal prices, the expressions for the expected discounted profits in equations (11)-(13) become

$$\begin{aligned} E\Pi^{PCP} &= \widetilde{\lambda}\left[E\left(\Omega S_{hv}^{\lambda}\right)\right]^{\lambda}\left[E\left(\mu\Omega S_{hv}^{\lambda}\right)\right]^{1-\lambda}, \\ E\Pi^{LCP} &= \widetilde{\lambda}\left[E\left(\Omega S_{hv} S_{fv}^{\lambda-1}\right)\right]^{\lambda}\left[E\left(\mu\Omega S_{fv}^{\lambda}\right)\right]^{1-\lambda}, \\ E\Pi^{VCP} &= \widetilde{\lambda}\left[E\left(\Omega S_{hv}\right)\right]^{\lambda}\left[E\left(\mu\Omega\right)\right]^{1-\lambda}, \end{aligned}$$

where $\widetilde{\lambda} \equiv \lambda^{-\lambda}(\lambda-1)^{\lambda-1}$. Following the solution technique in Appendix A, I take a second-order approximation for these equations and rewrite them as

$$\begin{aligned}\ln E\Pi^{PCP} \approx \ln\Sigma + \frac{1}{2}var(\ln\Omega) + \frac{1-\lambda}{2}var(\ln\mu) + \frac{\lambda^2}{2}var(\ln S_{hv}) \\ + \left[\begin{array}{c}\lambda cov(\ln\Omega, \ln S_{hv}) + (1-\lambda)cov(\ln\mu, \ln\Omega) \\ +\lambda(1-\lambda)cov(\ln S_{hv}, \ln\mu)\end{array}\right],\end{aligned} \tag{B1}$$

$$\begin{aligned}\ln E\Pi^{LCP} \approx \ln\Sigma + \frac{1}{2}var(\ln\Omega) + \frac{1-\lambda}{2}var(\ln\mu) \\ + \frac{\lambda}{2}var(\ln S_{hv}) + \frac{\lambda(1-\lambda)}{2}var(\ln S_{fv}) \\ + \left[\begin{array}{c}\lambda cov(\ln\Omega, \ln S_{hv}) + (1-\lambda)cov(\ln\mu, \ln\Omega) \\ +\lambda(1-\lambda)cov(\ln S_{fv}, \ln\mu) - \lambda(1-\lambda)cov(\ln S_{hv}, \ln S_{fv})\end{array}\right],\end{aligned} \tag{B2}$$

$$\begin{aligned}\ln E\Pi^{VCP} \approx \ln\Sigma + \frac{1}{2}var(\ln\Omega) + \frac{1-\lambda}{2}var(\ln\mu) + \frac{\lambda}{2}var(\ln S_{hv}) \\ + \left[\lambda cov(\ln\Omega, \ln S_{hv}) + (1-\lambda)cov(\ln\mu, \ln\Omega)\right],\end{aligned} \tag{B3}$$

where $\Sigma = \widetilde{\lambda}\exp\left[(1-\lambda)E\ln\mu\right]\exp\left[\lambda E\ln S_{hv}\right]\exp\left[E\ln\Omega\right]$.

Comparing (B3) with (B1) and (B2), the conditions (14) and (15) in the main text and Proposition 3 follow.