The University of Nottingham

research paper series

Globalisation, Productivity and Technology

Research Paper 2014/11

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

by

Wanyu Chung

GEP

The Author

Wanyu Chung, GEP and School of Economics, University of Nottingham

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Acknowledgements

I gratefully acknowledge HMRC for the use of data and in particular Daniele Bega and Lucy Nicholson at the HMRC datalab for their patience in answering my questions. I thank Dennis Novy, Natalie Chen, Thijs van Rens, Carlo Perroni, Gianluca Benigno, Dan Bernhardt and seminar participants at Nottingham, Warwick, the LSE, Copenhagen Business School, Essex, Sussex, Southampton, National Taiwan University, the SAEe conference and the RES 2014 annual conference for insightful comments. A special thank you to Guillermo Noguera for sharing the disaggregated VAX ratios, as well as useful discussions. Financial support from the Department of Economics at Warwick is gratefully acknowledged.

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Abstract

What determines the currency denomination of international trade? This is the first paper to consider in theory and data how exporters' dependence on imported inputs affects their choice of invoicing currency. My model predicts that exporters more dependent on foreign currency-denominated inputs are more likely to use foreign currency for pricing. Using a novel dataset that covers all UK trade transactions with non-EU countries, I provide firm-level evidence by matching import and export data and relate exporters' invoicing currency choice to their import behavior. I find considerable support for the model's predictions, and these findings have strong implications for the variation of exchange rate pass-through across industries.

JEL classification: F1, F31, F41.

Keywords: Invoicing Currency, Exchange Rate Pass-through, Trade in Intermediate Goods.

Outline

1 Introduction

When selling to a foreign market, an exporter can invoice the transaction in its own currency (producer currency pricing or PCP), in the currency of the destination country (local currency pricing or LCP), or in the currency of a third country (vehicle currency pricing or VCP). Currency denomination in international trade directly affects how trade balances and domestic prices respond to changes in exchange rates. Hence, from a policy perspective, it has far-reaching implications for the international transmission of macroeconomic shocks, the effectiveness of monetary policy and the choice of exchange rate regimes. While most studies treat the choice of invoicing currency as exogenous when examining its macroeconomic implications, the current paper focuses instead on the determinants of invoicing currency choice.[1]

More precisely, the contribution of this paper is to examine, theoretically and empirically, whether exporting firms' dependence on imported inputs affects their invoicing currency choice. Are there marked differences in invoicing currency choice between exporters that use imported inputs and exporters that do not? When choosing an invoicing currency, do exporting firms consider the currency used for their imported inputs? These questions are of particular interest as trade in intermediate inputs is an important empirical regularity. For example, trade in intermediate goods constitutes about 60% of total UK trade and the pattern varies significantly across sectors.[2]

Despite the relevance of trade in intermediate goods, theoretical work on its implications for invoicing currency and macroeconomic aggregates remains sparse.[3] From an empirical point of view, the limitation of the existing literature is due to the lack of disaggregated data on invoicing currency. For a long time, little was known beyond a number of broad stylized facts, based mainly on aggregated data. 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. It is also acknowledged that inflationary currencies are less likely to be used in foreign trade.[4] This paper aims at filling both the theoretical and the empirical gaps in the literature.

First, I derive a theoretical framework that features firm heterogeneity in the dependence on imported inputs together with endogenous invoicing currency choice. The

[1] See, among others, Corsetti and Pesenti (2005) and Devereux and Engel (2002) for the implications for monetary and exchange rate policies.

[2] Source: HMRC trade statistics. Trade in intermediate goods is also related to the following terms: vertical specialization, outsourcing and fragmentation. See Hummels, Ishii and Yi (2001) for definitions.

[3] Ghosh (2009) shows in a model that trade in intermediate goods may be the underlying factor of the empirical decline of exchange rate pass-through. However, he focuses on firms' pricing to market behavior and does not consider invoicing currency choice.

[4] See, for example, Grassman (1973), McKinnon (1979) and Tavlas (1991) for the early studies. Also, see Kamps (2006) for a discussion.

exporter is assumed to pre-set prices and an invoicing currency to maximize expected profits under exchange rate uncertainty. The model predicts that all else being equal, exporters more dependent on imported inputs are less likely to use their own currency. The intuition behind this result is that pricing in the foreign currency provides a natural hedge for firms that use foreign currency-denominated inputs. The model also predicts that a volatile currency is less likely to be used for invoicing (consistent with the finding of Devereux, Engel and Storgaard, 2004).

In order to test the theoretical predictions, I use a novel and highly disaggregated dataset on UK import and export transactions with non-EU countries in 2011, recorded by Her Majesty's Revenue and Customs (HMRC).[5] For each transaction, the invoicing currency is recorded along with the trader ID, country of dispatch or destination, product and industry codes, statistical value and other custom variables. The analysis comprises two parts. The main part focuses on the choice of invoicing currency for UK exports (2.54 million transactions). The second part examines the currency denomination for UK imports (7.31 million transactions).

In the main analysis, I first identify exporters' use of imported inputs together with the currencies used for these inputs.[6] To the best of my knowledge, this is the first paper matching trader IDs from both import and export data for a firm-level analysis of the invoicing currency. After controlling for firm size and destination effects, the first key result is that exporters using imported inputs are less likely to use sterling compared to exporters that do not rely on foreign inputs. Furthermore, the degree matters too. For example, a 1% decrease in the share of imported inputs priced in sterling decreases the probability that UK exporters invoice in sterling by about 18%. Another key result is that high exchange rate volatility significantly shifts UK exporters' invoicing choice away from the volatile currency. Overall, these results strongly support the theoretical predictions.

Other findings shed some light on relating currency choice to firm characteristics. For instance, larger UK exporters are less inclined to use their domestic currency. This supports the argument that larger firms are more likely to hedge using financial instruments because hedging incurs a fixed cost that large firms are more likely to afford.[7] In contrast, all else being equal, experienced firms (those trading for more than five years in exporting markets) are more inclined to use PCP rather than VCP. This might

[5] The dataset is confidential and not publicly available.

[6] I define imported inputs as goods imported for industrial use, and the categorization of goods is based on the Broad Economic Categories (BEC) classification. This classification decomposes goods into three end-use categories: consumption (final), intermediate and capital goods. Capital goods are divided into BEC 41 (capital goods except transport equipment) and BEC 521 (transport equipment for industrial use). I treat both intermediate and capital goods as industrial inputs.

[7] See, for instance, Martin and Méjean (2012) for survey results of 3,013 exporting firms located in five European Monetary Union (EMU) countries.

suggest higher bargaining power for more experienced firms.[8]

To complement my main analysis, I also look into the currency denomination for UK imports. As I do not observe the use of imported inputs for exporters from different exporting countries, I use a systematic measure of value added to gross exports (VAX ratios) computed by Johnson and Noguera (2012) as a proxy for the dependence on imported inputs at the country level. If a country heavily relies on imported inputs, the value added relative to gross exports should be lower. Hence, VAX ratios are inversely related to the dependence on imported inputs. This is the first paper to use VAX ratios in examining invoicing currency choice. I find that countries more dependent on foreign inputs systematically use less of their own currency for exports (PCP is less likely).[9]

In both analyses, I control for a number of other factors discussed in the existing literature. These include the following: (i) macroeconomic considerations, such as transaction costs of exchange (Devereux and Shi, 2013); (ii) industry characteristics, such as market competition (Bacchetta and van Wincoop, 2003) and price sensitivity of demand (Bacchetta and van Wincoop, 2005); (iii) strategic characteristics, such as bargaining between exporters and importers (Goldberg and Tille, 2008); and (iv) destination characteristics.

This paper is related to several strands of literature. There is an extensive theoretical literature on the determinants of invoicing currency.[10] My main contribution is to provide an alternative but complementary determinant of invoicing currency, namely firms' use of imported inputs. Empirical evidence on currency choice in international trade is scarce. Most existing studies document country- or industry-specific determinants of invoicing currency choice, rather than firm-level characteristics.[11] One exception is Friberg and Wilander (2008) who present a survey study on the currency considerations of Swedish exporting firms. They find that smaller Swedish firms and firms selling differentiated products are more likely to use Swedish kronor (PCP), a finding that is consistent with my results. The paper that is most similar to mine is that of Goldberg and Tille (2011), which documents the importance of strategic interaction and bargaining power in determining currency choice using a disaggregated dataset of Canadian import transactions.[12] Instead, my paper focuses on linking firm-level characteristics,

[8] Goldberg and Tille (2008) consider bargaining between importers and exporters when deciding on the invoicing currency. They argue that larger firms have a stronger bargaining power.

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

[10] See, among others, Baron (1976), Giovannini (1988), Donnenfeld and Zilcha (1991) and Friberg (1998) for the early literature that takes a micro perspective.

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

[12] They use industry-level variables such as market shares of exporting countries within an industry

firm experience and the dependence on imported inputs, to the choice of invoicing currency and offering evidence from UK transaction data.

This paper also relates to a growing literature that examines how invoicing currency affects firms' price adjustments and accordingly endogenous exchange rate pass-through. This literature documents the differences in price adjustments for goods invoiced in different currencies (Floden and Wilander, 2006; Gopinath, Itskhoki and Rigobon, 2010). Furthermore, recent studies have examined the direct relationship between the use of imported inputs and the degree of pass-through (Amiti, Itskhoki and Konings, 2014). In general, the pass-through literature has shifted the focus from industries and countries to firm heterogeneity (Berman, Martin and Mayer, 2014). Understanding the factors that drive the choice of invoicing currency sheds some light on the variation of pass-through into prices across firms.

Finally, there is an active literature on measuring the domestic content of exports.[13] This paper is an example of the applied use of the VAX ratios constructed by Johnson and Noguera (2012). I use these ratios as a proxy for the degree of dependence on imported inputs at the country and country-industry levels.

The paper is structured as follows. The next section outlines a simple model to show how firms' choice of invoicing currency is affected by the presence of imported inputs. Section 3 presents the dataset and offers descriptive statistics. Section 4 presents the main analysis of invoicing currency choice for UK exporters and provides robustness checks. The analysis of currency denomination in imports is undertaken in section 5. Section 6 concludes.

2 A Model of Imported Inputs and Currency Choice

In this section I develop a framework that relates the choice of invoicing currency to the dependence on imported inputs. The cost structure of the firm follows Halpern, Koren and Szeidl (2011) to allow for imported inputs.[14] I then build on Devereux et al. (2004) to derive the firm's decision rule for choosing an invoicing currency.[15]

2.1 Demand

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

and transaction sizes as a proxy for the bargaining power of exporters and importers, respectively.

[13] See, among others, Hummels et al. (2001).

[14] Halpern, Koren and Szeidl (2011) do not consider the currency of invoicing but focus on the relationship between firms' choice of import varieties and productivity.

[15] Devereux et al. (2004) consider endogenous currency choice without considering imported inputs.

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

where D is the quantity demanded, p_i is the firm's price, P^*_{hf} is the price index for all home goods sold in the foreign country and P^* is the foreign consumer price index (all denominated in 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

A risk-neutral firm i uses labor L_i and intermediate goods X_i in order to produce following a Cobb-Douglas production function with constant returns to scale:

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

where A_i is firm i'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 consist of two varieties, domestic and foreign, which 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 $(1+\theta) > 1$.[16] I assume that the price of the domestic input Z_i is Q, denominated in domestic currency. The foreign input M_i is priced in foreign currency with the price SQ^*, S being the exchange rate (defined as the domestic price of foreign currency) and Q^* being the price denominated in foreign currency (hence starred).[17]

The parameter a_i captures how productive firm i is in using the foreign inputs, which in this model varies across firms and directly determines the degree of dependence on imported inputs. A high a_i represents high productivity advantage for firm i in using the foreign inputs, and vice versa.[18]

[16] Since 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 under these cases.

[17] The model can be extended to allow a fraction of the imported inputs to be denominated in home currency. This extension reduces the degree of input price uncertainty, but it does not qualitatively change the model's predictions. In the empirical section, I will take into account each firm's fraction of imported inputs denominated in home currency.

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

Firm i pays a sunk cost f_i in terms of labor in order to import foreign inputs.[19] Given output, the firm first chooses the amount of inputs to minimize its total costs 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.

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

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

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

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

Home share of inputs depends on the productivity parameter a_i. A firm with higher productivity gain from using imported inputs (higher a_i) has higher dependence on imported inputs (lower $1-\psi_i$). The detailed model derivation is shown in Appendix A.

2.3 PCP versus LCP

After deciding on the amount of inputs, the firm is then assumed to pre-set optimal prices and invoicing currency one period ahead by maximizing its profits using a discount factor

productivity disadvantage. 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 Grossman and Helpman (1993)'s definition of 'quality' as the advantage in services provided by a good relative to its cost.

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

κ.[20] If the firm sets its price in its own currency (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 (LCP), then the expected discounted profit is:

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

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 $\Omega = \kappa P_{hf}^{*(\lambda-\delta)} P^{*\delta} D^*$.
Following Devereux et al. (2004), I take a second order approximation of the two expected profit functions and establish the firm's decision rule.

Proposition 1 *A domestic firm using foreign inputs sets its price for the foreign market in PCP if:*

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

The firm chooses LCP vice versa.

Proof. See Appendix B. ■

Proposition 1 says that all else being equal, exchange rate volatility, captured by high $var\left(\ln S\right)$ in (10), 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. Note that in the model setting, the exchange rates only affect the firm's total costs through the use of imported inputs denominated in the foreign currency. Therefore the right hand side in (10) is shut down for firms that do

[20] Note that the expectation takes place in period $t-1$ when the firms sets its price for period t. The time subscripts are omitted here for simplicity.

not use imported inputs. Given any exchange rate volatility ($var(\ln S) > 0$), they use only the home currency.[21] Below I discuss the two effects in turn.

The effect of exchange rate volatility enters the decision rule through the firm's consideration of expected revenues, as in Devereux et al. (2004). When the firm chooses PCP, the price is stable whereas the quantity (foreign demand) is subject to exchange rate uncertainty. On the other hand, when the firm chooses LCP, the quantity is stable whereas the price is subject to exchange rate uncertainty. The firm therefore faces a trade-off between stabilizing price and stabilizing quantity. The curvature of revenue functions matters for the optimal currency choice. Technically, the expected revenue function under PCP is convex in the exchange rate and linear under LCP. Holding all other variables constant, an increase in the exchange rate variance increases expected revenues under PCP relative to LCP.[22]

The right hand side in (10) enters the decision rule through the firm's consideration of expected costs. For example, if there is a depreciation in the home currency (higher S), foreign inputs become more expensive, which leads to a higher marginal cost. In this case, there will be an expenditure switching of the firm from using imported inputs to domestic inputs (higher $1-\psi_i$). The covariance term is positive and captures how responsive the firm is to input price uncertainty. A more responsive firm has more incentive to choose LCP for its exports. Also, this effect is stronger if domestic and foreign inputs are less substitutable (with lower elasticity of substitution θ). This result is consistent with the intuition that choosing LCP provides a natural hedge for the firm.

To see how the degree of dependence on imported inputs affects the decision rule, I rewrite the right hand side in (10) in terms of the productivity-enhancing effect b_i:

$$\begin{aligned} R.H.S &= \frac{\gamma}{\theta} cov\left[\ln\left(1-\psi_i\right), \ln S\right] \\ &= -\gamma cov\left(\ln b_i, \ln S\right), \end{aligned}$$

where the absolute value of $cov(\ln b_i, \ln S)$ is increasing in the degree of dependence on imported inputs ψ_i.[23] This implies that the right hand side is higher if the firm is more dependent on imported inputs, all else being equal. Put differently, a firm more dependent on imported inputs is more likely to use LCP. Based on the above discussion, the following testable hypotheses follow.

[21] This model result is supported by empirical evidence from UK data. The majority of UK exporters that do not use imported inputs price their exports in sterling only. See Section 3.3 for details.

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

[23] Note that $\partial \ln b_i / \partial \ln S = (-1/\gamma)\psi_i < 0$. See Appendix A for proof.

Testable hypothesis 1 *When exporting to a country with a more volatile exchange rate, exporters are more likely to use PCP relative to LCP, all else being equal.*

Testable hypothesis 2 *The more exporters are dependent on imported inputs priced in the foreign currency, the more likely they are in using the same currency for their exports.*

In this section I show in a two-country framework that the use of imported inputs denominated in the foreign currency alters a domestic firm's choice of invoicing currency. The model yields two testable hypotheses relating to exchange rate volatility and the use of imported inputs. The model can also be extended to allow for the case of vehicle currency pricing (VCP). In this case, a domestic firm's decision rule also depends on the covariance between the two exchange rates vis-à-vis the vehicle currency. This extension is shown in Appendix C.

3 The UK Trade Dataset and Descriptive Statistics

3.1 The Dataset

I use a highly disaggregated dataset for UK non-EU trade transactions in 2011 recorded by HMRC. The dataset is confidential and not publicly available.[24] For each trade transaction, I observe the trader ID, the country of dispatch (for imports) or the destination country (for exports), product and industry codes, the value of transaction and the currency of settlement. After dropping observations with no information on the invoicing currency, I am left with a sample that accounts for 95.1% of total imports (7.31 million observations) and 86.3% of total exports (2.54 million observations).

Arguably, one advantage of UK trade data is the diversity in trading partners. In 2011, the total number of trading partners is around 190 for both imports and exports. The main partners are the US, which represents 16% of imports and 29% of exports, and China which accounts for 15% of imports and 6% of exports.[25]

3.2 A Broad Assessment of Invoicing Currency for UK Trade

I first report a broad assessment of invoicing currency choice for UK trade. In 2011, 76 currencies were used for UK exports and 103 for imports. Table 1a presents the

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

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

shares of currency choice, the shares of pricing strategies in PCP/LCP/VCP and Table 1b shows the breakdowns of the shares of pricing strategies by industry, destination and the category of goods.

The first observation is that there is an asymmetry in the currency use for exports relative to imports—the dominant currency for imports is the US dollar (64.7%), whereas UK exports are mainly priced in sterling (57.4%). This pattern is at odds with Swedish evidence reported in Friberg and Wilander (2008) that Swedish exporters mainly use their customers' currencies for exports. The Euro accounts for a small share mainly because the data do not include trade with EU countries. Given that the US only represents 16% of total imports and 29% of exports, it is clear that the US dollar is used extensively as a vehicle currency, particularly for imports. As shown in Table 1a, VCP is the dominant strategy for imports whereas PCP is the dominant strategy for exports. The sectoral breakdown in Panel A of Table 1b also shows that these patterns hold across sectors, except for beverages and tobacco (SITC1) in imports.[26]

The breakdown by destination shown in Panel B of Table 1b shows that there is a significant variation in pricing strategies across destinations. In particular, almost all imports from the US are priced in dollar (82.6%). Also, imports from East and South East Asia have the highest share of goods priced in sterling (42.3%) compared to other destinations. Turning to exports, half of the exports to the US are priced in dollar (47.2%) whereas exports to other destinations are mainly priced in sterling.

Next, I decompose goods into final, intermediate and capital goods according to the Broad Economic Categories (BEC) classification.[27] To the best of my knowledge, this is the first paper using the BEC classification to examine invoicing currency for different categories of goods. As shown in Panel C of Table 1b, LCP is used more extensively for final goods relative to intermediate and capital goods (in value), especially for imports. This finding relates to the model assumption in Section 2 that imported inputs are priced exogenously in the foreign currency. Panel C shows that imports in intermediate goods, in particular, are mainly priced in currencies other than sterling.

The finding that LCP is used more extensively for final goods is also in line with the theoretical argument in Bacchetta and van Wincoop (2003) that final goods producers are more prone to use LCP due to local competition, compared to intermediate goods exporters.[28] I will test this theoretical prediction formally in the next section.

[26] VCP includes a wide range of currencies (57 for exports and 75 for imports).

[27] The trade shares of final, intermediate and capital goods for UK imports in 2011 are 24.2%, 58.2% and 13.9%, respectively. The figures are 18.4%, 56.8% and 15.7% for exports. Some goods are not classified by the BEC and account for 3.7% of UK imports and 9% of UK exports in 2011.

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

Table 1a. Invoicing Currency Choice for UK non-EU Trade in 2011

	Imports	Exports
Shares of Currency Choice (in Value)		
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 (in Value)		
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**

Table 1b. Shares of Pricing Strategy by Industry, Destination and Category

		Imports			Exports		
	1-digit SITC Industry	**PCP**	**LCP(£)**	**VCP**	**PCP(£)**	**LCP**	**VCP**
	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
Panel A	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:Not classified	37.3	0.7	62.0	50.7	0.5	48.8
	Destination Region/Country	**PCP**	**LCP(£)**	**VCP**	**PCP(£)**	**LCP**	**VCP**
	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
Panel B	East/SE 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
	The BEC Category	**PCP**	**LCP(£)**	**VCP**	**PCP(£)**	**LCP**	**VCP**
Panel C	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: classifications used are the Standard International Trade Classification (SITC) and the Broad Economic Categories (BEC).

3.3 Importing versus Non-importing Exporters

In the following discussion I turn to descriptive statistics for UK exporters active in 2011. I categorize UK exporters into two groups: *importing exporters* if they use imported inputs and *non-importing exporters* otherwise. The inputs imported by all importing exporters account for 63.4% of all UK imported inputs.[29] Table 2a presents the differences between the two groups according to their firm facts and pricing strategies. Table 2b presents their export sectors, destinations and the categories of goods.

The first fact I document is that importing firms are larger than non-importing exporters in terms of export market shares. Among all exporters 32,289 firms (55%) rely on imported inputs and account for 89.5% of total exports. Another characteristic of interest relates to firm experience. Within the group of importing exporters, 72% (i.e., 23,078 firms) have more than five years of experience in exporting, and they account for about 79.9% of total UK exports; in contrast, within non-importing exporters, only 47% (i.e., 12,520 firms) have more than five years of experience in exporting, with about 7.9% of export share.

Table 2a also shows that the difference in pricing strategy between importing and non-importing exporters is significant. I find that a large share of non-importing exporters (75.4%) only use PCP (sterling) for exports, whereas this figure is about 49.9% for importing exporters. Also, a larger share of non-importing exporters (8%) use only VCP, as opposed to 3.5% for importing exporters. More interestingly, only 14% of non-importing firms use a combination of two or three strategies, as opposed to 44% for importing firms.[30]

What causes the difference in pricing strategy between importing exporters and non-importing exporters? Is it because of their importing behavior and consideration of input price uncertainty, as proposed in this paper, or other firm characteristics such as firm size and firm experience? This is the main question that will be explored formally in the next section.

Table 2b shows that there is no substantial heterogeneity in export sectors and export destinations between importing and non-importing exporters. Comparing the export shares of different categories of goods, however, we can see that importing exporters have a higher share of exports in intermediate goods compared to non-importing exporters. This finding suggests that firms that use imported inputs also export more intermediate goods, and hence are more engaged in vertical specialization.

[29] The rest is imported by firms that only sell to domestic markets.

[30] Within the mixed group, the average shares (by value) of PCP, LCP, and VCP are: 60%, 16%, and 24% for importing firms and 59%, 15%, 26% for non-importing firms. It is worth noting that some firms use different currencies for the same good exported to the same country. This may be due to multiple importers.

Table 2a. Importing versus Non-importing Exporters: Firm Facts

	Importing	Non-importing
Firm Facts		
Share of Total Export	89.5	10.5
Number of Firms	32,289	26,618
w/ export value in upper 5th percentile	2,568	377
exporting for more than five years	23,078	12,520
(share of export)	(79.9%)	(7.9%)
Shares of Firms by Pricing Strategy (in Number of Firms)		
All PCP (£)	49.9	75.4
All LCP	2.2	2.5
All VCP	3.5	8.0
Mixed of Two or More Strategies	44.4	14.0
Sum	**100.0**	**100.0**

Table 2b. Importing versus Non-importing Exporters: Sectors, Destinations and Categories of Goods

	Importing	Non-importing
Shares of exports by 1-digit SITC Industry (in Value)		
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:Not classified	2.1	0.8
Sum	**100.0**	**100.0**
Shares of Exports by Destination (in Value)		
US	28.6	31.1
China	6.3	7.2
East/SE 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 (in Value)		
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**

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

4 The Determinants of Invoicing Currency Choice for UK Exporters

I now examine formally how the use of imported inputs affects exporters' choice of invoicing currency for their exports. I use the whole sample of UK exports (2.54 million transactions) and reduce it into the firm-product-destination-currency level (0.65 million observations). The dimension that is eliminated is the frequency of shipping for each exporter (at the product-destination-currency level) within a year.[31]

The dependent variables are dummy variables capturing whether the pricing strategy is PCP, LCP or VCP. The regressions are estimated using a multinomial logit procedure (MNL) which imposes the constraint that the three invoicing alternatives are mutually exclusive and exhaustive. Statistical significance in MNL specifications shows the direction in which the explanatory variables shift the likelihood of LCP and VCP away from the PCP (default) option. The estimating equation is:

$$\Pi^{i,c,k}\left(PCP\right) = \text{MNL}\ \left(Firm^{i}, Macro^{c}, Industry^{k}\right), \tag{11}$$

where superscripts i, c, and k denote firm, destination (country) and industry, respectively. $Firm^{i}$ is a set of factors relating to firm characteristics, including the use of imported inputs; $Macro^{c}$ is a set of macroeconomic factors relating to exchange rates; $Industry^{k}$ is a set of other measures at the industry level.

I control for within-industry correlation by clustering the standard errors at the HS4 level (1,191 clusters). For the sake of clarity, I only report a subset of results in Table 3 together with the associated Akaike Information Criteria (AIC) and Pseudo R-square statistics.[32] When including only constant terms (not reported), the coefficients are negative and significant for both LCP and VCP options (relative to PCP). This shows an unexplained prominence in PCP use for UK exports.

4.1 Imported Inputs Variables

Column (1) considers variables that are related to imported inputs. 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 model in section 2 predicts that the use of imported inputs increases the likelihood of firms to shift away from PCP, and this is supported by the data. The coefficients on the variable $Import^{i}$ are positive and highly significant, which reflects the more prominent use of both LCP and VCP (relative to PCP) for importing exporters.

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

[32] Note that in Table 3 the estimates for MNL regressions are odds ratios, not marginal effects.

Table 3. The Determinants of Currency Choice for UK Exporters

Dependent Variables	(1)		(2)		(3)		(4)		(5) Binary logistic	(6) Linear prob.	(7) Linear prob.
	LCP	VCP	LCP	VCP	LCP	VCP	LCP	VCP	nPCP=1	nPCP=1	nPCP=1
Firm Characteristics											
Import^{i}	0.78***	0.79***	0.73***	0.80***	0.74***	0.79**	0.72***	0.75***	0.08***	0.14***	0.19***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.11)	(0.02)	(0.02)
InputPCP^{i,c}	0.25***	-1.64***	0.27***	-1.63***	0.26***	-1.52***	0.24***	-1.56***	0.09***	0.12***	0.02*
	(0.03)	(0.08)	(0.03)	(0.08)	(0.03)	(0.08)	(0.03)	(0.08)	(0.04)	(0.01)	(0.03)
InputLCP^{i}	-0.40***	-1.11***	-0.42***	-1.12***	-0.39***	-0.11***	-0.40***	-1.11***	-0.18***	-0.17***	-0.20***
	(0.04)	(0.05)	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)	(0.10)	(0.02)	(0.00)
ratio$^{i.k}$			0.99***	0.76***	1.00***	0.73***	1.00***	0.73***	0.16***	0.17***	0.17***
			(0.14)	(0.14)	(0.15)	(0.14)	(0.15)	(0.13)	(0.14)	(0.03)	(0.06)
fiveyrold^{i}			0.00	-0.17***	0.12	-0.17***	0.00	-0.18***	-0.01	-0.02	-0.08***
			(0.03)	(0.02)	(0.02)	(0.03)	(0.02)	(0.03)	(0.07)	(0.01)	(0.02)
Top10^{k}			0.34***	0.11***	0.36***	0.11***	0.36***	0.13***	0.02***	0.04***	-0.00
			(0.03)	(0.02)	(0.03)	(0.02)	(0.02)	(0.01)	(0.02)	(0.00)	(0.01)
Macroeconomic Factors											
cvGBP^{c}					6.38***	1.49***	6.41***	1.46***	0.09**	0.09**	0.39**
					(0.41)	(0.17)	(0.49)	(0.16)	(0.23)	(0.04)	(0.17)
cvUSD^{c}					-1.70***	-0.68***	-1.67***	-0.64***	-0.34**	-0.32**	-0.17**
					(0.41)	(0.12)	(0.12)	(0.06)	(0.17)	(0.03)	(0.07)
Dpeg^{c}					-0.65***	-0.14***	-0.64***	-0.12***			-0.01
					(0.06)	(0.02)	(0.06)	(0.02)			(0.01)
Epeg^{c}					-1.98***	0.34***	-1.98***	0.35***			0.02
					(0.34)	(0.04)	(0.34)	(0.04)			(0.02)
FX^{c}					0.04***	-0.04***	0.04***	-0.04***			0.00***
					(0.00)	(0.00)	(0.00)	(0.00)			(0.00)
Industry Characteristics											
ClassC^{k}							0.11**	0.01			
vs. Intermediate							(0.05)	(0.06)			
ClassF^{k}							-0.09	-0.34***			
vs. Intermediate							(0.09)	(0.08)			
RauchR^{k}							-0.09	-0.17***			
vs. Homogeneous							(0.08)	(0.08)			
RauchN^{k}							-0.14*	-0.27***			
vs. Homogeneous							(0.08)	(0.08)			
Final goods											-0.09**
											(0.03)
Differentiated goods											-0.04
											(0.04)
Constant	-1.60***	-3.75***	-1.74***	-3.61***	-5.57***	-0.73**	-5.51***	-0.60***	0.29***	0.14***	0.21***
	(0.17)	(0.24)	(0.18)	(0.23)	(0.21)	(0.35)	(0.18)	(0.24)	(0.26)	(0.05)	(0.03)
Industry effects	Yes		Yes		Yes		Yes		Yes	Yes	No
Destination effects	Yes		Yes		Yes		Yes		No	No	No
Obs.	646,441		646,441		646,441		646,441		646,441	646,441	2,540,331
AIC	832,915		831,135		821,296		819,164		-	-	-
Pseudo-R^2	0.155		0.157		0.166		0.170		0.03	Adj. R^2=0.03	Adj. R^2=0.08

Notes: The default option is PCP. Industry effects are dummies for SITC 1-digit sectors. Destination effects are dummies for the US, China, East/SE Asia, Europe excluding EU, other American countries, and all other countries. Clustered standard errors in parentheses (at the HS4 level for column 1-4 and at the firm level for column 5-7). * significant at 10%; ** significant at 5%; *** significant at 1%.

In order to improve on the use of a dummy variable only, I compute a variable $InputPCP^{i,c}$ which measures the share of inputs that a firm i imports from country c priced in the currency of country c (PCP from the perspective of country c). This can be interpreted as firm i's "effective" dependence on inputs from country c. The results support Hypothesis 2 that firms highly dependent on imported inputs denominated in the foreign currency are more likely to use LCP relative to PCP.

Given that this variable only captures the bilateral (firm-destination) relationship, I also consider a firm-level ratio $InputLCP^{i}$ which captures the total share of firm i's sterling-denominated imported inputs. For example, suppose a UK exporter imports inputs from both the US (denominated in dollars) and China (denominated in sterling), and produces final goods sold to the US. The variable $InputPCP^{i,c}$ only captures the dollar-denominated inputs. Adding the variable $InputLCP^{i}$ would take all other sources of inputs into account. It is therefore a systematic measure of the overall degrees of input price uncertainty facing exporters. Higher $InputLCP^{i}$ is expected to increase the likelihood of firms to choose PCP. The results are in line with this prediction, particularly at the expense of VCP.

4.2 Other Firm Characteristics

In column (2) I add other factors relating to firm characteristics. First, I consider *firm relative size* in terms of market share of exports. I use the variable $ratio^{i,k}$, the share of exports of firm i into an HS4 industry, in order to proxy for firm relative size. I find evidence of currency choice tilted away from PCP for larger firms (with high $ratio^{i,k}$). One possible explanation is that larger firms highly involved in international activities have more incentives and resources to hedge against exchange rate uncertainty using financial instruments.[33] Hence, they are more likely to use LCP or VCP.

Second, I also consider *firm experience*. The dummy variable $fiveyrold^{i}$ takes the value one if firm i has more than five years of experience in the exporting markets and zero otherwise. The results suggest that more experienced firms are more likely to use PCP relative to VCP. One conjecture is that experienced firms may have more bargaining power since they know the market well and have more information on potential buyers.

Lastly, I consider *transaction size* by adding a dummy variable $Top10^{k}$ to capture whether a transaction falls in the top 10^{th} percentile of transactions in value within an HS4 industry. I find that larger transactions are less likely to be priced in PCP. These result support the theoretical prediction of Goldberg and Tille (2008) who argue that larger transactions capture the bargaining power of importers.[34] However, it might

[33] Large firms are more likely to operate as multinational firms and also more able to afford the cost of hedging.

[34] The results are also consistent with the findings of Friberg and Wilander (2008) and Goldberg and Tille (2011).

be the case that large transactions are performed by large firms, and therefore the variable $Top10^k$ simply captures a similar effect as the firm size variable $ratio^{i,k}$.

4.3 Macroeconomic Factors

In column (3) I add a set of macroeconomic factors. Two variables are used as a proxy for *exchange rate volatility*: the coefficients of variation of the importer's currency relative to sterling and the US dollar denoted by, respectively, $CVGBP^c$ and $CVUSD^c$. The variables are computed using the IMF's monthly exchange rate data during the period 2006-2010.[35] Under exchange rate uncertainty, the theory predicts that the currency of a country with more volatile macroeconomic conditions is unappealing for exporters (Devereux et al., 2004). Hypothesis 1 also says that exchange rate volatility makes PCP more appealing as opposed to LCP. When exporters sell to a country with a more volatile currency against the US dollar (high $CVUSD^c$), they are more likely to use PCP. Exchange rate volatility against sterling, however, gives the opposite result. This may be because sterling experienced an unusually high volatility during the 2006-2009 period.[36]

I also consider *exchange rate pegs*. I use two dummy variables to capture exchange rate pegs with respect to the US dollar and the Euro denoted by $Dpeg^c$ and $Epeg^c$, respectively. The peg definition follows the IMF's classification in 2007.[37] Exchange rate pegs might have mixed effects on exporters' currency choice. On the one hand, an exchange rate peg limits exchange rate volatility and so LCP should be more appealing (Goldberg and Tille, 2011). On the other hand, since the euro zone is excluded, an exchange rate peg might capture a low or unstable macroeconomic performance in emerging markets. Hence, LCP should be less appealing. The results are consistent with the second argument. I find that exporters are less likely to use LCP relative to PCP when exporting to countries with exchange rate pegs. Surprisingly, dollar pegs ($Dpeg^c = 1$) do not increase the probability that UK exporters settle for a third currency. In contrast, euro pegs ($Epeg^c = 1$) increase the probability that UK exporters settle for VCP relative to PCP.

The last factor I consider is *transaction cost of exchange*. Following Goldberg and Tille (2011), FX^c captures the share of the importer's currency in daily global foreign exchange market turnover, reported in the BIS Triennial Central Bank Survey in 2007.[38] Higher values of FX^c capture lower transaction costs for the importer's currency, and

[35] I use the period-average nominal exchange rate, IMF's International Financial Statistics series rf.

[36] In the section of robustness check, I exclude trade with the US and this effect disappears. The coefficients on $CVGBP^c$ become positive and therefore support Hypothesis 1.

[37] The various types of pegs are: (a) no separate legal tender; (b) pre announced peg or currency board arrangement; (c) pre announced horizontal band narrower than or equal to +/-2% and (d) de facto peg.

[38] The data include 35 currencies in 2007. Currencies not listed in the survey are assigned zero shares.

hence LCP should be used more (Goldberg and Tille, 2011).[39] The results shown in column (4) are in line with this argument.

4.4 Industry and Destination Characteristics

In column (4) I add two other factors relating to industry characteristics. The first one is *market competition*. Exporters of consumption goods may face higher local competition in the foreign market than exporters of intermediate goods. I use the BEC classification to define the end-use of goods. The set of variable $Class^k$ is defined at the 5-digit SITC level and consists of three dummy variables: Final or consumption ($ClassF^k$), intermediate ($ClassI^k$) and capital goods ($ClassC^k$). Due to local competition, final goods sold to consumers are more likely to be priced in LCP (Bacchetta and van Wincoop, 2003). The finding in column (4) suggests that final goods are more likely to be priced in PCP relative to VCP. The coefficient for LCP is not significant and therefore there is no evidence supporting the theoretical predictions for the role of market competition.[40]

The other factor I consider is *substitutability of goods*. I use the Rauch (1999) index to distinguish differentiated from homogeneous goods.[41] The Rauch variable is defined at the 4-digit SITC level and is captured by three dummy variables: Walrasian ($RauchW^k$), reference-priced ($RauchR^k$) and differentiated goods ($RauchN^k$). Walrasian and referenced-priced goods are viewed as more substitutable than differentiated goods. In theory, LCP is used more for homogeneous goods because exporters have the incentive to stabilize prices in the currency of the customers, when demand is highly elastic (Bacchetta and van Wincoop, 2005). Similarly, Goldberg and Tille (2008) document a coalescing effect: when goods are more homogeneous, an exporter is more prone to choose the currency used most extensively by its competitors. The coefficients on the Rauch variables support the argument that differentiated goods are more often priced in PCP, particularly relative to VCP.

I also add industry and destination fixed effects. In Table 3 the industry fixed effects are at the SITC 1-digit level.[42] Destination fixed effects are for the US, China, East and South East Asia, Europe excluding EU, other American countries, and all other countries. These variables are all significant.

[39] The theory also predicts that a currency that is traded extensively has lower transaction costs and is more likely to be considered as a vehicle currency (Devereux and Shi, 2013). Also see Swoboda (1968) and Rey (2001), among others, for earlier work on the role of currencies as a medium of exchange.

[40] In the previous section, I show that final goods are more priced in LCP (in value) than intermediate goods. This evidence is not significant in the regression results. One explanation is that final goods transactions are on average larger (in value) than intermediate goods transactions. The other explanation is that final goods are shipped more frequently and this dimension is eliminated in data collapsing.

[41] The Rauch classification of goods is originally constructed by Rauch (1999) and revised in 2007. I use the liberal rather than conservative classification.

[42] Other industry effects considered are the SITC 5-digit level and the HS4 level. The results do not change qualitatively.

4.5 Other Regression Models

In order to provide some interpretations for the magnitude of the estimates, I use two other regression models: binary logistic model and linear probability model. The dependent variable is dichotomous: whether a transaction is priced in non-sterling (nPCP=1) or sterling (nPCP=0).

Column (5) in Table 3 reports the estimated (average) marginal effects from binary logistic regression. Column (6) reports the results from a linear probability model. Overall the estimates are consistent with the results from the MNL model. I discuss only the results relating to the use of imported inputs below.

First, firms that use imported inputs are 8-14% more likely to use a foreign currency for exports than firms that do not use imported inputs. Second, a 1% increase in a firm's effective dependence on foreign inputs priced in the foreign currency ($InputPCP^{i,c}$) increases the probability of using a foreign currency by 9-12%. However, it is worth noting here that these two models do not separate the options of LCP and VCP. As shown in the results of MNL regressions, the variable $InputPCP^{i,c}$ has opposite effects for LCP and VCP (relative to PCP). The magnitude of the estimates would be higher if it is for the probability of using "the same" foreign currency (LCP) for exports. Lastly, a 1% increase in a firm's total share of inputs priced in sterling ($InputLCP^{i}$) increases the probability of using sterling by 17-18%.

Column (7) shows the results using a linear probability model with the full export dataset (2.54 millions). Overall the results predict the same directions as other specifications; however the magnitudes of the coefficients vary. These results therefore need to be interpreted with caution.

4.6 Robustness

I run a number of alternative regressions to ensure the robustness of the results. A subset of the results are reported in Table 4. I consider exclusively exporters that use imported inputs. Hence, the variable $Import^{i}$ is dropped. Column (8) and (9) show that my findings remain virtually unchanged. In column (10) I consider importing firms in the manufacturing sectors only (SITC 6-8). In 2011, UK manufactured goods account for about 56% of total non-EU exports. The estimates remain robust.

In column (11) I consider a subsample with firms involving in back-and-forth trade, i.e. importing inputs from and exporting goods to the same country. Again the results remain robust.

Table 4. Determinants of Currency Choice: Robustness Checks

Dependent Variable	(8) Importing Firms		(9) Importing Firms		(10) Importing Firms Manufacturing		(11) Firms with Back-and-forth Trade		(12) Importing Firms Excluding US	
	LCP	VCP	LCP	VCP	LCP	VCP	LCP	VCP	LCP	VCP
Firm Characteristics										
$InputPCP^{i,c}$	0.27***	-1.62***	0.24***	-1.47***	0.25***	-1.55***	1.22***	-0.80***	2.21***	-1.81***
	(0.03)	(0.08)	(0.03)	(0.08)	(0.03)	(0.08)	(0.03)	(0.08)	(0.08)	(0.12)
$InputLCP^{i}$	-0.40***	-1.12***	-0.43***	-1.11***	-0.48***	-1.15***	-0.62***	-1.93***	-0.30***	-1.16***
	(0.04)	(0.05)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)	(0.06)	(0.04)	(0.06)
$ratio^{i,k}$	0.97***	0.74***	1.13***	0.71***	1.03***	0.67***	0.68***	0.53***	1.66***	0.68***
	(0.15)	(0.15)	(0.19)	(0.15)	(0.21)	(0.19)	(0.15)	(0.16)	(0.18)	(0.15)
$fiveyrold^{i}$	0.01***	-0.15***	0.01	-0.16***	0.02	-0.17***	-0.03	-0.30***	-0.15**	-0.17***
	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.05)	(0.03)
$Top10^{k}$	0.32***	0.08***	0.34***	0.09***	0.32***	0.08***	0.25***	0.01	0.41***	0.11***
	(0.02)	(0.02)	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.02)
Macroeconomic Factors										
$cvGBP^{c}$			7.35***	1.20***	7.60***	1.22***	7.96***	0.95***	-1.14***	-0.27**
			(0.38)	(0.15)	(0.41)	(0.17)	(0.41)	(0.20)	(0.41)	(0.12)
$cvUSD^{c}$			-1.73***	-0.31***	-2.22***	-0.24**	-3.28***	-0.78***	-1.79***	-0.27**
			(0.34)	(0.11)	(0.41)	(0.12)	(0.51)	(0.18)	(0.41)	(0.11)
$Dpeg^{c}$			-1.18***	-0.04**	-1.14***	-0.04**	-1.13***	-0.03	-1.14***	-0.07**
			(0.08)	(0.02)	(0.08)	(0.02)	(0.08)	(0.03)	(0.07)	(0.02)
$Epeg^{c}$			-2.53***	0.30***	-2.37***	0.29***	-2.32***	0.53***	-2.44***	-0.27***
			(0.36)	(0.05)	(0.38)	(0.05)	(0.49)	(0.07)	(0.36)	(0.04)
FX^{c}			0.04***	-0.02***	0.04***	-0.02***	0.03***	-0.02***	0.04***	-0.04***
			(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Industry Characteristics										
$ClassC^{k}$			0.08**	0.03	0.08	0.02	0.08**	0.05	0.04	0.03
vs. Intermediate			(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.04)	(0.09)	(0.06)
$ClassF^{k}$			-0.09	-0.55***	-0.17***	-0.56***	-0.27***	-0.55***	0.27	-0.54***
vs. Intermediate			(0.08)	(0.08)	(0.06)	(0.08)	(0.06)	(0.09)	(0.14)	(0.08)
$RauchR^{k}$									0.60***	0.09
vs. Homogeneous									(0.18)	(0.08)
$RauchN^{k}$									0.55***	0.08
vs. Homogeneous									(0.12)	(0.08)
Constant	-0.95***	-2.86***	-4.27***	-0.65***	-4.83***	-0.39***	-7.04***	0.46***	-4.79***	-0.79***
	(0.19)	(0.27)	(0.08)	(0.05)	(0.39)	(0.08)	(0.40)	(0.09)	(0.13)	(0.08)
Industry effects	Yes		Yes		Yes		No		No	
Destination effects	Yes		Yes		Yes		No		No	
Obs.	529,890		529,890		452,404		216,845		371,538	
Pseudo-R^2	0.158		0.163		0.170		0.211		0.141	

Notes: The default option is PCP. Industry effects are dummies for SITC 1-digit sectors. Destination effects are dummies for the US, China, East/SE Asia, Europe excluding EU, other American countries, and all other countries. Clustered standard errors in parentheses (at the HS4 level). * significant at 10%; ** significant at 5%; *** significant at 1%.

As discussed in the previous section, the US is a special case where LCP is used extensively compared to other destinations. In column (12) I exclude the US from the sample and consider UK exports to non-US destinations only. The findings on the effects of imported inputs do not change qualitatively. Also, the coefficients on

the variable $fiveyrold^i$ are both negative and significant. This evidence suggests that experienced firms exporting to non-US markets are more likely to use sterling than any other currency.

Note that the results on macroeconomic factors differ from the previous analysis. In particular, the variable $CVGBP^c$ shows the same predicted effects as the variable $CVUSD^c$. High exchange rate volatility against sterling makes PCP more appealing, a result consistent with Hypothesis 1. Furthermore, the coefficients on the exchange rate pegs variables all have significant negative signs. This implies that UK exporters are more likely to use sterling when exporting to countries with exchange rate pegs.[43]

5 Currency Denomination in UK Imports

One challenge of relating imported inputs to currency denomination for imports is to measure systematically the dependence on imported inputs across exporters from different exporting countries. I use a measure of value added to gross exports (VAX ratio) computed by Johnson and Noguera (2012) to proxy for the dependence on imported inputs at the country and country-industry level. Countries with higher value added to gross exports are less dependent on imported inputs. VAX ratios are therefore inversely related to the dependence on imported inputs.

I take the full sample of UK imports from non-EU countries in 2011 (7.31 million transactions). The dependent variables are dummy variables capturing whether the pricing strategy is PCP, LCP or VCP. The regressions are estimated using a multinomial logit procedure (MNL), taking PCP as the default option. The estimating equation is:

$$\Pi^{c,k}\left(PCP\right) = \text{MNL}\ \left(VAX^c, Macro^c, Industry^k\right), \tag{12}$$

where VAX^c denotes the VAX ratios at the country level, $Macro^c$ is a set of macroeconomic factors relating to exchange rates, and $Industry^k$ is a set of other measures at the industry level.

I control for within-industry correlation by clustering the standard errors at the HS4 level (1,206 clusters). For the sake of clarity, I only report a subset of results in Table 5 together with the associated Akaike Information Criteria (AIC) and Pseudo R-square statistics. The first column only includes constant terms. The positive and significant coefficients show unexplained prominent use of LCP and VCP (relative to PCP).

[43] Another robustness check is replacing the liberal version of the Rauch indexes with the conservative one. The results are not reported here but I do not find significance in the explanatory power of the conservative version of the Rauch indexes.

Table 5. Currency Denomination in UK Imports

Dependent Variable	(1)		(2)		(3)		(4)		(5)	
	LCP(£)	VCP	LCP(£)	VCP	LCP(£)	VCP	LCP(£)	VCP	LCP(£)	VCP
VAX^c			-8.65***	-12.91***	-1.68**	-3.30***	-1.67**	-3.47***	-1.62**	-3.44***
			(0.72)	(0.52)	(0.73)	(0.15)	(0.69)	(0.64)	(0.71)	(0.60)
Macroeconomic Factors										
$cvGBP^c$					-5.36***	-8.12***	-6.64***	-8.15***	-6.89***	-8.33***
					(1.76)	(1.33)	(0.23)	(0.27)	(1.63)	(1.33)
$Dpeg^c$					0.98***	1.86***	1.22***	1.68***	0.60***	1.66***
					(0.23)	(0.27)	(0.23)	(0.27)	(0.23)	(0.27)
$Epeg^c$					1.11***	0.70**	1.22***	0.71***	1.31***	0.72**
					(0.35)	(0.30)	(0.36)	(0.29)	(0.34)	(0.29)
FX^c					-0.05***	-0.07***	-0.05***	-0.08***	-0.05***	-0.07***
					(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Industry Characteristics										
$ClassC^k$					-0.23	-0.37**	-0.15	-0.27	-0.17	-0.21
vs. Intermediate					(0.23)	(0.12)	(0.17)	(0.21)	(0.26)	(0.18)
$ClassF^k$					0.49***	-0.37	0.55***	-0.28	0.60***	-0.10
vs. Intermediate					(0.20)	(0.15)	(0.20)	(0.15)	(0.19)	(0.16)
$Mktshare^{k,c}$							1.61**	0.66	1.68***	0.68
							(0.39)	(0.42)	(0.39)	(0.42)
$Impct^k$							0.27	-0.13	0.44	-0.10
							(0.33)	(0.28)	(0.33)	(0.28)
$Top5^k$							-0.22**	0.30***	-0.22***	0.30***
							(0.08)	(0.08)	(0.08)	(0.08)
Constant	0.66***	0.62***	7.04***	9.89***	3.91***	5.60***	3.67***	5.65***	1.89***	4.62***
	(0.13)	(0.09)	(0.52)	(0.37)	(0.70)	(0.54)	(0.66)	(0.55)	(0.68)	(0.74)
Industry effects										Yes
Obs.(millions)	7.31		7.31		7.31		7.31		7.31	
AIC	15,507,253		14,238,974		10,437,866		10,338,805		10,275,217	
Pseudo-R^2	-		0.082		0.327		0.333		0.340	

Notes: The default option is PCP. Industry effects are dummies for SITC 1-digit sectors. Clustered standard errors in parentheses (at the HS4 level). * significant at 10%; ** significant at 5%; *** significant at 1%.

5.1 VAX Ratios

VAX ratios capture the share of value-added exports in total exports, ranging from 0 to 1.[44] In column (2) in Table 5, the two negative and significant coefficients show that high VAX ratios (low dependence on imported inputs) make PCP more likely. This result holds across columns, after controlling for other factors. This implies that countries more engaged in trade in intermediate goods use less of their own currencies for exports. I also use a further disaggregated VAX ratio series at the country-industry level, and the result still holds.[45]

[44] Countries not included in Johnson and Noguera (2011) are assigned the regional average in the analysis.

[45] Results are not reported. VAX ratios at the country-industry level are computed by Johnson and Noguera, including 93 countries, 19 regions and 57 sectors in GSC codes. These ratios are not published

5.2 Other Findings

With regards to macroeconomic factors, the results again support Hypothesis 1 that exchange rate volatility makes PCP more appealing relative to LCP. Also, UK imports from countries with exchange rate pegs are more likely to be priced in sterling or a third currency (LCP or VCP). The effects for transaction costs in foreign exchange market are also significant.

In column (3) I also consider the BEC classification of goods. Imports of final goods are more priced in LCP relative to PCP compared to intermediate goods. This finding supports the theoretical predictions in Bacchetta and van Wincoop (2003).

Following Goldberg and Tille (2011), I also control for three other industry characteristics: (i) *market share of exporters* is captured by the variable $Mktshare^{k,c}$, which is the overall market share of all exporters from country c in all UK imports in industry k (at the HS4 level); (ii) *concentration of the importers* is captured by the variable $Impct^{k}$, which is the share of imports in industry k accounted for by the top 10 importers and (iii) *transaction size* is captured by a dummy variable $Top5^{k}$, taking the value one if a transaction falls in the top 5^{th} percentile of sized transaction (in value) within any HS4 industry and zero otherwise.[46] The results are shown in column (4) and (5). Higher market shares of exporters make LCP more likely relative to PCP. The effects of $Impct^{k}$ are not significant. Also, the effects of transaction size differ for LCP and VCP.

6 Concluding Remarks

Invoicing currency choice is an example that micro-heterogeneity can influence aggregate outcomes. There are large differences in invoicing currency choice across firms, even across firms that export the same product to the same country at the same time. The explanation has to come from firm characteristics. The stylized facts documented in this paper are completely new and I view this as the main contribution.

The findings in the paper have strong policy implications for the degrees of exchange rate pass-through. Large variation in invoicing currency choice directly translates into large variation in the responses of domestic prices to the changes of exchange rates. One particular relevant fact is that the degree of pass-through to import prices exhibits significant heterogeneity across industries. The manufacturing and raw materials sectors in the UK, for example, have much higher short-run and long-run pass-through than the energy sector (Mumtaz, Oomen and Wang, 2006).[47] It is therefore important to

in their paper.

[46] In Goldberg and Tille (2011) market share of exporters is a proxy for the bargaining power of exporters, while concentration of the importers represents the bargaining power of importers.

[47] Their estimated average rates of pass-through are calculated with quarterly UK data from 1984 Q1 to 2004 Q1.

look into firm composition and currency denomination across industries in order to fully explain the heterogeneity of pass-through.

One limitation of the paper is not to account for intra-firm trade. Although some researchers have shown no potential difference in currency choice within and across firms (Friberg and Wilander, 2008), future analysis and firm evidence would further contribute to our understanding of the determinants of invoicing currency.

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Appendix A: Model Solutions

This appendix provides the detailed derivation for the model in Section 2.2. I drop the subscript i for brevity. Given output Y, the firm minimizes its total cost:

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

Denote by μ and χ the Lagrange multiplier on constraints (2) and (3) respectively. The first-order conditions of cost minimization are:

$$\begin{aligned} W &= \mu(1-\gamma)\frac{Y}{L}, \\ \chi &= \mu\gamma\frac{Y}{X}, \\ Q &= \chi\left(\frac{X}{Z}\right)^{1/(1+\theta)}, \\ SQ^* &= \chi\left(\frac{a^\theta X}{M}\right)^{1/(1+\theta)}. \end{aligned}$$

Rearranging these conditions yields:

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

$$QX = \mu\gamma Y\left(\frac{X}{Z}\right)^{1/(1+\theta)}, \tag{A-2}$$

$$\frac{SQ^*M}{QZ} = \left(\frac{a}{SQ^*/Q}\right)^\theta. \tag{A-3}$$

Substituting (A-3) into (3) we get $X = Z\left[1+\left(\frac{a}{SQ^*/Q}\right)^\theta\right]^{(1+\theta)/\theta}$. Together with (A-2) we get:

$$QX = \mu\gamma Y\left[1+\left(\frac{a}{SQ^*/Q}\right)^\theta\right]^{1/\theta}, \tag{A-4}$$

Substituting (A-4) and (A-1) into (2) we can solve for μ:

$$\mu = \frac{C}{Ab^\gamma}, \tag{A-5}$$

where $b \equiv \left[1+\left(\frac{a}{SQ^*/Q}\right)^{\theta}\right]^{1/\theta}$ and $C = \gamma^{-\gamma}(1-\gamma)^{\gamma-1}Q^{\gamma}W^{1-\gamma}$. Substituting (A-1), (A-2) and (A-3) into the total cost function yields:

$$\mathrm{TC}(Y) = \mu Y + Wf, \tag{A-6}$$

where μ is the marginal cost facing the firm.

Finally, the parameter ψ is defined as the fraction of total costs spent on imported inputs: $\psi = SQ^*M/(SQ^*M + QZ)$. Using (A-3) together with the expression for $SQ^*M = \gamma\mu Y\left(1-b^{-\theta}\right)$, I obtain the share of costs spent on imported inputs as:

$$\psi = \left(1-b^{-\theta}\right). \tag{A-7}$$

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 the import intensity:

$$\begin{aligned}\frac{\partial \ln \mu}{\partial \ln S} &= \frac{\partial \ln \mu}{\partial \ln b} \times \frac{\partial \ln b}{\partial \ln S} \\ &= (-\gamma)\left[-\left(1-b^{-\theta}\right)\right] \\ &= \psi. \end{aligned} \tag{A-8}$$

Appendix B: Proof of Proposition 1

In this appendix I first provide a proof of Proposition 1. Following the solution technique of Devereux et al. (2004), I drop the subscript i for simplicity. From (6) and (8), the expected discounted profits under PCP are given as:

$$\begin{aligned}E\Pi^{PCP} &= \left(\frac{\lambda}{\lambda-1}\frac{E\left(\mu \cdot S^{\lambda}\Omega\right)}{E\left(S^{\lambda}\Omega\right)}\right)^{1-\lambda} E\left(S^{\lambda}\Omega\right) \\ &- \left(\frac{\lambda}{\lambda-1}\frac{E\left(\mu \cdot S^{\lambda}\Omega\right)}{E\left(S^{\lambda}\Omega\right)}\right)^{-\lambda} E\left(\mu \cdot S^{\lambda}\Omega\right) \\ &= \widetilde{\lambda}\left[E\left(S^{\lambda}\Omega\right)\right]^{\lambda}\left[E\left(\mu \cdot S^{\lambda}\Omega\right)\right]^{1-\lambda}, \end{aligned} \tag{B-1}$$

where $\widetilde{\lambda} = \frac{1}{\lambda-1}\left(\frac{\lambda}{\lambda-1}\right)^{-\lambda}$, $\Omega = \kappa P_{hf}^{*(\lambda-\delta)} P^{*\delta} D^*$. Note that the last line of (B-1) follows because prices are preset one period in advance, i.e., $E_{t-1}(P_t) = P_t$. This expression may also be rewritten as:

$$\widetilde{\lambda}\left\{E\left[\exp(\lambda \ln S)\exp\left(\ln \Omega\right)\right]\right\}^{\lambda}\left\{E\left[\exp(\ln \mu)\exp(\lambda \ln S)\exp(\ln \Omega)\right]\right\}^{1-\lambda}. \tag{B-2}$$

In the next step I take the second order approximation for the first term in brackets in (B-2):

$$\begin{aligned} E\left[\exp(\lambda \ln S)\exp\left(\ln \Omega\right)\right] &\approx \exp\left[\lambda E\left(\ln S\right)\right]\exp\left[E\left(\ln \Omega\right)\right] \\ &\times\left[1+\frac{\lambda^2}{2}var(\ln S)+\frac{1}{2}var(\ln \Omega)+\lambda cov(\ln \Omega, \ln S)\right]. \end{aligned} \tag{B-3}$$

Using the same approximation for $E\left[\exp(\ln \mu)\exp(\lambda \ln S)\exp(\ln \Omega)\right]$, I get an approximation for $E\Pi^{PCP}$ as follows:

$$\begin{aligned} &\Sigma\left[1+\frac{\lambda^2}{2}var(\ln S)+\frac{1}{2}var(\ln \Omega)+\lambda cov(\ln \Omega, \ln S)\right]^{\lambda} \\ &\times\left[\begin{array}{c} 1+\frac{1}{2}var(\ln \mu)+\frac{\lambda^2}{2}var(\ln S)+\frac{1}{2}var(\ln \Omega) \\ +\lambda cov(\ln \mu, \ln S)+cov(\ln \mu, \ln \Omega)+\lambda cov(\ln S, \ln \Omega) \end{array}\right]^{1-\lambda} \end{aligned} \tag{B-4}$$

where $\Sigma = \widetilde{\lambda}\exp\left[\lambda E\left(\ln S\right)\right]\exp\left[E\left(\ln \Omega\right)\right]\exp\left[(1-\lambda)E\left(\ln \mu\right)\right]$. Taking logs and using the approximation $\ln(1+x) \approx x$, the expected discounted profits thus become:

$$\begin{aligned} \ln E\Pi^{PCP} \approx \ln \Sigma &+ \frac{\lambda^2}{2}var(\ln S)+\frac{1}{2}var(\ln \Omega)+\frac{1-\lambda}{2}var(\ln \mu) \\ &+\left[\begin{array}{c} \lambda cov(\ln S, \ln \Omega)+\lambda(1-\lambda)cov(\ln \mu, \ln S) \\ +(1-\lambda)cov(\ln \mu, \ln \Omega) \end{array}\right]. \end{aligned} \tag{B-5}$$

Now, from (7) and (9), the expected discounted profits under LCP are given as:

$$E\Pi^{LCP} = \widetilde{\lambda}\left[E\left(S\Omega\right)\right]^{\lambda}\left[E\left(\mu \cdot \Omega\right)\right]^{1-\lambda}. \tag{B-6}$$

Using the same approximation, this can be shown to be:

$$\ln E\Pi^{LCP} \approx \ln \Sigma + \frac{\lambda}{2} var(\ln S) + \frac{1}{2} var(\ln \Omega) + \frac{1-\lambda}{2} var(\ln \mu) + [\lambda cov(\ln S, \ln \Omega) + (1-\lambda) cov(\ln \mu, \ln \Omega)] . \quad \text{(B-7)}$$

Now, comparing (B-5) and (B-7) yields:

$$\begin{aligned} \ln E\Pi^{PCP} - \ln E\Pi^{LCP} &= \frac{1}{2} var(\ln S) - cov(\ln \mu, \ln S) \\ &= \frac{1}{2} var(\ln S) + \gamma cov(\ln b, \ln S) \\ &= \frac{1}{2} var(\ln S) - \frac{\gamma}{\theta} cov(\ln(1-\psi), \ln S) . \end{aligned} \quad \text{(B-8)}$$

The second line comes from the equation for marginal cost in (4) and the third line comes from the home share of inputs in (5). The firm's decision rule in Proposition 1 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 firms use imported inputs or not 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 the firm uses imported inputs only. In this case, the right hand side of the decision rule in (10) becomes $var(\ln S)$ and the firm uses LCP only. On the contrary, if a firm has no advantage in using imported inputs ($a_i/(SQ^*/Q) < 1$), then the firm uses domestic inputs only. In this case, the right hand side of the decision rule in (10) becomes zero and the firm uses PCP only. If the price-adjusted productivity is unity, the firm is indifferent between varieties of inputs and also indifferent between currencies.

When domestic and foreign inputs are perfect complements ($\theta \to 0$), firms use both varieties and are indifferent between currencies.

Appendix C: Currency Choice with the Option of VCP

This section extends the model of Devereux et al. (2004) to allow for the case of vehicle currency pricing (VCP). I consider a three-country environment where country C is the

vehicle currency country. Firm i in country A (Home) sells a differentiated good to country B (Foreign) and faces a CES demand curve:

$$T\left(p^i\right) = \left(\frac{p^i}{P_h^*}\right)^{-\lambda} \left(\frac{P_h^*}{P^*}\right)^{-\delta} D^*,$$

where T is the quantity demanded, p_i is the firm's price, P_h^* is the price index for all home goods sold in the foreign country and P^* is the foreign consumer price index (all denominated in the vehicle currency). D^* is the foreign demand shifter that is independent of prices. Parameter λ is the elasticity of substitution across varieties and $\lambda > 1$. Parameter δ is the foreign elasticity of demand for domestic goods.

The firm pre-sets prices and invoicing currency one period in advance. The expected discounted profits for PCP/LCP/VCP are:

$$E\Pi^{PCP} = E\left[\kappa\left(p^{PCP(i)} - \mu_i\right)\left(\frac{p^{PCP(i)}}{S_{AC}P_h^*}\right)^{-\lambda}\left(\frac{P_h^*}{P^*}\right)^{-\delta} D^*\right],$$

$$E\Pi^{LCP} = E\left[\kappa\left(S_{AB}p^{LCP(i)} - \mu_i\right)\left(\frac{p^{LCP(i)}}{S_{BC}P_h^*}\right)^{-\lambda}\left(\frac{P_{AB}^*}{P^*}\right)^{-\delta} D^*\right],$$

$$E\Pi^{VCP} = E\left[\kappa\left(S_{AC}p^{VCP(i)} - \mu_i\right)\left(\frac{p^{VCP(i)}}{P_h^*}\right)^{-\lambda}\left(\frac{P_{AB}^*}{P^*}\right)^{-\delta} D^*\right],$$

where μ is the marginal cost denominated in the home currency, S_{AC} is the exchange rate between currencies A and C (home currency price of the vehicle currency price), S_{BC} is the exchange rate between currency B and C (foreign currency price of the vehicle currency price).

The optimal prices which maximize the expected discounted profits, under PCP, LCP and VCP, respectively, can be derived as follows:

$$p^{PCP(i)} = \frac{\lambda}{\lambda - 1} \cdot \frac{E\left(\mu\Omega S_{AC}^{\lambda}\right)}{E\left(\Omega S_{AC}^{\lambda_B}\right)},$$

$$p^{LCP(i)} = \frac{\lambda}{\lambda - 1} \cdot \frac{E\left(\mu\Omega S_{BC}^{\lambda}\right)}{E\left(\Omega S_{AC}S_{BC}^{\lambda-1}\right)},$$

$$p^{VCP(i)} = \frac{\lambda}{\lambda - 1} \cdot \frac{E\left(\mu\Omega\right)}{E\left(\Omega S_{AC}\right)},$$

where $\Omega = \kappa P_h^{*(\lambda-\delta)} P^{*\delta} D^*$.
Using these optimal prices, the expressions for expected discounted profits become:

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

$$E\Pi^{LCP} = \widetilde{\lambda}\left[E\left(\Omega S_{AC}S_{BC}^{\lambda-1}\right)\right]^{\lambda}\left[E\left(\mu\Omega S_{BC}^{\lambda}\right)\right]^{1-\lambda}$$

$$E\Pi^{VCP} = \widetilde{\lambda}\left[E\left(\Omega S_{AC}\right)\right]^{\lambda}\left[E\left(\mu\Omega\right)\right]^{1-\lambda}$$

where $\widetilde{\lambda} = \frac{1}{\lambda-1}\left(\frac{\lambda}{\lambda-1}\right)^{-\lambda}$.
Using the second-order approximations for $E\Pi^{PCP}$, $E\Pi^{LCP}$, and $E\Pi^{VCP}$ and then taking logs, I obtain:

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

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

$$\begin{aligned}\ln E\Pi^{VCP} \approx \ln\Sigma + \frac{1}{2}var\left(\ln\Omega\right) + \frac{1-\lambda}{2}var\left(\ln\mu\right) + \frac{\lambda}{2}var(\ln S_{AC}) \\ + \left[\lambda cov(\ln\Omega, \ln S_{AC}) + (1-\lambda)cov(\ln\mu, \ln\Omega)\right],\end{aligned} \tag{C-3}$$

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

By comparing (C-1) and (C-3), we can get $E\Pi^{VCP} > E\Pi^{PCP}$ if and only if:

$$cov\left(\ln S_{AC}, \ln\mu\right) - \frac{1}{2}var\left(\ln S_{AC}\right) > 0. \tag{C-4}$$

By comparing (C-2) and (C-3), we can get $E\Pi^{VCP} > E\Pi^{LCP}$ if and only if:

$$\frac{1}{2}var\left(\ln S_{BC}\right) + cov\left(\ln S_{BC}, \ln\mu\right) - cov\left(\ln S_{AC}, \ln S_{BC}\right) > 0. \tag{C-5}$$

Firm's Decision Rule

Combining (C-4) and (C-5) we get the firm's decision rule. The firm in country A sets its price in the vehicle currency if and only if:

$$\begin{aligned} \frac{1}{2}var\left(\ln S_{BC}\right) + cov\left(s_{BC}, \ln \mu_i\right) - cov\left(\ln S_{AC}, \ln S_{BC}\right) &> 0 \quad \text{and} \\ cov\left(\ln S_{AC}, \ln \mu_i\right) - \frac{1}{2}var\left(\ln S_{AC}\right) &> 0. \end{aligned} \tag{C-6}$$

In this condition, the covariance between two exchange rates vis-à-vis the vehicle currency is a new element compared to a two-country setting. If the covariance between two existing exchange rates vis-à-vis the vehicle currency is negative, firms are more inclined to choose VCP. The condition also says that a more volatile exchange rate between countries B and C would lead the firm in country A to set its price in the vehicle currency rather than currency B. A more volatile exchange rate between countries A and C, on the other hand, would discourage the firm to set its price in the vehicle currency.

(Not for Publication) Appendix D: Summary and Descriptive Statistics for Explanatory Variables

This section provides a summary of the explanatory variables used in Section 4 and the descriptive statistics.

Appendix Table 1. Explanatory Variables

Determinant	Proxy	Variable
Firm Characteristics		
Imported inputs	• Dummy for importing	$Import^{i}$
	• Effective dependence on inputs from country c	$InputPCP^{i,c}$
	• Share of Sterling used for imported inputs	$InputLCP^{i}$
Market share of exports	Share of total exports in industry k	$ratio^{i,k}$
Firm experience	Dummy for over 5 yrs. trading	$fiveyrold^{i}$
Transaction size	Dummy for transaction size in top 10^{th} percentile	$Top10^{k}$
Macroeconomic Factors		
Exchange rate volatility	Coefficient of variation of nominal exchange rates	$CVGBP^{c}$ $CVUSD^{c}$
Exchange rate regime	Dummies for pegs	$Dpeg^{c}$ $Epeg^{c}$
Transaction costs of exchange	Volumes of currency transaction	FX^{c}
Industry Characteristics		
Market competition	End-use of goods	$Class^{k}$
Goods substitutability	Type of goods	$Rauch^{k}$

Appendix Table 2. Descriptive Statistics for Explanatory Variables

Variable	Mean	S.D.	Min	Max
$InputPCP^{i,c}$	0.06	0.20	0	1.00
$InputLCP^{i}$	0.15	0.27	0	1.00
$ratio^{i,k}$	0.03	0.09	0	1.00
$CVGBP^{c}$	0.12	0.04	0	0.27
$CVUSD^{c}$	0.06	0.05	0	0.37
FX^{c}	14.96	30.54	0	85.60