Online Appendix

Vehicle Currency Pricing and Exchange Rate Pass-Through*

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Abstract

Using detailed firm-level transactions data for UK imports, we find that invoicing in a vehicle currency is pervasive, with more than half of the transactions in our sample invoiced in neither sterling nor the exporter's currency. We then study the relationship between invoicing currencies and the response of import unit values to exchange rate changes. We find that for transactions invoiced in a vehicle currency, import unit values are much more sensitive to changes in the vehicle currency than in the bilateral exchange rate. Pass-through therefore substantially increases once we account for vehicle currencies. This result helps to explain why UK inflation turned out higher than expected when sterling depreciated during the Great Recession and after the Brexit referendum. Finally, within a conceptual framework we show why bilateral exchange rates are not suitable for capturing exchange rate pass-through under vehicle currency pricing. Overall, our results help to clarify why the literature often finds a disconnect between exchange rates and prices when vehicle currencies are not accounted for.

JEL Classification: F14, F31, F41.
Keywords: CPI; Dollar; Euro; Exchange Rate Disconnect; Exchange Rate Pass-Through; Inflation; Invoicing; Sterling; UK; Vehicle Currency Pricing.

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A Reconciling Coefficients with Population-Weighted Averages

A referee asked whether the bilateral exchange rate coefficient in column (1) of Table 5 (equal to 0.179) should be a population-weighted average of the bilateral exchange rate coefficients estimated separately for the PCP, LCP, and VCP transactions in column (2). If we use full-sample population weights (based on the data in Table 2), the weighted average is equal to 0.229 (and equal to 0.226 based on population weights that exclude the singletons which are omitted from the regressions). The weighted average is thus close but not equal to the 0.179 estimate in column (1). Where does the difference come from?

Let us consider a simple example where we compare two generic regressions:

$$y_{i,t} = \alpha_0 + \alpha_1 x_{i,t} + \gamma D_i + \epsilon_{i,t}, \tag{A1}$$

$$y_{i,t} = \beta_0 + \beta_1 x_{i,t} + \beta_2 D_i x_{i,t} + \psi D_i + \varepsilon_{i,t}. \tag{A2}$$

In (A1), the effect of $x_{i,t}$ is constrained to be the same for all observations. This is similar to column (1) of Table 5 where the effect of the bilateral exchange rate is the same for all transactions. In (A2), we instead let the effect of $x_{i,t}$ vary between two groups of observations by interacting $x_{i,t}$ with a dummy variable D_i which is equal to one for the observations of group 2. This specification is comparable to column (2) of Table 5 where we let the effect of the bilateral exchange rate vary between three invoicing choices. But for simplicity, we only consider two groups of observations instead of three.[1] The effect of $x_{i,t}$ is equal to β_1 for group 1 and $(\beta_1 + \beta_2)$ for group 2. To make equations (A1) and (A2) comparable, we also include in (A1) the D_i dummy variable (in column 1 of Table 5, we find that adding invoicing choice fixed effects leaves the bilateral exchange rate coefficient unchanged at 0.179).

When we define $M_{D_i=0}$ and $M_{D_i=1}$ as the number of observations in the subsamples for which $D_i = 0$ and $D_i = 1$, and $M = M_{D_i=0} + M_{D_i=1}$ as the total number of observations in the sample, is the estimate $\widehat{\alpha}_1$ a population-weighted average of $\widehat{\beta}_1$ and $\left(\widehat{\beta}_1 + \widehat{\beta}_2\right)$ with weights equal to $M_{D_i=0}/M$ and $M_{D_i=1}/M$, respectively?

To answer this question, let us assume that (A2) is the "true" model while (A1) can be viewed as suffering from an omitted variable bias (as $D_i x_{i,t}$ is omitted from the regression). We then have:

$$\begin{aligned} E\left(\widehat{\alpha}_1\right) &= \widehat{\beta}_1 + \widehat{\beta}_2 \frac{cov\left(x_{i,t}, D_i x_{i,t}\right)}{var\left(x_{i,t}\right)}, \\ &= \left(1 - \frac{cov\left(x_{i,t}, D_i x_{i,t}\right)}{var\left(x_{i,t}\right)}\right)\widehat{\beta}_1 + \frac{cov\left(x_{i,t}, D_i x_{i,t}\right)}{var\left(x_{i,t}\right)}\left(\widehat{\beta}_1 + \widehat{\beta}_2\right), \end{aligned} \tag{A3}$$

where $cov\left(x_{i,t}, D_i x_{i,t}\right) > 0$. The estimate $\widehat{\alpha}_1$ is thus a weighted average of $\widehat{\beta}_1$ and $\left(\widehat{\beta}_1 + \widehat{\beta}_2\right)$. But the weights depend on $cov\left(x_{i,t}, D_i x_{i,t}\right)$ and $var\left(x_{i,t}\right)$, not on population sizes.

[1] Our argument extends to more than one interaction term.

How can we economically interpret equation (A3) in relation to our estimates in columns (1) and (2) of Table 5?[2] As a hypothetical benchmark, suppose that invoicing choices are random. Under this assumption we would have $\frac{1}{M_{D_i=1}} \sum_{i,t|D_i=1} x_{i,t} = \frac{1}{M} \sum_{i,t} x_{i,t} \equiv \overline{x}$. That is, the mean of $x_{i,t}$ in the subsample would be the same as the mean in the full sample. We would also have $var_{D_i=1}(x_{i,t}) = var(x_{i,t})$, i.e., the variance in the subsample would be the same as the variance in the full sample. By definition we would obtain:

$$\begin{aligned} cov\left(x_{i,t}, D_i x_{i,t}\right) &= \frac{1}{M}\sum_{i,t}\left(x_{i,t} - \frac{1}{M}\sum_{i,t} x_{i,t}\right)\left(D_i x_{i,t} - \frac{1}{M}\sum_{i,t} D_i x_{i,t}\right) \\ &= \frac{1}{M}\sum_{i,t}\left(x_{i,t} - \overline{x}\right)\left(D_i x_{i,t} - \frac{M_{D_i=1}}{M}\overline{x}\right). \end{aligned}$$

It would follow:

$$\begin{aligned} cov\left(x_{i,t}, D_i x_{i,t}\right) &= \frac{1}{M}\sum_{i,t}\left(x_{i,t} D_i x_{i,t} - x_{i,t}\frac{M_{D_i=1}}{M}\overline{x} - \overline{x} D_i x_{i,t} + \frac{M_{D_i=1}}{M}\overline{x}^2\right) \\ &= \frac{1}{M}\sum_{i,t} x_{i,t} D_i x_{i,t} - \frac{M_{D_i=1}}{M}\overline{x}^2 \\ &= \frac{M_{D_i=1}}{M}\left(\frac{1}{M_{D_i=1}}\sum_{i,t} x_{i,t} D_i x_{i,t} - \overline{x}^2\right) \\ &= \frac{M_{D_i=1}}{M} var_{D_i=1}\left(x_{i,t}\right) = \frac{M_{D_i=1}}{M} var\left(x_{i,t}\right). \end{aligned}$$

Equation (A3) would therefore become:

$$E\left(\widehat{\alpha}_1\right) = \frac{M - M_{D_i=1}}{M}\widehat{\beta}_1 + \frac{M_{D_i=1}}{M}\left(\widehat{\beta}_1 + \widehat{\beta}_2\right).$$

That is, under the assumption of random invoicing choices the weights in equation (A3) would correspond to population weights.

The fact that the coefficients in columns (1) and (2) of Table 5 deviate from this hypothetical benchmark suggests that the conditions for random invoicing choices are not met and that invoicing choices may be endogenous.[3] Specifically, the estimated coefficients in the data imply:

$$\left(1 - \frac{cov\left(x_{i,t}, D_i x_{i,t}\right)}{var\left(x_{i,t}\right)}\right)\widehat{\beta}_1 + \frac{cov\left(x_{i,t}, D_i x_{i,t}\right)}{var\left(x_{i,t}\right)}\left(\widehat{\beta}_1 + \widehat{\beta}_2\right) < \frac{M - M_{D_i=1}}{M}\widehat{\beta}_1 + \frac{M_{D_i=1}}{M}\left(\widehat{\beta}_1 + \widehat{\beta}_2\right),$$

which is equivalent to:

$$\frac{cov\left(x_{i,t}, D_i x_{i,t}\right)}{var\left(x_{i,t}\right)}\widehat{\beta}_2 < \frac{M_{D_i=1}}{M}\widehat{\beta}_2.$$

[2] We are indebted to the referee for this type of interpretation.

[3] This observation is consistent with the finding in Figure 1 showing that pass-through rates across invoicing choices do not converge in the long run.

If group 1 captures transactions in producer and vehicle currencies ($D_i = 0$) and group 2 captures transactions in local currency ($D_i = 1$), we have $\widehat{\beta}_2 < 0$ since the local currency pass-through coefficient in column (2) of Table 5 is smaller. It follows:

$$\frac{cov\left(x_{i,t}, D_i x_{i,t}\right)}{var\left(x_{i,t}\right)} > \frac{M_{D_i=1}}{M}.$$

Given that $cov\left(x_{i,t}, D_i x_{i,t}\right) = var\left(x_{i,t}\right) - cov\left(x_{i,t}, \left(1 - D_i\right) x_{i,t}\right)$ it also follows:

$$\frac{cov\left(x_{i,t}, \left(1 - D_i\right) x_{i,t}\right)}{var\left(x_{i,t}\right)} < \frac{M_{D_i=0}}{M}.$$

That is, compared to the hypothetical benchmark of random invoicing choices, all else being equal local currency invoicing (in sterling) is more likely when the bilateral exchange rate is volatile relative to the full sample, i.e., the ratio $cov\left(x_{i,t}, D_i x_{i,t}\right)/var\left(x_{i,t}\right)$ is comparatively high. Producer and vehicle currency invoicing (in non-sterling currencies) are more likely when the bilateral exchange rate exhibits low volatility relative to the full sample. This conclusion is consistent with Devereux, Engel, and Storgaard (2004) and Engel (2006).

Table A1: Reconciling Coefficients with Population-Weighted Averages

	(1)	(2)	(3)	(4)	(5)
$\Delta \ln e_{ij,t}$	0.696*** (0.107)	0.059 (0.040)	0.123*** (0.033)	–	0.162*** (0.027)
$\Delta \ln e_{ij,t} \times D_{PCP}$	–	–	–	0.696*** (0.106)	–
$\Delta \ln e_{ij,t} \times D_{LCP}$	–	–	–	0.059 (0.040)	–
$\Delta \ln e_{ij,t} \times D_{VCP}$	–	–	–	0.123*** (0.033)	–
Invoicing currency	PCP	LCP	VCP	All	All
Firm-quarter fixed effects	Yes	Yes	Yes	No	No
Origin-product fixed effects	Yes	Yes	Yes	No	No
Firm-quarter-invoicing choice fixed effects	No	No	No	Yes	Yes
Origin-product-invoicing choice fixed effects	No	No	No	Yes	Yes
Observations	1,272,714	1,065,852	2,599,543	4,938,109	4,938,109
R-squared	0.186	0.206	0.176	0.184	0.184

Notes: Contemporaneous and eight lags of the origin country's quarterly inflation rate are included in (1) to (3), while their interactions with invoicing choice fixed effects are included in (4) and (5). Eight lags of the log change in each exchange rate are also included in all columns (not reported). Robust standard errors adjusted for clustering at the country-year level are reported in parentheses. *** indicates significance at the 1% level. The dependent variable is the quarterly log change import unit value (in sterling per kilogram). Source: HMRC administrative data sets.

Further evidence is provided in Table A1. Columns (1) to (3) estimate equation (1) separately on subsamples of import transactions invoiced in producer, local, and vehicle currencies (also reported in Table D1 in Online Appendix D). In column (4) we estimate equation (1) on the full sample of import transactions, but unlike in Table 5 we interact the bilateral exchange rates, the foreign inflation rates, and the fixed effects with invoicing choice dummy variables (due to the larger number of fixed effects the sample size is therefore smaller than in Table 5). The pass-through rates in column (4) are identical to the ones in columns (1) to (3) because the two approaches estimate the same model by allowing for the same slope coefficients and intercepts.

Similarly to column (4), column (5) lets the coefficients on the inflation rates and the fixed effects vary by invoicing choice, but the effect of the bilateral exchange rate is now constrained to be the same across invoicing currencies. According to the above analysis, the pass-through elasticity (equal to 0.162) is not necessarily the same as the population-weighted average of the bilateral exchange rate coefficients reported in column (4). In fact, the population-weighted average is equal to 0.263 if we use full sample weights, and to 0.258 with weights that exclude the singletons.

B Omitted Variable Bias in Standard Pass-Through Regressions

A referee was concerned that the pass-through elasticity for the PCP transactions in column (2) of Table 5 jumps from 0.445 to 0.620 in column (4) once we let the unit values of the VCP transactions depend on vehicle currency exchange rates. As we argue below, the 0.445 estimate in column (2) suffers from a negative omitted variable bias that results from the negative correlation between bilateral exchange rates interacted with the PCP dummy variable, and vehicle currency exchange rates interacted with the VCP dummy variable (which are omitted from the regression). The two variables are correlated as 81% and 89% of the PCP and VCP transactions are priced in US dollars.

Let us consider a generic two-variable example of the omitted variable bias problem:

$$y_t = \beta_0 + \beta_1 x_t + \beta_2 z_t + \epsilon_t, \tag{B1}$$

$$y_t = \alpha_0 + \alpha_1 x_t + \eta_t. \tag{B2}$$

The true model is (B1) while (B2) suffers from an omitted variable bias as z_t is omitted from the regression. We have:

$$E\left(\widehat{\alpha}_1\right) = \widehat{\beta}_1 + \widehat{\beta}_2 \frac{cov\left(x_t, z_t\right)}{var\left(x_t\right)}, \tag{B3}$$

where $\widehat{\beta}_1$ is the "true" coefficient and $cov\left(x_t, z_t\right)/var\left(x_t\right)$ is the coefficient we obtain if we regress the excluded variable z_t on the included variable x_t. The bias is given by $\widehat{\beta}_2\left(cov\left(x_t, z_t\right)/var\left(x_t\right)\right)$.

Our aim is to demonstrate that the PCP elasticity in column (2) of Table 5 suffers from an omitted variable bias (i.e., $cov\left(x_t, z_t\right)/var\left(x_t\right) \neq 0$), and to calculate the value of the bias according to (B3).[4] Assuming that column (4) of Table 5 is the "true" model, we proceed in three steps to make the problem tractable:

1. First, in contrast to equations (B1) and (B2) above, the specifications in columns (2) and (4) of Table 5 are not directly comparable: rather than including one more variable than in column

[4] In equations (B1) and (B2), y_t therefore corresponds to $\Delta \ln UV_{ijk,t}$, x_t corresponds to $\Delta \ln e_{ij,t} \times D_{PCP}$, and z_t corresponds to $\Delta \ln e_{iV,t} \times D_{VCP}$.

(2), column (4) *replaces*, for the VCP transactions, bilateral exchange rates with vehicle currency exchange rates. As the two models need to be comparable to calculate the bias in (B3), we therefore add to the specification in column (4) of Table 5 a control for bilateral exchange rates when explaining the unit values of VCP transactions.

2. Second, compared to column (4), column (2) omits not one but nine different variables (i.e., the vehicle currency exchange rates and their lags). As the expression in (B3) only applies to the case of one omitted variable, we perform the exercise below without lagged regressors.

3. Third, in addition to exchange rates, our regressions also include fixed effects and the foreign inflation rates. To calculate the bias in (B3), we therefore rely on partitioned regressions as they allow us to reduce our model with many controls to one with two variables only.

In column (1) of Table B1 we estimate the specification of column (2) in Table 5 without lags. The results are very similar to the ones of Table 5. Pass-through is relatively high for PCP transactions, low for VCP transactions, and negative but very small for LCP transactions. In column (2) we add vehicle currency exchange rates to explain the VCP transactions. Pass-through for the PCP transactions rises from 47.9% to 74.3%. Pass-through for the VCP transactions is high at 66.4% when vehicle currency exchange rates change, and low at 9.9% when bilateral exchange rates change.

Table B1: Omitted Variable Bias in Standard Pass-Through Regressions

	(1)	(2)
$\Delta \ln e_{ij,t} \times D_{PCP}$	0.479*** (0.048)	0.743*** (0.045)
$\Delta \ln e_{ij,t} \times D_{LCP}$	−0.083** (0.041)	0.049 (0.037)
$\Delta \ln e_{ij,t} \times D_{VCP}$	0.270*** (0.031)	0.099*** (0.032)
$\Delta \ln e_{iV,t} \times D_{VCP}$	–	0.664*** (0.056)
Firm-quarter fixed effects	Yes	Yes
Origin-product fixed effects	Yes	Yes
Invoicing choice fixed effects	Yes	Yes
Observations	5,212,592	5,212,592
R-squared	0.146	0.146

Notes: The origin country's quarterly inflation rate is also included (not reported). Robust standard errors adjusted for clustering at the country-year level are reported in parentheses. *** and ** indicate significance at the 1% and 5% levels, respectively. The dependent variable is the quarterly log change import unit value (in sterling per kilogram). Source: HMRC administrative data sets.

To calculate the bias in the pass-through coefficient for PCP transactions in column (1) of Table B1, we rely on partitioned regressions (without lags). In a first step we estimate three regressions:

$$\Delta \ln Y_{ijk,t} = \lambda \Delta \ln e_{ij,t} \times D_{LCP} + \theta \Delta \ln e_{ij,t} \times D_{VCP} + \chi \pi^*_{j,t} + D_{i,t} + D_{jk} + D_{PCP} + D_{VCP} + \varepsilon_{ijk,t}, \quad \text{(B4)}$$

where the dependent variables are $\Delta \ln Y_{ijk,t} = \{\Delta \ln UV_{ijk,t}, \Delta \ln e_{ij,t} \times D_{PCP}, \Delta \ln e_{iV,t} \times D_{VCP}\}$ and the residuals are saved as $\varepsilon^{UV}_{ijk,t}$, $\varepsilon^{ePCP}_{ijk,t}$, and $\varepsilon^{eVCP}_{ijk,t}$, respectively. The residuals capture the variation in each dependent variable (the unit values, bilateral exchange rates for PCP transactions, and vehicle currency exchange rates for VCP transactions) "purged" from the effects of all the controls in the model (bilateral exchange rates for LCP and VCP transactions, inflation rates, and the fixed effects), with the exception of bilateral exchange rates for PCP transactions and vehicle currency exchange rates for VCP transactions (which are the two variables we are interested in).

In a second step, we regress the (purged) unit values on the (purged) bilateral exchange rates for PCP transactions:

$$\varepsilon_{ijk,t}^{UV} = \gamma_0 \varepsilon_{ijk,t}^{ePCP} + \iota_{ijk,t}, \tag{B5}$$

and we obtain $\widehat{\gamma}_0 = 0.479$, i.e., the coefficient for PCP transactions in column (1) of Table B1.

In a third step, we regress the (purged) unit values on the (purged) bilateral exchange rates for PCP transactions and the (purged) vehicle currency exchange rates for VCP transactions:

$$\varepsilon_{ijk,t}^{UV} = \gamma_1 \varepsilon_{ijk,t}^{ePCP} + \gamma_2 \varepsilon_{ijk,t}^{eVCP} + \nu_{ijk,t}, \tag{B6}$$

and we find $\widehat{\gamma}_1 = 0.743$ and $\widehat{\gamma}_2 = 0.664$, i.e., the coefficients on bilateral exchange rates for PCP transactions and vehicle currency exchange rates for VCP transactions in column (2) of Table B1.

As we have reduced our main regression to a model with two variables only, and assuming that equation (B5) suffers from an omitted variable bias while (B6) is the "true" model, the bias between the "true" $\widehat{\gamma}_1$ and the biased coefficient $\widehat{\gamma}_0$ can be recovered based on (B3) as:

$$\begin{aligned} E\left(\widehat{\gamma}_0\right) &= \widehat{\gamma}_1 + \widehat{\gamma}_2 \frac{cov\left(\varepsilon_{ijk,t}^{ePCP}, \varepsilon_{ijk,t}^{eVCP}\right)}{var\left(\varepsilon_{ijk,t}^{ePCP}\right)}, \\ &= 0.743 + 0.664\left(-0.397\right) = 0.479, \end{aligned}$$

where $cov\left(\varepsilon_{ijk,t}^{ePCP}, \varepsilon_{ijk,t}^{eVCP}\right) / var\left(\varepsilon_{ijk,t}^{ePCP}\right) = -0.397$ is the coefficient we obtain by regressing $\varepsilon_{ijk,t}^{eVCP}$ on $\varepsilon_{ijk,t}^{ePCP}$. The negative omitted variable bias therefore results from the negative correlation between the (purged) bilateral exchange rates for PCP transactions and the (purged) vehicle currency exchange rates for VCP transactions.

C Passive Exchange Rate Pass-Through

Exchange rate pass-through is "passive" if it results from mechanical changes in sterling unit values when invoicing is in foreign currency. This would arise if exporters set a contract price in a given currency and do not adjust this price in response to exchange rate movements.

To check whether pass-through is passive, we estimate the following regression on a sample that for simplicity excludes vehicle currency transactions priced in non-US dollars:

$$\begin{aligned}\Delta \ln UV_{ijk,t} \quad = \quad & \sum_{n=0}^{N} \beta_{1,n} \Delta \ln e_{i\$,t-n} \times D_{PCP} + \sum_{n=0}^{N} \beta_{2,n} \Delta \ln e_{\$j,t-n} \times D_{PCP} \\ & + \sum_{n=0}^{N} \beta_{3,n} \Delta \ln e_{i\$,t-n} \times D_{LCP} + \sum_{n=0}^{N} \beta_{4,n} \Delta \ln e_{\$j,t-n} \times D_{LCP} \\ & + \sum_{n=0}^{N} \beta_{5,n} \Delta \ln e_{i\$,t-n} \times D_{VCP} + \sum_{n=0}^{N} \beta_{6,n} \Delta \ln e_{\$j,t-n} \times D_{VCP} \\ & + \sum_{n=0}^{N} \Pi_n \pi^*_{j,t-n} + D_{i,T} + D_{jk} + D_{PCP} + D_{VCP} + \iota_{ijk,t}, \end{aligned} \tag{C1}$$

where for all invoicing choices we decompose the bilateral exchange rate into the sterling to US dollar exchange rate $e_{i\$,t}$ and the US dollar to origin country exchange rate $e_{\$j,t}$. As $e_{i\$,t}$ is perfectly collinear with firm-quarter fixed effects, we control for firm-year fixed effects $D_{i,T}$ instead. If pass-through is passive, we would expect $\beta_{1,0} = \beta_{2,0} = \beta_{5,0} \approx 1$, $\beta_{3,0} = \beta_{4,0} = \beta_{6,0} \approx 0$, and the coefficients on all exchange rate lags should be jointly insignificant.

Table C1: Passive Exchange Rate Pass-Through

	(1)	(2)
$\Delta \ln e_{i\$,t} \times D_{PCP}$ $(\beta_{1,0})$	0.820*** (0.073)	0.764*** (0.045)
$\Delta \ln e_{\$j,t} \times D_{PCP}$ $(\beta_{2,0})$	0.708*** (0.072)	0.758*** (0.062)
$\Delta \ln e_{i\$,t} \times D_{LCP}$ $(\beta_{3,0})$	0.175*** (0.047)	0.234*** (0.042)
$\Delta \ln e_{\$j,t} \times D_{LCP}$ $(\beta_{4,0})$	0.039 (0.032)	0.105*** (0.028)
$\Delta \ln e_{i\$,t} \times D_{VCP}$ $(\beta_{5,0})$	0.839*** (0.054)	0.782*** (0.031)
$\Delta \ln e_{\$j,t} \times D_{VCP}$ $(\beta_{6,0})$	0.038 (0.060)	0.123*** (0.044)
Lags included	No	Yes
Firm-year fixed effects	Yes	Yes
Origin-product fixed effects	Yes	Yes
Invoicing choice fixed effects	Yes	Yes
Observations	5,328,761	5,328,761
R-squared	0.053	0.053

Notes: The origin country's quarterly inflation rate is also included, contemporaneously in column (1), and contemporaneously and with eight lags in column (2) (not reported). Robust standard errors adjusted for clustering at the country-year level are reported in parentheses. *** indicates significance at the 1% level. The dependent variable is the quarterly log change import unit value (in sterling per kilogram). Source: HMRC administrative data sets.

Column (1) in Table C1 only includes contemporaneous exchange rate changes, while column (2) includes up to eight lags (but we only report the contemporaneous elasticities). In column (2) we find that $\beta_{1,0}$, $\beta_{2,0}$, and $\beta_{5,0}$ are large but significantly lower than unity (at the 1% level). The coefficients $\beta_{3,0}$, $\beta_{4,0}$, and $\beta_{6,0}$ are small but significantly larger than zero. In addition, we can reject (at the 1% level) the hypothesis that the coefficients on all exchange rate lags are jointly insignificant. These results confirm that pass-through is not passive.

D Robustness

To ensure the robustness of our findings, we provide sensitivity checks. For simplicity we only report contemporaneous pass-through estimates. The long-run elasticities are available upon request.

Invoicing Subsamples In columns (1) to (3) of Table D1 we estimate equation (1) separately on three subsamples of import transactions invoiced in producer, local, and vehicle currencies. Columns (4) and (5) estimate equation (3) for vehicle currency transactions only (the exchange rate between the vehicle currency and the origin country's currency is omitted in column 5). As the coefficients on the foreign inflation rates and the fixed effects vary across invoicing choices, the pass-through estimates differ from those in Table 5 but our conclusions remain similar.[5]

Table D1: Robustness – Pass-Through for Invoicing Subsamples

	(1)	(2)	(3)	(4)	(5)
$\Delta \ln e_{ij,t}$	0.696*** (0.107)	0.059 (0.040)	0.123*** (0.033)	–	–
$\Delta \ln e_{iV,t}$	–	–	–	0.612*** (0.149)	0.535*** (0.155)
$\Delta \ln e_{Vj,t}$	–	–	–	0.094*** (0.035)	–
Invoicing currency	PCP	LCP	VCP	VCP	VCP
Firm-quarter fixed effects	Yes	Yes	Yes	Yes	Yes
Origin-product fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	1,272,714	1,065,852	2,599,543	2,599,543	2,599,543
R-squared	0.186	0.206	0.176	0.176	0.176

Notes: Contemporaneous and eight lags of the origin country's quarterly inflation rate, as well as eight lags of the log change in each exchange rate are also included (not reported). Robust standard errors adjusted for clustering at the country-year level are reported in parentheses. *** indicates significance at the 1% level. The dependent variable is the quarterly log change import unit value (in sterling per kilogram). Source: HMRC administrative data sets.

Third-Country Exchange Rates As pointed out by Gopinath and Itskhoki (2011), strategic complementarities in price setting at the firm level may affect exchange rate pass-through. To account for strategic complementarities, we control for the quarterly trade-weighted nominal exchange rate of the UK economy in our regressions (International Financial Statistics of the International Monetary Fund). Movements in the trade-weighted exchange rate may indeed capture the extent of competition that a firm faces against the exporters of other (third) countries. They may also impact the prices of a firm if it imports intermediate inputs from the rest of the world.

In Table D2 we estimate the same specifications as in Table 5 but we further control for the change in the trade-weighted exchange rate that we purge from movements in the bilateral or vehicle currency exchange rates included in each regression (Gopinath and Itskhoki, 2011; Gopinath and Rigobon, 2008). To do so, in a first step we regress the change in the trade-weighted exchange rate on the change in

[5] Note that columns (3) to (5) of Table D1 are the same as columns (2), (5), and (3) of Table 11. Also, columns (1) to (3) of Table D1 are the same as columns (1) to (3) of Table A1 in Online Appendix A.

Table D2: Robustness – Pass-Through and Third-Country Exchange Rates

	(1)	(2)	(3)	(4)
$\Delta \ln e_{ij,t}$	0.346^{***} (0.032)	–	–	–
$\Delta \ln e_{ij,t} \times D_{PCP}$	–	0.603^{***} (0.042)	0.710^{***} (0.040)	0.683^{***} (0.042)
$\Delta \ln e_{ij,t} \times D_{LCP}$	–	0.054^{*} (0.030)	0.103^{***} (0.027)	0.076^{***} (0.028)
$\Delta \ln e_{ij,t} \times D_{VCP}$	–	0.408^{***} (0.044)	–	–
$\Delta \ln e_{iV,t} \times D_{VCP}$	–	–	0.727^{***} (0.032)	0.664^{***} (0.038)
$\Delta \ln e_{Vj,t} \times D_{VCP}$	–	–	0.177^{***} (0.027)	–
residuals	0.114^{**} (0.052)	0.120^{**} (0.050)	0.057 (0.045)	0.076^{*} (0.045)
Firm-year fixed effects	Yes	Yes	Yes	Yes
Origin-product fixed effects	Yes	Yes	Yes	Yes
Invoicing choice fixed effects	No	Yes	Yes	Yes
Observations	5,674,778	5,674,778	5,674,778	5,674,778
R-squared	0.051	0.051	0.051	0.051

Notes: Contemporaneous and eight lags of the origin country's quarterly inflation rate, as well as eight lags of the log change in each exchange rate and the residuals are also included (not reported). Robust standard errors adjusted for clustering at the country-year level are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The dependent variable is the quarterly log change import unit value (in sterling per kilogram). Source: HMRC administrative data sets.

the bilateral or vehicle currency exchange rates and calculate the residuals.[6] The residuals capture movements in the trade-weighted exchange rate which are orthogonal to changes in the bilateral or vehicle currency exchange rates. In a second step we regress the change in import unit values on the change in each exchange rate and the corresponding residuals. To avoid collinearity we control for firm-year as opposed to firm-quarter fixed effects, and we include eight lags on each exchange rate and the residuals. Compared to Table 5 the magnitude of the contemporaneous pass-through elasticities is on average larger, and the elasticity for local currency transactions becomes significant. But overall, our results continue to hold.

EU Referendum As the depreciation of sterling against all major currencies following the EU referendum of June 2016 can be considered as permanent/long-lasting (by the time of writing the value of sterling had not returned to its pre-referendum levels), we investigate whether our results differ between the pre- and post-referendum periods.

In Table D3 we estimate the specifications reported in Table 5 but we interact all exchange rates with a dummy for the pre- (2010Q1–2016Q2) and a dummy for the post-referendum (2016Q3–2017Q4) period. The coefficients tend to be slightly smaller in the post- than in the pre-referendum period (the

[6] In Table D2 the residuals are obtained from regressing the change in the trade-weighted exchange rate on the change in the bilateral exchange rate in columns (1) and (2), the change in the bilateral exchange rate for PCP and LCP transactions and the change in the sterling to vehicle and vehicle to origin country's currency exchange rates for VCP transactions in column (3), and the change in the bilateral exchange rate for PCP and LCP transactions and the change in the sterling to vehicle currency exchange rate for VCP transactions in column (4).

sample is also shorter as it spans six quarters only). But we cannot reject the hypothesis that the coefficients remain the same in the two periods. We therefore conclude that our results remain robust to the depreciation of sterling following the EU referendum.

Table D3: Robustness – Pass-Through before and after the EU Referendum

	(1)	(2)	(3)	(4)
$\Delta \ln e_{ij,t} \times D_{pre}$	0.191^{***} (0.035)	–	–	–
$\Delta \ln e_{ij,t} \times D_{post}$	0.132^{***} (0.034)	–	–	–
$\Delta \ln e_{ij,t} \times D_{PCP} \times D_{pre}$	–	0.496^{***} (0.055)	0.682^{***} (0.059)	0.659^{***} (0.060)
$\Delta \ln e_{ij,t} \times D_{PCP} \times D_{post}$	–	0.383^{***} (0.089)	0.590^{***} (0.118)	0.584^{***} (0.120)
$\Delta \ln e_{ij,t} \times D_{LCP} \times D_{pre}$	–	−0.069 (0.049)	0.031 (0.044)	0.004 (0.044)
$\Delta \ln e_{ij,t} \times D_{LCP} \times D_{post}$	–	0.010 (0.058)	0.120^{*} (0.063)	0.107^{*} (0.064)
$\Delta \ln e_{ij,t} \times D_{VCP} \times D_{pre}$	–	0.257^{***} (0.039)	–	–
$\Delta \ln e_{ij,t} \times D_{VCP} \times D_{post}$	–	0.159^{***} (0.043)	–	–
$\Delta \ln e_{iV,t} \times D_{VCP} \times D_{pre}$	–	–	0.691^{***} (0.079)	0.619^{***} (0.083)
$\Delta \ln e_{iV,t} \times D_{VCP} \times D_{post}$	–	–	0.513^{***} (0.098)	0.483^{***} (0.106)
$\Delta \ln e_{Vj,t} \times D_{VCP} \times D_{pre}$	–	–	0.112^{**} (0.046)	–
$\Delta \ln e_{Vj,t} \times D_{VCP} \times D_{post}$	–	–	0.033 (0.053)	–
Firm-quarter fixed effects	Yes	Yes	Yes	Yes
Origin-product fixed effects	Yes	Yes	Yes	Yes
Invoicing choice fixed effects	No	Yes	Yes	Yes
Observations	5,212,592	5,212,592	5,212,592	5,212,592
R-squared	0.146	0.146	0.146	0.146

Notes: Contemporaneous and eight lags of the origin country's quarterly inflation rate, as well as eight lags of the log change in each exchange rate are also included (not reported). Robust standard errors adjusted for clustering at the country-year level are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The dependent variable is the quarterly log change import unit value (in sterling per kilogram). The dummy variables D_{pre} and D_{post} are equal to one for the 2010Q1–2016Q2 and 2016Q3–2017Q4 periods, respectively. Source: HMRC administrative data sets.

Trade-Weighted Estimates Table D4 reports the results of estimating the specifications of Table 5 once we weight observations by trade values. Compared to our benchmark results, the pass-through estimates for producer currency transactions are larger in magnitude, while the ones for vehicle currency transactions are smaller (the local currency estimates are insignificant). But overall, our results continue to hold. These findings are consistent with Gopinath et al. (2020) who show that trade weighting leads to quantitative but not qualitative differences in pass-through estimates.

Annual Frequency Table D5 shows that our results remain robust to aggregating the data at annual frequency. We estimate the same specifications as in Table 5 but we only include two lags on the exchange rates and the foreign inflation rates.

Table D4: Robustness – Trade-Weighted Pass-Through Estimates

	(1)	(2)	(3)	(4)
$\Delta \ln e_{ij,t}$	0.150*** (0.068)	–	–	–
$\Delta \ln e_{ij,t} \times D_{PCP}$	–	0.461*** (0.166)	0.728*** (0.166)	0.723*** (0.165)
$\Delta \ln e_{ij,t} \times D_{LCP}$	–	0.016 (0.112)	0.095 (0.109)	0.069 (0.104)
$\Delta \ln e_{ij,t} \times D_{VCP}$	–	0.148** (0.072)	–	–
$\Delta \ln e_{iV,t} \times D_{VCP}$	–	–	0.600*** (0.128)	0.541*** (0.120)
$\Delta \ln e_{Vj,t} \times D_{VCP}$	–	–	0.089 (0.073)	–
Firm-quarter fixed effects	Yes	Yes	Yes	Yes
Origin-product fixed effects	Yes	Yes	Yes	Yes
Invoicing choice fixed effects	No	Yes	Yes	Yes
Observations	5,212,592	5,212,592	5,212,592	5,212,592
R-squared	0.378	0.378	0.379	0.378

Notes: Observations are weighted by trade values. Contemporaneous and eight lags of the origin country's quarterly inflation rate, as well as eight lags of the log change in each exchange rate are also included (not reported). Robust standard errors adjusted for clustering at the country-year level are reported in parentheses. *** and ** indicate significance at the 1% and 5% levels, respectively. The dependent variable is the quarterly log change import unit value (in sterling per kilogram). Source: HMRC administrative data sets.

Table D5: Robustness – Pass-Through Based on Annual Frequency

	(1)	(2)	(3)	(4)
$\Delta \ln e_{ij,t}$	0.188*** (0.039)	–	–	–
$\Delta \ln e_{ij,t} \times D_{PCP}$	–	0.489*** (0.058)	0.728*** (0.045)	0.708*** (0.046)
$\Delta \ln e_{ij,t} \times D_{LCP}$	–	−0.069 (0.045)	0.099** (0.039)	0.072* (0.039)
$\Delta \ln e_{ij,t} \times D_{VCP}$	–	0.201*** (0.034)	–	–
$\Delta \ln e_{iV,t} \times D_{VCP}$	–	–	0.738*** (0.052)	0.701*** (0.054)
$\Delta \ln e_{Vj,t} \times D_{VCP}$	–	–	0.056* (0.030)	–
Firm-year fixed effects	Yes	Yes	Yes	Yes
Origin-product fixed effects	Yes	Yes	Yes	Yes
Invoicing choice fixed effects	No	Yes	Yes	Yes
Observations	2,543,425	2,543,425	2,543,425	2,543,425
R-squared	0.133	0.133	0.133	0.133

Notes: Contemporaneous and two lags of the origin country's annual inflation rate, as well as two lags of the log change in each exchange rate are also included (not reported). Robust standard errors adjusted for clustering at the country-year level are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The dependent variable is the annual log change import unit value (in sterling per kilogram). Source: HMRC administrative data sets.

Monthly Frequency Table D6 reports the results of estimating the specifications of Table 5 using monthly frequency data. We include twelve lags on the exchange rates and the foreign inflation rates. The table reports the coefficients on the contemporaneous and the first lag of each exchange rate change. All our results continue to hold, but interestingly the effects of exchange rate changes tend to kick in after one month only.

Table D6: Robustness – Pass-Through Based on Monthly Frequency

	(1)	(2)	(3)	(4)
$\Delta \ln e_{ij,t}$	0.068^{**} (0.028)	–	–	–
$\Delta \ln e_{ij,t-1}$	0.503^{***} (0.062)	–	–	–
$\Delta \ln e_{ij,t} \times D_{PCP}$	–	0.123 (0.083)	0.129 (0.082)	0.128 (0.082)
$\Delta \ln e_{ij,t-1} \times D_{PCP}$	–	0.787^{***} (0.099)	0.792^{***} (0.098)	0.791^{***} (0.099)
$\Delta \ln e_{ij,t} \times D_{LCP}$	–	0.043^{*} (0.024)	0.043^{*} (0.024)	0.042^{*} (0.024)
$\Delta \ln e_{ij,t-1} \times D_{LCP}$	–	0.162^{***} (0.036)	0.164^{***} (0.037)	0.162^{***} (0.037)
$\Delta \ln e_{ij,t} \times D_{VCP}$	–	0.067^{*} (0.038)	–	–
$\Delta \ln e_{ij,t-1} \times D_{VCP}$	–	0.574^{***} (0.086)	–	–
$\Delta \ln e_{iV,t} \times D_{VCP}$	–	–	0.085 (0.053)	0.084^{*} (0.046)
$\Delta \ln e_{iV,t-1} \times D_{VCP}$	–	–	0.916^{***} (0.089)	0.863^{***} (0.082)
$\Delta \ln e_{Vj,t} \times D_{VCP}$	–	–	0.004 (0.042)	–
$\Delta \ln e_{Vj,t-1} \times D_{VCP}$	–	–	0.155^{***} (0.052)	–
Firm-month fixed effects	Yes	Yes	Yes	Yes
Origin-product fixed effects	Yes	Yes	Yes	Yes
Invoicing choice fixed effects	No	Yes	Yes	Yes
Observations	8,059,400	8,059,400	8,059,400	8,059,400
R-squared	0.030	0.030	0.030	0.030

Notes: Contemporaneous and twelve lags of the origin country's monthly inflation rate, as well as twelve lags of the log change in each exchange rate are also included (not reported). Robust standard errors adjusted for clustering at the country-year level are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The dependent variable is the monthly log change import unit value (in sterling per kilogram). Source: HMRC administrative data sets.

PPI versus CPI As in Gopinath (2016) and Gopinath et al. (2010), in order to control for foreign costs our regressions include CPI-based quarterly foreign inflation rates. Table D7 reports the same specifications as in Table 5 but using PPI inflation rates instead (we use the PPI for all commodities from the International Financial Statistics of the International Monetary Fund). Due to lack of data availability our sample size is reduced by half, but our results continue to hold.

Products In Table D8 we estimate the specification of column (4) in Table 5 on subsamples that distinguish between different types of goods. In column (1) we only include manufacturing industries (SITC 6–8). In column (2) we restrict the sample to the goods produced in the origin country.[7]

[7] We use the variable "cooseq" which identifies the country where the goods are produced versus the country of dispatch.

Table D7: Robustness – Pass-Through Based on PPI Controls

	(1)	(2)	(3)	(4)
$\Delta \ln e_{ij,t}$	0.217*** (0.045)	–	–	–
$\Delta \ln e_{ij,t} \times D_{PCP}$	–	0.487*** (0.056)	0.668*** (0.061)	0.636*** (0.062)
$\Delta \ln e_{ij,t} \times D_{LCP}$	–	−0.058 (0.056)	0.013 (0.052)	−0.021 (0.049)
$\Delta \ln e_{ij,t} \times D_{VCP}$	–	0.218*** (0.055)	–	–
$\Delta \ln e_{iV,t} \times D_{VCP}$	–	–	0.695*** (0.079)	0.640*** (0.073)
$\Delta \ln e_{Vj,t} \times D_{VCP}$	–	–	0.098* (0.059)	–
Firm-quarter fixed effects	Yes	Yes	Yes	Yes
Origin-product fixed effects	Yes	Yes	Yes	Yes
Invoicing choice fixed effects	No	Yes	Yes	Yes
Observations	2,749,680	2,749,680	2,749,680	2,749,680
R-squared	0.161	0.161	0.161	0.161

Notes: Contemporaneous and eight lags of the origin country's quarterly PPI inflation rate, as well as eight lags of the log change in each exchange rate are also included (not reported). Robust standard errors adjusted for clustering at the country-year level are reported in parentheses. *** and * indicate significance at the 1% and 10% levels, respectively. The dependent variable is the quarterly log change import unit value (in sterling per kilogram). Source: HMRC administrative data sets.

Using information on the end use of goods as provided by the BEC classification, columns (3), (4), and (5) restrict the sample to intermediate, final, and capital goods. As firms tend to have more pricing power for differentiated goods, columns (6) and (7) distinguish between differentiated and homogeneous/reference priced products according to Rauch's (1999) conservative classification (the results are similar if we use the liberal classification). In all subsamples, our results continue to hold.

Table D8: Robustness – Pass-Through for Different Product Subsamples

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\Delta \ln e_{ij,t} \times D_{PCP}$	0.616*** (0.059)	0.628*** (0.052)	0.638*** (0.074)	0.642*** (0.087)	0.578*** (0.152)	0.607*** (0.058)	0.611*** (0.092)	0.575*** (0.060)	0.714*** (0.105)
$\Delta \ln e_{ij,t} \times D_{LCP}$	0.019 (0.044)	0.012 (0.035)	0.001 (0.058)	−0.011 (0.045)	0.041 (0.121)	0.009 (0.043)	−0.042 (0.045)	−0.007 (0.038)	−0.011 (0.057)
$\Delta \ln e_{iV,t} \times D_{VCP}$	0.586*** (0.066)	0.601*** (0.050)	0.549*** (0.077)	0.665*** (0.083)	0.621*** (0.155)	0.597*** (0.066)	0.488*** (0.093)	0.569*** (0.061)	0.573*** (0.095)
Sample	Manuf.	Origin	Interm.	Final	Capital	Diff.	Hom.	Mode=1	Mode>1
Firm-quarter fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Origin-product fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Invoicing choice fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,403,049	3,447,282	2,042,899	2,210,542	681,893	4,593,760	530,412	3,161,380	1,825,327
R-squared	0.147	0.189	0.169	0.176	0.195	0.147	0.227	0.177	0.171

Notes: Contemporaneous and eight lags of the origin country's quarterly inflation rate, as well as eight lags of the log change in each exchange rate are also included (not reported). Robust standard errors adjusted for clustering at the country-year level are reported in parentheses. *** indicates significance at the 1% level. The dependent variable is the quarterly log change import unit value (in sterling per kilogram). Source: HMRC administrative data sets.

Given the level of disaggregation of our data (at the 10-digit level), changes in unit values may conflate price changes with changes in the quality of traded goods. To address this issue we calculate the number of transportation modes by firm-product-country triplets (sea, rail, road, air), and we split our sample by triplets with one or more than one transportation modes. If a firm imports a given product from a given country using different modes of transportation, this might indicate that the goods have a different quality. Columns (8) and (9) show that our results remain robust to controlling for the number of transportation modes at the firm-product-country level (see column 4 of Table D10).

Excluding Commodities Table D9 shows that once we exclude homogeneous commodities such as "Crude materials" (SITC 2) and "Mineral fuels" (SITC 3) from the sample, the sign and the magnitude of our estimates remain similar to those in Table 5.

Table D9: Robustness – Pass-Through Excluding Commodities

	(1)	(2)	(3)	(4)
$\Delta \ln e_{ij,t}$	0.179^{***} (0.029)	–	–	–
$\Delta \ln e_{ij,t} \times D_{PCP}$	–	0.443^{***} (0.044)	0.648^{***} (0.050)	0.619^{***} (0.052)
$\Delta \ln e_{ij,t} \times D_{LCP}$	–	-0.068^{*} (0.041)	0.030 (0.035)	0.001 (0.037)
$\Delta \ln e_{ij,t} \times D_{VCP}$	–	0.245^{***} (0.033)	–	–
$\Delta \ln e_{iV,t} \times D_{VCP}$	–	–	0.653^{***} (0.057)	0.597^{***} (0.059)
$\Delta \ln e_{Vj,t} \times D_{VCP}$	–	–	0.108^{***} (0.038)	–
Firm-quarter fixed effects	Yes	Yes	Yes	Yes
Origin-product fixed effects	Yes	Yes	Yes	Yes
Invoicing choice fixed effects	No	Yes	Yes	Yes
Observations	5,131,177	5,131,177	5,131,177	5,131,177
R-squared	0.146	0.146	0.146	0.146

Notes: Contemporaneous and eight lags of the origin country's quarterly inflation rate, as well as eight lags of the log change in each exchange rate are also included (not reported). Robust standard errors adjusted for clustering at the country-year level are reported in parentheses. *** and * indicate significance at the 1% and 10% levels, respectively. The dependent variable is the quarterly log change import unit value (in sterling per kilogram). Source: HMRC administrative data sets.

Product-Specific Controls Apart from the origin country-product fixed effects, our regressions do not include any product-specific characteristics. To control for additional variation across products, we use annual frequency data at the 6-digit HS level from UN Comtrade to measure the growth over our sample period of each country's total exports by product category (excluding exports to the UK). This aims to control for the effects of productivity gains in each origin country that may shift export prices to all destinations. Column (1) of Table D10 shows that adding this variable to the specification of column (4) in Table 5 does not alter our conclusions.

We control for alternative sets of product fixed effects. Columns (2) to (5) include country-product-year fixed effects (to control for the time-varying demand or taste of UK importers for a country's products), country-product-quarter fixed effects (in which case pass-through can only be estimated for vehicle currency transactions), product-quarter fixed effects (to control for changes in the average quality of each product category over time, see also columns 8 and 9 of Table D8), and firm-country-product fixed effects (to account for contracts importers may have signed in some origin countries).

Table D10: Robustness – Pass-Through with Product-Specific Controls

	(1)	(2)	(3)	(4)	(5)
$\Delta \ln e_{ij,t} \times D_{PCP}$	0.626^{***} (0.052)	0.578^{***} (0.059)	–	0.627^{***} (0.055)	0.608^{***} (0.059)
$\Delta \ln e_{ij,t} \times D_{LCP}$	0.005 (0.038)	0.003 (0.041)	–	0.008 (0.039)	−0.014 (0.038)
$\Delta \ln e_{iV,t} \times D_{VCP}$	0.591^{***} (0.059)	0.576^{***} (0.066)	0.663^{**} (0.291)	0.612^{***} (0.063)	0.589^{***} (0.067)
Imported product growth	0.001 (0.001)	–	–	–	–
Sample	Full	Full	VCP	Full	Full
Firm-quarter fixed effects	Yes	Yes	Yes	Yes	Yes
Origin-product fixed effects	Yes	No	No	Yes	No
Invoicing choice fixed effects	Yes	Yes	No	Yes	Yes
Origin-product-year fixed effects	No	Yes	No	No	No
Origin-product-quarter fixed effects	No	No	Yes	No	No
Product-quarter fixed effects	No	No	No	Yes	No
Firm-origin-product fixed effects	No	No	No	No	Yes
Observations	5,080,407	5,132,943	2,210,499	5,147,652	4,843,562
R-squared	0.147	0.173	0.309	0.178	0.206

Notes: Contemporaneous and eight lags of the origin country's quarterly inflation rate, as well as eight lags of the log change in each exchange rate are also included (not reported). Robust standard errors adjusted for clustering at the country-year level are reported in parentheses. *** and ** indicate significance at the 1% and 5% levels, respectively. The dependent variable is the quarterly log change import unit value (in sterling per kilogram). Source: HMRC administrative data sets.

Firm Size In Table D11 we estimate the regression of column (4) in Table 5 but in column (1) we omit the 1% of firms with the largest import shares (to proxy for firm size). Column (2) includes these firms only. Columns (3) and (4) repeat this exercise for the 5% of firms with the largest import shares.

Table D11: Robustness – Pass-Through by Firm Size

	(1)	(2)	(3)	(4)
$\Delta \ln e_{ij,t} \times D_{PCP}$	0.635^{***} (0.059)	0.584^{***} (0.088)	0.563^{***} (0.075)	0.635^{***} (0.061)
$\Delta \ln e_{ij,t} \times D_{LCP}$	0.001 (0.046)	−0.009 (0.045)	0.048 (0.071)	−0.014 (0.037)
$\Delta \ln e_{iV,t} \times D_{VCP}$	0.643^{***} (0.067)	0.501^{***} (0.078)	0.579^{***} (0.078)	0.590^{***} (0.065)
Sample	Excl. top 1% firms	Top 1% firms	Excl. top 5% firms	Top 5% firms
Firm-quarter fixed effects	Yes	Yes	Yes	Yes
Origin-product fixed effects	Yes	Yes	Yes	Yes
Invoicing choice fixed effects	Yes	Yes	Yes	Yes
Observations	3,514,253	1,688,155	2,033,827	3,166,163
R-squared	0.206	0.051	0.276	0.074

Notes: Contemporaneous and eight lags of the origin country's quarterly inflation rate, as well as eight lags of the log change in each exchange rate are also included (not reported). Robust standard errors adjusted for clustering at the country-year level are reported in parentheses. *** indicates significance at the 1% level. The dependent variable is the quarterly log change import unit value (in sterling per kilogram). Source: HMRC administrative data sets.

Excluding Various Countries We check if our results in column (4) of Table 5 remain robust to excluding various origin countries from the sample. In column (1) of Table D12 we exclude the US as their exports are mostly in US dollars. In column (2) we exclude China due to its changing foreign exchange rate policy (in 2010 China changed its policy to a "crawl-like arrangement" relative to the US dollar, while in 2016 the flexibility of the renminbi became limited relative to a basket of currencies).

In columns (3), (4), (5), and (6) we exclude the countries with fixed exchange rate regimes, fixed exchange rates or crawling pegs, and the countries pegging their currency to the US dollar or the euro, respectively (the exchange rate regimes are identified using the International Monetary Fund's *De Facto* classification). In all cases our results remain robust.

Table D12: Robustness – Pass-Through Excluding Various Countries

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \ln e_{ij,t} \times D_{PCP}$	0.609*** (0.073)	0.616*** (0.055)	0.609*** (0.059)	0.610*** (0.059)	0.609*** (0.058)	0.622*** (0.051)
$\Delta \ln e_{ij,t} \times D_{LCP}$	0.004 (0.039)	0.001 (0.033)	−0.006 (0.034)	−0.005 (0.034)	−0.004 (0.034)	0.001 (0.036)
$\Delta \ln e_{iV,t} \times D_{VCP}$	0.610*** (0.067)	0.626*** (0.059)	0.556*** (0.055)	0.558*** (0.055)	0.563*** (0.054)	0.590*** (0.058)
Sample excluding	US	China	Fixed	Fixed/crawl	USD peg	Euro peg
Firm-quarter fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Origin-product fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Invoicing choice fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,966,909	3,536,819	3,034,515	3,031,115	3,051,771	5,196,440
R-squared	0.162	0.157	0.159	0.159	0.159	0.146

Notes: Contemporaneous and eight lags of the origin country's quarterly inflation rate, as well as eight lags of the log change in each exchange rate are also included (not reported). Robust standard errors adjusted for clustering at the country-year level are reported in parentheses. *** indicates significance at the 1% level. The dependent variable is the quarterly log change import unit value (in sterling per kilogram). Source: HMRC administrative data sets.

Different Combinations of Fixed Effects In Table D13 we investigate how the combination of fixed effects in our main regressions (i.e., firm-quarter and origin country-product fixed effects) impact our pass-through estimates. We estimate the specification of column (4) in Table 5 and as a benchmark we include no fixed effects in column (1). We then include origin country-product fixed effects in column (2), or firm-quarter dummy variables in column (3). Compared to column (4) of Table 5, the contemporaneous pass-through elasticities are marginally larger without any fixed effects, and they increase in magnitude with origin country-product fixed effects. They are similar in magnitude with firm-quarter fixed effects. Still, the pattern of our results across invoicing choices remains similar in all three columns.

Given that 88.5% of the transactions priced in a vehicle currency are in US dollars (Table 2), it is likely that in a given quarter many firms use exclusively the US dollar as a vehicle currency. For these firms, the variation in the sterling to vehicle currency exchange rate is therefore fully absorbed by

Table D13: Robustness – Pass-Through with Different Combinations of Fixed Effects

	(1)	(2)	(3)	(4)	(5)
$\Delta \ln e_{ij,t} \times D_{PCP}$	0.684^{***} (0.040)	0.689^{***} (0.039)	0.625^{***} (0.050)	0.697^{***} (0.039)	0.735^{***} (0.041)
$\Delta \ln e_{ij,t} \times D_{LCP}$	0.106^{***} (0.021)	0.118^{***} (0.021)	0.001 (0.035)	0.123^{***} (0.021)	0.122^{***} (0.024)
$\Delta \ln e_{iV,t} \times D_{VCP}$	0.606^{***} (0.022)	0.622^{***} (0.022)	0.587^{***} (0.056)	0.640^{***} (0.022)	0.707^{***} (0.028)
Firm-quarter fixed effects	No	No	Yes	No	No
Origin-product fixed effects	No	Yes	No	Yes	Yes
Invoicing choice fixed effects	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	No	No	No	Yes	No
Fim-year fixed effects	No	No	No	No	Yes
Observations	5,792,400	5,769,236	5,237,681	5,745,060	5,674,778
R-squared	0.001	0.011	0.135	0.023	0.051

Notes: Contemporaneous and eight lags of the origin country's quarterly inflation rate, as well as eight lags of the log change in each exchange rate are also included (not reported). Robust standard errors adjusted for clustering at the country-year level are reported in parentheses. *** indicates significance at the 1% level. The dependent variable is the quarterly log change import unit value (in sterling per kilogram). Source: HMRC administrative data sets.

firm-quarter fixed effects. To address this issue, in columns (4) and (5) we control for origin country-product and firm- or firm-year fixed effects (the specification in column 5 is thus the same as in column 6 of Table 9 in the main text). Compared to Table 5 the pass-through elasticities are somewhat larger, but across invoicing choices they remain low for local currency transactions, and large for producer and vehicle currency transactions.

Alternative Specification As suggested by a referee, another way of demonstrating that invoicing choices are driving heterogeneous pass-through is to estimate the effects of bilateral exchange rate changes on the unit values of firms importing a given product from a given country using different invoicing currencies. To do so, we estimate a modified version of equation (1):

$$\begin{aligned}\Delta \ln UV_{ijk,t} \quad = \quad & \sum_{n=0}^{N} \Theta_n \Delta \ln e_{ij,t-n} + \sum_{n=0}^{N} \Lambda_n \Delta \ln e_{ij,t-n} \times D_{LCP} + \sum_{n=0}^{N} \Xi_n \Delta \ln e_{ij,t-n} \times D_{VCP} \\ & + \sum_{n=0}^{N} \Pi_n \pi^*_{j,t-n} + D_{i,T} + D_{jk,T} + D_{PCP} + D_{VCP} + \varsigma_{ijk,t}, \qquad \text{(D1)}\end{aligned}$$

where we include origin country-product-year fixed effects $D_{jk,T}$ (as origin country-product-quarter fixed effects are perfectly collinear with bilateral exchange rates) and firm-year fixed effects $D_{i,T}$. We expect the contemporaneous coefficients Λ_0 and Ξ_0 to be negative because pass-through based on the bilateral exchange rate is only expected to be high for producer currency pricing. As shown in Table D14, whether we exclude (column 1) or include (column 2) firm-year fixed effects, the contemporaneous pass-through of bilateral exchange rate changes is high at around 79% for producer currency transactions, while it is significantly lower for local and vehicle currency transactions.

Table D14: Robustness – Alternative Specification

	(1)	(2)
$\Delta \ln e_{ij,t}$	0.787^{***} (0.043)	0.788^{***} (0.048)
$\Delta \ln e_{ij,t} \times D_{LCP}$	-0.555^{***} (0.051)	-0.559^{***} (0.054)
$\Delta \ln e_{ij,t} \times D_{VCP}$	-0.212^{***} (0.063)	-0.191^{***} (0.067)
Firm-year fixed effects	No	Yes
Origin-product-year fixed effects	Yes	Yes
Invoicing choice fixed effects	Yes	Yes
Observations	5,695,315	5,603,072
R-squared	0.035	0.076

Notes: Contemporaneous and eight lags of the origin country's quarterly inflation rate, as well as eight lags of the log change in each exchange rate are also included (not reported). Robust standard errors adjusted for clustering at the country-year level are reported in parentheses. *** indicates significance at the 1% level. The dependent variable is the quarterly log change import unit value (in sterling per kilogram). Source: HMRC administrative data sets.

E Export Unit Values

In this appendix we report results for export unit values. We describe our sample and proceed with the estimation of exchange rate pass-through for export unit values by invoicing choice.

E.1 Descriptive Statistics

Transaction-level FOB exports are obtained from HMRC. We observe a unique trader identifier, the destination country, the transaction date, the 5-digit SITC Revision 3 and the 4-digit HS Revision 2007 classifications, the 10-digit comcode product code, the value (in sterling), the mass (in kilograms), and the currency of invoicing between 2011 and 2017 for non-EU transaction values exceeding 100,000 pound sterling. In our data set, non-EU exports represent 54% of total UK exports. Export unit values are obtained by dividing the quarterly transaction value in sterling by the corresponding mass in kilograms.

Compared to our sample for imports, Table E1 shows that for exports we observe fewer firms (52,602), products (8,565), and destination countries (134), with a total of 2,675,099 observations. On average, these firms export 5.1 different products to 3.8 destination countries (at the 5^{th} and 95^{th} percentiles, the products per exporter are 1 and 17, while the destinations per exporter are 1 and 15). Exporters charge on average 232,731 pound sterling in each quarter, or 1,920.8 pound sterling per kilogram. The mean change in export unit values is equal to 0.6% per quarter.

The largest non-EU export markets of the UK are the US (34.4% of total non-EU exports between 2011 and 2017), China (9.7%), the United Arab Emirates (4.4%), Hong Kong (4.0%), Japan (3.5%), Canada (3.2%), and Singapore (3.2%).

Table E1: Summary Statistics for Export Data

	Mean	Median	Std. dev.	5^{th} percentile	95^{th} percentile
Exporters	52,602	–	–	–	–
Products	8,565	–	–	–	–
Destination countries	134	–	–	–	–
Products per exporter	5.1	2	22.1	1	17
Destinations per exporter	3.8	2	5.8	1	15
Unit values (sterling/kg)	1,920.8	56.2	126,106.2	1.8	2,417.5
Change in log unit values (~%)	0.6	0.1	0.9	−145.1	147.1
Transaction values (sterling)	232,731	12,177	4,094,784	1,110	504,090

Notes: For each variable, the table reports its mean, median, standard deviation, and values at the 5^{th} and 95^{th} percentiles. Changes in log unit values (in ~%) are calculated quarterly. Source: HMRC administrative data sets.

Table E2 reports descriptive statistics for exports by invoicing currency. The largest value share of exports is invoiced in producer currency (sterling) at 53.83%, followed by 23.99% in vehicle currency, and 22.18% in local currency. A total of 65 different vehicle currencies are used, but 85.46% of the value of transactions priced in a vehicle currency are in US dollars and 13.86% in euros. In terms of transaction counts, these correspond to shares of 73.73% and 24.47%. Unit values are highest for vehicle currency priced goods at 2,765 pound sterling per kilogram.

Table E2: Descriptive Statistics by Invoicing Currency for Export Data

	Observations	Firms	Products	Dest.	Products per firm	Dest. per firm	Unit values	Export values	Export shares
PCP	1,701,237	47,108	8,281	134	4.42	3.45	1,631.49	196,994	53.83
LCP	345,354	14,084	5,562	56	4.32	1.30	1,809.53	399,807	22.18
VCP	628,508	16,442	6,198	131	4.12	3.70	2,765.10	237,660	23.99
VCP (USD)	463,399	12,191	5,497	127	4.17	3.65	3,370.02	275,469	85.46
VCP (Euro)	153,822	8,778	4,633	123	2.94	2.52	872.94	134,542	13.86
VCP (Other)	11,287	1,021	1,225	92	2.42	1.81	3,719.52	90,676	0.69

Notes: For each invoicing choice, the table reports the number of observations, exporters, products, destinations, products per firm, destinations per firm, the mean unit value (in sterling per kilogram), the mean export value (in sterling), and exports as a share of total non-EU exports (in %). Source: HMRC administrative data sets.

The left panel of Table E3 reports export shares by invoicing currency and industry (at the 1-digit SITC level). Consistent with Table E2, producer currency pricing (sterling) is the dominant strategy for all industries. Its share varies from 43.05% for "Chemicals" to 69.35% for "Mineral fuels." The right panel of the table splits the data by region of destination. Producer currency pricing is the most widely used strategy for all regions except for the US where local currency pricing dominates.

E.2 Exchange Rate Pass-Through

To evaluate exchange rate pass-through for export unit values, we estimate the following specification:

$$\Delta \ln UV_{ijk,t} = \sum_{n=0}^{N} \gamma_n \Delta \ln e_{ij,t-n} + \sum_{n=0}^{N} \delta_n \pi^*_{j,t-n} + \sum_{n=0}^{1} \varrho_n Y^*_{j,t-n} + D_{i,t} + D_{jk} + \varepsilon_{ijk,t}, \tag{E1}$$

Table E3: Invoicing Currency Shares by Industry and Region for Export Data

Industry (SITC)	PCP	LCP	VCP	Share	**Destination**	PCP	LCP	VCP	Share
Food, live animals	63.70	14.80	21.50	1.87	US	47.02	50.83	2.15	35.44
Beverages, tobacco	49.51	34.76	15.73	3.44	China	65.60	5.45	28.95	10.01
Crude materials	64.92	5.00	30.08	2.94	East/S. East Asia	54.93	7.70	37.37	23.01
Mineral fuels	69.35	21.98	8.67	4.67	Europe excl. EU	63.65	6.45	29.90	10.42
Animal, vegetable oils	59.74	8.52	31.74	0.04	Other Americas	45.00	11.95	43.05	6.82
Chemicals	43.05	38.03	18.92	17.95	All others	57.75	2.52	39.73	14.30
Manufactured goods	53.78	12.57	33.65	9.05					
Machinery	53.68	18.88	27.44	47.28					
Miscellaneous	61.08	20.66	18.26	12.76					

Notes: The table reports the export share in terms of value (in %) by industry at the SITC 1-digit level, by destination country group, and by currency of invoicing. Source: HMRC administrative data sets.

where in contrast to equation (1), $UV_{ijk,t}$ is now the unit value of product k exported by firm i to country j in quarter t, expressed in sterling per kilogram, and j denotes the destination country for exports. In addition to controlling for the quarterly foreign inflation rate $\pi^*_{j,t}$, we also control for the annual growth of GDP in the destination country $Y^*_{j,t}$, included contemporaneously and with one lag (Gopinath et al., 2010).[8] Again, $e_{ij,t}$ is the bilateral exchange rate between sterling (i.e., the domestic currency of firm i) and the currency of country j in quarter t (an increase in $e_{ij,t}$ indicates a bilateral depreciation of sterling), and we include up to eight lags for the nominal exchange rate and the foreign inflation rate. We include firm-quarter $D_{i,t}$ and destination country-product fixed effects D_{jk}. Short-run pass-through into export unit values is captured by the coefficient γ_0 on the contemporaneous change in the exchange rate, whereas the cumulative estimate $\gamma(N) \equiv \sum_{n=0}^{N} \gamma_n$ evaluates long-run pass-through. Robust standard errors are adjusted for clustering at the destination country-year level.

We estimate equation (E1) using the full sample of exports. We then interact the bilateral exchange rates (and their lagged values) with dummy variables for export transactions invoiced in producer, local, and vehicle currencies (and we further include invoicing choice fixed effects). Finally, for the transactions in vehicle currencies, we decompose the change in the bilateral exchange rate $e_{ij,t}$ into the change in the sterling to vehicle currency exchange rate $e_{iV,t}$ and the change in the vehicle to destination country's currency exchange rate $e_{Vj,t}$. We then estimate:

$$\begin{aligned}\Delta \ln UV_{ijk,t} \quad = \quad & \sum_{n=0}^{N} \varkappa_n \Delta \ln e_{ij,t-n} \times D_{PCP} + \sum_{n=0}^{N} \xi_n \Delta \ln e_{ij,t-n} \times D_{LCP} \\ & + \sum_{n=0}^{N} \vartheta_n \Delta \ln e_{iV,t-n} \times D_{VCP} + \sum_{n=0}^{N} \zeta_n \Delta \ln e_{Vj,t-n} \times D_{VCP} \\ & + \sum_{n=0}^{N} \omega_n \pi^*_{j,t-n} + \sum_{n=0}^{1} \varpi_n Y^*_{j,t-n} + D_{i,t} + D_{jk} + D_{PCP} + D_{VCP} + \eta_{ijk,t}, \qquad \text{(E2)}\end{aligned}$$

[8]Nominal GDPs are from the International Financial Statistics of the International Monetary Fund. We use annual growth rates since quarterly growth rates are often unavailable.

where we allow for separate coefficients ϑ_n and ζ_n on the two exchange rates with the vehicle currency. Due to space constraints we only report and discuss the contemporaneous exchange rate elasticities. The long-run elasticities are available upon request.

Column (1) of Table E4 reports the results of estimating equation (E1) on the full sample of exports. The coefficient on the contemporaneous change in the bilateral exchange rate is equal to 0.036 but is not significant. Therefore, pass-through into import unit values is complete.

Table E4: Pass-Through into Export Unit Values

	(1)	(2)	(3)	(4)
$\Delta \ln e_{ij,t}$	0.036 (0.030)	–	–	–
$\Delta \ln e_{ij,t} \times D_{PCP}$	–	−0.010 (0.039)	0.019 (0.039)	0.018 (0.038)
$\Delta \ln e_{ij,t} \times D_{LCP}$	–	0.349^{***} (0.079)	0.447^{***} (0.085)	0.449^{***} (0.085)
$\Delta \ln e_{ij,t} \times D_{VCP}$	–	0.059 (0.038)	–	–
$\Delta \ln e_{iV,t} \times D_{VCP}$	–	–	0.412^{***} (0.075)	0.409^{***} (0.072)
$\Delta \ln e_{Vj,t} \times D_{VCP}$	–	–	−0.009 (0.038)	–
Firm-quarter fixed effects	Yes	Yes	Yes	Yes
Destination-product fixed effects	Yes	Yes	Yes	Yes
Invoicing choice fixed effects	No	Yes	Yes	Yes
Observations	2,432,614	2,432,614	2,432,614	2,432,614
R-squared	0.136	0.136	0.136	0.136

Notes: Contemporaneous and eight lags of the destination country's quarterly inflation rate, eight lags of the log change in each exchange rate, and the contemporaneous and one lag of the destination country's GDP growth rate are also included (not reported). Robust standard errors adjusted for clustering at the country-year level are reported in parentheses. *** indicates significance at the 1% level. The dependent variable is the quarterly log change export unit value (in sterling per kilogram). Source: HMRC administrative data sets.

Column (2) reports the results of estimating equation (E1) allowing for separate bilateral exchange rate coefficients for producer, local, and vehicle currency transactions. The effect of exchange rate changes varies substantially across invoicing choices. The coefficient on the bilateral exchange rate is insignificant for transactions in producer and vehicle currencies, and is equal to 0.349 for the ones in local currencies. As a result, pass-through into import unit values is complete for producer and vehicle currency transactions, and incomplete for the ones in local currencies. These findings are consistent with Corsetti et al. (2018).

We then regress equation (E2) where we decompose the bilateral exchange rate for the vehicle currency transactions. Column (3) shows that export unit values in vehicle currencies react to changes in the sterling to vehicle currency exchange rate, but not to changes in the vehicle to destination country's currency exchange rate. Column (4) excludes the exchange rate between the vehicle and the destination country's currency, and the coefficient on the sterling to vehicle currency exchange rate is equal to 0.409. In results available upon request we show that our findings remain similar if we let the pass-through elasticities vary across industries.

F Import and Export Quantities

The regressions for trade quantities take the same form as the pass-through regressions (1) and (3) for imports and regressions (E1) and (E2) for exports except that the dependent variable is the log change of import or export quantities (in kilograms). Also, the foreign inflation rates are omitted (but the results remain similar if we control for foreign inflation rates).

Table F1: The Effect of Exchange Rate Changes on Import and Export Quantities

	(1)	(2)	(3)	(4)
Imports				
$\Delta \ln e_{ij,t}$	0.039 (0.085)	–	–	–
$\Delta \ln e_{ij,t} \times D_{PCP}$	–	−0.085 (0.095)	−0.070 (0.107)	−0.054 (0.103)
$\Delta \ln e_{ij,t} \times D_{LCP}$	–	0.203 (0.141)	0.219 (0.134)	0.232* (0.129)
$\Delta \ln e_{ij,t} \times D_{VCP}$	–	−0.058 (0.079)	–	–
$\Delta \ln e_{iV,t} \times D_{VCP}$	–	–	−0.062 (0.156)	−0.036 (0.151)
$\Delta \ln e_{Vj,t} \times D_{VCP}$	–	–	−0.073 (0.079)	–
Observations	5,212,648	5,212,516	5,212,516	5,212,516
R-squared	0.156	0.156	0.156	0.156
Exports				
$\Delta \ln e_{ij,t}$	−0.004 (0.115)	–	–	–
$\Delta \ln e_{ij,t} \times D_{PCP}$	–	0.020 (0.020)	−0.027 (0.147)	−0.040 (0.144)
$\Delta \ln e_{ij,t} \times D_{LCP}$	–	−0.245 (0.164)	−0.413** (0.176)	−0.423** (0.171)
$\Delta \ln e_{ij,t} \times D_{VCP}$	–	−0.005 (0.092)	–	–
$\Delta \ln e_{iV,t} \times D_{VCP}$	–	–	−0.629*** (0.184)	−0.689*** (0.188)
$\Delta \ln e_{Vj,t} \times D_{VCP}$	–	–	0.098 (0.102)	–
Observations	2,432,696	2,432,602	2,432,602	2,432,602
R-squared	0.139	0.139	0.139	0.139
Firm-quarter fixed effects	Yes	Yes	Yes	Yes
Country-product fixed effects	Yes	Yes	Yes	Yes
Invoicing choice fixed effects	No	Yes	Yes	Yes

Notes: Eight lags of the log change in each exchange rate are also included (not reported). The contemporaneous and one lag of the destination country's GDP growth rate are included for exports (not reported). Robust standard errors adjusted for clustering at the country-year level are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The dependent variable is the quarterly log change of import or export quantities (in kilograms). Source: HMRC administrative data sets.

Table F1 reports contemporaneous exchange rate estimates. For imports, all exchange rate elasticities are insignificant (except for local currency transactions in column 4). For exports, the elasticities are either insignificant or negative (in columns 3 and 4 for local currency transactions and for vehicle currency transactions when the sterling to vehicle currency exchange rate changes). Our results remain similar if we measure export and import quantities in units as opposed to kilograms.

G Import Price Inflation

We explain how we calculate in Section 4 the effects of exchange rate shocks on import price inflation. We also provide additional results for the depreciation of sterling following the EU referendum.

G.1 Currency of Invoicing Shares of UK World Imports

In our data set, we only observe the currency of invoicing shares of UK non-EU imports. To derive the shares of world imports, we rely on aggregate data from Gopinath (2016). These data show that in 2015, total UK imports were priced in euros (14.78%), US dollars (47.16%), sterling (31.73%), and other currencies (6.33%). We assume that these shares do not change much over time and therefore remain valid for the 2010 to 2017 period we focus on in our analysis.[9] While the total LCP (sterling) share is 31.73%, the magnitude of the PCP and VCP shares is unknown as the data are unavailable by country of origin. Assuming that the US dollar and the euro are the main foreign currencies used to price UK imports, we therefore derive the PCP and VCP shares of world imports by combining the data from Gopinath (2016) with data from HMRC (for UK non-EU imports including the SITC 9 "Not classified" industry that we exclude from our regressions) and from the Direction of Trade Statistics of the International Monetary Fund (for UK world imports).[10] Those shares are different from HMRC's published currency of invoicing figures because they use a subsample with first differences in unit values.

To obtain the VCP share of UK world imports, we proceed as follows. First, to get the VCP share in US dollars, we subtract the import share from the US in US dollars from the total import share in US dollars (47.16%).[11] In our sample, imports from the US in US dollars represent 14.94% of total non-EU imports. As non-EU imports amount to 50.05% of total UK imports between 2010 and 2017 (IMF DOTS), the share of US imports in US dollars in total UK imports is 7.48% ($0.1494 \times 0.5005 = 0.0748$). The VCP share in US dollars is thus 39.68% ($47.16 - 7.48 = 39.68$). Second, we observe that 5.33% of non-EU imports are in euros. The VCP share in euros is thus 2.67% ($0.0533 \times 0.5005 = 0.0267$).[12] The total VCP share of UK world imports (in euros and US dollars) is 42.35% ($39.68 + 2.67 = 42.35$).

Table G1: Currency of Invoicing Shares of UK World Imports

Scenario 1		Scenario 2	
Currency choice	Share	Currency choice	Share
PCP	25.92%	PCP	19.60%
LCP	31.73%	LCP	31.73%
VCP	42.35%	VCP	48.67%

Source: HMRC administrative data sets.

Next, we measure the PCP share of UK world imports as the import share from the US in US

[9] Gopinath (2016) observes that aggregate invoicing shares tend to remain fairly stable over time.
[10] Our results remain very similar if we exclude the "Not classified" industry.
[11] We ignore here that some small countries use the US dollar as their main currency.
[12] We assume that all EU countries use the euro because our data set does not allow us to identify the currency of invoicing for the EU countries that have not adopted the euro.

dollars (7.48%), plus the import share from the EU in euros (i.e., 14.78% less 2.67%, or approximately 12.12%), which amounts to 19.60%. We then allocate the 6.33% of UK world imports invoiced in other currencies to either the VCP or PCP share, and we therefore consider two alternative scenarios for the magnitude of the invoicing shares, as reported in Table G1. See Section G.6.1 for more details.

G.2 Exchange Rate Changes

To measure the average appreciation or depreciation of sterling in each of the three quarterly episodes, we proceed in two steps. First, we calculate the log change of all sterling bilateral and sterling to vehicle currency exchange rates in the quarter of the exchange rate shock relative to the previous quarter. Second, we calculate weighted averages of these exchange rate changes using weights computed for UK world imports: (1) the average of bilateral exchange rate changes weighted by bilateral import shares, (2) the average of bilateral exchange rate changes weighted by LCP or PCP bilateral imports as a share of total LCP or PCP imports, and (3) the average of sterling to vehicle currency exchange rate changes weighted by imports in each vehicle currency as a share of total VCP imports.

To calculate the import weights by invoicing currency for UK world imports, we multiply the non-EU invoicing shares of each country by 0.5005 (the UK's import share from non-EU countries over the period from 2010 to 2017) to get the shares out of total UK imports. We then divide by the invoicing shares (two different scenarios) reported in Table G1 to get the shares as a proportion of total LCP or PCP imports. For the EU as a whole, the LCP and PCP shares are obtained by subtracting the sum of the shares for the other countries from 100%. For the import shares in vehicle currencies, we follow the same procedure and further assume that all VCP imports from the EU are in US dollars. According to Gopinath (2016), apart from invoicing in euros EU countries mostly invoice in US dollars.

G.3 Pass-Through into Import Price Inflation

For simplicity, we only explain how we calculate the estimates reported in columns (1) and (2) of Table 10 for the depreciation of sterling following the EU referendum of 2016. Based on column (1) of Table 5, where the contemporaneous bilateral exchange rate elasticity is equal to 0.179, we calculate that the 7.09% average bilateral depreciation of sterling (weighted by bilateral import shares) increases import price inflation by 1.271 percentage points on impact. This is calculated as $(0.0709 \times 0.179) = 1.271$ percentage points, where 0.0709 is the average bilateral depreciation and 0.179 is the pass-through elasticity. After eight quarters, the pass-through elasticity increases to 0.413 such that import price inflation rises by 2.927 percentage points.

Once we account for the currency of invoicing, our estimates reported in column (4) of Table 5 imply that the depreciation of sterling increases import price inflation by 2.788 percentage points on impact, and by 3.157 percentage points after eight quarters. The contemporaneous effect is calculated as $(0.0752 \times 0.002 \times 0.3173) + (0.0727 \times 0.620 \times 0.2592) + (0.0643 \times 0.592 \times 0.4235) = 2.788$ percentage points. The values 0.0752 and 0.0727 are the average bilateral depreciations of sterling for the LCP

Table G2: The Effects of Exchange Rate Shocks on UK Import Price Inflation

		(1)	(2)	(3)	(4)
		World imports		**Non-EU imports**	
Exchange rates	Currencies	$t = 0$	$t = 8$	$t = 0$	$t = 8$
EU Referendum (2016M6–2016M8)					
Bilateral	All	1.271*** (0.199)	2.927*** (0.447)	0.588*** (0.092)	1.354*** (0.207)
	USD	0.105*** (0.016)	0.243*** (0.037)	0.103*** (0.016)	0.237*** (0.036)
	Euro	0.668*** (0.104)	1.537*** (0.235)	–	–
Bilateral/vehicle	All	2.725*** (0.285)	3.055*** (0.617)	1.486*** (0.147)	1.620*** (0.317)
	USD	2.013*** (0.186)	2.050*** (0.397)	1.227*** (0.109)	1.267*** (0.233)
	Euro	0.574*** (0.084)	0.772*** (0.176)	0.120*** (0.012)	0.119*** (0.025)
Great Recession (2008M11–2009M1)					
Bilateral	All	2.321*** (0.363)	5.343*** (0.815)	1.213*** (0.190)	2.792*** (0.426)
	USD	0.323*** (0.050)	0.744*** (0.113)	0.315*** (0.049)	0.725*** (0.111)
	Euro	1.076*** (0.168)	2.477*** (0.378)	–	–
Bilateral/vehicle	All	7.345*** (0.729)	7.952*** (1.576)	4.208*** (0.400)	4.505*** (0.863)
	USD	6.166*** (0.569)	6.278*** (1.217)	3.757*** (0.334)	3.880*** (0.714)
	Euro	0.925*** (0.136)	1.244*** (0.283)	0.193*** (0.019)	0.192*** (0.040)
EU Debt Crisis (2015M1–2015M3)					
Bilateral	All	−0.477*** (0.075)	−1.098*** (0.167)	0.065*** (0.010)	0.150*** (0.023)
	USD	0.079*** (0.012)	0.182*** (0.028)	0.077*** (0.012)	0.177*** (0.027)
	Euro	−0.544*** (0.085)	−1.252*** (0.191)	–	–
Bilateral/vehicle	All	1.044*** (0.098)	0.921*** (0.197)	0.824*** (0.075)	0.866*** (0.161)
	USD	1.509*** (0.139)	1.537*** (0.298)	0.920*** (0.082)	0.950*** (0.175)
	Euro	−0.467*** (0.069)	−0.629*** (0.143)	−0.098*** (0.010)	−0.097*** (0.020)

Notes: The estimates show changes in UK import price inflation, reported in percentage points. The estimates in columns (1) and (2) for world imports are based on scenario 2 for the invoicing shares (Table G1). The estimates reported in the rows "Bilateral" are obtained based on the regression in column (1) of Table 5. The estimates reported in the rows "Bilateral/vehicle" are obtained using the regression in column (4) of Table 5. *** indicates significance at the 1% level. Source: HMRC administrative data sets.

and PCP transactions (weighted by LCP or PCP bilateral imports as a share of total LCP or PCP imports), while 0.0643 is the average depreciation of sterling against vehicle currencies for the VCP flows (weighted by the share of each vehicle currency in total VCP imports). The values 0.002, 0.620, and 0.592 are the short-run pass-through elasticities for the LCP, PCP, and VCP transactions. The values 0.3173, 0.2592, and 0.4235 are the LCP, PCP, and VCP invoicing shares of world imports (scenario 1). To derive the individual effects of the US dollar and the euro, we weight the exchange rate changes against these two currencies by their respective shares.

Table 10 in the main text reports our estimates based on scenario 1 for the invoicing shares, while columns (1) and (2) of Table G2 rely on scenario 2. Overall, the two scenarios yield very similar results (the estimates for the effects of bilateral exchange rate changes are identical for the two scenarios).

Columns (3) and (4) of Table G2 report our estimates for non-EU imports. These estimates are calculated in the same way as for world imports with two differences. First, we use the currency of invoicing shares that we observe in our sample for non-EU imports, and we compute the corresponding weighted averages of exchange rate changes with non-EU trading partners only. Second, all estimates are further multiplied by 0.5005 (which is the UK import share from non-EU countries between 2010 and 2017). The response of import price inflation to changes in exchange rates is therefore smaller in magnitude for non-EU than for world imports.

Overall, the results for non-EU imports are qualitatively similar to the ones for world imports but with a few differences. First, with bilateral exchange rates only, the euro plays no role. Second, once we consider invoicing currencies, the contribution of the euro is modest as it is only used as a vehicle currency in non-EU imports. Finally, for the European Sovereign Debt Crisis, bilateral exchange rate movements *increase* import price inflation as the effect of the appreciation against the euro is not accounted for. Once we consider invoicing currencies, fluctuations in exchange rates also increase import price inflation as the fall in inflation induced by the appreciation against the euro (only used as a vehicle currency in non-EU imports) is offset by the depreciation against the US dollar.

G.4 EU Referendum

In Table G3 we recalculate our back-of-the-envelope estimates for the depreciation of sterling following the EU referendum of June 2016 using the pass-through elasticities we estimate for the post-referendum period (reported in columns 1 and 4 of Table D3 in Online Appendix D) and the corresponding currency of invoicing shares for 2016Q3–2017Q4 (see Section G.6.2 for more details on those shares).

Table G3: UK Import Price Inflation after the EU Referendum

		(1)	(2)	(3)	(4)	(5)	(6)
Invoicing shares		**Scenario 1**		**Scenario 2**		**Non-EU imports**	
Exchange rates	Currencies	$t = 0$	$t = 8$	$t = 0$	$t = 8$	$t = 0$	$t = 8$
Bilateral	All	0.945*** (0.242)	2.333*** (0.699)	0.945*** (0.242)	2.333*** (0.699)	0.432*** (0.111)	1.066*** (0.319)
	USD	0.087*** (0.022)	0.215*** (0.064)	0.087*** (0.022)	0.215*** (0.064)	0.084*** (0.021)	0.206*** (0.062)
	Euro	0.496*** (0.127)	1.225*** (0.367)	0.496*** (0.127)	1.225*** (0.367)	–	–
Bilateral/vehicle	All	2.677*** (0.533)	3.104*** (0.849)	2.585*** (0.523)	2.915*** (0.835)	1.370*** (0.268)	1.498*** (0.437)
	USD	1.493*** (0.297)	1.494*** (0.498)	1.698*** (0.340)	1.688*** (0.570)	1.055*** (0.202)	1.092*** (0.341)
	Euro	0.969*** (0.226)	1.298*** (0.339)	0.667*** (0.171)	0.908*** (0.256)	0.096*** (0.021)	0.089** (0.035)

Notes: The estimates show changes in UK import price inflation, reported in percentage points. The estimates reported in the rows "Bilateral" are obtained based on the regression in column (1) of Table D3 in Online Appendix D. The estimates reported in the rows "Bilateral/vehicle" are obtained using the regression in column (4) of Table D3. *** and ** indicate significance at the 1% and 5% levels, respectively. Source: HMRC administrative data sets.

As the pass-through elasticities are slightly smaller in the post-referendum period than in the full sample, the magnitude of our back-of-the-envelope estimates is smaller (compared to the estimates reported in Tables 10 and G2). But the overall patterns remain very similar.

G.5 EU Referendum – Out-of-Sample Predictions

Another way of demonstrating that accounting for invoicing currencies results in more accurate forecasts of exchange rate pass-through is to perform an out-of-sample prediction of UK import unit values. We calculate our back-of-the-envelope estimates for the depreciation of sterling following the EU referendum based on *pre-referendum* pass-through elasticities (see columns 1 and 4 of Table D3 in Online Appendix D) and currency of invoicing shares (see Section G.6.3 for more details on those shares).

As the pre-referendum pass-through elasticities are larger than in the full sample and the post-referendum period, Table G4 shows that the magnitude of our back-of-the-envelope estimates is larger than in Tables 10, G2, and G3. But overall, the patterns are similar.

Table G4: UK Import Price Inflation after the EU Referendum: Out-of-Sample Predictions

		(1)	(2)	(3)	(4)	(5)	(6)
Invoicing shares		**Scenario 1**		**Scenario 2**		**Non-EU imports**	
Exchange rates	Currencies	$t = 0$	$t = 8$	$t = 0$	$t = 8$	$t = 0$	$t = 8$
Bilateral	All	1.367*** (0.249)	2.979*** (0.477)	1.367*** (0.249)	2.979*** (0.477)	0.625*** (0.114)	1.361*** (0.218)
	USD	0.126*** (0.023)	0.274*** (0.044)	0.126*** (0.023)	0.274*** (0.044)	0.121*** (0.022)	0.264*** (0.042)
	Euro	0.718*** (0.131)	1.564*** (0.250)	0.718*** (0.131)	1.564*** (0.250)	–	–
Bilateral/vehicle	All	2.933*** (0.350)	3.215*** (0.781)	2.860*** (0.360)	3.121*** (0.825)	1.518*** (0.185)	1.614*** (0.431)
	USD	1.885*** (0.223)	1.882*** (0.538)	2.142*** (0.257)	2.135*** (0.621)	1.252*** (0.142)	1.259*** (0.339)
	Euro	0.894*** (0.125)	1.098*** (0.241)	0.560*** (0.101)	0.746*** (0.196)	0.123*** (0.016)	0.121*** (0.040)

Notes: The estimates show changes in UK import price inflation, reported in percentage points. The estimates reported in the rows "Bilateral" are obtained based on the regression in column (1) of Table D3 in Online Appendix D. The estimates reported in the rows "Bilateral/vehicle" are obtained using the regression in column (4) of Table D3. *** indicates significance at the 1% level. Source: HMRC administrative data sets.

Column (1) shows that on impact, import price inflation increases by 1.367 percentage points when we only consider bilateral exchange rates, and by 2.933 percentage points once we account for invoicing currencies. How do these estimates compare with actual data on import price inflation? The quarterly import price index of the UK economy is equal to 94.19, 95.23, and 98.92 in December 2015–February 2016, March–May 2016, and June–August 2016, respectively (International Financial Statistics of the International Monetary Fund). Import price inflation (relative to the previous quarter) therefore rose from 1.108% in March–May 2016 to 3.767% in June–August 2016, which is a 2.659 percentage point increase.[13] This increase in import price inflation is comparable in magnitude to our prediction of a 2.933 percentage point increase when we account for invoicing currencies. Our prediction based on

[13] Those values differ from those in Figure 2 which plots the percentage change in the import price index over 12 months.

bilateral exchange rates is instead less accurate as it only predicts an increase of 1.367 percentage points.[14] Accounting for vehicle currencies therefore results in a more accurate prediction of the effects of exchange rate changes on import price inflation.[15]

G.6 Currency of Invoicing Shares: Calculations

In this section we explain in more detail how we calculate the currency of invoicing shares of UK world imports that we use in Table 10 in the main text and in Tables G2, G3, and G4.

G.6.1 Tables 10 and G2: Main Results

For Tables 10 and G2, we combine the data from Gopinath (2016) with data from HMRC and from the IMF DOTS for the full sample period 2010–2017.

LCP Share The LCP share of UK world imports (in sterling) is directly taken from Gopinath (2016):

$$LCP = 31.73\%$$

VCP Share We define the VCP share of UK world imports as the VCP share in USD plus the VCP share in euros.

VCP Share in USD For the period 2010–2017:

$$m_{usd}^{us}/m_{PCP}^{noneu} = 72.63\% \tag{G1}$$

$$m_{usd}^{us}/(0.2057 \times m^{noneu}) = 72.63\% \tag{G2}$$

$$m_{usd}^{us}/(0.2057 \times 0.5005 \times m) = 72.63\% \tag{G3}$$

In (G1), the share of imports from the US in USD m_{usd}^{us} (PCP) in total non-EU PCP imports m_{PCP}^{noneu} is equal to 72.63%. In (G2), the share of total non-EU PCP imports in total non-EU imports m^{noneu} is equal to 20.57% (HMRC). In (G3), the share of non-EU imports in world imports m is equal to 50.05% (IMF DOTS). Rearranging:

$$\begin{aligned} m_{usd}^{us}/m &= 72.63 \times 0.2057 \times 0.5005 \\ &= 7.48\% \\ &= PCP_{usd} \end{aligned}$$

[14] While our predictions are obtained by aggregating pass-through estimates using constant currency of invoicing shares, the change in import price inflation is calculated using the Laspeyres import price index of the International Monetary Fund (with weights based on nominal trade shares). As a result, the two measures are not exactly comparable.

[15] As our back-of-the-envelope estimates do not account for shocks between June–August 2016 and June–August 2018, which are likely to have impacted import price inflation over the period (for instance exchange rates have remained very volatile while the Bank of England reduced its official rate in August 2016 and then raised it in October 2017), we only compare our contemporaneous back-of-the-envelope estimates with actual data on import price inflation.

which is the PCP share of UK world imports in USD.

It follows that the VCP share of UK world imports in USD is:

$$\begin{aligned} VCP_{usd} &= 47.16\% - 7.48\% \\ &= 39.68\% \end{aligned}$$

where 47.16% is the share of UK world imports in USD (Gopinath, 2016).

VCP Share in Euros For the period 2010–2017:

$$m_{euros}^{noneu}/m_{VCP}^{noneu} = 9.66\% \tag{G4}$$

$$m_{euros}^{noneu}/(0.5516 \times m^{noneu}) = 9.66\% \tag{G5}$$

$$m_{euros}^{noneu}/(0.5516 \times 0.5005 \times m) = 9.66\% \tag{G6}$$

In (G4), the share of non-EU imports in euros m_{euros}^{noneu} (VCP) in total non-EU VCP imports m_{VCP}^{noneu} is equal to 9.66%. In (G5), the share of total non-EU VCP imports in total non-EU imports m^{noneu} is equal to 55.16% (HMRC). In (G6), the share of non-EU imports in world imports m is equal to 50.05% (IMF DOTS). Rearranging:

$$\begin{aligned} m_{euros}^{noneu}/m &= 9.66 \times 0.5516 \times 0.5005 \\ &= 2.67\% \\ &= VCP_{euros} \end{aligned}$$

which is the VCP share of UK world imports in euros.

Total VCP Share The VCP share of UK world imports is therefore:

$$\begin{aligned} VCP &= VCP_{usd} + VCP_{euros} \\ &= 39.68\% + 2.67\% \\ &= 42.35\% \end{aligned}$$

PCP Share We define the PCP share of UK world imports as the PCP share in USD plus the PCP share in euros.

PCP Share in USD From above, the PCP share of UK world imports in USD is:

$$PCP_{usd} = 7.48\%$$

PCP Share in Euros From Gopinath (2016), we know that the share of UK world imports in euros is equal to 14.78%. From above, the VCP share of UK world imports in euros is $VCP_{euros} = 2.67\%$. Therefore:

$$\begin{aligned} PCP_{euros} &= 14.78\% - 2.67\% \\ &\simeq 12.12\% \end{aligned}$$

Total PCP Share The PCP share of UK world imports is therefore:

$$\begin{aligned} PCP &= PCP_{usd} + PCP_{euros} \\ &= 7.48\% + 12.12\% \\ &= 19.60\% \end{aligned}$$

Other Invoicing Currencies According to Gopinath (2016), 6.33% of UK world imports are invoiced in other currencies than sterling, the USD, and the euro. As those imports can be VCP or PCP, we add their import share to either the VCP or PCP shares of UK world imports calculated above. This results in two possible scenarios for the currency of invoicing shares of UK world imports, as reported in Table G1 (in Section G.1). The shares of scenario 1 are used in Table 10 in the main text. The shares of scenario 2 are used in columns (1) and (2) of Table G2.

G.6.2 Table G3: EU Referendum

To calculate the currency of invoicing shares of UK world imports that we use in Table G3, we follow the same procedure as in Section G.6.1 but we combine the data from Gopinath (2016) with data from HMRC and from the IMF DOTS for the post-referendum period only (2016Q3–2017Q4).

LCP Share The LCP share of UK world imports (in sterling) is taken from Gopinath (2016):

$$LCP = 31.73\%$$

VCP Share

VCP Share in USD For the period 2016Q3–2017Q4:

$$\begin{aligned} m^{us}_{usd}/m^{noneu}_{PCP} &= 70.66\% \\ m^{us}_{usd}/(0.2293 \times m^{noneu}) &= 70.66\% \\ m^{us}_{usd}/(0.2293 \times 0.4913 \times m) &= 70.66\% \end{aligned}$$

The share of imports from the US in USD (PCP) in total non-EU PCP imports is equal to 70.66% and the share of total non-EU PCP imports in total non-EU imports is equal to 22.93% (HMRC). The share of non-EU imports in world imports is 49.13% (IMF DOTS).

The PCP share of UK world imports in USD is therefore:

$$\begin{aligned} m^{us}_{usd}/m &= 70.66 \times 0.2293 \times 0.4913 \\ &= 7.96\% \\ &= PCP_{usd} \end{aligned}$$

It follows that the VCP share of UK world imports in USD is:

$$\begin{aligned} VCP_{usd} &= 47.16\% - 7.96\% \\ &= 39.20\% \end{aligned}$$

where 47.16% is the share of UK world imports in USD (Gopinath, 2016).

VCP Share in Euros For the period 2016Q3–2017Q4:

$$\begin{aligned} m^{noneu}_{euros}/m^{noneu}_{VCP} &= 9.01\% \\ m^{noneu}_{euros}/(0.5522 \times m^{noneu}) &= 9.01\% \\ m^{noneu}_{euros}/(0.5522 \times 0.4913 \times m) &= 9.01\% \end{aligned}$$

The share of non-EU imports in euros (VCP) in total non-EU VCP imports is equal to 9.01% and the share of total non-EU VCP imports in total non-EU imports is equal to 55.22% (HMRC). The share of non-EU imports in world imports is 49.13% (IMF DOTS).

The VCP share of UK world imports in euros is therefore:

$$\begin{aligned} m^{noneu}_{euros}/m &= 9.01 \times 0.5522 \times 0.4913 \\ &= 2.44\% \\ &= VCP_{euros} \end{aligned}$$

Total VCP Share The VCP share of UK world imports is:

$$\begin{aligned} VCP &= VCP_{usd} + VCP_{euros} \\ &= 39.20\% + 2.44\% \\ &= 41.64\% \end{aligned}$$

PCP Share

PCP Share in USD From above, the PCP share of UK world imports in USD is:

$$PCP_{usd} = 7.96\%$$

PCP Share in Euros The PCP share of UK world imports in euros is:

$$\begin{aligned} PCP_{euros} &= 14.78\% - 2.44\% \\ &= 12.34\% \end{aligned}$$

where 14.78% is the share of UK world imports in euros (Gopinath, 2016) and 2.44% is the VCP share of UK world imports in euros VCP_{euros}.

Total PCP Share The PCP share of UK world imports is:

$$\begin{aligned} PCP &= PCP_{usd} + PCP_{euros} \\ &= 7.96\% + 12.34\% \\ &= 20.30\% \end{aligned}$$

Other Invoicing Currencies As shown in Table G5 we again consider two possible scenarios for the currency of invoicing shares of UK world imports. Those shares are used in columns (1) to (4) of Table G3.

Table G5: Currency of Invoicing Shares of UK World Imports: EU Referendum

Scenario 1		Scenario 2	
Currency choice	Share	Currency choice	Share
PCP	26.63%	PCP	20.30%
LCP	31.73%	LCP	31.73%
VCP	41.64%	VCP	47.97%

Source: HMRC administrative data sets.

G.6.3 Table G4: EU Referendum – Out-of-Sample Predictions

To calculate the currency of invoicing shares of UK world imports that we use in Table G4, we follow the same procedure as in Sections G.6.1 and G.6.2 but we combine the data from Gopinath (2016) with data from HMRC and from the IMF DOTS for the pre-referendum period only (2010Q1–2016Q2).

LCP Share The LCP share of UK world imports (in sterling) is taken from Gopinath (2016):

$$LCP = 31.73\%$$

VCP Share

VCP Share in USD For the period 2010Q1–2016Q2:

$$\begin{aligned} m_{usd}^{us}/m_{PCP}^{noneu} &= 73.35\% \\ m_{usd}^{us}/(0.1982 \times m^{noneu}) &= 73.35\% \\ m_{usd}^{us}/(0.1982 \times 0.5027 \times m) &= 73.35\% \end{aligned}$$

The share of imports from the US in USD (PCP) in total non-EU PCP imports is equal to 73.35% and the share of total non-EU PCP imports in total non-EU imports is equal to 19.82% (HMRC). The share of non-EU imports in world imports is 50.27% (IMF DOTS).

The PCP share of UK world imports in USD is therefore:

$$\begin{aligned} m_{usd}^{us}/m &= 73.35 \times 0.1982 \times 0.5027 \\ &= 7.31\% \\ &= PCP_{usd} \end{aligned}$$

It follows that the VCP share of UK world imports in USD is:

$$\begin{aligned} VCP_{usd} &= 47.16\% - 7.31\% \\ &= 39.85\% \end{aligned}$$

where 47.16% is the share of UK world imports in USD (Gopinath, 2016).

VCP Share in Euros For the period 2010Q1–2016Q2:

$$\begin{aligned} m_{euros}^{noneu}/m_{VCP}^{noneu} &= 9.87\% \\ m_{euros}^{noneu}/(0.5514 \times m^{noneu}) &= 9.87\% \\ m_{euros}^{noneu}/(0.5514 \times 0.5027 \times m) &= 9.87\% \end{aligned}$$

The share of non-EU imports in euros (VCP) in total non-EU VCP imports is equal to 9.87% and the share of total non-EU VCP imports in total non-EU imports is equal to 55.14% (HMRC). The share of non-EU imports in world imports is 50.27% (IMF DOTS).

The VCP share of UK world imports in euros is therefore:

$$\begin{aligned} m_{euros}^{noneu}/m &= 9.87 \times 0.5514 \times 0.5027 \\ &= 2.73\% \\ &= VCP_{euros} \end{aligned}$$

Total VCP Share The VCP share of UK world imports is:

$$\begin{aligned} VCP &= VCP_{usd} + VCP_{euros} \\ &= 39.85\% + 2.73\% \\ &= 42.58\% \end{aligned}$$

PCP Share

PCP Share in USD From above, the PCP share of UK world imports in USD is:

$$PCP_{usd} = 7.31\%$$

PCP Share in Euros The PCP share of UK world imports in euros is:

$$\begin{aligned} PCP_{euros} &= 14.78\% - 2.73\% \\ &= 12.05\% \end{aligned}$$

where 14.78% is the share of UK world imports in euros (Gopinath, 2016) and 2.73% is the VCP share of UK world imports in euros VCP_{euros}.

Total PCP Share The PCP share of UK world imports is:

$$\begin{aligned} PCP &= PCP_{usd} + PCP_{euros} \\ &= 7.31\% + 12.05\% \\ &= 19.36\% \end{aligned}$$

Other Invoicing Currencies The two possible scenarios for the currency of invoicing shares of UK world imports are reported in Table G6. Those shares are used in columns (1) to (4) of Table G4.

Table G6: Currency of Invoicing Shares of UK World Imports: EU Referendum (Out-of-Sample)

Scenario 1		**Scenario 2**	
Currency choice	Share	Currency choice	Share
PCP	25.69%	PCP	19.36%
LCP	31.73%	LCP	31.73%
VCP	42.58%	VCP	48.91%

Source: HMRC administrative data sets.

H A Conceptual Framework for Vehicle Currency Pass-Through

This appendix provides further details on the framework outlined in Section 5. We examine from a conceptual viewpoint how vehicle currency prices may depend on exchange rate movements. For this purpose, we build on the approach by Engel (2006) and extend it to vehicle currency pricing. We are interested in analyzing the pass-through behavior of firms that price in a vehicle currency. Figure 5 illustrates the setting. There are three currencies in the world: the currency of the foreign country j, the currency of the domestic country i (which is sterling), and a third-country vehicle currency (V). We follow Engel (2006) in assuming firms can commit to setting their prices as a log-linear function of the exchange rate. That is, firms index their price to the exchange rate. Exchange rate movements are exogenous from their perspective.

As outlined in Section 5, there are two types of exporting firms depending on which exchange rate they react to. We begin by discussing the type reacting to the vehicle currency exchange rate e_{iV}. These are symmetric monopolistic firms which set the vehicle currency price p_V^{iV}. Their log-linear index function is given as:

$$\ln p_V^{iV} = \ln p_{0,V}^{iV} + \mu_{iV} \ln e_{iV}, \tag{H1}$$

where $p_{0,V}^{iV}$ is denominated in the vehicle currency and μ_{iV} is the pass-through elasticity of the vehicle currency exchange rate into the vehicle price. Both $p_{0,V}^{iV}$ and μ_{iV} are chosen optimally by firms. Note that in Engel (2006) the price is set in "foreign currency," which refers to the destination country's currency. There is no vehicle currency in his paper.

Since consumers in the domestic country face prices in sterling, we have to convert p_V^{iV} into the sterling price p_i^{iV}, i.e., $\ln p_i^{iV} = \ln p_V^{iV} + \ln e_{iV}$. Substituting (H1) we obtain:

$$\ln p_i^{iV} = \ln p_{0,V}^{iV} + (1 + \mu_{iV}) \ln e_{iV},$$

where $1 + \mu_{iV}$ is the pass-through elasticity of the vehicle currency exchange rate into the domestic price. Intuitively, suppose firms choose the particular parameter value $\mu_{iV} = 0$. In that case, the vehicle currency price p_V^{iV} would not be adjusted in response to a change in the vehicle currency exchange rate, and the exchange rate movement would therefore fully pass through into the domestic price p_i^{iV}. In contrast, for $\mu_{iV} = -1$ the vehicle currency price would be reduced one-for-one in response to a sterling depreciation against the vehicle currency, and the domestic price would remain constant. This would mean zero pass-through. For intermediate values of μ_{iV} with $-1 < \mu_{iV} < 0$, firms would prefer incomplete pass-through. Our empirical evidence in Section 5 is consistent with $\mu_{iV} < 0$.

We now show how the firms' optimal choice of μ_{iV} depends on expected profits, their cost structure, and the properties of the exchange rate. Similar to Engel (2006), firms maximize the twice-differentiable concave profit function $\pi\left(\ln p_V^{iV}, \ln \mathbf{x}\right)$, where $\mathbf{x}$ is a cost vector of variables that affect firms' profits but are exogenous. This cost vector $\mathbf{x}$ may include the exchange rate e_{iV}. Firms have to choose the price for their products without knowledge of the realization of the cost vector $\mathbf{x}$. However, as described above, they can commit to setting their prices as a log-linear function of the exchange rate.

Firms are assumed to maximize a second-order approximation of the profit function. We then solve for the optimal pass-through elasticity $\widehat{\mu}_{iV}$ that firms choose to achieve their optimal forecast $\ln \widetilde{p}_V^{iV}$. The result is given by:

$$\widehat{\mu}_{iV} = \frac{-\pi_{px}\left(\ln \widetilde{p}_V^{iV}, \ln \bar{\mathbf{x}}\right)'}{\pi_{pp}\left(\ln \widetilde{p}_V^{iV}, \ln \bar{\mathbf{x}}\right)} \frac{\operatorname{cov}\left(\ln e_{iV}, \ln \mathbf{x}\right)}{\operatorname{var}\left(\ln e_{iV}\right)}, \tag{H2}$$

where $\ln \widetilde{p}_V^{iV}$ is the price that satisfies $\pi_p\left(\ln \widetilde{p}_V^{iV}, \ln \bar{\mathbf{x}}\right) = 0$, and $\ln \bar{\mathbf{x}}$ denotes the mean of $\ln \mathbf{x}$ around which we linearize the profit function.

The proof of the result in (H2) is as follows. We start with the first-order condition $\pi_p\left(\ln p_V^{iV}, \ln \mathbf{x}\right) = 0$. Using this condition and following Engel (2006) we derive a second-order approximation of the firms' expected profits given the uncertainty of $\mathbf{x}$, defined as the firms' objective function Π:

$$\begin{aligned} \Pi \equiv\ & \mathrm{E}\, D\pi\left(\ln p_V^{iV}, \ln \mathbf{x}\right) \approx \bar{D}\pi\left(\ln \widetilde{p}_V^{iV}, \ln \bar{\mathbf{x}}\right) + \pi\left(\ln \widetilde{p}_V^{iV}, \ln \bar{\mathbf{x}}\right) \mathrm{E}\left(D - \bar{D}\right) \\ & + \bar{D}\pi_p\left(\ln \widetilde{p}_V^{iV}, \ln \bar{\mathbf{x}}\right) \mathrm{E}\left(\ln p_V^{iV} - \ln \widetilde{p}_V^{iV}\right) + \bar{D}\pi_x\left(\ln \widetilde{p}_V^{iV}, \ln \bar{\mathbf{x}}\right)' \mathrm{E}\left(\ln \mathbf{x} - \ln \bar{\mathbf{x}}\right) \\ & + 0.5 \left\{ \begin{array}{c} \bar{D}\pi_{pp}\left(\ln \widetilde{p}_V^{iV}, \ln \bar{\mathbf{x}}\right) \mathrm{E}\left(\ln p_V^{iV} - \ln \widetilde{p}_V^{iV}\right)^2 \\ + \bar{D}\, \mathrm{E}\left(\ln \mathbf{x} - \ln \bar{\mathbf{x}}\right)' \pi_{xx}\left(\ln \widetilde{p}_V^{iV}, \ln \bar{\mathbf{x}}\right)\left(\ln \mathbf{x} - \ln \bar{\mathbf{x}}\right) \\ + 2\bar{D}\, \mathrm{E}\left(\ln p_V^{iV} - \ln \widetilde{p}_V^{iV}\right) \pi_{px}\left(\ln \widetilde{p}_V^{iV}, \ln \bar{\mathbf{x}}\right)'\left(\ln \mathbf{x} - \ln \bar{\mathbf{x}}\right) \end{array} \right\}, \end{aligned}$$

where D is an exogenous discount factor. The expansion is around $\bar{D}$ (the mean of D), $\widetilde{p}_V^{iV}$ and $\ln \bar{\mathbf{x}}$ (the mean of $\ln \mathbf{x}$), and $\pi_{px}\left(\ln \widetilde{p}_V^{iV}, \ln \bar{\mathbf{x}}\right)$ is a vector whose i^{th} element is $\partial^2 \pi\left(\ln p_V^{iV}, \ln \mathbf{x}\right) / \partial \ln p_V^{iV} \partial \ln x_i$.

Then, using $\mathrm{E}\left(D - \bar{D}\right) = 0$, $\mathrm{E}\left(\ln \mathbf{x} - \ln \bar{\mathbf{x}}\right) = 0$, and $\pi_p\left(\ln \widetilde{p}_V^{iV}, \ln \bar{\mathbf{x}}\right) = 0$ the objective function can be simplified as:

$$\Pi \propto \left\{ \begin{array}{l} \pi_{pp}\left(\ln \widetilde{p}_V^{iV}, \ln \bar{\mathbf{x}}\right) \mathrm{E}\left(\ln p_V^{iV} - \ln \widetilde{p}_V^{iV}\right)^2 \\ + \mathrm{E}\left(\ln \mathbf{x} - \ln \bar{\mathbf{x}}\right)' \pi_{xx}\left(\ln \widetilde{p}_V^{iV}, \ln \bar{\mathbf{x}}\right)\left(\ln \mathbf{x} - \ln \bar{\mathbf{x}}\right) \\ + 2\, \mathrm{E}\left(\ln p_V^{iV} - \ln \widetilde{p}_V^{iV}\right) \pi_{px}\left(\ln \widetilde{p}_V^{iV}, \ln \bar{\mathbf{x}}\right)'\left(\ln \mathbf{x} - \ln \bar{\mathbf{x}}\right) \end{array} \right\}.$$

Replacing $\ln p_V^{iV}$ with $\ln p_{0,V}^{iV} + \mu_{iV} \ln e$ (and dropping the subscript of e for simplicity), we find the first-order conditions for $p_{0,V}^{iV}$ and μ_{iV}, respectively:

$$\pi_{pp}\left(\ln \widetilde{p}_V^{iV}, \ln \bar{\mathbf{x}}\right) \mathrm{E}\left(\ln p_{0,V}^{iV} + \widehat{\mu}_{iV} \ln e - \ln \widetilde{p}_V^{iV}\right) = 0,$$

$$\pi_{pp}\left(\ln \widetilde{p}_V^{iV}, \ln \bar{\mathbf{x}}\right) \mathrm{E} \ln e\left(\ln p_{0,V}^{iV} + \widehat{\mu}_{iV} \ln e - \ln \widetilde{p}_V^{iV}\right) + \pi_{px}\left(\ln \widetilde{p}_V^{iV}, \ln \bar{\mathbf{x}}\right)' \mathrm{E} \ln e\left(\ln \mathbf{x} - \ln \bar{\mathbf{x}}\right) = 0,$$

where $\widehat{\mu}_{iV}$ is the value of μ_{iV} that maximizes the objective function Π.

From the first condition above, we have $\ln p_{0,V}^{iV} = -\widehat{\mu}_{iV} \ln \bar{e} + \ln \widetilde{p}_V^{iV}$, where $\ln \bar{e}$ denotes the mean of $\ln e$. Substituting this into the second condition we obtain:

$$\widehat{\mu}_{iV}\pi_{pp}\left(\ln\widetilde{p}_V^{iV},\ln\bar{\mathbf{x}}\right)\mathrm{E}\ln e\left(\ln e-\ln\bar{e}\right)+\pi_{px}\left(\ln\widetilde{p}_V^{iV},\ln\bar{\mathbf{x}}\right)'\mathrm{E}\ln e\left(\ln\mathbf{x}-\ln\bar{\mathbf{x}}\right)=0.$$

Solving for $\widehat{\mu}_{iV}$ we yield equation (H2) as:

$$\begin{aligned}
\widehat{\mu}_{iV} &= \frac{-\pi_{px}\left(\ln\widetilde{p}_V^{iV},\ln\bar{\mathbf{x}}\right)'\mathrm{E}\ln e\left(\ln\mathbf{x}-\ln\bar{\mathbf{x}}\right)}{\pi_{pp}\left(\ln\widetilde{p}_V^{iV},\ln\bar{\mathbf{x}}\right)\mathrm{E}\ln e\left(\ln e-\ln\bar{e}\right)} \\
&= \frac{-\pi_{px}\left(\ln\widetilde{p}_V^{iV},\ln\bar{\mathbf{x}}\right)'}{\pi_{pp}\left(\ln\widetilde{p}_V^{iV},\ln\bar{\mathbf{x}}\right)}\frac{\mathrm{E}\ln e\left(\ln\mathbf{x}-\ln\bar{\mathbf{x}}\right)-\mathrm{E}\ln\bar{e}\left(\ln\mathbf{x}-\ln\bar{\mathbf{x}}\right)}{\mathrm{E}\ln e\left(\ln e-\ln\bar{e}\right)-\mathrm{E}\ln\bar{e}\left(\ln e-\ln\bar{e}\right)} \\
&= \frac{-\pi_{px}\left(\ln\widetilde{p}_V^{iV},\ln\bar{\mathbf{x}}\right)'}{\pi_{pp}\left(\ln\widetilde{p}_V^{iV},\ln\bar{\mathbf{x}}\right)}\frac{\mathrm{E}\left(\ln e-\ln\bar{e}\right)\left(\ln\mathbf{x}-\ln\bar{\mathbf{x}}\right)}{\mathrm{E}\left(\ln e-\ln\bar{e}\right)^2} \\
&= \frac{-\pi_{px}\left(\ln\widetilde{p}_V^{iV},\ln\bar{\mathbf{x}}\right)'}{\pi_{pp}\left(\ln\widetilde{p}_V^{iV},\ln\bar{\mathbf{x}}\right)}\frac{\mathrm{cov}\left(\ln e,\ln\mathbf{x}\right)}{\mathrm{var}\left(\ln e\right)},
\end{aligned}$$

where the second line is obtained by using $\mathrm{E}\left(\ln\mathbf{x}-\ln\bar{\mathbf{x}}\right)=0$ and $\mathrm{E}\left(\ln e-\ln\bar{e}\right)=0$.

Next, we discuss the other firm type. These are firms reacting to the bilateral exchange rate e_{ij} and setting the vehicle currency price p_V^{ij}. Their log-linear pricing function is given as:

$$\ln p_V^{ij}=\ln p_{0,V}^{ij}+\mu_{ij}\ln e_{ij}, \tag{H3}$$

where $p_{0,V}^{ij}$ is denominated in the vehicle currency and μ_{ij} is the pass-through elasticity of the bilateral exchange rate into the vehicle price. Both $p_{0,V}^{ij}$ and μ_{ij} are chosen optimally by firms. Since consumers in the domestic country face prices in sterling, we have to convert p_V^{ij} into the sterling price p_i^{ij}, i.e., $\ln p_i^{ij}=\ln p_V^{ij}+\ln e_{iV}$. Substituting (H3) we obtain:

$$\ln p_i^{ij}=\ln p_{0,V}^{ij}+\mu_{ij}\ln e_{ij}+\ln e_{iV}.$$

How do firms choose μ_{ij}? Similar to expression (H2) and using analogous notation, we can derive the solution as follows:

$$\widehat{\mu}_{ij}=\frac{-\pi_{px}(\ln\widetilde{p}_V^{ij},\ln\bar{\mathbf{x}})'}{\pi_{pp}(\ln\widetilde{p}_V^{ij},\ln\bar{\mathbf{x}})}\frac{\mathrm{cov}\left(\ln e_{ij},\ln\mathbf{x}\right)}{\mathrm{var}\left(\ln e_{ij}\right)}. \tag{H4}$$

This gives rise to the optimal bilateral exchange rate pass-through elasticity $\widehat{\mu}_{ij}$.

In summary, the above derivations outline the background of the log-linear first-difference pricing equations (5) and (6) in the main text. The pass-through elasticities can thus be interpreted as optimally chosen by firms.

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