Dominant Currencies

How firms choose currency invoicing and why it matters*

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Abstract

We analyze how firms choose the currency of invoicing and the implications of this choice for exchange rate pass-through into export prices and quantities. Using a new dataset for Belgian firms, we find currency invoicing to be an active firm-level decision, shaped by the firm's size, exposure to imported inputs, and the currency choices of its competitors. Our results show that the firm's currency choice, in turn, has a direct causal impact on the exchange rate pass-through into prices and quantities. Moreover, the differential price response of similar firms that invoice in different currencies is large, persists beyond a one-year horizon, and gradually wanes in the long run. This results in allocative expenditure-switching effects on export quantities, which build up over time, suggesting a role for quantity adjustment frictions in addition to price stickiness. Our findings shed light on the mechanisms that make or break a dominant currency and the consequences it has for the international transmission of shocks.

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1 Introduction

Does the currency of invoicing used in price setting matter for the international transmission of shocks? A large literature has shown that exchange rate pass-through (ERPT) into destination prices is incomplete when exports are invoiced in a foreign currency. However, establishing whether this foreign price stickiness is causal has faced two major challenges. First, the relationship could be driven by confounding macroeconomic variables, whereby exchange rates comove with macroeconomic shocks (e.g., during global financial crisis) that also affect the trade prices and trade quantities. Second, this relationship could be due to selection, where certain firm characteristics determine simultaneously the firm's currency choice and the exchange rate pass-through into its prices and quantities. Whether the firms' currency choice has a direct causal effect on the the dynamics of prices and quantities in response to exchange rate movements, as assumed in workhorse international macro models, has a direct bearing on the way shocks are transmitted internationally and the design of the optimal macroeconomic policy in an open economy.

In this paper, we analyze how firms choose the currency of invoicing and the implications of this choice for exchange rate pass-through into export prices and quantities at different time horizons. We overcome the identification challenges that have plagued previous studies by developing a new data set that combines a rich set of firm-level characteristics with the firm's currency choice in exports and imports — a combination which has not been previously available. By comparing firms with similar characteristics that choose to price in different currencies, we are able to isolate the effect of the firm's currency choice on ERPT, controlling for the selection effects. Moreover, we exploit the cross-sectional variation for identification, holding constant the general equilibrium macro-economic environment. This new dataset, from the National Bank of Belgium, covers all of Belgium's extra-EU trade, comprising information on the firm's currency of invoicing in exporting and importing; firm characteristics, such as firm size and variable costs, as well as their imports and exports by product and country of origin and destination at very fine levels of product disaggregation.

To guide the empirical analysis, we draw on existing theory to develop a unified framework of currency choice and exchange rate pass-through from which we derive structural estimating equations. As there are a number of competing assumptions in models of currency choice, we turn to the patterns in the data to inform our modeling choices. Two key patterns in the data stand out. First, we find that the dollar and the euro play nearly equal roles, while third currencies — including those of destination and source countries — play much more modest, yet still noticeable, roles. Therefore, the data are characterized by the prevalence of dominant currency pricing — rather than producer or destination currency pricing — with the dollar exhibiting the status of the global dominant currency and the euro emerging as the dominant regional currency.[1] Second, the Belgian data feature substantial variation in the use of currencies — across countries, industries and firms — an essential feature for the analysis of currency choice. The data further reveal that much of this variation is at the firm level within industry-

[1]A distinctive feature of a dominant currency paradigm is that the same currency is equally prevalent in both imports and exports, a feature common to both the dollar and the euro in our data. Nonetheless, a clear distinction between the two is that the dollar in many cases is also a *vehicle* currency, not used domestically by either importing or exporting country.

destinations, suggesting that the currency choice is an active (albeit persistent) firm-level decision, which is the focus of our empirical analysis.

Our theoretical framework — combining heterogeneous firms with variable markups, international input sourcing and staggered price setting with endogenous currency choice — generates testable hypothesis that we take to the data. The theory predicts that the desired (flexible-price) ERPT is shaped by the import intensity of the firm and its strategic complementarities in price setting with other firms in the market. The currency choice of the firm is determined, in turn, by the desired ERPT during the period of price stickiness.[2] The short-run ERPT, during the period of price non-adjustment, is directly determined by the currency choice of the firms, which feeds back into price setting and currency choice decisions via strategic complementarities across firms. This results in a two-way feedback between currency choice and ERPT, which are jointly determined in equilibrium.

Our empirical analysis uncovers four sets of new results. First, we consider the determinants of the firm's export currency choice, initially as a binary choice between euros (producer currency) and other currencies, and then also the choice between the destination currency and the dollar. As predicted by the theory, we find that firm *size*, proxying for strategic complementarities with local competitors, and the cost share of *imported* inputs are the two key determinants of currency choice: larger and more import-intensive firms are more likely to deviate from producer currency pricing and choose foreign-currency invoicing in exports. Furthermore, the firms that rely more on imported inputs, in particular those invoiced in dollars, are more likely to adopt the dollar in export pricing, while larger firms are more likely to adopt the destination currency. Using instrumental variables, we find evidence of strategic complementarities in currency choice, whereby the currency used by the firm's competitors has a strong impact on the firm's own currency choice.[3]

Second, our results show that the firm's currency choice is, in turn, a key determinant of the exchange rate pass-through into prices and quantities. In our empirical pass-through specifications, we control for both flexible-price determinants of ERPT (firm size and import intensity), as well as the currency choice, which shapes the short-run response of prices to the movements in both the euro-destination and the dollar-destination exchange rates. This structural specification offers a new test of the allocative effects of price stickiness, by estimating the *treatment* effect of invoicing currency on the dynamic responses of prices and quantities to exchange rate changes, beyond what is predicted by the flexible-price determinants of ERPT.[4] This inference is based on the differential response of firms to the same exchange rate shocks in the same equilibrium environment, thus excluding confounding macroeconomic variation.

We find that the effects of foreign-currency price stickiness are still significant beyond the one-year horizon, gradually dissipating in the long run. Specifically, small Belgian exporters with no exposure to foreign inputs that price their exports in euros exhibit complete pass-through of the euro-destination

[2]The firms use the currency choice decision to approximate the variation in their desired prices when prices cannot adjust.

[3]We further extend the baseline theoretical and empirical analyses of currency choice to allow for additional determinants capturing fixed costs of currency use, participation in global value chains and firm financing constraints. We also extend our analysis to currency use in imports, which appears to be a less active endogenous choice at the level of the importing firm.

[4]Effectively, we compare the response of two subsets of firms — pricing in dollars and in the destination currency — relative to the subset pricing in euros, while holding fixed firm characteristics that shape firms' desired flexible-price pass-through.

exchange rate into destination prices at all horizons, and are insensitive to the dollar-destination exchange rate. By contrast, large firms with high foreign-input intensity have a significantly lower pass-through of the euro exchange rate, and a positive pass-through of the dollar exchange rate into the destination prices. These effects are present after controlling for the currency choice of the firms, and their magnitude gradually builds up over time, consistent with a greater role of the flexible-price determinants of pass-through over longer horizons. Firms that instead price their exports in a foreign currency, whether local or dominant, exhibit a much lower pass-through of the euro-destination exchange rate, especially in the short run, with the gap slowly decreasing over time. In addition, firms that price in dollars exhibit large pass-through of the dollar exchange rate into destination prices in the short run, which also gradually decays over time.

Third, our theoretical framework provides a clear structural interpretation of both sticky-price and flexible-price coefficients in the dynamic pass-through regressions. We show that the non-parametrically estimated dynamics of ERPT are consistent with a Calvo model of staggered price setting in different currencies, with roughly a 10% monthly probability of price adjustment, or in other words with an average duration of prices of 10 months.[5] This extent of price stickiness implies that about 30% of firms have yet to adjust their prices a year after the shock and the differential pass-through across firms pricing in different currencies is approximately 50% for 12-month changes in prices, consistent with our empirical estimates. By controlling for firm characteristics, our results provide the first evidence of the long-run convergence in ERPT for firms pricing in different currencies that is consistent with the theoretical predictions.

Finally, the cross-currency differential pass-through into prices translates into consistent differences in the response of quantities, with an estimated negative export quantity elasticity of around 1.5. This establishes the allocative effects of sticky prices in the endogenously chosen currency of invoicing. The quantities, however, take time to adjust, with the effects becoming significant only about a year after the shock, suggesting a role for quantity adjustment frictions in addition to price stickiness.

Our results have broad macroeconomic implications. In particular, they emphasize the forces that currently lock in the dominant role of the dollar in world trade, but may also ultimately lead to the demise of the dollar and its replacement by either another single dominant currency or a basket of currencies. While currency choice is an active firm-level decision, it is taken under strategic complementarities with other firms, resulting in a persistent currency choice equilibrium. This, however, may also cause a profound shift in the patterns of currency use and international transmission of shocks in response to accumulated changes in the equilibrium environment, such as shifts in monetary policy in certain regions of the world, as we discuss in the concluding section.

[5] This estimate is broadly consistent with somewhat higher direct estimates in the literature (see Gopinath and Rigobon 2008, Nakamura and Steinsson 2008), which are based on nominal price durations that we do not observe in our dataset. Our estimate is, instead, obtained from the dynamic response of prices to exchange rates, which we show has allocative expenditure-switching consequences.

Literature review The international macro literature has long emphasized the importance of currency of invoicing for the dynamics of terms of trade and expenditure switching (see e.g. the debate in Obstfeld and Rogoff 2000 and Engel 2003 and a more recent analysis in Boz, Gopinath, and Plagborg-Møller 2017), as well as for the direction of international policy spillovers (see e.g. summary in Corsetti and Pesenti 2007) and for the optimal exchange rate policy (see e.g. Devereux and Engel 2003 and Egorov and Mukhin 2020). Barbiero, Farhi, Gopinath, and Itskhoki (2019) emphasize the role of the currency of invoicing for the trade balance consequences of tax and tariff policies.

International macro models rely, for the most part, on an exogenously assumed pattern of currency invoicing. In particular, the original frameworks of Mundell (1963) and Fleming (1962), as well as of Dornbusch (1976) and Obstfeld and Rogoff (1995), relied on the assumption of producer currency pricing (PCP), whereby exporters use the currency of their home country for invoicing. The evidence of low exchange rate pass-through in the aftermath of the Bretton-Woods system (see Dornbusch 1987, Krugman 1987), led to a shift towards the assumption of local currency pricing (LCP), whereby firms set prices in the destination currency (see e.g. Bacchetta and van Wincoop 2000, Betts and Devereux 2000, Chari, Kehoe, and McGrattan 2002). The emergence of micro-level data sets with information on the currency of invoicing at the transaction level (see e.g. Gopinath, Itskhoki, and Rigobon 2010) has emphasized the role of the US dollar as the universal currency of invoicing, and led to the growing prominence of the dominant currency paradigm (DCP), whereby a single dominant currency is used for invoicing of all global trade (see Gopinath, Boz, Casas, Díez, Gourinchas, and Plagborg-Møller 2020).[6] In this paper, we document that none of the exogenous invoicing paradigms (PCP, LCP or DCP) approximates well the patterns in our data, where invoicing is an active firm-level decision, which results in a co-existence of two dominant currencies with endogenous relative prominence.

Our work draws on important earlier contributions to the analysis of currency choice at the firm level and its implications for exchange rate pass-through. In a seminal paper, Engel (2006) provides an equivalence result between currency choice and exchange rate pass-through in a one-period sticky-price model, showing how existing theories of currency choice map into this equivalence result.[7] Gopinath, Itskhoki, and Rigobon (2010) generalize this result to a dynamic multi-period framework, separately identifying the feedback effects between currency choice and the dynamics of ERPT. Mukhin (2017) nests this framework in a general equilibrium model of the international price system with endogenously-emerging dominant currencies, which relies on firms with variable markups (as in Amiti, Itskhoki, and Konings 2019) and international input sourcing (as in Amiti, Itskhoki, and Konings 2014). We combine the insights from this literature to derive our structural estimating equations.

Our paper relates to the growing empirical literature on the dominant role of the US dollar in

[6]The dominant currency assumption was first explored in an earlier literature, both theoretical (see e.g. Corsetti and Pesenti 2007, Goldberg and Tille 2009) and empirical (see Goldberg and Tille 2008, Gopinath 2016), based on global trends in the aggregate data. Prior to the availability of micro-level data, Friberg (1998) used a survey approach to elicit information on the currency of invoicing for exports.

[7]Other important early contributions to the literature on currency choice include Corsetti and Pesenti (2004), Devereux, Engel, and Storgaard (2004), Bacchetta and van Wincoop (2005), as well as more recent work by Bhattarai (2009) and Cravino (2017). Our work is also related to a vast exchange rate pass-through literature summarized in a number of survey articles, most recently by Burstein and Gopinath (2013) and Itskhoki (2020).

international trade flows, following Goldberg and Tille (2008) and Gopinath (2016).[8] The empirical evidence in support of these models largely stems from data on countries which almost exclusively rely on the dollar in both their exports and their imports (e.g., Gopinath, Itskhoki, and Rigobon 2010 examine the evidence for the US and Casas, Díez, Gopinath, and Gourinchas 2016 study the case of a developing country—Colombia). The advantage of studying a Euro Area country, like Belgium, is that there is much greater variation in currency choice, with the euro used at least as intensively as the dollar. This additional variation enables us to shed light on the competition between two dominant currencies — an established global leader and a regional contender — a case of intense theoretical interest.

More recently, currency data has become available on other countries (e.g., UK, France, Switzerland, Canada and some developing countries) with interesting cross-currency variation at the transaction level that has been exploited to analyze either currency choice or ERPT (see Chung 2016, Chen, Chung, and Novy 2018, Corsetti, Crowley, and Han 2020, Barbiero 2020, Auer, Burstein, and Lein 2020, Goldberg and Tille 2016, Devereux, Dong, and Tomlin 2017, Drenik and Perez 2018). A distinguishing feature of our study is that we can match the currency invoicing data with detailed firm-level characteristics required by the theory in order to estimate a structural specification for both currency choice and the resulting ERPT, capturing the contribution of both its flexible-price and sticky-price determinants.

The rest of the paper is organized as follows. Section 2 presents our theoretical framework of endogenous currency choice and exchange rate pass-through, which informs our estimating equations and empirical strategy. Section 3 describes our dataset and the construction of the variables for the empirical analysis, and then documents a number of stylized facts on the currency use in export and import transactions of Belgian firms. Section 4 contains our empirical firm-level analysis of the currency choice in exports. Section 5 presents the results on pass-through of exchange rates into export prices and quantities, first at the annual frequency and then non-parametrically for various horizons using the monthly data. Section 6 offers concluding remarks on the likely scenarios for the changing status of dominant currencies.

2 Theoretical Framework

In this section, we draw on new insights developed in the recent literature to provide a unified theory of currency choice and exchange rate pass-through in order to derive a structural empirical framework. We consider an industry equilibrium in a given industry s in foreign destination k, and we omit notation s and k when it causes no confusion. We focus on the problem of a home (Belgian) firm i exporting to market k, and consider in turn its desired price, optimal preset price and optimal currency choice. We begin with a baseline one-period model of price stickiness and then extend the analysis to a dynamic environment, as well as discuss possible additional determinants of currency choice.

[8] An even larger literature, summarized in Gourinchas (2019), explores the other roles of the dollar as the dominant currency — in firm financing (see e.g. Gopinath and Stein 2020, Maggiori, Neiman, and Schreger 2020), as reserve and global safe-asset currency (see e.g. Farhi and Maggiori 2017, He, Krishnamurthy, and Milbradt 2019), and for exchange rate pegging and monetary anchoring (see e.g. Ilzetzki, Reinhart, and Rogoff 2019). An earlier literature has explored the role of the US dollar as the dominant currency from the transaction-cost point of view (see e.g. Krugman 1980, Rey 2001, Devereux and Shi 2013 and more recently Drenik, Kirpalani, and Perez 2019).

2.1 Baseline model of price setting and currency choice

Desired price Firm i's profit from exporting to destination k is denoted by $\Pi_i(p_i) \equiv \Pi_i(p_i|\Omega)$, where p_i is the log export price in producer currency (euros), with all lower-case letters corresponding to logarithms of the variables. The vector Ω describes the state of the world, which includes exogenous shocks (e.g. productivity), endogenous shocks (e.g. exchange rate movements), and the firm's competitor prices. The *desired* price of firm i is given by:[9]

$$\tilde{p}_i = \arg\max_{p_i} \Pi_i(p_i). \tag{1}$$

That is, $\tilde{p}_i \equiv \tilde{p}_i(\Omega)$ is the price that the firm would choose in state Ω, if it were setting prices flexibly.

The log desired price of the firm can be converted to any currency ℓ, including the destination currency $\ell = k$ or the dollar $\ell = D$:

$$\tilde{p}_i^\ell = \tilde{p}_i + e_\ell, \tag{2}$$

where e_ℓ is the log bilateral exchange rate between currency ℓ and the euro. Specifically, e_ℓ is equal to the number of units of currency ℓ for one euro, and hence an increase in e_ℓ corresponds to a *depreciation* of currency ℓ against the euro. We reserve the $*$ notation for the destination currency k, that is $\tilde{p}_i^* \equiv \tilde{p}_i^k$.

Price stickiness and preset prices The firm presets the price $\bar{p}_i^\ell$ in currency ℓ before the state Ω is observed, and with probability δ this price stays in effect. That is, the realized price in the producer currency is then $p_i = \bar{p}_i^\ell - e_\ell$. With the complementary probability $(1-\delta)$, the firm adjusts its price to the desired level, and in this case the realized price is $p_i = \tilde{p}_i$.

The optimal preset price in currency ℓ solves:

$$\bar{p}_i^\ell = \arg\max_{\bar{p}_i^\ell} \mathbb{E}\,\Pi_i(\bar{p}_i^\ell - e_\ell|\Omega), \tag{3}$$

where the expectation is taken over all possible realizations of the state vector Ω.[10] One can prove the following characterization of the optimal preset price $\bar{p}_i^\ell$, extending the logic of Proposition 1 in Gopinath, Itskhoki, and Rigobon (2010):[11]

Lemma 1 (Preset prices) *For any currency ℓ, the first-order approximation to the optimal preset price is:*

$$\bar{p}_i^\ell = \mathbb{E}\{\,\tilde{p}_i + e_\ell\,\} = \mathbb{E}\,\tilde{p}_i^\ell, \tag{4}$$

where $\tilde{p}_i^\ell = \tilde{p}_i + e_\ell$ is the desired price expressed in currency ℓ.

[9] The analysis here goes through if the profit function $\Pi_i(\cdot)$ is replaced with the joint surplus function of the supplier and the buyer of product i, and hence the currency choice is not necessarily a unilateral decision of the supplier, but could also be the outcome of a bargaining game. We use the profit function interpretation, however, in Section 2.2 to derive the expansion for the desired price $\tilde{p}_i$. Also note that since we do not impose any structure on the profit function, apart from double differentiability in price, it can additionally incorporate any stochastic discount factor.

[10] This implicitly assumes that the firm's opportunity to adjust the price (with probability $1-\delta$) is idiosyncratic, as in the Calvo model (see e.g. Gopinath and Itskhoki 2010, which extends this analysis to a model of state-contingent price adjustment).

[11] Formally, this lemma obtains from the Taylor expansion of the first-order condition (FOC) for $\bar{p}_i^\ell$ in (3) around $\tilde{p}_i^\ell$, which in turn satisfies $\Pi_i'(\tilde{p}_i^\ell - e_\ell) = 0$, i.e. the FOC for $\tilde{p}_i$ in (1).

That is, under any currency choice ℓ, the firm chooses its preset price to target the average desired price $\tilde{p}_i^\ell$ expressed in currency ℓ.

Currency choice When choosing $\bar{p}_i^\ell$, the firm also chooses the currency ℓ in which it presets the price. The optimal currency choice solves:

$$\ell = \arg\max_\ell \Big\{ \max_{\bar{p}_i^\ell} \, \mathbb{E}\, \Pi_i\big(\bar{p}_i^\ell - e_\ell | \Omega\big) \Big\}. \tag{5}$$

In other words, given that prices are sticky (with probability δ), the firm has the option to choose the currency ℓ, which minimizes the loss from price stickiness, $\Pi_i(\tilde{p}_i) - \Pi_i(\bar{p}_i^\ell - e_\ell)$, averaged across states Ω.

Following the insights in Engel (2006), Gopinath, Itskhoki, and Rigobon (2010), and Mukhin (2017), the complex problem in (5) with a general profit function $\Pi_i(\cdot)$ can be shown to be approximately equivalent to a simpler problem, connecting the currency choice to the covariance properties of the desired prices with exchange rates. Specifically, we have:[12]

Lemma 2 (Currency choice) *Under a second-order approximation to the general profit function $\Pi_i(\cdot)$, the optimal currency choice in (5) is equivalent to:*

$$\ell = \arg\min_\ell \big\{ \mathrm{var}\big(\, \tilde{p}_i + e_\ell \,\big) \big\}, \tag{6}$$

where $\tilde{p}_i + e_\ell = \tilde{p}_i^\ell$, i.e. the desired price expressed in currency ℓ.

The optimal currency of pricing ℓ ensures the minimal variation in the desired price $\tilde{p}_i^\ell$ expressed in currency ℓ. This result may at first appear surprising; nonetheless, it is very intuitive upon reflection. The preset price attempts to target the desired price on average (Lemma 1). When the desired price expressed in currency ℓ is volatile across states, currency ℓ is a poor choice for presetting the price, as it results in large gaps between $\bar{p}_i^\ell$ and $\tilde{p}_i^\ell$, and thus large profit losses across states of the world. In contrast, when the desired price is stable in a given currency ℓ, fixing the price in that same currency results in little loss relative to the flexible price setting $p_i = \tilde{p}_i^\ell$, as it can be accurately targeted by a constant $\bar{p}_i^\ell$. In other words, a moving target is easy when its movement is limited. This explains the result in Lemma 2.

Using Lemma 2, the choice of currency ℓ would be favored over the default option of pricing in euros if $\mathrm{var}(\tilde{p}_i) > \mathrm{var}(\tilde{p}_i^\ell) = \mathrm{var}(\tilde{p}_i + e_\ell)$. Expanding the last variance term and manipulating the inequality, this condition is equivalent to:

$$\frac{\mathrm{cov}\big(\, \tilde{p}_i + e_\ell, e_\ell \,\big)}{\mathrm{var}\big(\, e_\ell \,\big)} < \frac{1}{2}, \tag{7}$$

where a specific threshold of $1/2$ comes from the second-order (quadratic) approximation. Note that the left-hand side is the projection of the desired price in currency ℓ on the corresponding bilateral

[12]To prove this lemma, Taylor expand around $\tilde{p}_i$ the gap in average profits between currencies ℓ and d to obtain: $\mathbb{E}\,\Pi_i\big(\bar{p}_i^\ell - e_\ell\big) - \mathbb{E}\,\Pi_i\big(\bar{p}_i^d - e_d\big) \approx \frac{1}{2}\mathbb{E}\{-\tilde{\Pi}_i''(\tilde{p}_i)\}\cdot\big[\mathrm{var}(\tilde{p}_i^d) - \mathrm{var}(\tilde{p}_i^\ell)\big]$, and thus currency ℓ is chosen when $\mathrm{var}(\tilde{p}_i^\ell) < \mathrm{var}(\tilde{p}_i^d)$ for all alternatives d; the proof uses $\Pi_i'(\tilde{p}_i) = 0$ and $\Pi_i''(\tilde{p}_i) < 0$, as well as Lemma 1, which implies $\mathbb{E}(\tilde{p}_i^\ell - \bar{p}_i^\ell)^2 = \mathrm{var}(\tilde{p}_i^\ell)$.

exchange rate, or the exchange rate pass-through (ERPT) elasticity for the desired price. Currency ℓ is favored if the exchange rate pass-through into $\tilde{p}_i^\ell$ is low, or equivalently $\tilde{p}_i^\ell$ does not vary closely with the exchange rate. In the opposite case, if the inequality in (7) is reversed for every currency ℓ, the optimal choice for the firm is the producer currency (euro), which ensures high (complete) ERPT in every currency ℓ other than the euro.[13]

We consider three modes of pricing — producer currency pricing (PCP, euro), dominant/vehicle currency pricing (DCP, dollar), and local currency pricing (LCP, destination currency k) — with the realized destination-currency price *conditional on price non-adjustment* given by:

$$p_i^* = \begin{cases} \bar{p}_i + e_k, & \text{under PCP (euro)}, \\ \bar{p}_i^D + e_k^D, & \text{under DCP (dollar)}, \\ \bar{p}_i^*, & \text{under LCP (destination currency } k), \end{cases} \tag{8}$$

where e_k^D is the dollar-destination exchange rate measuring the depreciation of currency k against the dollar. Thus, PCP is favored if the destination-currency desired price $\tilde{p}_i^*$ tracks closely the euro-destination bilateral exchange rate e_k, as PCP ensures complete pass-through of e_k into p_i^* in the short run. Similarly, DCP is favored if $\tilde{p}_i^*$ tracks closely the dollar-destination exchange rate e_k^D, or in other words the desired price is stable in dollars. Finally, LCP is favored if $\tilde{p}_i^*$ is itself stable and does not track any exchange rate, as LCP ensures zero short-run pass-through of all exchange rates into the destination-currency price p_i^*.

2.2 Exchange rate pass-through and currency choice

Desired pass-through The desired price defines the desired (log) markup of the firm $\tilde{\mu}_i$ according to the following price identity:

$$\tilde{p}_i = \tilde{\mu}_i + mc_i, \tag{9}$$

where mc_i is the log marginal cost of the firm. In the remainder of the analysis, all lower-case letters denote the *log deviations* from a constant-price steady state.

We follow Amiti, Itskhoki, and Konings (2019) and adopt the following decomposition of the desired price of the firm, based on the structure of the desired markup, which applies across a general class of models of monopolistic and oligopolistic competition:[14]

$$\tilde{p}_i = \frac{1}{1+\Gamma_i} mc_i + \frac{\Gamma_i}{1+\Gamma_i}(z_k^* - e_k) + \varepsilon_i, \tag{10}$$

where z_k^* is the competitor price index in the destination currency (in a given industry-destination), ε_i is the demand (markup) shock, and Γ_i is the elasticity of the desired markup with respect to price,

[13] Note that currency choice is akin to an indexing decision: it ensures that, in the instance of price non-adjustment, the realized destination price of the firm $p_i^* = \bar{p}_i^\ell + e_k^\ell$ tracks one-for-one the bilateral exchange rate e_k^ℓ between the destination currency k and the currency of pricing ℓ. The goal of the currency choice is to find such ℓ that allows $p_i^* = \bar{p}_i^\ell + e_k^\ell$ to closely track $\tilde{p}_i^*$. Lemma 2 and equation (7) formalize this idea as a condition on the low volatility of the desired price $\tilde{p}_i^\ell$ expressed in currency ℓ, or equivalently the low exchange rate pass-through into $\tilde{p}_i^\ell$. Also note that the volatility in $\tilde{p}_i^*$ that is orthogonal to exchange rates is of *no* relevance for currency choice, as it cannot be addressed.

[14] Formally, (10) is the full differential of (9) with the desired markup given by $\tilde{\mu}_i = \mathcal{M}(p_i + e_k - z_k^*; \varepsilon_i)$ and decreasing in the relative price of the firm, so that $\Gamma_i \equiv -\mathcal{M}'(\tilde{p}_i + e_k - z_k^*; \varepsilon_i) > 0$.

$\Gamma_i \equiv -\partial\tilde{\mu}_i/\partial p_i$. As a result, $\frac{1}{1+\Gamma_i}$ is the own cost pass-through elasticity of the firm and $\frac{\Gamma_i}{1+\Gamma_i}$ reflects the strength of strategic complementarities in price setting.

We now explore the elasticity of the desired price in the destination currency, $\tilde{p}_i^* = \tilde{p}_i + e_k$, with respect to bilateral euro-destination and dollar-destination exchange rates, e_k and e_k^D. By convention, an increase in e_k and e_k^D corresponds to the depreciation of the destination currency against the euro and the dollar respectively. We approximate the projection of the firm's desired export price on the two exchange rates as follows:

Lemma 3 (Desired pass-through) *Firm i's desired export price to k in the destination currency, $\tilde{p}_i^*$, comoves with the euro-destination and the dollar-destination exchange rates as follows:*

$$\mathrm{d}\tilde{p}_i^* = (1 - \varphi_i - \gamma_i)\,\mathrm{d}e_k + \left(\varphi_i^D + \gamma_i^D\right)\mathrm{d}e_k^D, \tag{11}$$

where $\varphi_i \equiv -\frac{\partial mc_i}{\partial e_k}$ and $\varphi_i^D \equiv \frac{\partial mc_i}{\partial e_k^D}$ capture the exposure of the firm's marginal cost to foreign currencies and to the dollar specifically, and $\gamma_i \equiv -\frac{\Gamma_i}{1+\Gamma_i}\frac{\partial[z_k^* - mc_i - e_k]}{\partial e_k}$ and $\gamma_i^D \equiv \frac{\Gamma_i}{1+\Gamma_i}\frac{\partial[z_k^* - mc_i - e_k]}{\partial e_k^D}$ capture the exposure of the firm's desired markup to foreign currencies and to the dollar via the competitor prices.

This result follows directly from (9), by noting from (10) that $\tilde{\mu}_i = \frac{\Gamma_i}{1+\Gamma_i}(z_k^* - e_k - mc_i) + \varepsilon_i$, and assuming that the firm's idiosyncratic demand shifter ε_i is orthogonal with the exchange rates. A firm exhibiting no strategic complementarities in price setting, namely $\Gamma_i = 0$, has $\gamma_i = \gamma_i^D = 0$; and a firm with a marginal cost mc_i stable in the producer currency has $\varphi_i = \varphi_i^D = 0$. If both are true, the firm exhibits complete pass-through of the euro-destination exchange rate into its desired destination price, $\partial\tilde{p}_i^*/\partial e_k = 1$, and zero pass-through of the dollar-destination exchange rate, $\partial\tilde{p}_i^*/\partial e_k^D = 0$. This is the complete ERPT benchmark. In contrast, if the firm's marginal cost is sensitive to the euro or the dollar exchange rate, e.g. due to the use of foreign intermediate inputs or if the firm's optimal markup is sensitive to the prices of its competitors in the destination market, then such a firm would exhibit an incomplete pass-through of the euro-destination exchange rate and a non-zero pass-through of the dollar-destination exchange rate into its desired destination-currency price.

In practice, we proxy for φ_i and φ_i^D with the firm's share of imported inputs in total variable costs, sourced in all foreign currencies and in dollars in particular. The firms that source all their intermediates domestically, or within the eurozone, are assumed to have $\varphi_i = \varphi_i^D = 0$. For the markup channel, we follow Amiti, Itskhoki, and Konings (2019) who show, both theoretically and empirically, that markup elasticity Γ_i is increasing in firm size and is zero for firms with negligible sales shares. We, therefore, expect $\gamma_i = \gamma_i^D = 0$ for the smallest firms, $\gamma_i, \gamma_i^D > 0$ for larger firms and increasing in firm size.

Currency choice Lemma 3 provides a convenient decomposition of the variation in the desired price $\tilde{p}_i^*$. We now combine it with equation (8) to determine whether PCP, DCP or LCP best tracks the desired price. The three limiting cases are as follows:

(i) PCP (euro) if $\mathrm{d}p_i^* \approx \mathrm{d}e_k$, corresponding to $\varphi_i, \gamma_i, \varphi_i^D, \gamma_i^D \approx 0$;

(ii) DCP (dollar) if $\mathrm{d}\tilde{p}_i^* \approx \mathrm{d}e_k^D$, when $\varphi_i + \gamma_i \approx \varphi_i^D + \gamma_i^D \approx 1$;

(iii) LCP (destination currency) if $\mathrm{d}\tilde{p}_i^* \approx 0$, when $\varphi_i + \gamma_i \approx 1$ and $\varphi_i^D + \gamma_i^D \approx 0$.

Outside of these limiting cases, one can use Lemma 2 and condition (7) to establish the optimal currency choice pairwise. For example, LCP is favored over PCP if $\frac{\mathrm{d}\tilde{p}_i^*}{\mathrm{d}e_k} < \frac{1}{2}$, which requires $\varphi_i + \gamma_i > \frac{1}{2}$, and PCP is favored otherwise.

To summarize, marginal costs and desired markups stable in producer currency (i.e., low φ_i and γ_i) favor PCP, while marginal costs and markups that respond to exchange rates favor the use of foreign currencies (LCP or DCP). For example, importing intermediate inputs in dollars (high φ_i^D) favors the use of the dollar in exports, while strong strategic complementarities in price setting with local competitors (high γ_i) favors the use of the local currency (see Gopinath, Itskhoki, and Rigobon 2010, Mukhin 2017).

Realized pass-through The realized pass-through is shaped by a combination of the currency choice, conditional on price non-adjustment which occurs with probability δ, and of the desired ERPT, conditional on a price change. As a result, the realized price of the firm satisfies:

$$\mathrm{d}p_i^* = \left[\begin{array}{ll} \mathrm{d}[\bar{p}_i^\ell + e_k^\ell] = \mathrm{d}e_k^\ell, & \text{with probability } \delta, \\ \mathrm{d}\tilde{p}_i^*, & \text{with probability } 1-\delta, \end{array} \right.$$

where $\mathrm{d}\tilde{p}_i^*$ is given by (11) and $e_k^\ell = e_k - e_\ell$ is the exchange rate between the currency of pricing ℓ and the destination currency k. The expected price change is therefore $\mathbb{E}\,\mathrm{d}p_i^* = \delta \mathrm{d}e_k^\ell + (1-\delta)\mathrm{d}\tilde{p}_i^*$.

We again focus on the three cases — PCP, DCP and LCP — denoting with $\iota_i^L, \iota_i^D \in \{0,1\}$ the indicators for whether the firm adopts LCP or DCP respectively. Then, the choice of PCP corresponds to $\iota_i \equiv \iota_i^D + \iota_i^L = 0$ and $\iota_i = 1$ indicates the choice of any foreign currency. Using this notation, we combine (8) and (11) to obtain the expression for the expected observed price change:

$$\mathbb{E}\mathrm{d}p_i^* = \mathrm{d}e_k + \delta\big[-\iota_i\,\mathrm{d}e_k + \iota_i^D \mathrm{d}e_k^D\big] + (1-\delta)\big[-(\varphi_i+\gamma_i)\mathrm{d}e_k + (\varphi_i^D + \gamma_i^D)\mathrm{d}e_k^D\big]. \tag{12}$$

The first term ($\mathrm{d}e_k$) isolates the complete pass-through of the euro-destination exchange rate (that is, $\mathrm{d}p_i^*/\mathrm{d}e_k = 1$) of a firm pricing in euros (PCP, with $\iota_i = \iota_i^D = 0$) and not exposed to foreign currency fluctuations either via its marginal cost ($\varphi_i = \varphi_i^D = 0$) or desired markup ($\gamma_i = \gamma_i^D = 0$).

The next terms in (12), in the first square brackets pre-multiplied by δ, isolate the direct effect of price stickiness in local or dominant currency. This effect occurs conditional on no price adjustment, which happens with probability δ, and results in zero pass-through of the euro-destination exchange rate under LCP and a complete pass-through of the dollar-destination exchange rate under DCP. The larger the extent of price stickiness δ, the greater is the impact of this sticky price term on the realized ERPT.

The last term in (12), in square brackets pre-multiplied by $(1-\delta)$, isolates the effect of the flexible-price (or desired-price) determinants of ERPT, conditional on a price adjustment which occurs with probability $(1-\delta)$. As emphasized by Lemma 3, the desired pass-through reflects the exposure of the firm's marginal cost and desired markup to foreign exchange (φ_i and γ_i) and the dollar in particular (φ_i^D and γ_i^D). Therefore, equation (12) offers a convenient way to decompose the observed incomplete ERPT into the direct effect of foreign-currency price stickiness (LCP and DCP) and the incomplete pass-through into the desired price (11) conditional on a price adjustment.

The one-period model does not specify a time unit, and as such can be applied at any time horizon. In particular, equation (12) describing the realized ERPT can be applied over any time interval, where parameter δ decreases over time to reflect the fact that prices become more flexible over longer horizons. In the very short run, we expect $\delta \approx 1$, and in the long run $\delta \to 0$. Therefore, as we consider longer time horizons, the relative weight in (12) shifts away from the sticky-price term and towards the flexible-price (desired-price) term. We approach the data non-parametrically, and estimate a sequence of equations (12) over varying time horizons.

2.3 Dynamics of ERPT

We now extend the analysis to a dynamic price-setting problem with a Calvo price-setting friction, in order to aid the interpretation of our empirical estimates.[15] That is, we consider a firm that has an exogenous opportunity to reset its price with a probability $(1-\lambda)$ each period, while with probability λ it keeps its price unchanged from the previous period. We characterize below how λ maps into the regression coefficient δ in (12). Consider a firm that sets its price in currency ℓ, which may correspond to PCP, LCP or DCP, with the realized destination-currency price given by:

$$p_{it}^{*} = \left[\begin{array}{ll} \bar{p}_{it}^{\ell} + e_{kt}^{\ell}, & \text{with probability } 1-\lambda, \\ p_{i,t-1}^{\ell} + e_{kt}^{\ell}, & \text{with probability } \lambda, \end{array} \right.$$

where the optimal *reset* price $\bar{p}_{it}^{\ell} = (1-\beta\lambda)\sum_{j=0}^{\infty}(\beta\lambda)^{j}\mathbb{E}_t\tilde{p}_{i,t+j}^{\ell}$ is a weighted average of current and future desired prices expressed in the invoicing currency ℓ (using the probability of non-adjustment λ and the discount factor β as weights, see e.g. Galí 2008). This generalizes the concept of preset price (3) in the static model to a dynamic environment. For simplicity, we assume that all bilateral exchange rates follow a random walk with $\mathbb{E}_t\Delta e_{k,t+1}^{\ell} = 0$, and we consider the special case of the desired price in (11) with $\Delta\tilde{p}_{it}^{*} = \psi_i\Delta e_{kt} + \psi_i^{D}\Delta e_{kt}^{D}$, where $\psi_i \equiv 1-\varphi_i-\gamma_i$ and $\psi_i^{D} \equiv \gamma_i^{D}+\varphi_i^{D}$.

With this data generating process, we show in Appendix D that by estimating equation (12) over any time horizon h (months), one can recover both the structural parameter of price stickiness λ, as well as the causal treatment effect of currency of pricing. In particular, by projecting an h-period change in the observed prices, $\Delta_h p_{it}^{*} \equiv p_{it}^{*} - p_{i,t-h}^{*}$, on the h-period change in the exchange rates, $\Delta_h e_{kt}$ and $\Delta_h e_{kt}^{D}$, interacted with dummies for foreign currency choice $\{\iota_i, \iota_i^{D}\}$, and controlling for the desired pass-through terms, as in (12), one obtains the following regression equation:

$$\mathbb{E}\Delta_h p_{it}^{*} = \Delta_h e_{kt} + \hat{\delta}(h)\big[-\iota_i\,\Delta_h e_{kt} + \iota_i^{D}\,\Delta_h e_{kt}^{D}\big] + \big(1-\hat{\delta}(h)\big)\big[-\psi_i\Delta_h e_{kt} + \psi_i^{D}\Delta_h e_{kt}^{D}\big], \tag{13}$$

where the regression coefficients are now shaped by the following function of horizon h and the Calvo parameter λ:

$$\hat{\delta}(h) = \frac{1}{h}\frac{\lambda}{1-\lambda}(1-\lambda^{h}). \tag{14}$$

[15] One can adopt alternative models of price and quantity dynamics, and use our non-parametric dynamic estimates to discipline the structural coefficients in those models.

Therefore, the flexible-price coefficients increase with horizon h in proportion with $1 - \hat{\delta}(h)$, while the sticky-price coefficients equal $\hat{\delta}(h)$.[16] The parameter λ allows us to evaluate the average price duration given by $1/(1-\lambda)$ and the fraction of prices that have not yet been adjusted h periods after the shock given by a declining geometric progression λ^h, which also measures the *causal* effect of the foreign-currency price stickiness on the realized ERPT h periods out.

2.4 Additional determinants of currency choice

The analysis thus far has focused on a baseline model of currency choice that isolates the desired pass-through as a sufficient statistic. A straightforward generalization of the currency choice problem in (5) incorporates an additional fixed cost $F_{\ell,i}$ associated with the use of currency ℓ and possibly idiosyncratic to firm i:

$$\ell = \arg\max_{\ell} \left\{ \max_{\bar{p}_i^\ell} \mathbb{E}\,\Pi_i\big(\bar{p}_i^\ell - e_\ell|\Omega\big) - F_{\ell,i} \right\}. \tag{15}$$

This formulation allows us to consider a number of possible extensions that identify additional determinants of currency choice.

First, consider the case where some firms find it particularly costly to adopt a certain currency ℓ, or all firms (in a given industry or at large) find it costly to use a specific currency ℓ. This interpretation of (15) captures a number of possible narratives, starting from macroeconomic country-level risk which makes certain currencies ill-suited for pricing (e.g., due to the risk of unexpected inflation or devaluation) and ranging to institutional path-dependency of using a particular currency in pricing certain products (e.g., the use of the dollar in pricing commodities). It also allows for firm-specific determinants such as participation in global value chains that make the use of a particular currency more likely in firm's trade, independent of its desired ERPT. Testing such theories requires the use of variables that proxy for the fixed cost $F_{\ell,i}$ after controlling for the desired pass-through of the firm.

Second, another interpretation of (15) is one in which a firm must adopt a single invoicing currency across multiple destinations or pay a fixed cost associated with using non-uniform pricing policies across destination markets. Formally, this can be captured by a fixed cost $F_{\ell,i}$ which equals zero under uniform pricing and is positive if the firm chooses a different currency or price for sales to a given destination relative to its other exports. In other words, under such fixed costs, firms have a motive to avoid using different currencies in different destinations. Indeed, there is evidence that firms adopt common invoicing and pricing policies, at least across a subset of their export destinations (see e.g. Cavallo, Neiman, and Rigobon 2014, Crowley, Han, and Son 2021). Testing this theory requires a firm-level proxy that compels the firm to adopt some currency in one of its destinations, which then makes the use of that currency more likely in other destinations independently of the destination-specific desired pass-through.

Lastly, a third extension features the financing channel of currency choice, whereby the balance

[16] Note that $\hat{\delta}(1) = \lambda$ and $\hat{\delta}(h) > \lambda^h$ for $h > 1$, and the convergence of the sequence $\delta_h = \hat{\delta}(h) \to_h 0$ is hyperbolic in h. This is because $\hat{\delta}(h)$ is a regression coefficient of the change in prices on the contemporaneous change in the exchange rates over increasingly longer windows h, and thus estimates the average response over these windows as opposed to an impulse response. An alternative projection of a one-period price change on the distributed lag of past exchange rate changes recovers a geometrically decreasing impulse responses, λ^h, which is in a one-to-one relationship with $\hat{\delta}(h)$ (see Appendix D).

sheet of the firm affects the optimal currency invoicing either as way of hedging or relaxing the firm's financial constraints (see e.g. Gopinath and Stein 2020, Drenik and Perez 2021).[17] These theories suggest that the optimal price of the firm is no longer shaped exclusively by the static desired markup, but incorporates expected shadow costs associated with the effects of invoicing and pricing decisions on financing constraints of the firm. As a result, variables characterizing firm financing and financial constraints are likely to shape the optimal currency choice beyond the determinants of the desired ERPT.

3 Empirical Analysis

In this section, we describe our data sets and the construction of the main variables. We then present new stylized facts on currency invoicing, before delving into a more formal empirical analysis of currency choice and exchange rate pass-through in Sections 4 and 5.

3.1 Data Description

To empirically implement the theoretical framework of Section 2, it is critical to have firm-level currency data as well as good proxies for the flexible-price firm-level characteristics. The availability of this combination of data is unique to Belgium. The Belgian Customs Office began compiling the currency of invoicing data at a disaggregated level at the beginning of 2017, which were then processed by the National Bank of Belgium. These data report the value, quantity, and currency of invoicing for exports and imports at the firm-product level by destination and source country outside the EU with each product classified at the 8-digit combined nomenclature (CN), comprising around 10,000 distinct products. All international trade transactions that take place within the EU are collected by a different authority, the Intrastat Survey, which does not report the currency of invoicing, but does report all the values and quantities of trade at the same level of disaggregation.[18]

To understand the determinants of currency choice and exchange rate pass-through, we combine the currency invoicing data with firm characteristics drawn from annual income statements of all incorporated firms in Belgium. In particular, we use the quarterly VAT declarations, which all firms are required to submit to the tax office, for information on the cost of total material inputs used. We draw on data from the Social Security Office for the wage bill, where all firms have to report their employment and wages paid. It is straightforward to merge these data with the currency data as they both include a unique firm identifier common across datasets.

Using these data, we construct the following firm-level determinants. The first is the firm's import intensity from outside the eurozone (ex-EZ), as a proxy for the firm's marginal cost sensitivity to the exchange rate:

$$\varphi_i \equiv \frac{\text{Total ex-EZ import value}_i}{\text{Total variable costs}_i}, \tag{16}$$

[17] Incorporating this formulation within our framework requires augmenting the decision problem in (15) with an additional constraint $G(\bar{p}_i^\ell, x_i|\Omega) \leq 0$, where x_i are the other decision variables of the firm, which for example can represent firm financing or working capital constraints.

[18] Belgian trade with ex-EU countries accounts for 27% of their exports and 34% of imports in 2018. Nonetheless, as Belgium is a very open economy, with a trade (exports plus imports) to GDP ratio of 151% in 2018, its ex-EU trade flows are still large as a share of GDP.

where total variable costs comprise a firm's total wage bill and total material costs. Note that φ_i is measured at the firm-level, and thus applies to all CN8-products i exported by multi-product firms. We measure a firm's import intensity in each year and then average it over time. A novelty with our data is that we can further split a firm's import intensity by the currency of invoicing, to get a measure of the share of imports invoiced in euros and other currencies. We denote the euro- and non-euro-invoiced import intensities with E and X superscripts respectively, so that the overall import intensity of the firm can be decomposed as $\varphi_i = \varphi_i^E + \varphi_i^X$. In some cases we further split the non-euro import intensity into its dollar component φ_i^D and the remaining other currencies.

Second, we construct two measures of firm size to proxy for strategic complementarities in price setting and markup sensitivity to the exchange rate. We use the firm's average log employment $\log L_i$ to capture its absolute size and the destination-specific sales share S_{ik} to reflect its relative size. In particular, we proxy the firm's market share in a given destination by its sales share relative to the total sales of all Belgian products in a given industry-destination, with industries defined at the HS 4-digit level.[19] Third, we construct variables to proxy for additional firm-level determinants of currency choice, comprising the firm's export share in total sales, share of exports to eurozone destinations, inward and outward FDI, R&D intensity, measured TFP, and various financial (balance sheet) variables, as we describe in our robustness analysis in Section 4.

We estimate two types of equations. First, we estimate the determinants of currency choice, in which we use the full sample of monthly currency data available to us, from March 2017 to December 2020. In the main specifications, the dependent variable ι_{ikt} is equal to 0 if the currency choice for a given firm-product-destination-month is the euro and 1 for non-euro (any other currency). In cases where we consider the subset of products invoiced in non-euros, we construct an indicator variable ι_{ikt}^D equal to 1 if the currency choice for a given firm-product-destination-month is the dollar.

Second, we estimate exchange rate pass-through (ERPT) by regressing changes in export prices on changes in exchange rates interacted with firm characteristics. We start with annual data on trade flows and firm characteristics for the period 2012 to 2020 as our benchmark specification; we then turn to estimating the dynamics of ERPT by using the monthly data and varying the horizon of the change in each variable. The dependent variable is the log change in the export price of firm-product i to destination country k at time t, measured as the ratio of export value to export quantity (unit value):

$$\Delta p_{ikt}^* \equiv \Delta \log \left(\frac{\text{Export value}_{ikt}^*}{\text{Export quantity}_{ikt}} \right), \tag{17}$$

where values are converted to the destination currencies k (hence $*$ superscript) and quantities are measured as weights (where available) or units.[20] Summary statistics for all variables and further details on data construction are provided in Appendix B.

[19]From theory, it is desirable to know the firm's sales as a share of total industry sales (including all imports *and* local sales) rather than just sales by Belgian firms; however, obtaining such a measure for all destination countries is infeasible.

[20]Despite the high degree of disaggregation in the CN product codes, unit values may still be an imprecise proxy for prices because there may be more than one product within a CN 8-digit code exported by the firm, resulting in unit value changes due to compositional changes in aggregation, or because of errors in measuring quantities. To minimize these issues, we clean the data by dropping the observations with abnormally large price jumps, with year-to-year price ratios above 3 or below 1/3.

In some of our analysis, we separate the subsets of dollar-pegged and floating destinations. We follow Ilzetzki, Reinhart, and Rogoff (2019) and use monthly data (from 2012 to 2018) to classify as pegs and partial pegs all countries with an annualized root mean squared error of exchange rate changes against the dollar below 5%, identifying 65 dollar pegs (in addition to the US) among 179 destination countries, which jointly account for 44% of Belgian exports outside the EU.

3.2 Stylized facts on currency choice

We start by documenting the overall incidence of different currencies in Belgian exports and imports. In Table 1, we report the shares of currency use (for the euro, dollar, and other currencies combined) in Belgian ex-EU exports and imports for our full sample (March 2017 to December 2020). We report the shares both by the number of observed transactions (at firm-product-country-month level) and by the value of trade flows. For exports, the euro accounts for two-thirds of the observations, yet only 35% of the value, suggesting that it is the smaller transactions that are denominated in euros. In contrast, the dollar accounts for just 23% of observations, yet around half (51%) of the value of exports, making the dollar the dominant export currency. The other currencies combined account for under 14% of Belgian exports, both in count and in value terms, and for the most part correspond to the destination currency. Therefore, the incidence of local (destination) currency pricing — other than the dollar — is not very high in Belgian exports.[21]

For imports, the distribution of value shares across these different currency categories is similar to exports, with a somewhat larger role of the euro at the expense of the share of other currencies: the dollar still accounts for around half of the value of imports, the euro accounts for 43%, and all other currencies combined account for only 6%. For imports, however, there is almost no discrepancy between the shares in terms of number of observations and in value terms, suggesting that on average there is no difference in the size of the transactions across the three currency bins that we consider. The limited role of the other currencies suggests that producer currency pricing — again outside of the case of the dollar — is an infrequent phenomenon in Belgian imports.

Differentiated goods (defined by the Rauch classification) account for more than 80% of the observations and 60% of the value of trade (for both exports and imports). The distributions across currency categories for differentiated goods show similar patterns to the overall value shares, with a more pronounced role for other currencies at the expense of the dollar share. Unsurprisingly, the role of the dollar is particularly dominant for commodities and homogeneous goods (non-differentiated category, where the dollar accounts for 66% of exports and 72% of imports), while it is smaller for the differentiated products (42% and 39%, respectively). The euro share is equally prominent for differentiated exports (37%) and it is even larger for differentiated imports (53%). Note that the use of third currencies, which are nearly absent in the non-differentiated trade invoicing, becomes considerably more prevalent

[21]Importantly, these invoicing patterns are not driven by the US, which is the largest Belgian trade partner outside the EU, accounting for about 20% of Belgian ex-EU exports and imports. When we drop the US as an export destination, the share of the dollar use in Belgian ex-EU export invoicing only falls from 51% to 44%, and it hardly changes for ex-EU imports. This highlights the dominant role of the US dollar as the *vehicle* currency in international trade, consistent with the patterns documented by Gopinath (2016).

Table 1: Currency use in exports and imports

	Exports				Imports			
	Count share	Value share			Count share	Value share		
		All	Diff	Non-diff		All	Diff	Non-diff
Euro	0.653	0.349	0.371	0.316	0.387	0.425	0.532	0.265
Dollar	0.229	0.514	0.420	0.658	0.508	0.519	0.386	0.720
Other	0.118	0.137	0.209	0.026	0.104	0.055	0.082	0.015

Note: The currency data are at the firm-product (CN8)-country-month level for 2017:03 to 2020:12, for all ex-EU countries. "Other" row refers to currencies other than the euro or the dollar (in most cases, corresponding to the destination or source currency). "Diff" columns refer to differentiated goods as defined by the Rauch classification; "Non-diff" are all other goods.

for differentiated goods, in particular for differentiated exports (21%).

A clear message from Table 1 is that the currency patterns are at odds with standard macro models that assume either producer (PCP) or local (LCP) currency pricing. The *co-dominance* of euros and dollars in both importing and exporting suggests that neither LCP nor PCP accurately reflect currency choices. Instead, the patterns are more in line with recent work emphasizing the role of the dominant currencies (DCP). A distinctive feature of DCP relative to PCP and LCP is that the same currency is equally dominant in both imports and exports (see Gopinath and Itskhoki 2021). This feature is common to both the dollar and the euro in our data.

Nonetheless, a clear distinction between the dollar and the euro is that the dollar in many cases is also a vehicle currency, not used domestically by either importing or exporting country. Indeed, the dollar plays an outsized role relative to the US trade share. However, to gauge the relative importance of the US dollar, a more informative benchmark may be the Belgian trade share with dollarized and dollar-pegged countries. Indeed, for differentiated products, the value share of dollar invoicing of around 40% is smaller than the combined Belgian trade share of the US and dollar-pegged countries, equal to 47% for exports and 53% for imports.[22]

Bilateral trade flows The prominence of the two dominant currencies is also apparent in Belgian bilateral trade as shown in Figure 1, where we plot the dollar and the euro share of trade, for exports in the left panel and imports in the right panel. Each circle corresponds to a separate country outside the EU and the size of the circles depicts the share of the country in total Belgian trade. The fact that most circles lie on the negative diagonal, or slightly below it, reflects the dominance of the combined use of the dollar and the euro in trade invoicing with virtually every trade partner. Furthermore, exports to the US and India, among major trade partners, are invoiced largely in the US dollar, while trade with Switzerland and Turkey is invoiced largely in euros, with a lot of variation in the relative shares of the two dominant currencies across other trade partners, suggesting a role for country-level determinants of currency invoicing.

Figure 1 also shows that there are bigger departures towards third currencies in exports than in

[22]For all goods, where commodities account for a large portion of trade, the value share of dollar invoicing of 51% slightly exceeds the trade share of the US and pegged countries combined, equal to 44% for exports and 50% for imports.

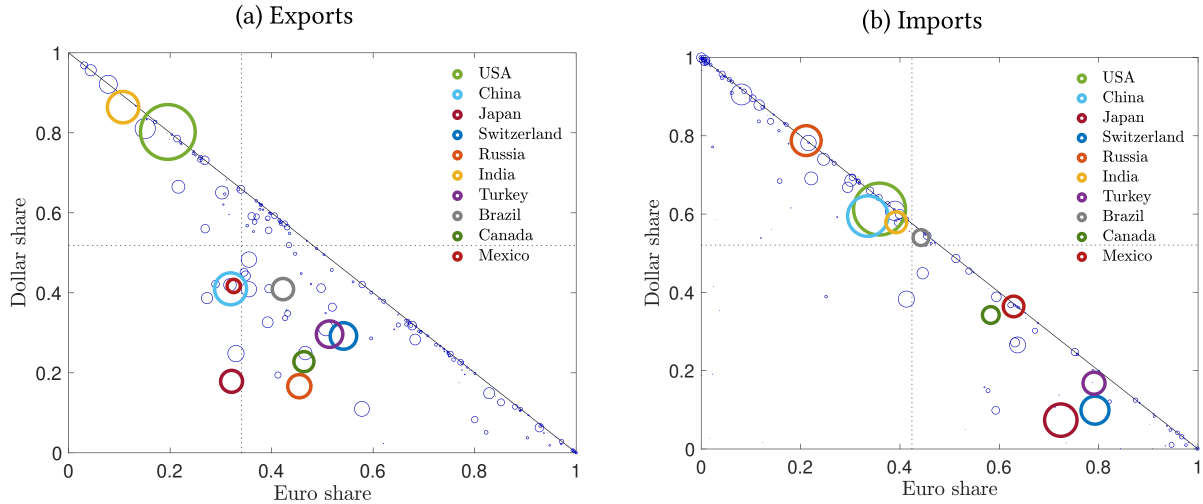


Figure 1: Dominant currencies in Belgian bilateral trade

Note: The figures plot the share of dollar invoicing against the share of euro invoicing by country, for Belgium ex-EU exports (on the left) and imports (on the right); circles represent the size of individual countries in Belgian trade; the distance to the diagonal corresponds to the share of third currencies (other than the dollar and the euro). The legends identify the top-10 Belgian trade partners outside the EU in terms of total trade. The dotted lines plot the average currency shares from Table 1.

imports. For imports, only Japan among the main trade partners has a sizeable third-currency share, which in particular implies that very few major industrial countries use their own currency when exporting to Belgium. However, for Belgian exports, there are more countries below the diagonal with a sizable share of trade invoiced in third currencies, which is in most cases the currency of the destination country. This includes China, Japan, Switzerland, Turkey and Russia, as well as a number of other smaller trading partners. The patterns are similar when we focus on the subsample of differentiated products in Appendix Figure A1, yet with a noticeable shift away from the dollar and towards the euro and third currencies for many destination and source countries.

Variance decomposition Lastly, we explore the dimensions of variation in export currency invoicing across the firm-product-destination-month observations in our sample. Specifically, in Table 2, we project the currency choice dummy ι_{ikt} (equal to one for non-euro use in exports) on various subsets of fixed effects, and report the adjusted R^2 from a value-weighted projection.[23] The first thing to note from column 1 is that firm fixed effects alone explain nearly two-thirds of the variation in export currency invoicing, and interacting firm fixed effects with country destinations in column 2 boosts that to 90%. That is, the bulk of the variation in export currency invoicing can be traced to the behavior of firms within given export destinations, with very little variation in currency choice over time: over the 45-month sample period, there was a switch between euros and non-euros for only 2.6% of observations.

In contrast, the variation across destination countries alone in column 3 accounts for only a small share, 15%, of the variation in the currency choice in our panel, while the variation across industries (at HS4 level) accounts for 40% in column 4. Interacting industry and destination-country fixed effects in

[23]The patterns for the unweighted projections and for imports are similar, albeit with slightly lower R^2s.

Table 2: Currency invoicing in exports: variance decomposition

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Adjusted R^2	0.657	0.899	0.147	0.400	0.648	0.767	0.915	0.935
# of observations ('000)	6,181.3	6,139.3	6,189.0	6,189.0	6,173.7	6,109.8	6,124.7	6,062.0
# of fixed effects ('000)	20.7	111.9	0.2	1.2	69.2	215.7	179.1	320.9
· firm	✓							
· firm×destination		✓					✓	✓
· destination			✓					
· HS4 industry				✓				
· HS4 industry×destination					✓		✓	
· CN8 product×destination						✓		✓

Note: Value-weighted projections of ι_{ikt}, a dummy for whether a given firm-product-destination-month export observation is in non-euros, on different sets of fixed effects; numbers of observations and included fixed effects (in thousands).

column 5 boosts the share of explained currency choice to 65%, almost the same as with the firm fixed effects alone.[24] The more micro-level dimensions of our data explain a greater share of variation in currency invoicing: interacting CN8-product and destination-country fixed effects in column 6 explains a large share, over 75%, of the variation, yet still not as much as with firm-destination fixed effects. Interestingly, adding industry-destination or even product-destination fixed effects to the firm-destination fixed effects, in columns 7 and 8, hardly changes the explanatory power of the firm-destination fixed effects alone. These patterns are suggestive of a central role played by the differential behavior across firms within industry-destinations in explaining the variation in currency choice in the data, consistent with the theory presented in Section 2.

4 Currency Choice

This section analyzes the firm-level determinants of currency choice in exports using an empirical framework motivated by the theoretical predictions in Section 2. To begin the analysis, Figure 2 illustrates the variation in currency choice across firms of different size by splitting all firms into eight bins ranked by employment.[25] The left panel presents the results for exports to all ex-EU destinations, showing a stark downward gradient in the use of the euro (PCP, plotted with the red bars): the smallest firms invoice their exports in euros with a nearly 80% incidence, the average-sized firms with around 60% incidence, and the largest firms with only a 40% incidence. For the majority of firms, the alternative currency is the dollar (the dark and light blue bars combined); and it is only the largest firms that have a non-trivial incidence of invoicing in the destination currency other than the dollar (the white bars), which is still very modest.

[24]Note that the number of included fixed effects is generally two orders of magnitude smaller than the number of observations; furthermore, the number of firm×destination fixed effects in column 2 is comparable to the number of industry×destination fixed effects in column 5, and smaller than the number of product×destination fixed effects in column 6.

[25]Specifically, we group all firms into non-overlapping bins with less than 50, 100, 200, 350, 550, 850, 2,000 employees, and a final bin combining all firms with more than 2,000 employees. The first 7 bins roughly correspond to the first 7 deciles of firms by ex-EU Belgian manufacturing exports, while the last bin contains only 12 firms that together account for 36% of exports and 50% of imports, as we show in Appendix Table A1.

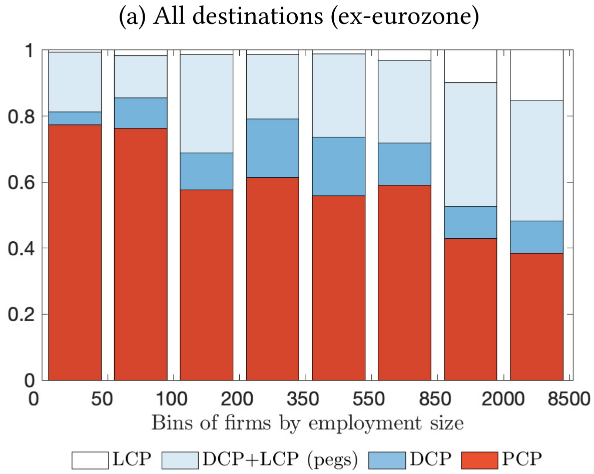


Figure 2: Firm size and currency choice in exports

Note: Export currency invoicing shares by employment size bins of firms: the red bars correspond to euros (PCP), the dark blue bars to dollars (DCP), the white bars to destination currency (LCP); the left panel additionally separates the category of dollar pricers to the US and dollar-peg destinations using the light-blue bars (DCP+LCP). The use of other currencies is less than 1.1% in every size bin, and we exclude it from totals. See also Appendix Table A1 and Appendix Figure A2.

Separating dominant and local currency pricing is challenging for dollar-pegged destinations, and is impossible to do so for the United States and other fully dollarized economies. Thus, the right panel of Figure 2 focuses on the subset of ex-EU destinations that excludes the United States and the dollar-pegged countries, to enable us to cleanly differentiate between LCP and DCP. Again we observe a clear pattern of decreasing incidence of the euro invoicing with firm size, but now we also see that the destination currency pricing in non-dollars (LCP) has a high incidence among the very large firms, exceeding the incidence of dollar pricing (DCP). The dollar-currency pricing is most pronounced among large firms with employment between 200 and 850 employees.

Figure 2 establishes a systematic pattern of currency choice across firms of different employment size, and Appendix Table A2 further describes the variation in firm characteristics across different bins of currency invoicing.[26] Since firm size correlates with many exogenous and endogenous firm characteristics, this suggests that the currency choice is indeed an active decision made at the level of the firm. In particular, these patterns of currency invoicing are consistent with the theory laid out in Section 2, where the size of the firm proxies for the strength of strategic complementarities in pricing. However, such patterns could also be consistent with alternative mechanisms, as firm size may correlate with other potential determinants of currency choice, as we further explore below.[27]

[26] Almost 90% of Belgian ex-EU exporters rely on euro invoicing, 9% use the dollar, and only 22 out of 2,765 use the destination currency for the majority of their exports. Firms invoicing in euros are much smaller in terms of employment, sales, exports and imports, while firms using destination currencies are the largest. Exporters that use the dollar are more import intensive (ex-EZ) and most likely to source their imports in dollars, as well as export to dollar-pegged destinations. There is less variation in the average export intensity or the share of ex-EU exports across the three subsets of firms.

[27] Appendix Figure A2 plots the relationship between firm size and currency use in imports, showing a lack of any robust pattern in contrast with exports. This is consistent with the common theoretical approach whereby currency choice in exports is a more active firm-level decision than in imports: exporters make currency-choice and price-setting decisions, while importers choose quantities given prices. We provide a further discussion of currency use in imports in Appendix C.

The main firm-level determinants We now study the determinants of currency choice in exports more formally, by estimating an empirical specification following the theory in Section 2.2, which emphasizes the firm's size and import intensity, as well as its competitors' currency choice in shaping the firm's own currency choice decision.

Specifically, we estimate a linear probability regression:

$$\mathbb{P}\{\iota_{ikt}=1\}=a_{t,sk}+b\varphi_i+c_S S_{ik}+c_L\log L_i+d\bar{\iota}_{-ik}. \tag{18}$$

The dependent variable is a dummy $\iota_{ikt}\in\{0,1\}$ at the firm-product(CN8)-destination-time level, with 0 corresponding to the use of the euro in export transaction (PCP) and 1 corresponding to any other currency, including the destination currency (LCP) and the dollar (DCP). We explore further the choice between the dollar and the destination currency below. The fixed effects $a_{t,ks}$ are at the date (month-year) and country-industry (HS4) level, respectively, thus we focus on the variation in currency choice across firms within industry-destinations.[28] As described in Section 3, φ_i is the firm's ex-EZ import intensity, S_{ik} is the firm's industry-destination sales share (relative to other Belgian exporters), and $\log L_i$ is the firm's employment. Lastly, $\bar{\iota}_{-ik}$ is the export-weighted average currency use of the firm's Belgian competitors in a given destination-industry (HS4) to capture *strategic complementarities* in currency choice.[29]

We report the results in Table 3. The first three specification focus on the firm-level determinants, and the next three add in the competitor currency choice. The specification in column 1 includes only the import intensity and the firm's destination market share. Both variables are positive and significant in predicting the currency choice outcome. That is, firms that use a larger share of imported (ex-EZ) intermediate inputs in their production costs and have a larger destination sales share among their Belgian competitors are less likely to invoice their exports in euros and thus more likely to use other currencies — the dollar or the destination currency.

In column 2, we split the import intensity variable into the share of imports sourced in euros and in all other currencies, and we find that it is only the non-euro import intensity that is statistically associated with the foreign currency use in exports, in line with the theoretical predictions.[30] That is, import-intensive firms are more likely to adopt non-euros in their export transactions only if their imports are themselves priced in non-euros, which in the vast majority of cases is the dollar. In other words, the higher the share of imports in dollars, the more likely the firm is to invoice its exports

[28]Our data is an unbalanced panel. Only 2.6% of the observations record a change in currency use across any two months, and therefore the results in the panel are essentially the same as the ones in a between cross-sectional regression (see Appendix Table A3). However, by including all time periods we capture more transactions as firms generally do not trade in each product-destination every period. We cluster the standard errors at the firm level, which corresponds to the most aggregate right-hand-side variable.

[29]Theoretically, it is desirable to know the currency use of all of the firm's competitors in a given destination, including the local competitors, however, the currency choice data for non-Belgian firms are unavailable to us, and thus we use $\bar{\iota}_{-ik}$ as a proxy. The same applies to the destination sales share variable S_{ik}, which is measured relative to other Belgian firms. Note that the industry-destination fixed effects alleviate this problem to some extent, albeit incompletely.

[30]Our baseline specifications use the overall ex-EZ import intensity φ_i, as the import currency data do not have complete coverage, and in particular we are missing currency data on all ex-EZ imports from within the EU (e.g., from the UK); the specification in column 2 of Table 3 includes a control for the missing currency portion of the firm's import intensity.

Table 3: Currency choice in exports

	Firm-level determinants			and competitor currency choice		
				OLS	IV	
Dep. var.: ι_{ikt}	(1)	(2)	(3)	(4)	(5)	(6)
φ_i	0.411^{***} (0.123)		0.286^{***} (0.105)	0.311^{***} (0.104)	0.308^{***} (0.112)	0.304^{***} (0.110)
φ_i^E		0.102 (0.195)				
φ_i^X		0.414^{***} (0.159)				
S_{ik}	0.125^{***} (0.032)	0.119^{***} (0.031)	-0.020 (0.033)	-0.011 (0.020)	0.024 (0.024)	
$\log L_i$			0.088^{***} (0.015)	0.085^{***} (0.014)	0.089^{***} (0.015)	0.088^{***} (0.015)
$\bar{\iota}_{-ik}$				0.031^{*} (0.018)	0.536^{***} (0.150)	0.364^{**} (0.150)
$\bar{\iota}_{-ik}$ × High S_{ik}						0.220^{**} (0.092)
# obs.	1,265,885	1,265,885	1,265,885	1,185,771	1,142,082	1,142,082
R^2_{adj}	0.528	0.532	0.579	0.387	–	–
Cragg-Donald F-stat					1,865.4	1,054.4
Hansen J-test [p-val]					2.95 [0.567]	8.26 [0.409]
Fixed Effects:						
month×year	✓	✓	✓	✓	✓	✓
industry & destination				✓	✓	✓
industry×destination	✓	✓	✓			

Notes: The observations are at the firm-product(CN8)-destination-month level for all ex-EU destinations from March 2017 to December 2020. The dependent variable $\iota_{ikt} = 0$ if the export transaction is invoiced in euros and 1 otherwise. Import intensity φ_i, destination sales share S_{ik} and log employment $\log L_i$ are as defined in Section 3; $\bar{\iota}_{-ik}$ is competitors' export-weighted foreign-currency use; High S_{ik} is a dummy for whether S_{ik} is above 0.1. Column 2 splits φ_i into euro and non-euro components φ_i^E and φ_i^X, additionally controlling for the "missing currency" component (not reported). Standard errors clustered at the firm level. Columns 1–4 are estimated with OLS; column 5–6 with IV (see text for description of instruments).

in dollars, which ensures *real hedging* by coordinating the pass-through into export prices with the movements in the marginal costs.[31]

Column 3 builds on the specification in column 1 by adding log employment as a measure of the overall firm size. This firm size variable is strongly statistically significant in shaping the currency choice, as illustrated in Figure 2, however, it also positively correlates with other firm-level variables, in particular the import intensity and the destination market share. Including firm employment in

[31]Note that financial hedging (by means of forward exchange rate contracts) is not a substitute for real hedging. Although it can insure against financial risk and/or relax financial constraints, it cannot affect the realized or the desired price of the firm. Currency choice and real hedging instead make it possible to bring the two prices closer together during periods of price stickiness. See Fauceglia, Shingal, and Wermelinger (2012), Lyonnet, Martin, and Mejean (2021) and Alfaro, Calani, and Varela (2021) on the mechanisms of real and financial hedging of exchange rate risk.

column 3 reduces somewhat the coefficient on the firm's import intensity, yet still leaves it positive, statistically significant and economically large.[32] The coefficient on the destination market share, however, becomes statistically insignificant and close to zero, which may be due to a number of reasons: (i) Employment is a less noisy measure of firm size than our proxy for the destination-specific market share S_{ik}, which does not capture the sales of non-Belgian competitors of the firm; (ii) Currency choice is decided at the level of the firm, rather than firm-destination, and thus a firm-level size variable has more predictive power; and (iii) Currency choice is shaped by other forces that correlate with the overall firm size, such as fixed costs, as we explore further below.

Strategic complementarities In columns 4–6 of Table 3 we augment the specification in column 3 with the competitor currency choice variable $\bar{\iota}_{-ik}$, which is constructed as the value of exports invoiced in non-euros by all other Belgian exporters within an HS4 industry-destination. Since the variation in this variable is mostly across industry-destinations, we replace the interactive industry-destination fixed effects with the industry and destination fixed effects included separately. The OLS specification in column 4 results in a small positive coefficient on the competitor currency choice, significant at the 10% level. However, this specification suffers from possible *simultaneity* and *reflection* problems, which we address using instrumental variables estimation in the subsequent columns.

Our instrument set comprises two distinct types of instruments. The first set proxies for the marginal costs and markups of the firm's Belgian competitors: we calculate the export-weighted average within industry (HS4)-destination of all *other* Belgian firms' import intensity φ_i and log employment for 2017–2019. These instruments should correlate with the firm's own currency choice only via strategic complementarities with other firms, thus satisfying the exclusion restriction. As we do not have this information available for non-Belgian competitors, we construct a second set of instruments of the Bartik type, relying on macroeconomic variation. We use UN COMTRADE annual bilateral trade data at the HS 6-digit industry level for 2017–2019, excluding Belgium, to construct the shares of exports from the US, China and other dollar-pegged countries to country k at the HS4 industry level. For example, for a Belgian firm exporting to Japan, these instruments measure the share of Japan's imports from dollar-pegged countries, which increase the likelihood that the firm's competitors use dollar invoicing. The variation in these instruments relies on the monetary-policy decisions of countries to peg their exchange rates, which are plausibly exogenous to the variation in currency choice across Belgian exports within industries.

In our baseline specification, column 5, we include both sets of instruments and find a large and highly statistically significant coefficient on competitor currency choice, suggesting that a 10 percentage point increase in the incidence of foreign currency pricing by competitors increases the likelihood of a given firm to adopt foreign currency invoicing by 5.4 percentage points. The coefficients on the firm-level determinants of currency choice are very close to the baseline specification in column 3. The

[32] The overall ex-EU import intensity of Belgian exporters varies in our sample from 0.5% at the 5th percentile to 45% at the 95th percentile, with a mean of 14% percent (see summary statistics in Appendix Table A6). Thus, the variation across these percentiles of import intensity corresponds to a reduction of 13 percentage points (=0.29*0.44) in the probability of choosing euros for export invoicing. For comparison, the variation in employment is about 500 log points from the 5th to the 95th percentile (that is, almost 200 times), which corresponds to a 45 percentage point (=0.09*500) reduction in the probability of the euro invoicing, consistent with Figure 2.

instruments pass the overidentification J-test and the weak instrument test according to the Cragg-Donaldson F-stat.[33] Furthermore, the estimation results are very similar when we include each set of instruments separately (see columns 5–6 of Appendix Table A3), providing confidence in the validity of the instruments as they use very different type of variation for identification.

The theoretical analysis in Section 2.2 suggests that strategic complementarities should be particularly strong among firms with large destination market shares, which is the main reason we include firm destination sales share as a determinant of currency choice in our baseline specification. This determinant of currency choice only operates in industries where the firm's competitors are themselves pricing in foreign currencies, either in local or dollar. Therefore, a more complete specification should additionally include an interaction of S_{ik} and $\bar{\iota}_{-ik}$, as we add in column 6.[34] Indeed, using IV as in column 5, we find that this interaction is positive and statistically significant, identifying a much stronger response to competitor currency choice by the large firms. That is, strategic complementarities in currency choice are particularly pronounced among the large market-share exporters, in line with theoretical predictions.

Additional determinants Table 4 augments the baseline currency choice specification in column 3 of Table 3 with a number of additional firm-level determinants, motivated by the theoretical discussion in Section 2.4. To proxy for the fixed cost of using a currency, we include the firm's share of exports that are shipped within the eurozone in column 1. If there is a fixed cost involved with the use of different currencies, firms may choose to use the same currency across multiple destination markets, which is likely to be the euro for firms with a high export share to the eurozone. Indeed, this is a robust and pronounced pattern, which holds conditional on firm size. An alternative proxy for the fixed cost mechanism is the firm's overall export intensity, as more export intensive firms should be more willing to pay the fixed cost and adopt a foreign currency to invoice their exports. Interestingly, this more direct proxy for fixed costs does not affect the magnitude or significance of our baseline determinants of currency choice, including the firm size, suggesting a complementary role for a fixed cost mechanism.[35]

In column 2, we include the export intensity of the firm as an alternative proxy for fixed costs, measured as the ratio of the firm's total exports to total sales. However, we find it to be statistically insignificant when controlling for the overall size of the firm. In columns 3 and 4 we include another set of the firm's export currency choice correlates, namely dummies for its participation in international FDI, whether inward or outward.[36] These variables proxy for the international nature of the firm and/or whether the firm is part of a global value chain, which we expect increases the likelihood of choosing the dollar or another foreign currency in export pricing. This is indeed the case, and both dummies sig-

[33]The instruments also comfortably pass the alternative Montiel-Pflueger weak instrument test (equal to 21.6) and the Anderson-Rubin 95% confidence interval $[0.1, 0.97]$ rejects zero (see Andrews, Stock, and Sun 2019).

[34]More precisely, we interact $\bar{\iota}_{-ik}$ with a dummy variable for whether S_{ik} is at least 10%, separating large and small firms into two bins. The high bin accounts for 48% of the observations.

[35]We also experiment with alternative measures of firm size, including log total revenues and log total assets. All these variables are positively associated with non-euro invoicing; however, they are strongly positively correlated with firm log employment (with a correlation above 0.9), and thus cannot be included simultaneously.

[36]Specifically, we use two dummies that indicate whether a firm has inward or outward FDI: the dummies equal 1 if the firm has at least 10% inward or any outward FDI, respectively.

Table 4: Currency choice in exports: additional determinants

Dep. var.: ι_{ikt}	EZ share in exports (1)	Export share (2)	FDI inward (3)	FDI outward (4)	R&D (5)	Log TFP (6)	Financial variables (7)
φ_i	0.321^{***} (0.091)	0.281^{***} (0.106)	0.297^{***} (0.102)	0.267^{**} (0.103)	0.287^{***} (0.103)	0.344^{***} (0.101)	0.291^{***} 0.108
$\log L_i$	0.086^{***} (0.013)	0.087^{***} (0.015)	0.072^{***} (0.013)	0.059^{***} (0.014)	0.084^{***} (0.014)	0.074^{***} (0.009)	0.090^{***} (0.016)
Additional control	-0.265^{***} (0.056)	0.032 (0.025)	0.093^{***} (0.035)	0.140^{***} (0.035)	1.002^{**} (0.417)	0.075^{***} (0.024)	$\checkmark^{\dagger}$
# obs.	1,265,885	1,265,084	1,265,885	1,265,885	1,265,885	1,253,624	1,252,839
R^2_{adj}	0.588	0.580	0.583	0.586	0.582	0.588	0.599
Fixed Effects:							
month×year	✓	✓	✓	✓	✓	✓	✓
industry×destination	✓	✓	✓	✓	✓	✓	✓

Notes: Baseline specification (3) from Table 3 with additional controls (named in the title of each column); each specification additionally includes S_{ik}, which remains insignificant as in the baseline (not reported). EZ share in exports is the ratio of the firm's exports to the eurozone destination to its total exports. Export share is the ratio of the firm's total exports to all destinations relative to its total revenues from domestic sales and exports combined. FDI variables are dummies for whether the firm has inward and outwards FDI respectively. R&D is the R&D expenditure share in total sales. †Financial variables in column 7 include three measures of the firm's financial/liquidity constraints and solvency, as described in the text.

nificantly increase the likelihood of foreign currency invoicing: a firm that engages in inward (outward) FDI is 10 (14) percentage points less likely to use the euro in pricing of its exports. We also experiment with alternative measures of firm performance and find that the firm's R&D intensity and measured TFP correlate positively with the likelihood of foreign currency invoicing (see columns 5 and 6).

Finally, we explore the possibility that export currency invoicing is shaped by the firm's financial decisions and/or financing constraints. Our data do not contain information on the currency of the firm's financing (which is likely disproportionately in euros in the eurozone), instead we have a variety of conventional balance sheet variables. In column 7 of Table 4 we include three variables commonly viewed to capture the firm's financial/liquidity constraints and solvency: namely, the cash ratio (to short-term debt), the coverage ratio (profits relative to debt service) and the leverage ratio (debt relative to assets). The first of these variables is positively associated with foreign-currency invoicing, the second correlates negatively, while the third is not significant. While this might be suggestive of a financial channel of currency invoicing, a complete study requires measurable variation in the currency of financing, which we leave to future research.[37] What we establish here is that the inclusion of the commonly used balance-sheet variables does not affect our main coefficients of interest on the import intensity and the size of the firm, thus suggesting that the financial channel is complementary to the main determinants emphasized in Table 3.

[37] The currency of financing, as well as the prevalence of hedging, may be correlated with firm size, as suggested recently by Lyonnet, Martin, and Mejean (2021) and Alfaro, Calani, and Varela (2021).

Robustness We conduct further robustness checks on our baseline specification in Appendix Table A3. First, we consider different subsamples of our full sample in column 3 of Table 3. In column 1, we show that our baseline results are stronger in the subsample of differentiated products, where the theory applies most directly, and are less precisely estimated for the set of non-differentiated products in column 2. To address the possibility of mismeasurement of variables for multi-product firms, column 3 only includes the firm's main product, with the results also holding strongly for this subsample.[38] We also show, in column 4, that the results are not driven by pooling observations over time: the results hold for a given cross-section of the data (e.g., June of 2017), and the standard errors are of similar size to those in the full sample, suggesting that the firm-level clustering results in an appropriate correction of the standard errors in the pooled panel.

Second, we experiment with aggregate macroeconomic determinants at the country and industry level in place of the interactive industry-destination fixed effects. We find that the likelihood of invoicing in euros (producer currency) is lower for exports to the dollar-pegged destinations, the destinations with low CPI inflation, high GDP per capita, and to larger trade partners (in line with the patterns documented in the earlier literature, see e.g. Goldberg and Tille 2008, 2016). None of these controls, which are absorbed into fixed effects in our baseline specification, have any impact on the estimated coefficients for our main firm-level variables of interest.

Vehicle currency use So far, we have focused on the determinants of a firm's choice between invoicing in euros and any other foreign currency, without distinguishing whether the foreign currency is a *vehicle* currency. There are two main reasons for this approach. First, theoretically, there is a clear mapping between firm characteristics and the choice between producer currency and other currencies. Firms with low exposure to foreign inputs and weak strategic complementarities in pricing are likely to adopt producer currency pricing, which ensures high short-run exchange rate pass-through into destination prices. In contrast, firms with high exposure to foreign inputs and strong strategic complementarities are more likely to adopt foreign currencies. However, the theory provides a less sharp prediction regarding which foreign currency will be chosen. For example, for exporters that intensively rely on foreign inputs, the choice between local and vehicle currencies also depends on the statistical properties of the exchange rates and the composition of currencies used in import invoicing. Similarly, strong strategic complementarities can favor either the dominant or local currency, depending on the composition of competitors and their pricing decisions in the foreign market.

Second, distinguishing between the choice of local and dominant currency is complicated by the fact that many countries peg their exchange rates to the dollar. From a theoretical point of view, the differential benefit of using the dollar versus the local currency is minimal for these countries. And in practice, almost all exports to dollar-pegged destinations are invoiced in either euros or dollars, and almost never in destination currencies, thus limiting the empirical variation needed for identification.

To cleanly distinguish between the choice of vehicle and local currency, we focus on the subsample of firms that choose non-euros in their export pricing and consider only export destinations with a

[38]The main product subsample consists of all firm's HS8 varieties that correspond to its largest HS4 industry, which jointly account for at least 60% of the firm's total exports.

Table 5: Vehicle currency choice in exports

Dep. var.: ι^D_{ikt}	All products (1)	(2)	(3)	(4)	(5)	Differentiated products (6)	(7)
φ_i	0.005 (0.106)						
φ_i^E		−0.106 (0.142)	−0.113 (0.142)	−0.060 (0.124)	−0.045 (0.142)	−0.123 (0.139)	−0.090 (0.136)
φ_i^X		0.503*** (0.158)					
φ_i^D			0.526*** (0.165)	0.626*** (0.160)	0.541*** (0.170)	0.705*** (0.178)	0.632*** (0.193)
$\log L_i$	− 0.092*** (0.010)	− 0.081*** (0.010)	− 0.080*** (0.009)	− 0.095*** (0.013)	− 0.081*** (0.011)	− 0.085*** (0.010)	− 0.088*** (0.011)
in-FDI				0.094** (0.040)			
$\bar{\iota}^D_{-ik}$					0.386* (0.209)		0.582** (0.280)
# obs.	202,412	202,412	202,412	202,412	191,016	158,939	154,152
R^2_{adj}	0.874	0.879	0.879	0.881	–	0.880	–
Cragg-Donald F-stat					349.3		395.6
Hansen J-stat [p-val]					12.356 [0.030]		7.070 [0.215]
Fixed Effects:							
month×year	✓	✓	✓	✓	✓	✓	✓
industry & destination					✓		✓
industry×destination	✓	✓	✓	✓		✓	

Notes: The observations are at the firm-product (CN8)-destination-month level for the subsample of non-euro-invoiced exports to non-pegged destinations only (i.e., excluding the US and dollar-pegged countries) from March 2017 to December 2020. The dependent variable is $\iota^D_{ikt} = 1$ for exports invoiced in dollar (DCP) and 0 in destination currency (LCP). Each specification includes S_{ik}, which is insignificant as in column 3 of Table 3 (not reported); in-FDI is the inward FDI dummy, as used in column 3 of Table 4. Columns 3–7 split import intensity φ_i into its euro and dollar components, φ_i^E and φ_i^D, controlling for the residual import intensity in other currencies (not reported). Standard errors are clustered at the firm level. Columns 5 and 7 are estimated using IV with the same instrument set as in column 5 of Table 3.

floating exchange rate with the dollar.[39] Using this smaller sample of firm-product-destinations, we estimate a specification for export currency choice between the vehicle and the local currency, which parallels the baseline specification in Table 3. Specifically, we define a dummy $\iota^D_{ikt} = 1$ when the US dollar is used in the export transaction and 0 if the destination currency is used.

We report the results in Table 5. The first column shows that the choice between local and vehicle currency is not affected by the overall ex-EZ import intensity. However, in the subsequent columns, where we split import intensity by currency, we find that importing in non-euros (φ_i^X), and in particular in dollars (φ_i^D), favors the use of the dominant currency in exporting, and the effect is both strong and economically large.

There is also a robust *negative* association between the absolute size of the firm (log employment) and the use of the dollar: the largest firms adopt local currency pricing instead of the dollar. Note,

[39]This subsample also drops observations where the currency choice is neither the dollar nor the destination currency, which occurs in 3% of non-euro observations (1.7% of all observations). Including these observations and classifying any third-currency use as vehicle does not change the results reported in Table 5.

however, that this sample only comprises the larger firms, as we limit the sample to firms that do not price their exports in the producer currency (euro). Even if surprising at first, this pattern is consistent with theory: to the extent that firm size proxies for strategic complementarities, we expect larger firms to adopt local currency pricing to ensure that their prices are better aligned with their local competitors in the destination country, who use the local currency by default.

In addition to firm size, the FDI variables used in columns 3 and 4 of Table 4 also correlate positively with the use of the dollar in exports, likely proxying for the international nature of the firm and its role in global value chains. We display the result for inward FDI in column 4 of Table 5, and the results for outward FDI are comparable. Finally, using instrumental variables as in Table 3, we find evidence of strong strategic complementarities in the dominant currency choice across Belgian exporters: firms with competitors invoicing in dollars are themselves more likely to adopt dollars in their exports (column 5). These effects are particularly pronounced in the subsample of differentiated products (columns 6–7), where the theory applies most directly.

5 Currency Invoicing and Exchange Rate Pass-through

Having established the firm-level determinants of currency choice, we now analyze the exchange rate pass-through (ERPT) into prices and quantities. We start with the analysis of ERPT into prices at an annual horizon, and then explore the dynamics of ERPT into both prices and quantities with monthly data. We focus on the differential impact of the flexible-price and sticky-price determinants of ERPT, and in particular on the contribution of the currency invoicing channel.

5.1 ERPT into prices at the annual horizon

We begin our analysis by studying how firm-product-destination prices respond to movements in both the euro-destination and the dollar-destination exchange rates, using annual data for the period 2012–2020. We interact exchange rate changes with flexible- and sticky-price determinants of pass-through to capture the realized ERPT both during the period of price stickiness and after price adjustment. Specifically, we estimate an empirical counterpart to the theoretical relationship (12) derived in Section 2:

$$\Delta p^*_{ikt} = \big[\alpha + \beta\varphi_i + \gamma \log L_i + \delta\iota_{ik}\big]\Delta e_{kt} + \big[\beta^D\varphi_i + \gamma^D \log L_i + \delta^D\iota^D_{ik}\big]\Delta e^D_{kt} + \nu_{skt} + \epsilon_{ikt}, \quad (19)$$

where the dependent variable Δp^*_{ikt} is the annual change in the firm's export price in the destination currency k, and Δe_{kt} and Δe^D_{kt} measure the depreciation of the destination currency k against the euro and the dollar, respectively.[40] We use the firm's ex-EZ import intensity φ_i to proxy for the marginal cost channel of ERPT and measures of its size (log employment $\log L_i$, and destination sales share S_{ik} in certain specifications) to proxy for the markup channel. The currency choice dummy ι_{ik} is equal to one if the firm prices in any currency other than the euro, and the dummy ι^D_{ik} is equal to

[40] The bilateral exchange rates are average monthly rates from the IMF, reported for each country relative to the U.S. dollar and converted to be relative to the euro for Δe_{kt}. The annual rates are averages of the monthly rates.

one if the currency choice is dollars specifically.[41] Finally, ν_{skt} are either industry$\times$destination$\times$year or industry$\times$destination *and* year fixed effects, depending on the specification; each specification additionally controls for the level terms corresponding to all interaction terms.

The coefficients in (19) have a clear mapping to the theory in Section 2. The coefficient α measures the ERPT of a counterfactual small Belgian firm that uses no inputs imported outside of the eurozone and prices all of its exports in euros. The theory predicts that $\alpha = 1$, corresponding to a complete ERPT of the euro-destination exchange rate into destination prices. The coefficients β, γ and δ are expected to be negative, reflecting the lower (incomplete) ERPT for firms that rely on foreign intermediate inputs (marginal cost channel), that are large in the destination market (markup channel), or price in foreign currency (sticky price channel), respectively. Symmetrically, we expect positive coefficients β^D, γ^D and δ^D to capture the pass-through of the dollar-destination exchange rate into destination prices for firms that rely on imported inputs, are large and invoice their exports in dollars. Lastly, the coefficients δ and δ^D measure the extent of price stickiness at the annual horizon.

The firm-level determinants of currency choice (φ_i and $\log L_i$, see (18)) and the currency choice itself (ι_i and ι_i^D) appear jointly in (19) as, respectively, the flexible-price and the sticky-price determinants of ERPT. This raises the question of how one can identify separately the contributions of these two sets of ERPT determinants — an identification challenge posed by Engel (2006). The resolution rests in the fact that the realized currency choice is both observable and has a direct effect on ERPT in the second stage, rather than just indirectly via sample selection as in e.g. the Heckman selection model. Indeed, the residual in (19) is driven by *idiosyncratic changes* in marginal costs and markups (e.g., productivity and demand shocks) that are plausibly orthogonal with currency choice and other *cross-sectional* firm-level variables.[42] As a result, estimation of (19) can be carried out directly with OLS without the need to conjecture functional forms or seek exogenous variation and exclusion restrictions, as we show in Appendix D.

We report our estimation results in Table 6, starting with the baseline specification (19) in column 1 for the full sample of ex-EU destinations. We find:

$$\alpha \approx 1, \qquad \beta \approx -\beta^D \approx -0.3, \qquad \gamma \approx -\gamma^D \approx -0.01, \qquad \delta \approx -\delta^D \approx -0.4,$$

with signs and magnitudes in line with the theory. All coefficients are strongly statistically significant, apart from the size coefficients γ and γ^D, which are only marginally significant at the 10% level.[43]

[41] Since we do not have currency data prior to 2017, we extrapolate currency invoicing from 2017-2020 backward to 2012-2016 at the firm-destination level. Specifically, we calculate each firm's share of exports by destination invoiced in non-euros and dollars, ι_{ik} and ι_{ik}^D. For 87% of the observations, these firm-destination shares are zero-one dummy variables; otherwise, we use fractional values. Our approach relies on the high persistence in the currency of invoicing we observe in the data (see Section 3); to the extent persistence is incomplete, our estimates of δ and δ^D provide lower bounds on the effects of price stickiness due to potential attenuation bias.

[42] The fact that currency choice is, in most cases, a zero-one dummy, while its flexible-price determinants are continuous variables, means that multicollinearity is also not an issue in practice. There is always a possibility of omitted variable bias; to address this, we experimented with including additional terms, used in Table 4 and Appendix Table A3, interacted with exchange rates, and found them to be insignificant and did not affect our main coefficients of interest (see the analysis in Table 7 below).

[43] Berman, Martin, and Mayer (2012) were the first to emphasize the differential ERPT across firms of different size and productivity. Once we control for the firm's import intensity and currency invoicing, the significance of the size interaction

Table 6: Exchange rate pass-through: annual horizon

	Baseline	Only flexible	Only sticky	Detailed fixed effects	Subsamples	
					US & Pegs	Non-pegs
Dep. var.: Δp^*_{ikt}	(1)	(2)	(3)	(4)	(5)	(6)
Δe_{kt}	1.007*** (0.029)	1.038*** (0.031)	1.004*** (0.009)	–	1.133*** (0.073)	1.026*** (0.029)
$\Delta e_{kt} \cdot \varphi_i$	– 0.257*** (0.080)	– 0.481*** (0.076)		– 0.251** (0.102)	– 0.322** (0.133)	– 0.238** (0.105)
$\Delta e^D_{kt} \cdot \varphi_i$	0.328*** (0.075)	0.500*** (0.071)		0.351*** (0.113)		0.339*** (0.087)
$\Delta e_{kt} \cdot \log L_i$	– 0.013* (0.007)	– 0.029*** (0.007)		– 0.020* (0.010)	−0.009 (0.011)	−0.015 (0.009)
$\Delta e^D_{kt} \cdot \log L_i$	0.010 (0.008)	0.016** (0.008)		0.012 (0.011)		0.008 (0.009)
$\Delta e_{kt} \cdot \iota_{ik}$	– 0.383*** (0.037)		– 0.406*** (0.036)	– 0.305*** (0.051)	– 0.421*** (0.048)	– 0.344*** (0.054)
$\Delta e^D_{kt} \cdot \iota^D_{ik}$	0.411*** (0.041)		0.434*** (0.040)	0.349*** (0.055)		0.379*** (0.050)
# obs.	339,684	339,684	339,684	276,146	128,537	211,147
$R^2_{adj.}$	0.060	0.059	0.060	0.085	0.016	0.077
Fixed Effects:						
year	✓	✓	✓		✓	✓
ind.×dest.	✓	✓	✓		✓	✓
ind.×dest.×year				✓		

Notes: The data are at the firm-product-destination-annual level for 2012-2020. The dependent variable Δp^*_{ikt} is the log change in the export unit value in the destination currency, as defined in (17); Δe_{kt} and Δe^D_{kt} are the log changes in the bilateral euro-destination and dollar-destination exchange rates. Standard errors are clustered at the destination-year level.

Therefore, we find that small non-import-intensive firms that invoice their exports in euros exhibit *complete* pass-through of the euro-destination exchange rate. The firms that rely intensively on the ex-EZ imported inputs exhibit markedly lower pass-through of the euro-destination exchange rate and significant pass-through of the dollar-destination exchange rate. Finally, currency invoicing dummies have a large impact on pass-through consistent with a large fraction of prices ($\approx 40\%$) still being sticky at the annual horizon in the currency they are invoiced, as we further discuss below.

In columns 2 and 3 of Table 6, we consider the flexible-price and the sticky-price determinants of pass-through separately. When the currency choice dummies are omitted in column 2, we find larger coefficients (in absolute value) on the flexible-price determinants of ERPT, consistent with omitted variable bias, since flexible-price variables predict the currency choice of the firms, as we showed in Section 4. Similarly, omitting flexible-price determinants of ERPT in column 3 inflates somewhat the coefficients on the currency choice dummies, although quantitatively more modestly. This is again

varies from sample to sample and depends on the specific size variable used. The sign of the coefficient is, however, robustly consistent with the theory, and the coefficient is economically significant since L_i varies by 500 log points from 5th to 95th percentiles of the firm size distribution. If, for example, we were to instead use employment size bins, with 500-employee cutoff, the significance of both size interactions increases as we show in column 2 of Appendix Table A4.

consistent with omitted variable bias, underscoring the importance of controlling simultaneously for the flexible-price and sticky-price determinants of ERPT, as predicted by the theory in (12).

Columns 4–6 of Table 6 estimate various robustness specifications. First, in column 4, we include a full set of industry×destination×year fixed effects. The advantage of this specification, which includes over 60,000 fixed effects, is that all of the identification is from firms' differential responses to the same exchange rate movement within a given industry-destination at a given point in time, and thus facing the same general equilibrium environment. However, it comes at the cost of not being able to identify the level of ERPT captured by α, because the fixed effects in this specification fully absorb the exchange rate variation, thus allowing us to identify only the differential pass-through across firm-products. Nonetheless, we find that all estimated coefficients remain similar to our baseline specification in column 1, which included industry×destination and year fixed effects separately.

The last two columns consider two sets of export destinations with distinct exchange rate regimes. In column 5, we include all countries that are pegged to the dollar as well as the US, and in column 6 we include all other destinations. By construction, the pegged countries lack sufficient variation in the dollar-destination exchange rate, and thus we omit Δe^D_{kt} from this specification, while we keep it for the non-pegged countries. Both specifications display the same patterns of coefficients, even though they comprise very different destinations and column 5 omits the dollar-destination interactions. In contrast, if we were to omit the dollar-destination exchange rate Δe^D_{kt} interactions in the subsample of non-pegged countries, this would result in a strong downward omitted variables bias on the euro-destination exchange rate Δe_{kt} interactions, making them small and insignificant (see column 7 in Appendix Table A4). This emphasizes the importance of working with the theoretically-consistent ERPT equation, which in particular must include the dollar-destination exchange rate where it is relevant.[44]

Currency invoicing: causal effect or selection The large non-zero coefficients on the currency invoicing dummies ι_{ik} and ι^D_{ik} in shaping ERPT at the annual horizon in Table 6 suggest an important role for price stickiness in the currency of invoicing. One potential concern, however, is that these effects arise due to selection of particular types of firms with different desired ERPT into different currency of pricing rather than a direct causal effect of foreign-currency price stickiness. The specifications in columns 1–3 of Table 6 address this to some extent by showing the importance of including jointly both the flexible-price and the sticky-price determinants of ERPT.[45] We now provide further evidence in support of a direct causal effect of currency invoicing on the realized ERPT at the annual horizon.

To check whether we are merely picking up a selection effect, we construct proxies of currency choice denoted with z_{ik} and z^D_{ik}, in three different ways. The first one, included in columns 1 and 2 of Table 7, is constructed as the predicted values for ι_{ik} and ι^D_{ik} from the baseline currency choice regressions in columns 3 of Tables 3 and 5, respectively. That is, we set $z_{ik} = \widehat{\iota_{ik}}$ and $z^D_{ik} = \widehat{\iota^D_{ik}}$ based on the linear probability specifications for currency choice that we estimate in Section 4. The idea is

[44] We show that our estimation results are robust to different subsamples in Appendix Table A4, including separately for differentiated and non-differentiated products, for the firms' main product, in exports to OECD destinations and to the US only.

[45] Column 1 of Appendix Table A4 provides a further robustness which augments the baseline specification with firm fixed effects that absorb unobserved firm-level variation.

Table 7: ERPT: predicted versus actual currency choice

	Predicted currency $z_{ik}=\widehat{\iota_{ik}}$ and $z^D_{ik}=\widehat{\iota^D_{ik}}$		Competitor currency $z_{ik}=\bar{\iota}_{-ik}$ and $z^D_{ik}=\bar{\iota}^D_{-ik}$		EZ share in exports $z_{ik}=z^D_{ik}=\chi^E_i$	
Dep. var.: Δp^*_{ikt}	(1)	(2)	(3)	(4)	(5)	(6)
Δe_{kt}	1.025***	1.020***	1.072***	1.029***	1.041***	1.019***
	(0.035)	(0.034)	(0.033)	(0.031)	(0.029)	(0.029)
$\Delta e_{kt}\cdot\varphi_i$	– 0.282***	– 0.244***	– 0.501***	– 0.317***	– 0.476***	– 0.267***
	(0.088)	(0.088)	(0.078)	(0.080)	(0.076)	(0.080)
$\Delta e^D_{kt}\cdot\varphi_i$	0.454***	0.426***	0.557***	0.422***	0.495***	0.343***
	(0.087)	(0.087)	(0.075)	(0.078)	(0.072)	(0.075)
$\Delta e_{kt}\cdot\iota_{ik}$		– 0.318***		– 0.363***		– 0.359***
		(0.047)		(0.037)		(0.036)
$\Delta e^D_{kt}\cdot\iota^D_{ik}$		0.360***		0.394***		0.370***
		(0.060)		(0.042)		(0.038)
$\Delta e_{kt}\cdot z_{ik}$	– 0.466***	– 0.175***	– 0.170***	– 0.070**	0.096**	0.027
	(0.043)	(0.056)	(0.038)	(0.034)	(0.045)	(0.044)
$\Delta e^D_{kt}\cdot z^D_{ik}$	0.466***	0.126*	0.177***	0.054	– 0.098**	−0.061
	(0.053)	(0.075)	(0.047)	(0.041)	(0.048)	(0.047)
# obs.	247,507	247,507	293,710	293,710	303,993	303,993
$R^2_{adj.}$	0.059	0.059	0.060	0.061	0.057	0.057
Fixed Effects:						
date	✓	✓	✓	✓	✓	✓
ind.×dest.	✓	✓	✓	✓	✓	✓

Notes: The sample is at the firm-product-destination-annual level for 2012-2020, as in column 1 of Table 6, but there are fewer observations due to missing z_{ik}, and we keep the same observations in each pair of columns for ease of comparison. The z_{ik} in the first two columns is the predicted currency choice estimated from columns 3 in Tables 3 and 5; the z_{ik} in columns 3 and 4 is the competitor currency choice in non-euros and in dollars; and in the final two columns it is the EZ export share.

to separate the selection effect, captured by the currency choice proxies z_{ik} and z^D_{ik}, from the causal effects of actual realized currency choice given by ι_{ik} and ι^D_{ik}. If the selection effect is dominant, we expect z_{ik} and z^D_{ik} to reduce the impact of ι_{ik} and ι^D_{ik}, when included jointly. If the direct causal impact is important, we instead expect that the inclusion of ι_{ik} and ι^D_{ik} should dominate the impact of z_{ik} and z^D_{ik}.

In columns 3 and 4 of Table 7 we instead use the firm's competitor currency choice, $z_{ik}=\bar{\iota}_{-ik}$ and $z^D_{ik}=\bar{\iota}^D_{-ik}$, used in column 5 of Tables 3 and Table 5 respectively to predict the firm's own currency choice. Finally, in columns 5 and 6 of Table 7 we use the firm's export share to the eurozone χ^E_i as a measure of both z_{ik} and z^D_{ik}, since it is a strong predictor of the use of the euro in exports to the ex-EU destinations (recall column 1 of Table 4), but should not otherwise impact pass-through dynamics in these destinations, thus offering a test of an exclusion restriction.

The results in Table 7 provide support for a direct causal effect of currency invoicing on ERPT. When the realized currency invoicing dummies ι_{ik} and ι^D_{ik} are not included (in the odd numbered columns), the predictors/proxies of currency choice z_{ik} and z^D_{ik} have a strong impact on ERPT. However, once we also control for the actual currency of invoicing (in the even columns), the role of the predictors becomes quantitatively much smaller and often insignificant. Most importantly, the coefficients on the actual currency choice dummies are not significantly different from those reported in the baseline specification in column 1 of Table 6 when we control for the predictors of currency choice z_{ik} and z^D_{ik}. This evidence suggests that it is the actual realized currency choice that directly matters for ERPT rather than selection of firms into differential invoicing based on endogenous or exogenous characteristics.

5.2 Dynamics of pass-through into prices and quantities

We now turn to the dynamics of exchange rate pass-through by re-estimating (19) using monthly data for the period January 2012 to December 2020, for different time horizons from 1 to 24 months, gradually increasing the horizon over which we measure price and exchange rate changes. Indeed, the regression specification (19) applies, in general, over any time interval, with the coefficients changing to reflect the relative importance of the sticky- and flexible-price determinants of pass-through at different horizons.

Concretely, we estimate the following specification for each regression horizon h, as in (13):

$$\Delta_h p^*_{ikt} = \big[\alpha_h + \beta_h \varphi_i + \delta_h \iota_{ik}\big]\Delta_h e_{kt} + \big[\beta^D_h \varphi_i + \delta^D_h \iota^D_{ik}\big]\Delta_h e^D_{kt} + \nu_{skt} + \epsilon_{ikt}, \tag{20}$$

where Δ_h is the h-month difference, e.g. $\Delta_h e_{kt} \equiv e_{kt} - e_{k,t-h}$, and the other variables are as in the benchmark specification (19) above. We also include log employment (as a measure of firm size) interacted with exchange rate changes, which tend to be insignificant at most horizons. In addition, we include firm fixed effects to control for possible omitted firm characteristics, as in column 1 of Appendix Table A4. The estimates at very short horizons are noisy due to the standard unobserved timing issue of the shock and price adjustment, therefore we report the results starting from a four-month horizon and up to 24 months, $h \in \{4, .., 24\}$, where the timing issue no longer results in noisy ERPT estimates.[46]

The sticky-price coefficients δ_h and δ^D_h in (20) estimate respectively the differential pass-through of the euro- and dollar-destination exchange rates for the euro- and dollar-pricing firms relative to a comparable firm pricing in the destination currency. From theory in Section 2.2, we expect $\delta_h < 0 < \delta^D_h$, $\alpha_h = 1$ for all h, and $\beta_h < 0 < \beta^D_h$. As prices become more flexible over longer horizons, we expect the sticky-price coefficients to decline in absolute value towards zero with h, while the flexible-price coefficients β_h and β^D_h increase in magnitude reflecting the adjustment of prices towards their desired levels that are shaped, in part, by the import intensity of the firms (recall (12)).

These are exactly the patterns we find in the data, as we show in Figure 3 which plots the estimated coefficients from the dynamic specification (20). The left panel plots the dynamics of the euro-destination ERPT for the euro-pricing firms in yellow, α_h, and for the non-euro-pricing firms in blue, $\alpha_h + \delta_h$, as well as the dynamics of the dollar-destination ERPT for the dollar-pricing firms in red, δ^D_h. The results show that we cannot reject that the pass-through of the euro-destination exchange rate into destination prices is complete ($\alpha_h = 1$) at all horizons h for the euro pricing firms, while the pass-through of non-euro pricing firms is incomplete and gradually increases over time, from around 40%

[46] An advantage of the monthly data is that we do not need to average the exchange rates over the year, as we did in Table 6, and therefore the pass-through estimates have a cleaner timing interpretation for various horizons h. An alternative approach is a distributed lags specification, which projects a one-month price change Δp^*_{ikt} on an increasing number of lags of the monthly exchange rate changes, $\{\Delta e_{k,t-j}, \Delta e^D_{k,t-j}\}^{j=h}_{j=0}$, and estimates an impulse response. However, this approach is too demanding of the data since we focus on the differential response to exchange rates across firms captured by the interaction terms. We discuss below the one-to-one relationship between our estimates and the impulse response.

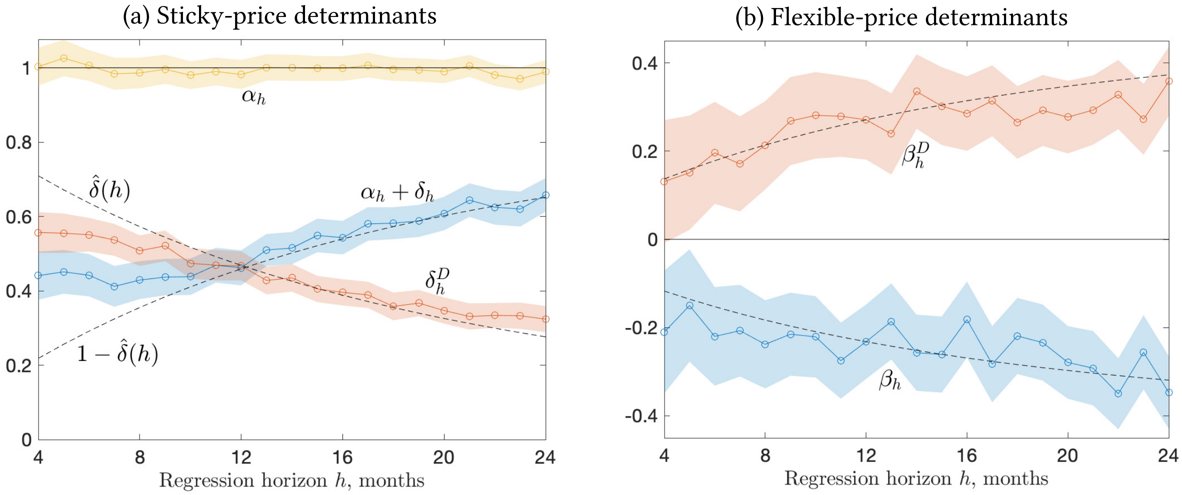


Figure 3: Exchange rate pass-through dynamics

Note: Coefficient estimates from the ERPT specification (20), with firm, industry-destination and time fixed effects, for different horizons h; shaded areas reflect 95% confidence intervals. The left panel plots the sticky-price coefficients: α_h depicts the euro-destination ERPT for the PCP firms and $\alpha_h + \delta_h$ for the foreign-currency (LCP and DCP) pricing firms; δ_h^D corresponds to the additional dollar-destination ERPT of the DCP firms (see text). The right panel plots the flexible-price coefficients: β_h and β_h^D depict the euro-destination and the dollar-destination ERPT per unit of the firm's ex-EZ import intensity φ_i.

over 4 months to 65% over 24 months. The dollar ERPT of the dollar-pricing firms is high (nearly 60%) in the short run and gradually decreasing with horizon h, to slightly above 30% over 24 months.[47]

The right panel of Figure 3 shows, in turn, that the more a firm relies on foreign inputs in production (as captured by ex-EZ import intensity φ_i), the lower is the pass-through of the euro exchange rate and the higher the pass-through of the dollar exchange rate into its destination price, for any given currency of invoicing. These effects are mute in the short run and gradually build up over time, continuing to increase beyond the one-year horizon, which was the benchmark in our analysis in Table 6.

How sticky are prices? We now use a structural model of price setting to evaluate the duration of price stickiness implied by our dynamic ERPT estimates. Towards this end, we compare our estimates $\{\delta_h, \delta_h^D, \beta_h, \beta_h^D\}_h$ with the structural predictions of a Calvo model described in Section 2.3, which suggests that the sticky-price coefficients $|\delta_h| = \delta_h^D = \hat{\delta}(h)$, where $\hat{\delta}(h) = \frac{1}{h}\frac{\lambda}{1-\lambda}(1-\lambda^h)$ as derived in (14) and λ is the Calvo non-adjustment probability. Furthermore, $|\beta_h|$ and β_h^D increase in proportion with $1-\hat{\delta}(h)$. We depict these theoretical predictions with black dashed lines in both panels of Figure 3. Specifically, we match the estimated pass-through rates at $h = 12$ by setting the Calvo parameter $\delta \approx 0.90$ in the left panel, and we use this calibrated value of λ and plot $\pm\bar{\beta}\cdot(1-\hat{\delta}(h))$ in the right panel, setting the value of the long-run elasticity $\bar{\beta} \approx 0.50$ to again match the estimated coefficients at $h = 12$.

Comparing the black dashed lines with our estimates, we find that the dynamic patterns in the data are broadly in line with the quantitative predictions of the Calvo sticky price model. Furthermore, both δ_h and δ_h^D follow $\hat{\delta}(h)$, while β_h and β_h^D in the right panel evolve nearly perfectly in line with $1-\hat{\delta}(h)$

[47] From the left panel of Figure 3 note also that δ_h (the gap between the yellow and blue lines) is a near mirror image of δ_h^D (the red curve), suggesting the same patterns of price stickiness for goods priced in euros and in dollars.

across the full range of estimation horizon h. Note that we do not use information on the dynamics of (β_h, β_h^D) to calibrate λ, and therefore the right panel of the figure offers an over-identification test for the Calvo model calibrated to match ERPT estimates in the left panel at $h = 12$.

Our dynamic estimates indicate an expected price duration of nearly 10 months (equal to $1/(1-\lambda)$), consistent with many direct estimates of price durations in the data (see e.g. Nakamura and Steinsson 2008, Gopinath and Rigobon 2008). What are the implications of this estimate? First, $\lambda^{12} = 0.28$ means that about 28% of export prices have not yet been adjusted a year after the shock. This fraction falls to $\lambda^{24} = 0.08$ two years after the shock. Second, the impulse response of the differential price response to the exchange rate across currency of invoicing, which is the causal effect of foreign-currency price stickiness, is also given by λ^h (see Section 2.3). This is different from our estimates δ_h and δ_h^D which are larger in absolute value than λ^h for all $h > 1$. For example, the ERPT estimates at $h = 12$ are around 0.5 as opposed to 0.28. Indeed, δ_h and δ_h^D in the estimating equation (20) capture *average* pass-through differentials over the estimation horizon h rather than the impulse response at h, but there is a general one-to-one mapping between the two, as we illustrate here in the parametric case of the Calvo model.

The one notable discrepancy with the Calvo model is in the ERPT in the short run, for horizons of 3 quarters or less, where the data exhibit lower rates of ERPT relative to the model. In contrast, the observed empirical dynamics from 3 quarters out to 8 quarters line up well with the predictions of the Calvo model. Therefore, we cannot reject the model prediction that pass-through differentials across comparable firms pricing in different currencies are expected to disappear in the long-run at a rate consistent with the Calvo model of price adjustment (*cf.* Gopinath, Itskhoki, and Rigobon 2010).

What are the possible reasons for the discrepancy between the Calvo model and the empirical ERPT dynamics at short horizons? One possibility is measurement error since we do not know the exact timing of price changes and exchange rate shocks within a month, which leads to attenuation bias over short horizons. Another possibility is model misspecification. If the Calvo model is correct for each firm-product, but firms or products are heterogeneous in their Calvo adjustment probability, then we expect the observed coefficients in the short run to reflect the early adjustments by the more flexible firm-products, while the long-run ERPT patterns are dominated by the more sticky firm-products taking a long time to adjust their prices. For example, differentiated products exhibit longer price durations than homogenous products: this is evident from the differential pass-through patterns between the two categories of goods in columns 3–4 of Appendix Table A4. Estimating the monthly dynamic specification (20) for differentiated and non-differentiated products separately, we find that the implied λ's are 0.9 and 0.8, respectively, corresponding to average price durations of 10 and 5 months for differentiated and non-differentiated products.

In sum, our results establish an important role played by both flexible-price and sticky-price determinants of ERPT. The international dimension of our data offers a new test of the sticky price mechanism by comparing outcomes for firms that export in the same industry to the same destination and are similar in terms of their observable characteristics, such as size and import intensity, yet differ in the currency of invoicing. Our results provide new evidence for the long-run convergence of ERPT across firms invoicing exports in different currencies, conditional on the same observable firm characteristics.

Response of export quantities A crucial question is whether prices are allocative, and specifically whether the differential pass-through into prices across different currencies of invoicing translates into a differential response of quantities as well. After all, most of international trade is either among related parties or between long-term trade partners, and as such export prices might not be allocative. In contrast, direct evidence of the allocative role of currency of invoicing and sticky prices is an essential test of the modern international macroeconomic framework which emphasizes these features as central to the international transmission of shocks and the design of optimal policies. We provide such evidence here.

Towards this end, we estimate a two-stage specification in which the price pass-through equation (20) plays the role of the first stage, and the second-stage equation is given by:

$$\Delta_h q^*_{ikt} = \theta_h \Delta_h p^*_{ikt} + f_i + v_{skt} + u_{ikt}, \tag{21}$$

where θ_h is the elasticity of demand over horizon h, and both stages include a full set of firm and industry×destination×time fixed effects, which absorb all macroeconomic variation including exchange rate movements. As a result, the identification relies on the differential response of prices across firms with different characteristics, including the invoicing currency of their exports, to the same exchange rate fluctuations in the same general equilibrium environment of a given industry-destination.[48] Thus, the estimates of θ_h capture the differential change in quantities in response to differential changes in prices across firm-products with different characteristics.

We report the results in Figure 4, for all products in the left panel and the subset of differentiated products in the right panel.[49] Specifically, we plot the estimated quantity elasticity θ_h for two sets of instruments. In the first specification, the first stage includes the full set of firm characteristics — capturing both flexible-price and sticky-price determinants — interacted with exchange rates (blue lines), as in (20). In the second specification, it includes only the currency choice dummy interactions capturing only the sticky-price determinants of price adjustment (red lines). We see that the estimated elasticity is similar across the two specifications, and if anything larger in absolute value in the second specification. This implies that export quantities respond as strongly to the differential movements in prices caused by price stickiness in different currencies as to differential movements in prices caused by the flexible price determinants of pass-through, such as the firm's import intensity.

In terms of point estimates, the elasticity is always negative, as expected, yet very small in absolute value and insignificant for horizons under one year ($h < 12$ months). The quantity elasticity gradually increases in absolute value becoming both significant and exceeding unitary elasticity past the 18-month horizon for all products, with the long-run absolute value of this elasticity approaching 1.5. The magnitude of the quantity elasticities for the subset of differentiated products are larger, exceeding 1 already by $h = 12$ months and exceeding 2 by $h = 24$ months.[50]

[48]Note that our identification is robust to demand shocks correlated with exchange rates. Since we include both sticky-price and flexible-price interaction terms as instruments in estimating ERPT into prices, we alleviate the potential concern of a systematic difference in the correlation of idiosyncratic demand shocks with exchange rates for firms with different characteristics (e.g., different currency invoicing).

[49]Appendix Table A5 reports first stages, second stages and reduced forms for select $h \in \{6, 12, 18, 24\}$.

[50]As with ERPT estimates, this is not a point elasticity at h, but rather the average elasticity over the period 1-to-h months.

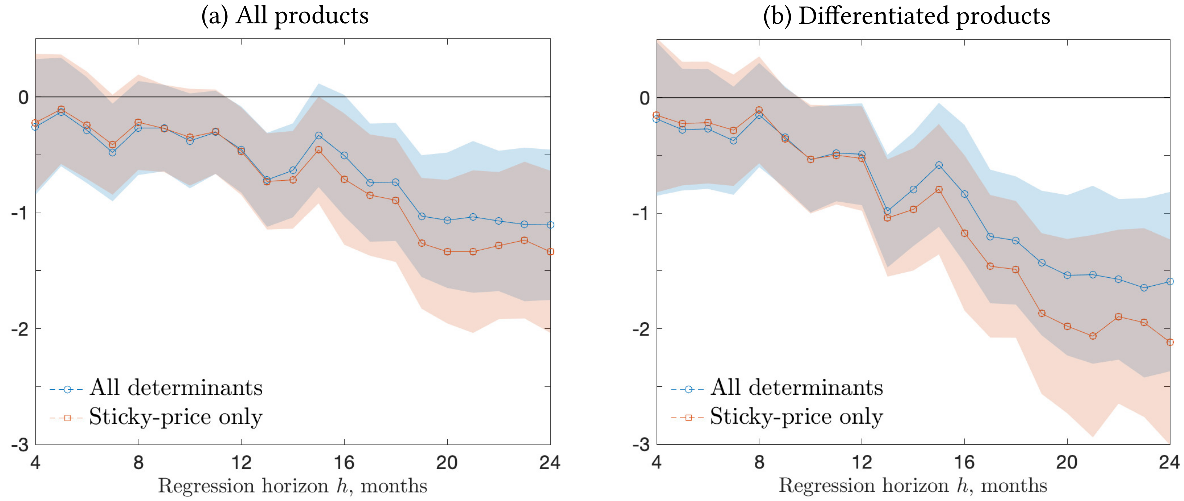


Figure 4: The dynamics of quantity elasticity

Note: The figures plot the non-parametric dynamic estimates of the quantity elasticity θ_h over varying horizons h in the second stage (21), for all products (left panel) and differentiated products (right panel); shaded areas reflect 95% confidence intervals. The first stage either includes the full set of ERPT determinants (as in (20); blue lines) or only the sticky-price determinants (ι_{ik} and ι_{ik}^D; red lines). All specifications include firm and industry×destination×time fixed effects.

These long-run quantity elasticities are consistent with the estimates in the time-series macro literature (Feenstra, Luck, Obstfeld, and Russ 2018, Boehm, Levchenko, and Pandalai-Nayar 2020), yet still small compared to the micro-level elasticities conventional in the international trade literature (Broda and Weinstein 2006). Note, however, that the prices we work with are the factory-gate export prices, after which there may be multiple further rounds of incomplete pass-through into final consumer prices, reducing the quantity response (see Auer, Burstein, and Lein 2020). As a result, our estimates may well be consistent with a much higher structural elasticity of the final product demand.

To summarize, we provide evidence of the allocative effects of price stickiness in different currencies of invoicing, which is consistent with the recent international macro framework. Yet, we also find that the response of quantities is very sluggish in the first year after the shock, suggesting the presence of additional frictions limiting the response of quantities on impact and in the short run (*cf.* the J-curve literature), in addition to sticky prices.

6 Conclusion

In this paper, we show that the currency of invoicing is an active firm-level decision, which affects how much of the exchange rate movements are passed through into destination prices and quantities. The currency choice in exports is shaped by the exposure to imported inputs and is responsive to competitors' pricing and currency choice decisions. The impact of currency invoicing on price dynamics persists beyond a one-year horizon, generating allocative expenditure-switching effects on export quantities, and wanes in the long run.

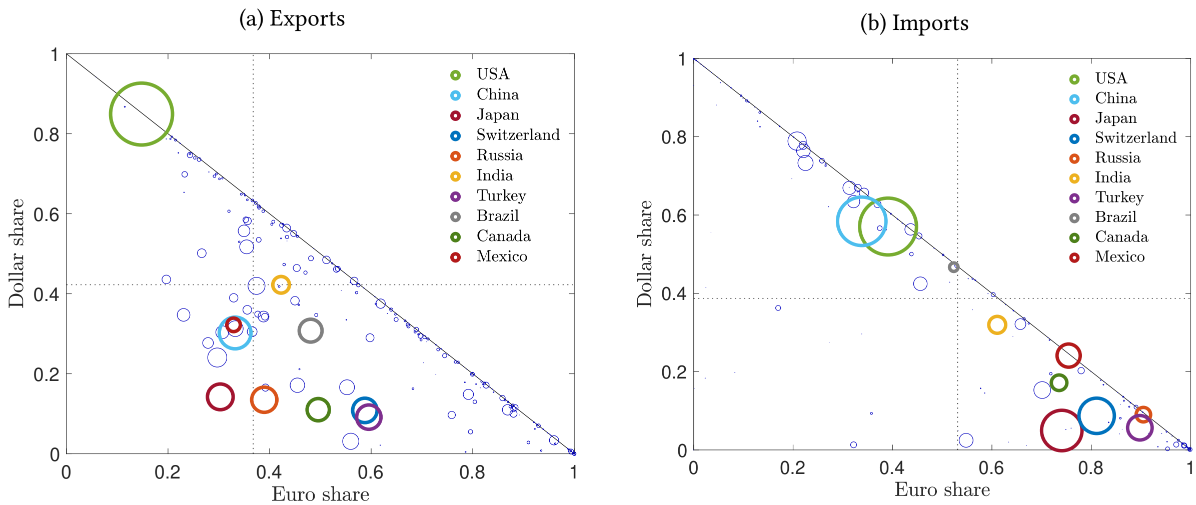
Our results have important implications for the international transmission of shocks and macroeconomic policies. The large cross-firm heterogeneity in currency choice combined with the persistence of dominant currencies over time suggest interesting counterfactuals. One possibility is that the US dollar strengthens its position as the dominant global currency. This could happen with greater globalization of production and more intensive reliance on global value chains, as our results show that cross-border FDI — a proxy for global value chains — is associated with more US dollar currency invoicing. This would render exchange rates less relevant as determinants of relative prices and expenditure switching in the global supply chain. In contrast, fragmentation and localization of production chains, e.g. in response to a global pandemic shock, can reverse this trend and speed up the transition to a multi-currency equilibrium, with more intensive regional trade and greater barriers to cross-regional trade. This, in turn, may increase the expenditure-switching role of bilateral exchange rate movements.

Alternatively, a shift in the exchange rate anchoring policies of the major trade partners, such as China, could trigger a long-run shift in the equilibrium environment. If China were to freely float its exchange rate, encouraging Chinese exporters to price more intensively in renminbi, the equilibrium environment would change for exporting firms around the world. In particular, this would alter both the dynamics of prices in the input markets, as well as the competitive environment in the output markets across many industries. As our results show, the currency in which a firm's imports are invoiced and the currency in which its competitors price are key determinants of an exporting firm's currency choice, and hence this shift could dramatically change the optimal invoicing patterns for exporting firms. Despite the persistence in currency use that we observe, the fact that the currency choice is an endogenous firm-level decision means that such a major shock to the long-run equilibrium environment can lead to abrupt changes in the optimal invoicing patterns. Our empirical estimates, combined with a general-equilibrium international macro model, allow for a quantitative counterfactual analysis of such tectonic shifts in the global monetary system.

Appendix

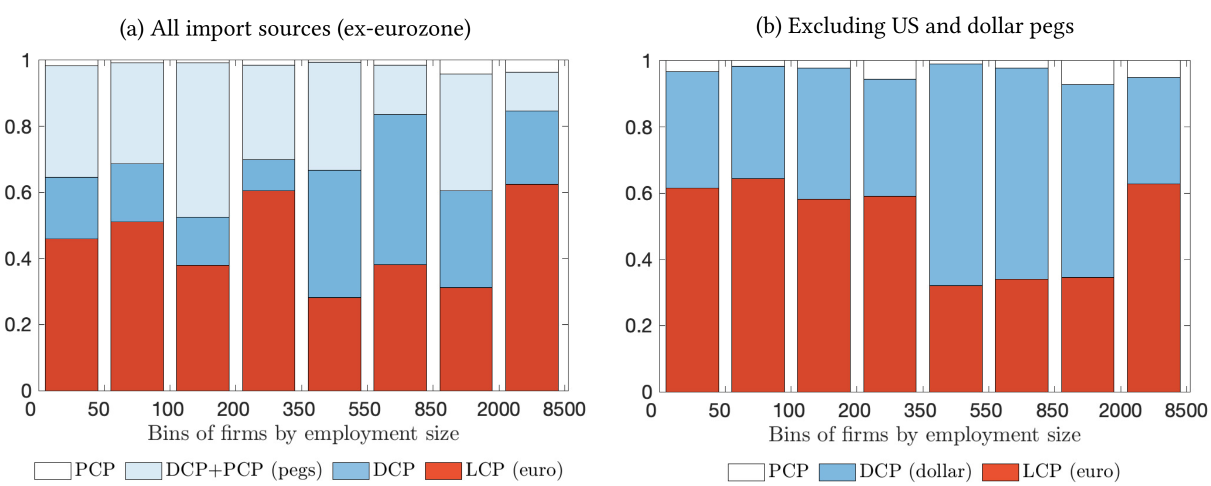
A Additional Figures and Tables

Figure A1: Dominant currencies in Belgian bilateral trade: differentiated goods



Note: as Figure 1, but for the subsample of the differentiated products, where we observe a shift away from dollar invoicing and towards euro and foreign-currency invoicing relative to the full sample of products.

Figure A2: Firm size and import currency invoicing



Note: Import currency invoicing shares by employment size bins of firms. Unlike for exports in Figure 2, the incidence of currency use in imports does not robustly change with firm size. See also Appendix C.

Table A1: Firm-size distribution

Employment size bins	<50	50–100	100–200	200–350	350–550	550–850	850–2000	≥2,000
Number of firms	1,937	299	247	115	60	36	23	12
Share in total exports	6%	7%	12%	10%	7%	9%	13%	36%
Share in total imports	5%	3%	8%	9%	7%	10%	8%	50%

Note: Firms are sorted by employment into 8 size bins roughly corresponding to the first 7 deciles of export revenues and the last bin consisting of the largest 12 firms that together account for 36% (50%) of Belgian manufacturing exports (imports).

Table A2: Firm characteristics by export currency use

	Euro	Dollar	Other
Number of firms	2,489	254	22
Employment (FTE)	71.6	214.8	325.9
Sales (million)	39.9	157.1	271.9
Exports (million)	21.1	100.8	144.0
Imports (million)	15.3	57.5	158.1
Exports/total sales	0.400	0.503	0.377
Ex-EU export share	0.632	0.648	0.564
EZ export share	0.368	0.352	0.436
US+Dollar Peg export share	0.210	0.372	0.095
Average destination market share, S_{ik}	0.149 [0.055, 0.594]	0.223 [0.137, 0.747]	0.177 [0.122, 0.499]
Ex-EZ import share in total variable costs, φ_i	0.071 [0.018, 0.335]	0.144 [0.093, 0.471]	0.090 [0.039, 0.456]
— non-euro, φ_i^X	0.027	0.095	0.019
— dollar, φ_i^D	0.024	0.092	0.011

Note: We assign firms to the three currency categories based on the largest share currency use in the firm's ex-EU exports. Other currencies almost always correspond to the destination currency (LCP). The table reports average firm characteristics within each category; for S_{ik} and φ_i we also report the median and the 95th percentile in brackets.

Table A3: Currency choice in exports: robustness

Dep. var.: ι_{ikt}	Sample				IV subsets		Destination country variables				HS-4 industry
	Diff	Non-Diff	Main product	One month 2017:06	Macro only	Micro only	USD peg	CPI inflation	GDP per capita	Log exports	world log exports
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
φ_i	0.288^{***} (0.098)	0.337^{*} (0.183)	0.361^{***} (0.094)	0.326^{***} (0.113)	0.304^{***} (0.114)	0.304^{***} (0.109)	0.357^{**} (0.153)	0.345^{**} (0.155)	0.319^{**} (0.158)	0.325^{**} (0.153)	0.315^{**} (0.157)
$\log L_i$	0.097^{***} (0.015)	0.049^{***} (0.015)	0.033^{***} (0.007)	0.085^{***} (0.015)	0.089^{***} (0.016)	0.087^{***} (0.014)	0.096^{***} (0.024)	0.093^{***} (0.024)	0.097^{***} (0.026)	0.098^{***} (0.025)	0.092^{***} (0.024)
S_{ik}	−0.004 (0.031)	−0.017 (0.049)	0.128^{**} (0.054)	−0.023 (0.022)	0.033 (0.025)	0.015 (0.027)	−0.067 (0.042)	−0.074 (0.049)	−0.043 (0.043)	−0.005 (0.038)	−0.056 (0.049)
$\bar{\iota}_{-ik}$					0.672^{***} (0.249)	0.407^{*} (0.219)					
Additional control							0.190^{***} (0.033)	-0.008^{***} (0.003)	0.041^{***} (0.011)	0.047^{***} (0.007)	0.012^{**} (0.006)
# obs.	957,090	308,634	360,102	29,467	1,148,459	1,179,137	1,238,039	1,199,904	1,225,822	1,195,267	1,273,380
R^2_{adj}	0.582	0.580	0.689	0.392	–	–	0.184	0.144	0.152	0.174	0.142
Fixed Effects:											
month×year	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
industry&destination				✓	✓	✓					
industry×destination	✓	✓	✓								

Notes: Robustness for the baseline specification 3 from Table 3. Columns 1 to 4 explore different subsamples: column 1 only includes differentiated products as defined by the Rauch index and column 2 the nondifferentiated goods; column 3 only includes the firm's main products defined as all observations within an HS4 that accounts for at least 60% of the firm's exports; column 4 only includes one cross-section for June 2017. Columns 5 and 6 check the robustness of the IV specification in column 5 of Table 3 using different subsets of the instruments for the competitor currency share: column 5 uses the macro instruments and column 5 the micro ones. Columns 7 to 10 include additional controls measuring various macroeconomic characteristics of the destination country as follows: a dummy variable indicating a USD-peg country; CPI inflation; log GDP per capita; log total exports of the destination country. Column 11 includes the world log exports in the HS4 industry as a measure of the industry size.

Table A4: Exchange rate pass-through: robustness

	Baseline	Large	Subsamples							Non-dollar
	w/Firm FEs	Dummy	Diff	Non-diff	OECD	US only	Non-pegs	Main Prod	Drop 2020	vehicle
Dep. var.: Δp^*_{ikt}	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Δe_{kt}	1.026^{***}	0.994^{***}	1.010^{***}	1.027^{***}	0.911^{***}	–	1.069^{***}	1.032^{***}	1.008^{***}	1.006^{***}
	(0.029)	(0.010)	(0.033)	(0.042)	(0.061)		(0.027)	(0.050)	(0.031)	(0.027)
$\Delta e_{kt} \cdot \varphi_i$	-0.228^{***}	-0.242^{***}	-0.170^{*}	-0.446^{***}	-0.468^{***}	-0.647^{***}	0.029	−0.221	-0.294^{***}	-0.216^{***}
	(0.078)	(0.080)	(0.094)	(0.122)	(0.141)	(0.129)	(0.081)	(0.151)	(0.080)	(0.078)
$\Delta e^D_{kt} \cdot \varphi_i$	0.304^{***}	0.309^{***}	0.309^{***}	0.372^{**}	0.516^{***}			0.471^{***}	0.342^{***}	0.273^{***}
	(0.073)	(0.075)	(0.091)	(0.118)	(0.140)			(0.137)	(0.076)	(0.075)
$\Delta e_{kt} \cdot \log L_i$	-0.014^{**}	-0.061^{**}	-0.021^{**}	0.005	−0.004	−0.011	-0.012^{**}	-0.047^{***}	−0.009	-0.012^{*}
	(0.007)	(0.027)	(0.009)	(0.010)	(0.009)	(0.023)	(0.006)	(0.010)	(0.007)	(0.006)
$\Delta e^D_{kt} \cdot \log L_i$	0.007	0.057^{*}	0.017^{*}	−0.011	0.015			0.040^{***}	0.007	0.011
	(0.008)	(0.030)	(0.010)	(0.010)	(0.011)			(0.011)	(0.008)	(0.007)
$\Delta e_{kt} \cdot \iota_{ik}$	-0.388^{***}	-0.387^{***}	-0.434^{***}	-0.271^{***}	-0.373^{***}	-0.279^{**}	-0.123^{***}	-0.547^{***}	-0.357^{***}	-0.389^{***}
	(0.038)	(0.036)	(0.046)	(0.044)	(0.069)	(0.084)	(0.037)	(0.054)	(0.037)	(0.034)
$\Delta e^D_{kt} \cdot \iota^D_{ik}$	0.410^{***}	0.413^{***}	0.519^{***}	0.228^{***}	0.160			0.540^{***}	0.373^{***}	0.402^{***}
	(0.041)	(0.041)	(0.055)	(0.048)	(0.121)			(0.057)	(0.039)	(0.040)
# obs.	339,087	339,684	240,186	99,382	110,119	25,720	211,147	94,097	292,274	387,796
$R^2_{adj.}$	0.061	0.060	0.049	0.110	0.016	0.018	0.077	0.067	0.060	0.053
Fixed Effects:										
year	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
ind.×dest.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
firm	✓									

Notes: Robustness for the baseline ERPT specification in column 3 of Table 6. Column 1 includes firm fixed effects; column 2 replaces the employment interaction terms with a large bin interaction, defined as firms with at least 500 workers. The next seven columns re-estimate column 3 for different subsamples as indicted in the column headings. The last column includes observations with non-dollar vehicle currency that were dropped in the main analysis.

Table A5: ERPT: first-stage and reduced-form specifications

	A. First stage: $\Delta_h p^*_{ikt}$				B. Reduced form: $\Delta_h q^*_{ikt}$			
	$h=6$	$h=12$	$h=18$	$h=24$	$h=6$	$h=12$	$h=18$	$h=24$
$\Delta_h e_{kt} \cdot \varphi_i$	0.004	−0.066	− 0.178*	− 0.186**	0.002	−0.092	−0.440	−0.223
	(0.117)	(0.091)	(0.094)	(0.093)	(0.483)	(0.346)	(0.346)	(0.330)
$\Delta_h e^D_{kt} \cdot \varphi_i$	0.217*	0.219**	0.289***	0.265***	−0.565	0.123	0.876**	0.549
	(0.121)	(0.094)	(0.092)	(0.087)	(0.490)	(0.374)	(0.363)	(0.346)
$\Delta_h e_{kt} \cdot \iota_{ik}$	− 0.516***	− 0.451***	− 0.338***	− 0.216***	0.099	0.200**	0.287***	0.289***
	(0.032)	(0.027)	(0.027)	(0.026)	(0.126)	(0.089)	(0.096)	(0.085)
$\Delta_h e^D_{kt} \cdot \iota^D_{ik}$	0.515***	0.427***	0.341***	0.252***	−0.267	− 0.307**	− 0.441***	− 0.373***
	(0.047)	(0.037)	(0.034)	(0.031)	(0.205)	(0.129)	(0.129)	(0.114)
	C. Second stage: $\Delta_h q^*_{ikt}$ (all IV)				D. Second stage: $\Delta_h q^*_{ikt}$ (sticky-price IV only)			
$\Delta_h p^*_{ikt}$	−0.287	− 0.455**	− 0.735***	− 1.104***	−0.244	− 0.470**	− 0.892***	− 1.337***
	(0.233)	(0.190)	(0.260)	(0.331)	(0.236)	(0.193)	(0.272)	(0.357)
# obs.	643,652	573,496	483,203	427,013	643,652	573,496	483,203	427,013
$R^2_{adj.}$	0.076	0.124	0.167	0.209	0.076	0.071	0.088	0.087
Fixed Effects:								
ind.×dest.×date	✓	✓	✓	✓	✓	✓	✓	✓
firm	✓	✓	✓	✓	✓	✓	✓	✓

Notes: The table reports first stages (panel A), reduced forms (panel B), and second stages (panel C for all instruments and panel D for sticky-price instruments ι_{ik} and ι^D_{ik} only) for the quantity elasticity estimates in (21), as depicted in Figure 4 (see also Figures 3), for select horizons $h \in \{6, 12, 18, 24\}$.

Table A6: Summary statistics

Variable	*Mean*	*St Dev.*	5 *pctl*	*Median*	95 *pctl*	Count
Currency choice (Tables 3 and 5)						
ι_{ikt}	0.323	0.463	0	0	1	1,273,384
φ_i	0.138	0.133	0.005	0.097	0.445	1,273,384
φ^X_i	0.052	0.081	0.000	0.033	0.227	1,273,384
$\log L_i$	5.708	1.788	2.657	5.745	7.850	1,273,384
S_{ik}	0.246	0.307	0.000	0.085	0.923	1,273,384
ι^D_{ikt}	0.544	0.498	0	1	1	204,403
Exchange rate pass-through (Table 6)						
Δp^*_{ikt}	0.038	0.353	−0.596	0.030	0.682	344,560
Δe_{kt}	0.029	0.096	−0.116	0.019	0.192	344,560
Δe^D_{kt}	0.0429	0.093	−0.046	0.011	0.201	344,560

Notes: The upper panel reports summary statistics for the variables used in the currency choice regressions, where the observations are at the firm-product-country-month level for March 2017 to December 2020; the lower panel for the ERPT regressions at the firm-product-destination-year level for 2012 to 2020.

B Data Appendix

B.1 Data Sources and Coverage

Our data come from a variety of sources, all of which are easily merged together by the firm's VAT, which is a unique firm identifier. We restrict the sample of firms to those that report their main product in manufacturing, identified as NACE 2-digit categories 10 to 33. We do not include firms that switch between manufacturing and non-manufacturing (only 2% of the sample).

Currency invoicing data These data are collected by the Belgium Customs Office and then processed by the National Belgium Bank on a monthly basis, beginning in 2017. The unit of observation is at the firm-CN8-country-month level for both exports and imports, indicating the currency of invoicing of the transaction and its value. These data comprise the universe of transactions for Belgian trade with ex-EU countries; a small number of firms were suppressed due to confidentiality, nonresident status of the firm, or missing information at the NBB statistical department. The currency data covers nearly 90% of the value of the transactions.

Trade data The within EU trade transaction data are collected by the Intrastat Survey at the same level of disaggregation that the Customs Office collects the ex-EU trade data – at the firm-CN8-country-month level. The first 6-digits of the CN codes correspond to the World Hamonized System (HS). These data report values and quantities in weights for most observations and units in other cases. For extra-EU trade all transactions are reported; all transactions above one million euros (0.4 million euros) are reported for intra-EU exports (imports).

Accounts data The firm characteristic data are drawn from annual income statements, the quarterly VAT declarations, which all firms are required to submit to the tax office, and from the Social Security Office.

B.2 Variable Definitions

Exchange rates The bilateral exchange rates are from the IMF. They are reported as monthly averages relative to the US dollar, which we convert to be relative to the euro for the log change in the euro-destination exchange rate.

Prices (unit values) used as the dependent variable in the ERPT regressions, are measured in log changes as:

$$\Delta p^*_{ikt} \equiv \Delta \log \left(\frac{\text{Export value}^*_{ikt}}{\text{Export quantity}_{ikt}} \right),$$

at the firm-CN8-destination level. We clean the data for outliers in changes in unit values, only keeping those observations where the unit values ratio in t and $t-1$ is no smaller than 1/3 and no greater than 3.

Imported input intensity The φ_i is the firm's share of imports from ex-EZ countries as a share of its total variable costs, defined as the wage bill plus the total material costs. This is further split into the portion of ex-EZ imports that are invoiced in euros and those in non-euros. However, these measures are incomplete because we do not have currency data for the ex-EZ imports within the EU: Bulgaria, Croatia, Czech Republic, Denmark, Hungary, Poland, Romania, Sweden, and the United Kingdom, account for 10% of Belgium imports (and 15% of its exports).

Firm destination sales share is measured as

$$S_{ik} \equiv \frac{\text{Export value}_{f(i)sk}}{\sum_{f' \in F_{sk}} \text{Export value}_{f'sk}}, \tag{A1}$$

where Export value$_{fsk}$ is the combined export value of all products i of firm f in industry s shipped to destination k, and F_{sk} is the set of all Belgian exporters to destination k in industry s, where we construct S_{ikt} in each year t and then average it over the years in which the firm has positive exports to k.

Additional firm characteristics The R&D variable is defined as the firm's total R&D expenditure as a share of its total sales in 2017. The firm-level R&D expenditure is from the Center for R&D monitoring, ECOOM. The FDI inward and outward variables are zero/one dummies indicating whether FDI that constitutes at least 10% over the sample period, sourced from the NBB annual FDI survey.

Competitor variables We define the competitor currency variables as the share of exports within an HS4-destination that are invoiced in non-euro currency; and similarly for the dollar competitor currency, averaged over the sample period. The Belgium competitor instruments are constructed as the export weighted average of the competitors' import intensity and employment size within an HS4-destination. These variables are constructed at the annual level and then averaged over 2017-2019.

Country-level data The instruments for non-Belgium competitors are constructed using COMTRADE bilateral data at the HS6 level for 2017-2019. The peg countries are identified as those with a root mean squared error less than 0.05, using monthly bilateral exchange rates for 2012-2020. The country-level macroeconomic variables, comprising GDP and CPI, are from the World Bank.

Total factor productivity We compute total factor productivity (TFP) using a standard Törnqvist index approach as proposed by Caves, Christensen, and Diewert (1982). Each firm is compared to its NACE 2-digit sector average with average log output $\log \bar{Q}_t$, average log number of jobs $\log \bar{L}_t$, average log capital $\log \bar{K}_t$ and the average labor share $\tilde{s}_t$. In particular, the TFP index number is then given for each firm i by the following:

$$\log TFP_{it} - \log \overline{TFP}_t = (\log Q_{it} - \log \bar{Q}_t) - \tilde{s}_{it}(\log L_{it} - \log \bar{L}_t) - (1 - \tilde{s}_{it})(\log K_{it} - \log \bar{K}_t),$$

where $\tilde{s}_{it} = (s^L_{it} + s^L_t)/2$. We proxy output by value added, labor by the number of full time equivalent jobs, capital by tangible fixed assets, and the labor share is computed by the ratio of the wage bill to value added. The main advantage of this approach is that no estimation is required and it allows a flexible production technology. Van Biesebroeck (2007) compares different non-parametric and parametric methods to compute TFP and shows that the index number approach produces consistently accurate productivity growth estimates when data are not subject to a lot of measurement error. Since the index approach is a deterministic one, it is straightforward to include as a control in our estimations.

C Import Currency Invoicing

Next, we explore the firm-level determinants of currency choice in imports. Now, the dependent variable is $\iota^M_{ikt} \in \{0, 1\}$ corresponding to the firm-product (CN8)-source country dummy for the invoicing currency of firm imports, where zero corresponds to euro invoicing and one otherwise. We construct firm-level determinants analogous to those in the export regressions in Table 3, adjusting the variables appropriately. In particular, instead of the ex-EZ import intensity variables we include the share of ex-EZ exports χ_i in total sales of the firm (overall and split by currency of exports); instead of the industry-destination export market share variable, we construct the share of the firm's imports S^M_{ijk} in total Belgian imports by HS4-industry$\times$source country; and in parallel with the competitor currency in exports we include the average competitor share of foreign-currency inputs in total variable costs, $\bar{\iota}^M_{-ikt}$.

Table A7 shows that a key correlate of the firm import currency invoicing is the currency the firm adopts in its total sales, proxied by the ex-EZ export share χ_i in total revenues in column 1, and the foreign-currency export share in revenues χ^X_i in columns 2–4. This pattern is the mirror image of the results for the export currency choice. Firms that use foreign currency in export pricing also tend to use it in importing, consistent with the real hedging mechanism and marginal cost channel for desired pass-through, and this may reflect two-way causality.

Furthermore, strategic complementarities in import currency choice also play a large role, just like in exports. Firms with competitors that import in non-euros are themselves more likely to import in foreign currencies. The OLS estimate in column 3 is quantitatively small, but the IV specification in column 4 recovers a large coefficients, comparable with that for exports. If all of a firm's competitors switch from euros to foreign currency in importing, that firm is 56 percentage points more likely to also use the foreign currency (controlling for industry and source country fixed effects).

Interestingly, we do not find a similar effect of firm size on import currency choice as we did for export currency choice. Here, the coefficient on the overall firm size (log employment) is insignificantly different from zero in almost all of the specifications, consistent with Appendix Figure A2 and with the currency choice in imports being a less active firm-level decision. However, controlling for the firm's overall employment size, if a firm is a large importer of a particular good (relative to the size of the Belgian import market in an industry), then it is more likely to source its imports in local currency (euros) — that is, the coefficient on the import market share variable is negative and significant. This is more characteristic of the inward-looking domestically-oriented firms whose sales are predominantly denominated in euros.

Table A7: Currency choice in imports

Dep. var.: ι^M_{ikt}	(1)	(2)	(3)	(4)
χ_i	0.095^{*} (0.049)			
χ^E_i		-0.034 (0.064)	-0.058 (0.072)	-0.048 (0.074)
χ^X_i		0.302^{***} (0.080)	0.339^{***} (0.086)	0.330^{***} (0.094)
S^M_{ik}	-0.139^{***} (0.032)	-0.137^{***} (0.032)	-0.112^{***} (0.031)	-0.140^{***} (0.036)
$\log L_i$	-0.007 (0.005)	-0.012^{**} (0.005)	-0.006 (0.010)	-0.006 (0.010)
$\bar{\iota}^M_{-ikt}$			0.035^{**} (0.018)	0.564^{***} (0.211)
# obs.	460,093	460,093	441,491	420,457
R^2_{adj}	0.477	0.480	0.357	–
Fixed Effects:				
month×year	✓	✓	✓	✓
industry & destination			✓	✓
industry×destination	✓	✓		

Notes: The observations are at the firm-product (CN8)-source country-month level for all ex-EU source countries from March 2017 to December 2020. The dependent variable is $\iota^M_{ikt} = 0$ for import transactions invoiced in euros and 1 otherwise. Standard errors are clustered at the firm level. Columns 1–3 are estimated with OLS; column 4 with IV (the instrument set is constructed analogously to the macro instruments in the export regression, and it also passes the weak IV test with a Cragg-Donald F-stat of 969.3 and the over-id Hansen J-test with a p-value of 0.33).

D Dynamic of Pass-through

Setup Consider a dynamic Calvo model of price setting, with prices preset in different currencies. We assume that the desired price of the firm in the destination currency is given by:

$$\tilde{p}^*_{it} = (1-\psi_i)e_t + \psi_i^D e_t^D + \omega_{it},$$

where $\psi_i, \psi_i^D \geq 0$ are desired pass-through coefficients, and e_t and e_t^D are euro-destination and dollar-destination exchange rates, and ω_{it} combines all the components of the desired price uncorrelated with exchange rates.[51] We assume that exchange rates follow random walks:

$$\mathbb{E}_t \Delta e_t = \mathbb{E}_t \Delta e_t^D = 0,$$

and Δe_t and Δe_t^D are possibly correlated. Note that the desired price can be converted to the producer currency (euro) and the dollar as follows: $\tilde{p}^*_{it} = \tilde{p}_{it} + e_t = \tilde{p}^D_{it} + e_t^D$, and therefore

$$\begin{aligned}\tilde{p}_{it} &= -\psi_i e_t + \psi_i^D e_t^D + \omega_{it},\\ \tilde{p}^D_{it} &= (1-\psi_i)e_t - (1-\psi_i^D)e_t^D + \omega_{it},\end{aligned}$$

in euros and in dollars, respectively. Lastly, note that $\psi_i = 1-\varphi_i-\gamma_i$ and $\psi_i^D = \varphi_i^D + \gamma_i^D$, as a special case of Lemma 3.

The firm sets prices either in local (LCP), producer (PCP) or dominant (DCP) currency, and adjusts them in any given period with a Calvo probability $(1-\lambda)$ to a reset price:

$$\begin{aligned}\bar{p}^*_{it} &= (1-\beta\lambda)\sum\nolimits_{j=0}^{\infty}(\beta\lambda)^j \mathbb{E}_t \tilde{p}^*_{t+j} = (1-\psi_i)e_t + \psi_i^D e_t^D + \Omega_{it},\\ \bar{p}_{it} &= (1-\beta\lambda)\sum\nolimits_{j=0}^{\infty}(\beta\lambda)^j \mathbb{E}_t \tilde{p}_{t+j} = -\psi_i e_t + \psi_i^D e_t^D + \Omega_{it},\\ \bar{p}^D_{it} &= (1-\beta\lambda)\sum\nolimits_{j=0}^{\infty}(\beta\lambda)^j \mathbb{E}_t \tilde{p}^D_{t+j} = (1-\psi_i)e_t - (1-\psi_i^D)e_t^D + \Omega_{it},\end{aligned}$$

where the second equalities obtain due to the random walk properties of exchange rates and $\Omega_{it} \equiv (1-\beta\lambda)\sum_{j=0}^{\infty}(\beta\lambda)^j \mathbb{E}_t \omega_{i,t+j}$ is the same independently of the currency of invoicing.

With probability λ the prices remain unchanged in the currency in which they were preset. Therefore, price dynamics for LCP, PCP and DCP firms in the destination currency, euros and dollars satisfy, respectively:

$$\begin{aligned}p^*_{it} &= \lambda p^*_{i,t-1} + (1-\lambda)\bar{p}^*_{it},\\ p_{it} &= \lambda p_{i,t-1} + (1-\lambda)\bar{p}_{it},\\ p^D_{it} &= \lambda p^D_{i,t-1} + (1-\lambda)\bar{p}^D_{it}.\end{aligned}$$

[51]Without loss of generality, ω_{it} can be viewed as the residual from the projection of $\tilde{p}^*_{it}$ on e_t and e_t^D.

The realized price in the destination currency is:

$$p_{it}^* = \begin{bmatrix} p_{it}^*, & \text{if LCP,} \\ p_{it} + e_t, & \text{if PCP,} \\ p_{it}^D + e_t^D, & \text{if DCP.} \end{bmatrix}$$

Lastly, to complete the description of the environment, we model currency choice as follows:

$$\iota_i = \mathbf{1}\{\psi_i + \eta_i \geq 0\},$$
$$\iota_i^D = \mathbf{1}\{\psi_i^D + \eta_i^D \geq 0, \iota_i = 1\} = \iota_i \cdot \mathbf{1}\{\psi_i^D + \eta_i^D \geq 0 | \iota_i = 1\},$$

where $\iota_i \in \{0, 1\}$ is an indicator equal to one under non-euro invoicing (i.e., in any foreign currency, destination or dominant) and $\iota_i^D \in \{0, 1\}$ is an indicator equal to one under dominant currency pricing. Note that $\iota_i^D = 1$ implies $\iota_i = 1$. Currency choice is shaped by both the desired pass-through (ψ_i, ψ_i^D) and idiosyncratic shocks (η_i, η_i^D), which capture additional channels such as fixed costs.

Results 1 (Distributed Lag Regression) The projection of price changes Δp_{it}^*, Δp_{it} and Δp_{it}^D (in respective currencies) on exchange rates Δe_t and Δe_t^D all follow AR(1) processes with persistence λ.[52] The impulse responses of these prices to exchange rates, h periods out, are thus proportional to $(1 - \lambda)\lambda^h$, and the cumulative impulse response is proportional to $[1 - \lambda^{h+1}]$. For example, under LCP:

$$\mathbb{E}\big\{\Delta p_{it}^* | \{\Delta e_{t-j}, \Delta e_{t-j}^D\}_{j \geq 0}\big\} = (1 - \lambda) \sum_{j=0}^{\infty} \lambda^j [(1 - \psi_i)\Delta e_{t-j} + \psi_i^D \Delta e_{t-j}^D], \tag{A2}$$

and similarly under PCP and DCP. This also characterizes the distributed-lag regression coefficients of $\Delta p_{it}^* = p_{it}^* - p_{i,t-1}^*$ on $\{\Delta e_{t-j}, \Delta e_{t-j}^D\}_{j \in [0,..,\ell]}$ for any ℓ, since exchange rates follow a random walk.

Result 2 (Long Difference Regression) The projection of an h-period difference of the destination-currency price $\Delta_h p_{it}^* = p_{it}^* - p_{i,t-h}^*$ on the contemporaneous h-period differences in exchange rates $\Delta_h e_t = e_t - e_{t-h}$ and $\Delta_h e_t^D = e_t^D - e_{t-h}^D$ interacted with the currency choice dummies ι_i and ι_i^D and the desired pass-through coefficients ψ_i and ψ_i^D, respectively, results in the following regression equation:

$$\begin{aligned} \mathbb{E}\{\Delta_h p_{it}^* | \Delta_h e_t, \Delta_h e_t^D, \iota_i, \iota_i^D, \psi_i, \psi_i^D\} = \Delta_h e_t - \hat{\delta}(h)[\iota_i \Delta_h e_t - \iota_i^D \Delta_h e_t^D] \\ - \big(1 - \hat{\delta}(h)\big)\big[\psi_i \Delta_h e_t - \psi_i^D \Delta_h e_t^D\big], \end{aligned} \tag{A3}$$

where $\hat{\delta}(h) \equiv \frac{1}{h}\frac{\lambda}{1-\lambda}(1 - \lambda^h)$, as in (13)–(14) in the text. Note that $\hat{\delta}(1) = \lambda$, $\hat{\delta}(h) \to 0$ as $h \to \infty$, and $\hat{\delta}(h) > \lambda^h$ for $h > 1$.[53]

[52]**Proof:** From price dynamics equations, under LCP, we have $\Delta p_{it}^* = \lambda \Delta p_{i,t-1}^* + (1 - \lambda)\Delta \bar{p}_{it}^*$, and the reset price satisfies $\mathbb{E}\{\Delta \bar{p}_{it}^* | \Delta e_t, \Delta e_t^D\} = (1 - \psi_i)\Delta e_t + \psi_i^D \Delta e_t^D \sim iid$, since Ω_{it} is orthogonal to exchange rates and exchange rates follow random walks. Therefore, the projection of $\Delta \bar{p}_{it}^*$ on exchange rates follows an AR(1) with persistence λ, and similarly under PCP and DCP in euros and dollars, respectively ■

[53]Note that $\frac{1}{h}\frac{\lambda}{1-\lambda}(1 - \lambda^h) = \frac{1}{h}(\lambda + \ldots + \lambda^h) > \frac{1}{h} h \lambda^h = \lambda^h$, if $h > 1$ and $\lambda < 1$.

Proof: We use (A2), under LCP, to calculate:

$$\Delta_h p^*_{it} = (1-\delta)\sum_{k=0}^{h-1}\sum_{j=0}^{\infty}\delta^j[(1-\psi_i)\Delta e_{t-j-k} + \psi_i^D \Delta e^D_{t-j-k}],$$

where by default we consider projection on exchange rates (thus, omitting terms in Ω_{it}). Similar expressions hold for $\Delta_h p_{it}$ and $\Delta_h p^D_{it}$ under PCP and DCP, in euros and dollars, respectively. Note that $\Delta_h p_{it} + \Delta_h e_t$ and $\Delta_h p^D_{it} + \Delta_h e^D_t$ converts the price changes to the destination currency, under PCP and DCP respectively. Also note that $\Delta_h e_t = \sum_{k=0}^{h-1}\Delta e_{t-k}$ and $\Delta_h e^D_t = \sum_{k=0}^{h-1}\Delta e^D_{t-k}$.

We calculate the following conditional expectations (also conditioning on firm characteristics ψ_i, ψ_i^D):

$$\begin{aligned}
\mathbb{E}\{\Delta_h p^*_{it}|\Delta_h e_t, \Delta_h e^D_t, \iota_i = 1, \iota_i^D = 0\} &= [(1-\psi_i)\Delta_h e_t + \psi_i^D \Delta_h e^D_t]\,\overbrace{\frac{1}{h}(1-\lambda)\sum_{k=0}^{h-1}\sum_{j=0}^{h-k-1}\lambda^j}^{=\frac{1}{h}\sum_{\ell=1}^{h}[1-\lambda^\ell]} \\
&= \big(1-\hat{\delta}(h)\big)[(1-\psi_i)\Delta_h e_t + \psi_i^D \Delta_h e^D_t], \\
\mathbb{E}\{\Delta_h p^*_{it}|\Delta_h e_t, \Delta_h e^D_t, \iota_i = 0, \iota_i^D = 0\} &= \mathbb{E}\{\Delta_h p_{it}|\Delta_h e_t, \Delta_h e^D_t, \iota_i = 0, \iota_i^D = 0\} + \Delta_h e_t \\
&= \Delta_h e_t + \big(1-\hat{\delta}(h)\big)[-\psi_i \Delta_h e_t + \psi_i^D \Delta_h e^D_t] \\
\mathbb{E}\{\Delta_h p^*_{it}|\Delta_h e_t, \Delta_h e^D_t, \iota_i = \iota_i^D = 1\} &= \mathbb{E}\{\Delta_h p^D_{it}|\Delta_h e_t, \Delta_h e^D_t, \iota_i = \iota_i^D = 1\} + \Delta_h e^D_t \\
&= \Delta_h e^D_t + \big(1-\hat{\delta}(h)\big)[(1-\psi_i)\Delta_h e_t - (1-\psi_i^D)\Delta_h e^D_t].
\end{aligned}$$

Note that $\iota_i = 1, \iota_i^D = 0$ corresponds to LCP; $\iota_i = \iota_i^D = 0$ to PCP; and $\iota_i = \iota_i^D = 1$ to DCP. In our calculations, we use the fact that $\text{var}(\Delta_h e_t) = h\sigma_e^2$, where $\sigma_e^2 = \text{var}(\Delta e_t)$, and

$$\text{cov}\Big((1-\lambda)\textstyle\sum_{k=0}^{h-1}\sum_{j=0}^{\infty}\lambda^j(1-\psi_i)\Delta e_{t-j-k}, \sum_{k=0}^{h-1}\Delta e_{t-j}\Big) = \sigma_e^2(1-\psi_i)(1-\lambda)\sum_{k=0}^{h-1}\sum_{j=0}^{h-k-1}\lambda^j.$$

The three conditional expectations above imply the regression specification (A3). ■

Lastly, we note that ι_i and ψ_i are not collinear, as $\iota_i = \mathbf{1}\{\psi_i + \eta_i \geq 0\}$, and similarly for ι_i^D and ψ_i^D. The estimation of (A3) does not require instrumentation for ι_i and ι_i^D, as long as ψ_i and ψ_i^D interactions are controlled for.

References

Alfaro, L., M. Calani, and L. Varela (2021): "Currency Hedging: Managing Cash Flow Exposure," NBER Working Paper No. 28910.

Amiti, M., O. Itskhoki, and J. Konings (2014): "Importers, Exporters, and Exchange Rate Disconnect," *American Economic Review*, 7(104), 1942–1978.

——— (2019): "International Shocks, Variable Markups and Domestic Prices," *Review of Economic Studies*, 6(86), 2356–402.

Andrews, I., J. H. Stock, and L. Sun (2019): "Weak Instruments in Instrumental Variables Regression: Theory and Practice," *The Annual Review of Economics*, 11(5), 727–52.

Auer, R., A. T. Burstein, and S. Lein (2020): "Exchange Rates and Prices: Evidence from the 2015 Swiss Franc Appreciation," *American Economic Review*, forthcoming.

Bacchetta, P., and E. van Wincoop (2000): "Does Exchange-Rate Stability Increase Trade and Welfare?," *American Economic Review*, 90(5), 1093–1109.

——— (2005): "A Theory of the Currency Denomination of International Trade," *Journal of International Economics*, 67(2), 295–319.

Barbiero, O. (2020): "The Valuation Effects of Trade," https://obarbiero.github.io/files/VET.pdf.

Barbiero, O., E. Farhi, G. Gopinath, and O. Itskhoki (2019): "The Macroeconomics of Border Taxes," in *NBER Macroeconomics Annual 2018*, vol. 33. forthcoming.

Berman, N., P. Martin, and T. Mayer (2012): "How do different exporters react to exchange rate changes?," *Quarterly Journal of Economics*, 127(1), 437–492.

Betts, C., and M. Devereux (2000): "Exchange Rate Dynamics in a Model of Pricing-to-Market," *Journal of International Economics*, 50(1), 215–44.

Bhattarai, S. (2009): "Optimal currency denomination of trade: Theory and quantitative exploration," https://sites.google.com/site/bhattaraisaroj/.

Boehm, C. E., A. A. Levchenko, and N. Pandalai-Nayar (2020): "The Long and Short (Run) of Trade Elasticities," NBER Working Paper No. 27064.

Boz, E., G. Gopinath, and M. Plagborg-Møller (2017): "Global Trade and the Dollar," NBER Working Paper No. 23988.

Broda, C., and D. Weinstein (2006): "Globalization and the Gains from Variety," *Quarterly Journal of Economics*, 121(2), 541–85.

Burstein, A., and G. Gopinath (2013): "International Prices and Exchange Rates," in *Handbook of International Economics*, ed. by G. Gopinath, E. Helpman, and K. Rogoff, vol. IV.

Casas, C., F. J. Díez, G. Gopinath, and P.-O. Gourinchas (2016): "Dominant Currency Paradigm," NBER Working Paper No. 22943.

Cavallo, A., B. Neiman, and R. Rigobon (2014): "Currency Unions, Product Introductions, and the Real Exchange Rate," *The Quarterly Journal of Economics*, 129(2), 529–595.

Caves, D. W., L. Christensen, and E. W. Diewert (1982): "Multilateral Comparisons of Output, Input and Productivity Using Superlative Index Numbers," *Economic Journal*, 92(365), 73–86.

Chari, V., P. Kehoe, and E. McGrattan (2002): "Can Sticky Price Models Generate Volatile and Persistent Exchange Rates?," *Review of Economic Studies*, 69(3), 533–63.

Chen, N., W. Chung, and D. Novy (2018): "Vehicle Currency Pricing and Exchange Rate Pass-Through," CEPR Discussion Papers No. 13085.

Chung, W. (2016): "Imported inputs and invoicing currency choice: Theory and evidence from UK transaction data," *Journal of International Economics*, 99, 237–250.

Corsetti, G., M. A. Crowley, and L. Han (2020): "Invoicing and Pricing-to-market: Evidence on international pricing by UK exporters," CEPR Discussion Paper No. 13282.

Corsetti, G., and P. Pesenti (2004): "Endogenous Pass-Through and Optimal Monetary Policy: A Model of Self-Validating Exchange Rate Regimes," CEPR Working Paper No. 8737.

——— (2007): "The Simple Geometry of Transmission and Stabilization in Closed and Open Economies [with Comments]," *NBER International Seminar on Macroeconomics*, pp. 65–129.

Cravino, J. (2017): "Exchange Rates, Aggregate Productivity and the Currency of Invoicing of International Trade," https://sites.google.com/a/umich.edu/javiercravino/.

Crowley, M. A., L. Han, and M. Son (2021): "Dominant currency dynamics: Evidence on dollar-invoicing from UK exporters," Cambridge-INET Working Paper No. 2051.

Devereux, M., and C. Engel (2003): "Monetary Policy in the Open Economy Revisited: Price Setting and Exchange Rate Flexibility," *Review of Economic Studies*, 70, 765–84.

Devereux, M., C. Engel, and P. Storgaard (2004): "Endogenous Pass-through when Nominal Prices are set in Advance," *Journal of International Economics*, 63(2), 263–291.

Devereux, M. B., W. Dong, and B. Tomlin (2017): "Importers and exporters in exchange rate pass-through and currency invoicing," *Journal of International Economics*, 105(C), 187–204.

Devereux, M. B., and S. Shi (2013): "Vehicle Currency," *International Economic Review*, 54(1), 97–133.

Dornbusch, R. (1976): "Expectations and Exchange Rate Dynamics," *Journal of Political Economy*, 84(6), 1161–1176.

——— (1987): "Exchange Rate and Prices," *American Economic Review*, 77(1), 93–106.

Drenik, A., R. Kirpalani, and D. Perez (2019): "Currency Choice in Contracts," http://www.andresdrenik.com/research/.

Drenik, A., and D. Perez (2018): "Pricing in Multiple Currencies in Domestic Markets," http://www.andresdrenik.com/research/.

Drenik, A., and D. J. Perez (2021): "Domestic Price Dollarization in Emerging Economies," *Journal of Monetary Economics*, forthcoming.

Egorov, K., and D. Mukhin (2020): "Optimal Policy under Dollar Pricing," https://sites.google.com/site/dmitry0mukhin/.

Engel, C. (2003): "Expenditure Switching and Exchange Rate Policy," in *NBER Macroeconomics Annual 2002*, vol. 17, pp. 231–272.

——— (2006): "Equivalence Results for Optimal Pass-Through, Optimal Indexing to Exchange Rates, and Optimal Choice of Currency for Export Pricing," *Journal of European Economic Association*, 4(6), 1249–60.

Farhi, E., and M. Maggiori (2017): "A Model of the International Monetary System," *The Quarterly Journal of Economics*, 133(1), 295–355.

Fauceglia, D., A. Shingal, and M. Wermelinger (2012): "'Natural hedging' of exchange rate risk: The role of imported input prices," http://www.alexandria.unisg.ch/publications/citation/Martin_Wermelinger/.

Feenstra, R. C., P. Luck, M. Obstfeld, and K. N. Russ (2018): "In Search of the Armington Elasticity," *The Review of Economics and Statistics*, The Review of Economics and Statistics(1), 135–150.

Fleming, J. M. (1962): "Domestic financial policies under fixed and floating exchange rates," *IMF Staff Papers No. 9*, pp. 369–379.

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

Galí, J. (2008): *Monetary Policy, Inflation and the Business Cycle: An Introduction to the New Keynesian Framework*. Princeton University Press.

Goldberg, L. S., and C. Tille (2008): "Vehicle currency use in international trade," *Journal of International*

Economics, 76(2), 177–192.

——— (2009): "Macroeconomic interdependence and the international role of the dollar," *Journal of Monetary Economics*, 56(7), 990–1003.

——— (2016): "Micro, macro, and strategic forces in international trade invoicing: Synthesis and novel patterns," *Journal of International Economics*, 102, 173–187.

Gopinath, G. (2016): "The International Price System," *Jackson Hole Symposium Proceedings*.

Gopinath, G., E. Boz, C. Casas, F. J. Díez, P.-O. Gourinchas, and M. Plagborg-Møller (2020): "Dominant Currency Paradigm," *American Economic Review*, 110(3), 677–719.

Gopinath, G., and O. Itskhoki (2010): "Frequency of Price Adjustment and Pass-through," *Quarterly Journal of Economics*, 125(2), 675–727.

——— (2021): "Dominant Currencies in International Pricing," in *Handbook of International Economics*, ed. by G. Gopinath, E. Helpman, and K. Rogoff, vol. IV. forthcoming.

Gopinath, G., O. Itskhoki, and R. Rigobon (2010): "Currency Choice and Exchange Rate Pass-through," *American Economic Review*, 100(1), 306–336.

Gopinath, G., and R. Rigobon (2008): "Sticky Borders," *Quarterly Journal of Economics*, 123(2), 531–575.

Gopinath, G., and J. C. Stein (2020): "Banking, Trade, and the making of a Dominant Currency," *Quarterly Journal of Economics*, forthcoming.

Gourinchas, P.-O. (2019): "The Dollar Hegemon? Evidence and Implications for Policymakers," the 6th Asian Monetary Policy Forum, Singapore.

He, Z., A. Krishnamurthy, and K. Milbradt (2019): "A Model of Safe Asset Determination," *American Economic Review*, 109(4), 1230–62.

Ilzetzki, E., C. M. Reinhart, and K. S. Rogoff (2019): "Exchange Arrangements Entering the Twenty-First Century: Which Anchor will Hold?," *The Quarterly Journal of Economics*, 134(2), 599–646.

Itskhoki, O. (2020): "The Story of the Real Exchange Rate," http://scholar.princeton.edu/itskhoki/.

Krugman, P. R. (1980): "Vehicle Currencies and the Structure of International Exchange," *Journal of Money, Credit and Banking*, 12, 513–26.

——— (1987): "Pricing to Market when the Exchange Rate Changes," in *Real Financial Linkages among Open Economies*, ed. by S. Arndt, and J. Richardson, pp. 49–70. MIT Press, Cambridge.

Lyonnet, V., J. Martin, and I. Mejean (2021): "Invoicing Currency, Firm Size, and Hedging," *Journal of Money, Credit and Banking*, forthcoming.

Maggiori, M., B. Neiman, and J. Schreger (2020): "International Currencies and Capital Allocation," *Journal of Political Economy*, forthcoming.

Mukhin, D. (2017): "An Eqilibrium Model of the International Price System," https://sites.google.com/site/dmitry0mukhin/.

Mundell, R. A. (1963): "Capital mobility and stabilization policy under fixed and flexible exchange rates," *Canadian Journal of Economics and Political Science*, 29(4), 475–485.

Nakamura, E., and J. Steinsson (2008): "Five Facts about Prices: A Reevaluation of Menu Cost Models," *Quarterly Journal of Economics*, 123(4), 1415–1464.

Obstfeld, M., and K. Rogoff (1995): "Exchange Rate Dynamics Redux," *Journal of Political Economy*, 103, 624–60.

——— (2000): "New Directions for Stochastic Open Economy Models," *Journal of International Economics*, 50, 117–153.

Rey, H. (2001): "International Trade and Currency Exchange," *Review of Economic Studies*, 68(2), 443–464.

Van Biesebroeck, J. (2007): "Robustness of Productivity Estimates," *Journal of Industrial Economics*, (3), 529–568.