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HOW FIRMS CHOOSE CURRENCY INVOICING AND WHY IT MATTERS

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Dominant Currencies: How Firms Choose Currency Invoicing and Why it Matters
Mary Amiti, Oleg Itskhoki, and Jozef Konings
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ABSTRACT

Using new data on currency invoicing for Belgian firms, we analyze how firms make their currency choice, for both exports and imports, and the implications of this choice for exchange rate pass-through into prices and quantities. We derive our estimating equations from a theoretical framework featuring variable markups, international input sourcing, and staggered price setting with endogenous currency choice. Our structural specification provides a new test of the allocative consequences of nominal rigidities, by estimating the treatment effect of foreign-currency price stickiness on the dynamic response of prices and quantities, controlling for the endogeneity of the firm's currency choice. We show that flexible-price determinants of exchange rate pass-through are also the key firm characteristics that determine currency choice. In particular, small non-importing firms tend to price their exports in euros (producer currency) and exhibit complete exchange-rate pass-through into destination prices at all horizons. In contrast, large import-intensive firms tend to denominate their exports in foreign currencies, especially in the US dollar, exhibiting a lower pass-through of the euro-destination exchange rate and a pronounced sensitivity to the dollar-destination exchange rate. The effects of foreign-currency price stickiness are still significant beyond the one-year horizon, but gradually dissipate in the long run.

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1 Introduction

The currency of invoicing used in price setting is central for the international transmission of shocks, as well as for macroeconomic policies in an open economy. Not only does it matter for the size of the international spillovers, but also for their direction. If firms price their exports in the producer currency, a depreciation of their currency leads to a terms of trade improvement for the foreign country, whereas pricing in the destination currency has the opposite effect, with the terms of trade improvement for the home country (Obstfeld and Rogoff 2000). To further complicate matters, if firms were to price their exports in dollars, a third currency, then the depreciation of the home currency has no effect on export prices, while a depreciation of the dollar against the destination currency results in a terms-of-trade deterioration for the home country (Gopinath 2016). This matters enormously for macroeconomic policy, as movements in terms of trade shape expenditure switching between domestic and foreign products, and are thus key factors in policy decisions to optimally peg or float the exchange rate (see Friedman 1953, and the literature that followed).¹

In this paper, we analyze — both theoretically and empirically — how firms choose the currency of invoicing, in both their exports and imports, and the implications of this choice for exchange rate pass-through into prices and quantities, at different time horizons. We start by identifying two new stylized facts. First, the currency choice is an active firm-level decision, yet with substantial persistence over time. Using a new data set on Belgium firms, which combines information on the choice of currency invoicing at the firm-product-country-month level, we find that firm-destination characteristics explain 85% of currency-use variation, significantly more than the industry-destination or even the highly-detailed product-destination determinants. This motivates our focus on identifying the specific firm characteristics that have explanatory power for the currency choice. It is generally difficult to obtain trade data that specify the currency of invoicing, and those that are available typically lack information on firm characteristics, which we show are central for understanding the currency choice, consistent with theory. Therefore, the Belgian firm-product-country-level trade data with information on values, quantities, and currency of invoicing, merged with domestic census data on general firm characteristics, is uniquely suitable for this analysis.

The second new stylized fact to emerge from this dataset is that the euro is a dominant currency, at least as important as the US dollar, for both Belgian imports and exports outside of the European Union. The combined share of the two currencies accounts for about 90% of all ex-EU trade flows. Consequently, producer (source) currency pricing, known as PCP, is uncommon for Belgian imports and local (destination) currency pricing, known as LCP, is uncommon for Belgian exports. Thus, the invoicing patterns in the data are at odds with conventional international macro models that assume exogenously either PCP or LCP pricing, and instead are consistent with a framework that allows for endogenously emerging dominant currencies (DCP) — namely, the dollar as the established global dominant currency and the euro as the emerging regional dominant currency. Furthermore, the Belgian data

¹The use of the US dollar in international trade invoicing and as the nominal anchor for pegging the exchange rates in many countries are two of the complementary and interrelated forces in the emergence of the dollar as the global dominant currency, as emphasized recently by Gourinchas (2019).

features substantial variation in the use of the two dominant currencies – both across country-sectors and across firms within detailed industry-destinations – another rare feature necessary for the analysis of endogenous currency choice at the firm level.

We derive our estimating equations building on a theoretical framework, which combines heterogeneous firms with variable markups (as in [Amiti, Itskhoki, and Konings 2019](#)), endogenous international input sourcing (as in [Amiti, Itskhoki, and Konings 2014](#)) and staggered price setting with endogenous currency choice (as in [Gopinath, Itskhoki, and Rigobon 2010](#)), allowing additionally for the DCP option. This framework predicts that the desired (flexible-price) exchange rate pass-through (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, in turn, is determined by the desired ERPT of the firm during the period of price non-adjustment. Since the currency choice directly determines the short-run ERPT of the firm, it feeds back, via strategic complementarities in pricing, into the currency choice and price adjustment decisions of other firms, affecting the equilibrium exchange rate pass-through at the industry level. Thus, changes in the equilibrium environment – in particular related to the prevalence in the use of different currencies – can result in profound shifts in the overall patterns of exchange rate pass-through into export prices and the international transmission of shocks.

We analyze the firm’s currency choice in exporting and importing within this framework, initially as a binary choice between euros and other currencies, and then as the choice between the destination currency and the dollar.² 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, with larger, more import-intensive firms more likely to deviate from producer currency pricing and choose non-euros for pricing their exports. The currency in which the imported inputs are invoiced is positively associated with the export currency choice, providing real hedging. Furthermore, the firms that rely more on imported intermediate inputs, in particular those invoiced in non-euros and specifically in dollars, are more likely to adopt the dollar to price their exports, while larger firms, other things equal, are more likely to adopt the destination currency (LCP). Firm participation in global value chains, proxied by cross-border ownership and FDI, also increases the likelihood of foreign-currency – and specifically dollar – use in exports. We also find evidence of strategic complementarities in currency choice, whereby the currency choice of the firm’s competitors within its industry-destination has a strong impact on the firm’s own currency choice. This mechanism can propagate the currency choice equilibrium over time, resulting in inertia and resistance to change.

For currency choice in imports, we also observe strong strategic complementarities with other firms importing the same products from the same source countries. However, unlike for exports, the other firm characteristics, and in particular firm size, are uncorrelated with the firm’s importing currency choice. This lack of correlation with currency use in imports suggests that currency choice is a less active firm-level decision for importing than for exporting. This finding is in line with the baseline model of currency choice, in which the supplier makes the currency and price-setting decisions, while the downstream firms choose quantities given the realized prices.

²Note that the analysis of the choice between the destination currency and the dollar requires us to focus on the subset of destination countries that do not peg their currency to the dollar, as we further explain below.

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.

Specifically, we find that small Belgian exporters with no exposure to foreign inputs that price their exports in euros exhibit complete pass-through of the euro-destination 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 local or dominant currency 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, the firms that price in dollars exhibit significant pass-through of the dollar exchange rate into destination prices, especially in the short run and also gradually decaying over time. At the one year horizon, the differential pass-through of the PCP firms relative to LCP firms is around 33%, and similarly for the DCP firms on the dollar-destination exchange rate, in both cases after controlling for the flexible-price ERPT determinants.

We show that the estimated dynamics of ERPT into prices are consistent with a simple Calvo model of staggered price setting in different currencies, with roughly a 13% monthly probability of price adjustment, or in other words with an average duration of price setting of 8.3 months.³ 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 at the annual horizon. 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.

One drawback of our dataset is that we only observe unit values instead of the transaction-level individual price changes, and hence cannot condition our analysis on a price change (as in [Gopinath, Itskhoki, and Rigobon 2010](#)). However, the ability to observe firm characteristics, combined with the currency invoicing, is a major novel benefit of these data. This enables us to address the selection of firms into different currencies of pricing, and thereby establish the direct causal effects of foreign-currency price stickiness on the dynamics of export prices and quantities. Our data allows us to estimate this non-parametrically at various horizons, effectively comparing the response of treated subsets of

³This 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.

firms — pricing in dollars and in the destination currency — relative to the control group pricing in euros, while holding fixed firm characteristics that shape the desired pass-through of the firms conditional on price adjustment. As a result, we are able to provide new evidence of gradual convergence of pass-through across currency groups of firms, consistent with the theoretical predictions.

There are two further noteworthy features of our analysis. First, we focus on the within-industry-destination heterogeneous response across firms to the same exchange rate shocks. In other words, our analysis includes highly disaggregated industry-destination-time fixed effects, and our inference is based on the differential behavior of firms within the same general equilibrium environment, thus excluding confounding macroeconomic factors. Second, our analysis relies on a structural estimating equation, which emphasizes the importance of including both the euro-destination and the dollar-destination exchange rates interacted with firm characteristics. We show that conventional exchange rate specifications, which fail to include the interactions terms with the dominant-currency exchange rate result in estimates biased towards zero.

We discuss the related literature next, and 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 new stylized facts on the currency use in import and export transactions of Belgian firms. Section 4 contains our empirical analysis of the currency choice at the firm level, for export and import transactions. Section 5 presents the results on pass-through of bilateral and dominant exchange rates into export prices and quantities at the annual frequency, while Section 6 studies the ERPT dynamics and the relative contribution of sticky-price and flexible-price determinants of pass-through over various horizons. Section 7 offers concluding remarks on the likely scenarios for the changing status of dominant currencies.

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 a more recent analysis in [Egorov and Mukhin 2020](#)).⁴

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

⁴[Barbiero, Farhi, Gopinath, and Itskhoki \(2019\)](#) emphasize the role of the currency of invoicing for the trade balance consequences of tax and tariff policies.

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](#)).⁵ In this paper, we document that neither 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 \(2006\)](#) provided 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. [Gopinath, Itskhoki, and Rigobon \(2010\)](#) generalized this result to a dynamic multi-period framework, separately identifying the feedback effects between currency choice and the dynamics of ERPT. More recently, [Mukhin \(2017\)](#) nested this framework in a general equilibrium model of the international price system with endogenously-emerging dominant currencies.⁶ 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 international trade flows, following [Goldberg and Tille \(2008\)](#) and [Gopinath \(2016\)](#).⁷ 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

⁵The 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.

⁶Other 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 \(2020\)](#).

⁷An 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](#), [Maggiore, Neiman, and Schreger 2020](#)), as reserve and global safe-asset currency (see e.g. [Farhi and Maggiore 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](#)).

our study is that we can match the currency invoicing data with 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.

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, the optimal preset price and the optimal currency choice. We begin with a simple one-period model of price stickiness and then extend the analysis to a dynamic environment.

2.1 Environment

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 export price in producer currency (euros). 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 log *desired* price of firm i is given by:

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

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

$$\tilde{p}_i^\ell = \tilde{p}_i + e_\ell, \quad (2)$$

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 an *appreciation* of 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^ℓ in currency ℓ before the state Ω is realized, 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:

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

where the expectation is taken over all possible realizations of the state vector Ω .⁸ One can prove

⁸This 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).

the following characterization of the optimal preset price \bar{p}_i^ℓ , extending the logic of Proposition 1 in [Gopinath, Itskhoki, and Rigobon \(2010\)](#):⁹

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

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

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

Under any currency choice ℓ , the firm chooses its preset price to target the average desired price \tilde{p}_i^ℓ , expressed in this currency.

Currency choice When choosing \bar{p}_i^ℓ , the firm also chooses the currency ℓ , in which it presets the price. The optimal currency choice solves:¹⁰

$$\ell = \arg \max_\ell \left\{ \max_{\bar{p}_i^\ell} \mathbb{E} \Pi_i(\bar{p}_i^\ell - e_\ell | \Omega) \right\}. \quad (5)$$

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, $\Pi_i(\tilde{p}_i) - \Pi_i(\tilde{p}_i^\ell - e_\ell)$, on average 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 the exchange rates. Specifically, we have:¹¹

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:*

$$\ell = \arg \min_\ell \left\{ \text{var}(\tilde{p}_i + e_\ell) \right\}, \quad (6)$$

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

The optimal currency of pricing ℓ ensures the minimal variation in the desired price expressed in currency ℓ , \tilde{p}_i^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^ℓ and \tilde{p}_i^ℓ , and thus large profit losses across states of the world.

⁹Formally, this lemma obtains from the Taylor expansion of the first-order condition (FOC) for \bar{p}_i^ℓ in (3) around \tilde{p}_i^ℓ , which according to the FOC for \tilde{p}_i in (1) satisfies $\Pi_i'(\tilde{p}_i^\ell - e_\ell) = 0$.

¹⁰The 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 accommodate any stochastic discount factor.

¹¹To prove this lemma, Taylor expand around \tilde{p}_i the gap in average profits between currencies ℓ and d : $\mathbb{E} \Pi_i(\bar{p}_i^\ell - e_\ell) - \mathbb{E} \Pi_i(\bar{p}_i^d - e_d) \approx \frac{1}{2} \mathbb{E}\{-\Pi_i''(\tilde{p}_i)\} \cdot [\text{var}(\tilde{p}_i^d) - \text{var}(\tilde{p}_i^\ell)]$, and thus currency ℓ is chosen when $\text{var}(\tilde{p}_i^\ell) < \text{var}(\tilde{p}_i^d)$ 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 $\mathbb{E}(\tilde{p}_i^\ell - \bar{p}_i^\ell)^2 = \text{var}(\tilde{p}_i^\ell)$.

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^ℓ . 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 $\text{var}(\tilde{p}_i) > \text{var}(\tilde{p}_i^\ell) = \text{var}(\tilde{p}_i + e_\ell)$. Expanding the last variance term and manipulating the inequality, this condition is equivalent to:

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

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 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^ℓ is low, or equivalently \tilde{p}_i^ℓ 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 ERPT in every currency ℓ other than the euro.

Finally, we point out that currency choice is an indexing decision. Specifically, 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 between the destination currency k and the currency of pricing ℓ given by $e_k^\ell \equiv e_k - e_\ell$. The goal of the currency choice is to find such ℓ and e_k^ℓ that allows $\bar{p}_i^\ell + e_k^\ell$ to closely track \tilde{p}_i^ℓ . Lemma 2 and equation (7) formalize this idea as a condition on the low volatility of the desired price \tilde{p}_i^ℓ , or equivalently the low exchange rate pass-through into \tilde{p}_i^ℓ .

In what follows, we focus on the three most common cases, namely those of 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 non-adjustment* given by:

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

as the relevant exchange rate e_k^ℓ is $e_k^E = e_k$, e_k^D , and $e_k^k = 0$ in these three cases respectively. 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 in the short run. Similarly, DCP is favored if \tilde{p}_i^* tracks closely the dollar-destination exchange rate e_k^D , that is 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.

2.2 ERPT and currency choice

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

$$\tilde{p}_i = \tilde{\mu}_i + mc_i, \quad (9)$$

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 log deviation) 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:¹²

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

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, $\Gamma_i \equiv -\partial\tilde{\mu}_i/\partial p_i$. 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 the bilateral euro-destination exchange rate e_k and the dollar-destination exchange rate e_k^D . By convention, an increase in both e_k and e_k^D correspond 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 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:*

$$d\tilde{p}_i^* = (1 - \varphi_i - \gamma_i) de_k + (\varphi_i^D + \gamma_i^D) de_k^D, \quad (11)$$

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.¹³ 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 desired 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

¹²Formally, (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, that is $\Gamma_i = -\mathcal{M}'(\tilde{p}_i + e_k - z_k^*) > 0$.

¹³In our empirical specification, the aggregate demand shocks, which may be correlated with the exchange rate movements, are absorbed into the industry-destination-time fixed effects.

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 can proxy for φ_i and φ_i^D with the firm's share of imported intermediate 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 Γ_i is increasing in firm size (market share) and is zero for firms with negligible market shares. We, therefore, expect γ_i and γ_i^D to increase in firm size, and $\gamma_i = \gamma_i^D = 0$ for the smallest firms.¹⁴ We generally expect $\varphi_i \geq \varphi_i^D \geq 0$ and $\gamma_i \geq \gamma_i^D \geq 0$, as φ_i and γ_i correspond to the marginal cost and markup sensitivity to any foreign currency (including the dollar), while φ_i^D and γ_i^D correspond to the sensitivity to the dollar specifically.

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:

1. PCP (euro) if $d\tilde{p}_i^* \approx de_k$, corresponding to $\varphi_i, \gamma_i, \varphi_i^D, \gamma_i^D \approx 0$;
2. DCP (dollar) if $d\tilde{p}_i^* \approx de_k^D$, when $\varphi_i + \gamma_i \approx \varphi_i^D + \gamma_i^D \approx 1$;
3. LCP (destination currency) if $d\tilde{p}_i^* \approx 0$, 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. Accordingly, LCP is favored over PCP if $\frac{d\tilde{p}_i^*}{de_k} < \frac{1}{2}$, which requires $\varphi_i + \gamma_i > \frac{1}{2}$, and PCP is favored otherwise. Similarly, DCP is favored over PCP if $\frac{d[\tilde{p}_i^* - e_k^D]}{de_D} < \frac{1}{2}$, where $e_D \equiv e_k - e_k^D$ is the euro-dollar exchange rate, which holds if $\varphi_i^D + \gamma_i^D > \frac{1}{2}$. Lastly, in the comparison of DCP vs LCP, the DCP is chosen when $\frac{d\tilde{p}_i^*}{de_k^D} \geq \varphi_i^D + \gamma_i^D > \frac{1}{2}$, and LCP may be chosen when $\varphi_i^D + \gamma_i^D < \frac{1}{2}$.

To summarize, low exposure to foreign currencies (low φ_i and γ_i) favors PCP; high exposure to the dollar (high φ_i^D and γ_i^D) favors DCP; LCP is chosen in the interim range where φ_i and γ_i are high, and φ_i^D and γ_i^D are low. Therefore, the choice between producer currency and a foreign currency is clear cut – PCP is favored when the firm has a stable desired markup and marginal cost in the producer currency. In contrast, the choice between different foreign currencies – LCP vs DCP – is more subtle. Following the approximation suggested in footnote 14, $\gamma_i = \gamma S_i$ and $\gamma_i^D = \gamma^D S_i$ with $\gamma > \gamma^D$, which suggests that larger firms should favor LCP over DCP. Indeed, to the extent that larger firms exhibit stronger strategic complementarities in pricing, they are more likely to adopt LCP to ensure that their prices are better aligned with their local competitors in the destination country, who price in the local currency by default.

¹⁴The markup elasticity Γ_i is increasing with the size of the firm in a broad class of oligopolistic and monopolistic competition models. For example, in the [Atkeson and Burstein \(2008\)](#) oligopolistic competition model, the markup elasticity is simply $\Gamma_i = (\rho - 1)S_i$, where $\rho > 1$ is the within-industry elasticity of substitution and S_i is a measure of firm size (destination market share). We approximate $\frac{\Gamma_i}{1+\Gamma_i} \frac{\partial[z_k^* - mc_i - e_k]}{\partial e_k} \approx -\gamma S_i$ and $\frac{\Gamma_i}{1+\Gamma_i} \frac{\partial[z_k^* - mc_i - e_k]}{\partial e_k^D} \approx \gamma^D S_i$, and we expect $\gamma \geq \gamma^D \geq 0$. [Berman, Martin, and Mayer \(2012\)](#) were first to document the systematic ERPT heterogeneity between large and small firms.

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:

$$dp_i^* = \begin{cases} d[\bar{p}_i^\ell + e_k^\ell] = de_k^\ell, & \text{with probability } \delta, \\ d\tilde{p}_i^*, & \text{with probability } 1 - \delta, \end{cases}$$

where $d\tilde{p}_i^*$ 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 $\mathbb{E}dp_i^* = \delta de_k^\ell + (1 - \delta)d\tilde{p}_i^*$.

We again focus on the three main 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. Assuming that no other cases are observed in equilibrium, we can denote the choice of the PCP (euro) as $\iota_i = \iota_i^D + \iota_i^L = 0$, and the choice of any foreign currency as $\iota_i = 1$. Using this notation, we combine (8) and (11) to obtain the expression for the expected observed price change:

$$\mathbb{E}dp_i^* = de_k + \delta[-\iota_i de_k + \iota_i^D de_k^D] + (1 - \delta)[-(\varphi_i + \gamma_i)de_k + (\varphi_i^D + \gamma_i^D)de_k^D]. \quad (12)$$

The first term (de_k) isolates the complete pass-through of the euro-destination exchange rate (that is, $dp_i^*/de_k = 1$) of a counterfactual 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 via its 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 – holding constant the desired price of the firm. This effect occurs conditional on no price adjustment, which happens with probability δ , and results in incomplete (zero) pass-through of the euro-destination exchange rate for LCP; and in a complete pass-through of the dollar-destination exchange rate into destination prices if DCP is adopted. The greater the extent of price stickiness, the larger is δ and thus the expected 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 desired price pass-through on the realized 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.

Importantly, equation (12) is robust to the underlying selection of heterogeneous firms into different currencies of pricing based on the characteristics of their desired pass-through. By controlling for the desired pass-through conditional on a price adjustment, we can estimate the direct causal effect of the currency of pricing on the realized ERPT, captured by the parameter δ . In other words, this allows us to estimate the treatment effect of randomly assigning a given firm to a particular currency of pricing given its desired pass-through, even though in the data the assignment of firms to currency bins is not random and is shaped, at least in part, by the desired pass-through itself.

2.3 Dynamics of ERPT

The one-period model introduced above 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 $\delta \rightarrow 0$. Therefore, as we consider longer time horizons, the relative weight in (12) shifts away from the sticky-price term and towards the desired-price (flexible-price) term. We approach the data non-parametrically, and estimate a sequence of equations (12) over varying time horizons.

To aid the interpretation of our estimates, we now extend the analysis to a dynamic price setting problem with a Calvo price setting friction.¹⁵ That is, we consider a firm that has an exogenous opportunity to reset its price with a probability $(1 - \delta)$ each period, while with probability δ it keeps its price unchanged from the previous period. We consider a firm setting prices in currency ℓ , which may correspond to PCP, LCP or DCP. Therefore, the firm's realized destination-currency price satisfies:

$$p_{it}^* = \begin{cases} \bar{p}_{it}^\ell + e_{kt}^\ell, & \text{with probability } 1 - \delta, \\ p_{i,t-1}^\ell + e_{kt}^\ell, & \text{with probability } \delta, \end{cases}$$

where the optimal *reset* price $\bar{p}_{it}^\ell = (1 - \beta\delta) \sum_{j=0}^{\infty} (\beta\delta)^j \mathbb{E}_t \bar{p}_{i,t+j}^\ell$ is a weighted average of current and future desired prices (using the probability of non-adjustment δ and the discount factor β as weights), generalizing the concept of preset price (3) in the static model (see e.g. Galí 2008). 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 $\bar{p}_{it}^* = \alpha_i e_{kt}$, where $\alpha_i = 1 - \varphi_i - \gamma_i$.¹⁶

With this data generating process, we show in Appendix B that by estimating equation (12) over any time horizon h (e.g., in months), one can recover both the structural parameter of price stickiness δ , as well as the causal treatment effect of currency of pricing, as discussed above. In particular, by projecting an h -period change in the observed prices, $p_{i,t+h}^* - p_{it}^*$, on the h -period change in the exchange rate, $e_{k,t+h} - e_{kt}$, interacted with a dummy for foreign currency choice ι_i and controlling for the desired pass-through terms, as in (12), one obtains the following coefficient (as a function of horizon h):

$$\hat{\delta}(h) = \frac{1}{h} \frac{\delta}{1 - \delta} (1 - \delta^h), \quad (13)$$

from which it is easy to obtain the price stickiness parameter δ . Furthermore, by varying the time horizon h , one obtains a sequence of estimates, which can be used to check whether a simple Calvo model with a single parameter δ offers a good approximation to the observed dynamics of prices. Indeed, (13) suggests that $\hat{\delta}(h)$ should decrease hyperbolically in h , and converge to zero in the long run, as the effect of price stickiness wanes.¹⁷ Finally, with a known δ , the fraction of prices that have not yet

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

¹⁶This implicitly assumes $\gamma_i^D = \varphi_i^D = 0$ and that α_i is constant over time, which we do not impose in the estimation.

¹⁷Note that the convergence is not geometric because it is a projection of the contemporaneous change in prices on the change in the exchange rate, over increasingly longer time horizons, thus mixing the short-run and the long-run responses. An alternative projection of a one-period price change on the distributed lag of past exchange rate changes recovers a geometrically decreasing pattern of coefficients, δ^h , but is considerably more demanding to estimate. Appendix B provides details.

been adjusted h periods after the shock is given by a declining geometric progression δ^h , which also measures the *causal* effect of the foreign-currency price stickiness on the realized ERPT h periods out.

3 Empirical Analysis

In this section, we describe our data sets and the construction of the main variables. We then present new empirical facts on currency invoicing.

3.1 Data Description

The novel data we use for our analysis is the information on the currency choice at the firm-product-country-month level for imports and exports from February 2017 to March 2019. The Belgian Customs Office began to compile these data at this disaggregated level at the beginning of 2017, which were then processed by the National Bank of Belgium. Because the Customs Office only records transactions for trade with countries outside the European Union (EU), the currency data are only available for ex-EU trade transactions. 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. Importantly, we have the invoicing information for both exports and imports for all ex-EU countries, with the importing side rarely observed in other data sets. These data report the value, quantity, and currency of invoice for exports and imports at the firm-product level by destination and source country with each product classified at the 8-digit combined nomenclature (CN), comprising around 10,000 distinct products. The first 6-digits of the CN codes correspond to the World Harmonized System (HS).

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. This combination of invoicing data with firm characteristics is unique to Belgium. It is straightforward to merge these datasets as both include a unique firm identifier. 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 component of total variable costs, where all firms have to report their employment and wages paid.

Using these data, we construct two key variables – the firm’s import intensity from outside the EU φ_{it} and its destination- k market share S_{ikt} , measured for each firm-product i . Specifically:

$$\varphi_{it} \equiv \frac{\text{Total non-euro import value}_{it}}{\text{Total variable costs}_{it}}, \quad (14)$$

where total variable costs comprise a firm’s total wage bill and total material cost. Note that φ_{it} is measured at the firm-level, and thus applies to all CN8-products i exported by multi-product firms. We usually average this measure over time to obtain a firm-level average import intensity denoted by φ_i . 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 non-euros. 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 $\varphi_i = \varphi_i^E + \varphi_i^X$.

The firm's market share is constructed as follows:

$$S_{ikt} \equiv \frac{\text{Export value}_{fskt}}{\sum_{f' \in F_{skt}} \text{Export value}_{f'skt}}, \quad (15)$$

where $\text{Export value}_{fskt}$ is the combined export value of all products of firm f in industry s (corresponding to firm-product i) shipped to destination k at time t , and F_{skt} is the set of all Belgian exporters to destination k in industry s at time t . Therefore, S_{ikt} measures the market share of the firm relative to all Belgium exporters in a given industry-destination.¹⁸ We define industries s at the HS 4-digit level, at which we both obtain a nontrivial distribution of market shares and avoid having too many industry-destinations served by a single Belgian exporter.

For the import and export currency choice estimation, we use the full sample of monthly data available to us from February 2017 to March 2019, and define the dependent variables as equal to 0 if the currency choice is the euro and 1 otherwise. For the export regressions, we run additional specifications for a subset of non-peg destinations, with the dependent variable equal to 1 for dollar choice and zero otherwise. We follow [Ilzetki, Reinhart, and Rogoff \(2019\)](#), and use monthly data (from 2012 to 2018) to classify as pegs all currencies with an annualized root mean squared error of exchange rate changes against the dollar below 5%, identifying 65 dollar pegs among 151 destination countries, which account for 43% of Belgian exports outside the EU.

When we turn to the baseline exchange rate pass-through analysis, we start with annual data on trade flows and firm characteristics for the period 2012 to 2018, as we are interested in studying the equilibrium relations following the theoretical framework described in Section 2. Since our data does not include information on the currency of invoicing prior to 2017, we take the currency of invoicing from the monthly trade data from 2017 to 2019 and extrapolate it to the years 2012-2016. In doing so, we calculate each firm's share of exports by destination invoiced in noneuros, and assume that it is persistent over time in the previous five years.¹⁹ This assumption is based on the high persistence in the currency choice in exporting: over our 26-month sample period, there was a switch between euros and noneuros for only 3.2% observations (3.7% value).

The dependent variable in the ERPT analysis 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):

$$\Delta p_{ikt}^* \equiv \Delta \log \left(\frac{\text{Export value}_{ikt}^*}{\text{Export quantity}_{ikt}} \right), \quad (16)$$

where values are converted to the destination currencies k (hence * superscript) and quantities are measured as weights (where available) or units. 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

¹⁸Theoretically, the relevant market share is relative to all firms supplying the destination market, including exporters from other countries and local competitors. Since our analysis is across Belgian exporters within industry-destinations, the competitive stance in a particular industry-destination is common for all Belgian exporters and absorbed into industry-destination-time fixed effects, thus letting S_{ikt} capture all relevant variation.

¹⁹For 70% of the observations, this firm-destination share is a zero-one dummy variable; even when fractional (for firms with multiple products), it is in the (0.2,0.8) range for only 8.3% of the observations.

one firm-product within a CN 8-digit code, 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, namely with year-to-year price ratios above 3 or below 1/3. Summary statistics for all variables are provided in the Appendix Table A2.

3.2 Stylized facts on currency choice

We start by documenting the overall incidence of different currencies in Belgian exports and imports. The currency data is available only for the ex-EU trade, which accounts for 27% of total Belgian exports and 34% of imports in 2018.²⁰ 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, while accounting for only about a third of its total trade flows, are still significant as a share of GDP.

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 (February 2017 to March 2019). We report the shares of both the observed transactions (at firm-product-country-month level) and 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 more than half (52%) of the value of exports, making the dollar the dominant export currency. The other currencies combined account for just over 10% of Belgian exports, both in count and in value terms. 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 almost the same as for exports: the euro accounts for 38% of the value of imports, the dollar accounts for 54% and all other currencies combined account for 8%. 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 almost 60% of the value of trade (for both exports and imports). The distribution across currency categories for differentiated goods show similar patterns to the overall value shares, with a somewhat more pronounced role of the euro. Indeed, one noticeable difference is that the role of the dollar is somewhat smaller in the differentiated trade flows – accounting for just under 40% of both differentiated exports and imports, versus over 50% in the overall trade. The euro share is equally

²⁰Most of the EU countries are also in the eurozone (which accounts for 57% of Belgian exports and 55% of imports), and thus the euro is the most likely currency for trade with these countries. However, there are eight EU countries not in the eurozone for which we also do not have currency data – Bulgaria, Croatia, Czech Republic, Denmark, Hungary, Poland, Romania, Sweden and the United Kingdom (accounting for 15% of Belgian exports and 10% of imports). For the countries that do report the currency of invoicing, we have at least 90% coverage, both in count and value terms.

²¹Importantly, these invoicing patterns are not driven by the US, which is Belgium’s largest trade partner outside the EU. For example, if we drop the US as an export destination, the share of the dollar use in export invoicing only falls from 52% to 46% of Belgium’s ex-EU exports and 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	0.659	0.353	0.398	0.293	0.377	0.380	0.484	0.244
Dollar	0.230	0.516	0.393	0.681	0.526	0.536	0.378	0.742
Other	0.111	0.131	0.209	0.026	0.097	0.084	0.137	0.014

Note: The currency data are at the firm-product (CN8)-country-month level for February 2017 to March 2019, for all ex-EU countries. “Other” row refers to all transactions in currencies other than the euro or dollar. “Diff” columns refer to differentiated goods as defined by the Rauch classification; “Non-diff” are all other goods.

prominent for exports and even larger for imports at 48%. Unsurprisingly, the dollar is a much more prevalent currency for commodities and homogeneous goods (non-differentiated category), where the dollar accounts for around 70% of the trade. Also note that the use of third currencies, which are nearly absent in the non-differentiated trade invoicing, becomes more prevalent for differentiated goods — accounting for 21% of exports and 14% of imports.

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. Under PCP, exports should be predominantly invoiced in euros and imports in the currency of the source country, whereas under LCP, exports should be invoiced in the destination currency and imports in euros. The *co-dominance* of euros and dollars in both importing and exporting suggests that neither LCP nor PCP accurately reflect the currency choices. Instead, the patterns are more in line with recent work emphasizing the dollar as the dominant currency (see [Gopinath, Boz, Casas, Díez, Gourinchas, and Plagborg-Møller 2020](#)).

As in the recent literature, we also find an outsized role of the US dollar relative to the share of US trade, with the share of dollar invoicing over 50% versus the 20% share of the US in Belgian ex-EU trade. 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. For the pegged countries, whether Belgian exporters choose to invoice in the destination currency or in dollars is essentially the same. Indeed, we find that the value share of dollar invoicing of 52% is fairly close to the Belgian trade share with the US and pegged countries combined, equal to 47% for exports and 55% for imports (in line with the complementarity emphasized in [Gourinchas 2019](#)). If we focus only on the differentiated products, we find the trade shares with the US and pegged countries to be higher, equal to 44% for exports and 60% for imports, than the 39% dollar invoicing share reported in Table 1. Even though a large share of transactions are in dollars, both in number and value, the pattern that we emphasize is the emergence of the euro as another dominant currency, at least in Belgian trade outside the EU in differentiated goods (for a theoretical analysis of multiple dominant currencies see [Mukhin 2017](#)).

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 reflects the share of the country in total Belgian trade. The fact that most circles lie on the negative

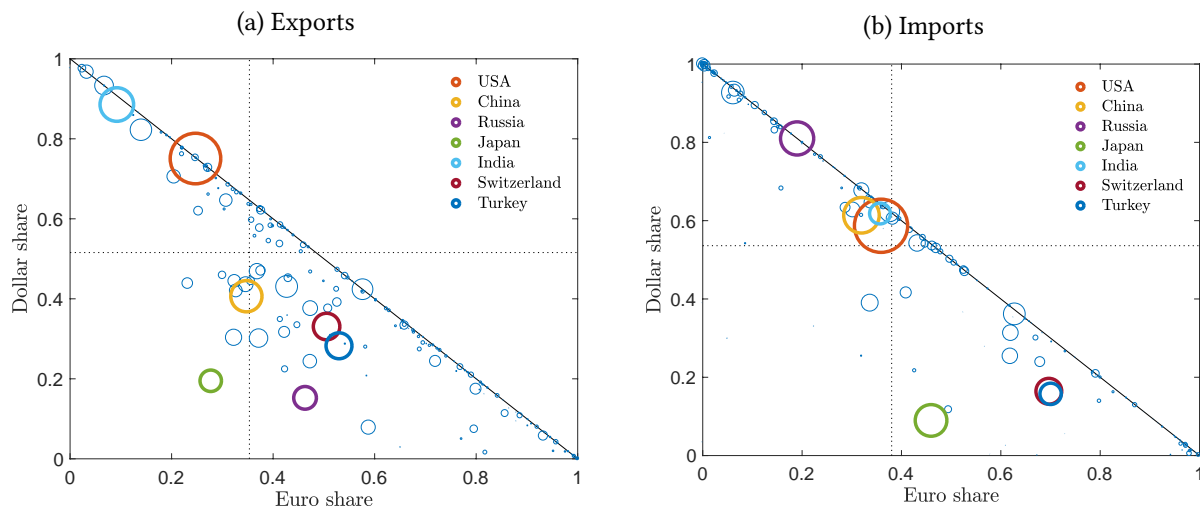


Figure 1: Dominant currencies in Belgian bilateral trade

Note: The figures plot the share of dollar invoicing against the share of euro invoicing by country, for Belgium exports on the left and imports on the right; circles represent the size of individual countries (outside the EU) 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-7 Belgian trade partners outside the EU in terms of total trade. The dotted lines plot the average currency shares from Table 1.

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 and imports from Russia, among major trade partners, are invoiced disproportionately in the US dollar, while trade with Switzerland and Turkey is invoiced disproportionately in euros, with a lot of variation in the relative shares of the two dominant currencies across other trade partners.

Figure 1 also shows that there are bigger departures towards third currencies in exports than in imports. For imports, only Japan among the main trade partners has a large 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, typically the currency of the destination country. This includes China, Japan, Switzerland, Turkey and Russia, as well as a number of other smaller trading partners.

Variance decomposition Drilling deeper and focusing on exports, we now explore the patterns of variation in currency invoicing at the firm-product-country-month level, which is the unit of observation in our currency choice regression analysis. We define a currency dummy variable for firm-product i , export-destination k , in month t :

$$\iota_{ikt} = \begin{cases} 0, & \text{if export transaction is in euro,} \\ 1, & \text{otherwise, if in non-euro.} \end{cases} \quad (17)$$

From Table 1 we know that $\iota_{ikt} = 0$ for two-thirds of export observations, accounting for 35% of the total value of exports. As noted above, there is very little variation in currency choice over time t , so we explore the patterns of cross-sectional variation in currency choice – across country-destinations, industries and firms.

Table 2: Currency invoicing in exports: variance decomposition

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Adjusted R^2	0.619	0.850	0.155	0.371	0.612	0.713	0.865	0.877
# of observations ('000)	3,491.2	3,458.7	3,497.3	3,497.3	3,483.3	3,430.8	3,445.7	3,394.3
# of fixed effects ('000)	16.5	84.8	0.2	1.2	58.7	171.1	141.5	249.6
• 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).

In Table 2, we project the currency dummy ι_{ikt} for export observations on various subsets of fixed effects, and report the adjusted R^2 from a value-weighted projection.²² The first thing to note from column 1 is that firm fixed effects alone explain 62% of the variation in export currency invoicing, and interacting firm fixed effects with country destinations in column 2 boosts that to 85%. That is, the bulk of the variation in export currency invoicing can be traced to the behavior of firms within given export destinations.

In contrast, the variation across destination countries alone in column 3 accounts for only a small share, 16%, of the variation in the currency choice in our panel, while the variation across industries (at HS4 level) accounts for 37% in column 4. Interacting industry and destination-country fixed effects in column 5, boosts the share of explained currency choice to 61%, nearly the same as with the firm fixed effects alone.²³ Using the more micro-level dimension of our data, we can explain a great share of variation in currency invoicing: interacting CN8-product and destination-country fixed effects in column 6 explains a large share, over 70%, 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.

Consistent with the firm-level theory presented in Section 2, the differential behavior across firms does appear to be central in explaining the variation in currency choice in the data, and is at least as important as the variation across industry-destinations. The remainder of the analysis leverages the micro-level features of our data, with a focus on the variation across firms within industry-destinations.

²²The patterns for the unweighted projections and for imports are similar, albeit with slightly lower R^2 s.

²³Note 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.

4 Currency choice

This section analyzes the firm-level determinants of currency choice in export and import transactions, guiding our empirical specification with the theoretical predictions laid out in Section 2.

Exports We estimate the firm-level determinants of currency choice in export transactions using a linear probability specification, controlling for time, destination and HS4-digit-industry fixed effects, thus focusing on the variation across firms within industry-destinations.²⁴ Following the theory laid out in Section 2.2, our baseline specification is given by:

$$\mathbb{P}\{l_{ikt} = 1\} = a_{ks} + b\varphi_i + cS_{ik}. \quad (18)$$

The dependent variable is a dummy $l_{ikt} \in \{0, 1\}$ at the firm-CN8 product-destination-time level, with 0 corresponding to the use of the euro for export transaction (PCP) and 1 corresponding to the use of all other currencies, 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_{ks} are at the country-industry level, φ_i is the firm import intensity, and S_{ik} is a measure of firm size, with φ_i and S_{ik} proxying for the determinants of the desired price pass-through in (11). We later upgrade this specification with additional controls for other firm characteristics, as well as the currency choice by the firm's competitors.

Table 3 reports the results. We start in columns 1 and 2 with a simple projection of the export currency choice l_{ikt} on the ex-eurozone import intensity of the firm φ_i and two characteristics of firm size. The first one is the log of the firm's average employment $\log L_i$, providing an absolute measure of the firm size; and the second is the firm's market share S_{ik} in a destination-industry relative to all Belgian firms, providing a relative measure of the prominence of the firm in a specific industry-destination. Column 1 controls only for time and country fixed effects, while column 2 replaces country fixed effects with detailed country \times industry (HS4-digit) fixed effects. In both specifications, the firm's import intensity and its absolute size are strong determinants of the currency choice. Larger firms and those with a greater share of ex-eurozone imports in variable costs are more likely to invoice their exports in a currency other than the euro (within a given industry-destination). This implies that such firms are more likely to adopt either the dollar or the destination currency in pricing their exports. Conditional on the absolute size of the firm, we find that the relative destination-specific firm market share is not statistically significant.²⁵

While the coefficient on the employment measure of firm size changes very modestly from column 1 to column 2, the coefficient on import intensity shrinks by a third with the inclusion of the industry

²⁴While our data has the time-series dimension, only about 3% of observations record a change in currency use across any two periods, and therefore the results in the panel are essentially the same as the ones in a between cross-sectional regression. By including all time periods we capture more transactions as not all firms trade every month. We cluster the standard errors at the firm level.

²⁵The coefficient on the market share is positive and significant, however, when it is included on its own (not reported in the table), suggesting perhaps that log employment is a less noisy measure of firm size; an alternative interpretation is that the currency choice is decided at the level of the firm, rather than firm-destination.

Table 3: Currency choice in exports

Dep. var.: ι_{ikt}	(1)	(2)	(3)	(4)	(5)	(6)	(7)
φ_i	0.417*** (0.143)	0.270** (0.107)					
φ_i^E			0.057 (0.148)	0.064 (0.150)	-0.004 (0.189)	0.121 (0.141)	0.074 (0.160)
φ_i^X			0.326** (0.165)	0.316* (0.162)	0.565*** (0.197)	0.358** (0.180)	0.368* (0.194)
$\log L_i$	0.092*** (0.024)	0.084*** (0.016)	0.082*** (0.015)	0.055*** (0.013)	0.061*** (0.018)	0.053*** (0.012)	0.054*** (0.013)
S_{ik}	-0.028 (0.029)	-0.022 (0.030)	-0.024 (0.030)	-0.021 (0.029)	-0.020 (0.026)	-0.012 (0.017)	0.027 (0.025)
out-FDI _{<i>i</i>}				0.125*** (0.041)	0.089** (0.045)	0.115*** (0.040)	0.121*** (0.043)
in-FDI _{<i>i</i>}				0.016 (0.039)	0.051 (0.047)	0.026 (0.039)	0.026 (0.041)
$\bar{\iota}_{ikt}$					0.174*** (0.027)	0.037** (0.018)	0.620*** (0.277)
# obs.	741, 565	734, 012	734, 012	734, 012	676, 966	676, 937	656, 389
R_{adj}^2	0.290	0.575	0.577	0.582	0.327	0.391	—
Fixed Effects:							
destination	✓				✓	✓	✓
industry (HS4)						✓	✓
industry×destination		✓	✓	✓			
month×year	✓	✓	✓	✓	✓	✓	✓

Notes: The observations are at the firm-product (CN8)-destination-month level for all ex-EU destinations from February 2017 to March 2019. The dependent variable $\iota_{ikt} = 0$ if the export transaction is invoiced in euros and 1 otherwise. Std errors clustered at the firm level. Columns 1–6 are estimated with OLS; column 7 with IV (see footnote 30 for description of instruments, which pass the weak IV test with a Cragg-Donald F -stat of 609.9, as well as the over-id Hansen J -test with a p -value of 0.15).

fixed effects. This suggests that there is selection of high import-intensive firms into industries characterized by a lower prevalence of producer currency pricing in exports. Nonetheless, firm import intensity remains a strong determinant – both statistically and economically – for export currency choice across firms within industry-destinations. The overall ex-eurozone import intensity of Belgian exporters varies in our sample from zero at the 5th percentile to 44% at the 95th percentile, with a mean of 14% percent (see summary statistics in Appendix Table A2). Based on the estimates from column 2, the variation across these percentiles of import intensity corresponds to a reduction of 12 percentage points ($=0.27 \times 0.44$) in the probability of choosing euros in the pricing of exports.

In addition, there is a wide variation in firm size across Belgian exporters – firm employment increases by about 500 log points from the 5th to the 95th percentile (that is, almost 200 times). Given the coefficient of 0.084, this variation corresponds to a 42 percentage point lower incidence of the use of the euro in exports by the very large firms. Euro invoicing is disproportionately characteristic of the

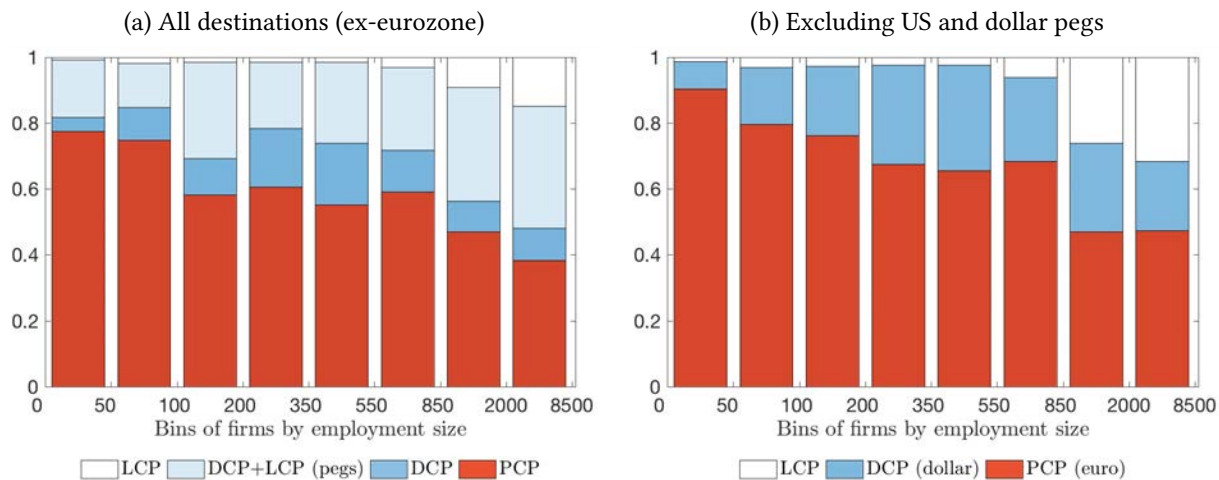


Figure 2: Firm size and currency choice in exports

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 DCP+LCP category for the US+dollar-peg destinations using the light-blue bars.

smaller firms, as we already anticipated from the data description in Table 1.

In the remaining columns of Table 3, we split the ex-eurozone import intensity of the firm by currency of imports — into euros φ_i^E and non-euros φ_i^X (dollars and other currencies).²⁶ Column 3 reports the results from a specification as in column 2 (with detailed industry \times destination fixed effects), but splitting the import intensity variable by currency. As expected, it is only the imports in non-euros that are strongly statistically related with the use of non-euros in firm exports. That is, import-intensive firms are more likely to adopt non-euros in their export transactions only if their imports are themselves priced in currencies other than the euro, 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 in dollars, which ensures *real hedging* by coordinating the pass-through into export prices with the movements in the marginal costs.²⁷

In column 4, we upgrade the specification in column 3 with two dummies that indicate whether a firm has inward or outward FDI.²⁸ 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 that the firm adopts the dollar or another foreign currency in export pricing. This is indeed the case. When we include one of the FDI dummies at a time, each is positive and significant (not reported). However, when we include both dummies together, it is only the outward-FDI that remains statistically and

²⁶As noted in Section 3, the currency data is only reported for ex-EU countries, hence we do not know the currency of imports from within the EU; where relevant, we control for the share of missing currency observations, $\varphi_i - \varphi_i^E - \varphi_i^X$.

²⁷Note 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 the periods of price stickiness. See Fauceglia, Shingal, and Wermelinger (2012) and Martin and Méjean (2012) on the mechanisms of real and financial hedging of the exchange rate risk.

²⁸The FDI dummies equal 1 if the firm has at least 10% inward or any outward FDI, respectively, during the sample period, as reported in the National Bank of Belgium FDI survey.

economically significant. A firm that engages in outward FDI is 12 percentage points less likely to use euros in pricing its exports. Intuitively, firms that are more global are more likely to adopt foreign currencies in export pricing. Inclusion of these dummies does not affect the coefficient on import intensity, yet it reduces the coefficient on the firm size by about a third, as it is the large firms that are more likely to engage in cross-border FDI. Nonetheless, both firm size and outward FDI are strongly statistically significant when included jointly.

The last three columns of the table explore whether the invoicing choices of a firm’s competitors, defined within HS4 industry-destinations, affect the firm’s own currency choice, that is *strategic complementarities* in currency choice.²⁹ We measure firm- i ’s competitors’ currency choice, \bar{v}_{-ikt} , as the export-weighted average currency choice of all Belgian exporters, excluding firm i , in a given industry-destination. Columns 5 and 6 report the results with and without HS4-industry fixed effects (with the time and country fixed effects always included). While in both cases we find a positive and significant strategic complementarity coefficient, its magnitude is reduced to nearly zero when we include country and industry fixed effects together in column 6. The positive coefficient on \bar{v}_{-ikt} may be due to a *reflection problem*, and to address it, we use country-industry-level instruments in column 7 to proxy for the competitor currency choice.³⁰ While instrumenting does not change the coefficient estimates on other variables, the competitor currency choice now features a lot more prominently as a determinant of the firm’s currency choice. If within an industry-destination all competitors of the firm switch from euro to non-euro export pricing, the firm itself is 62 percentage points more likely to adopt non-euros in its pricing of exports — suggesting strong strategic complementarity in currency choice.

Imports Next, we explore the firm-level determinants of currency choice in imports. Now, the dependent variable is $v_{ikt}^M \in \{0, 1\}$ corresponding to the firm-product-source country dummy for the invoicing currency of firm imports by CN8-digit product category, 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-eurozone import intensity variables we include the share of ex-eurozone 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_{ijk}^M 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{v}_{-ikt}^M .

Table 4 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-eurozone export share in total revenues in columns 1 and 2, and the foreign-currency export share in revenues in columns 3–7. 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

²⁹In Section 2.2, strategic complementarities in currency choice emerge from the strategic complementarities that shape the desired price: the second term in (10) with the behavior of z_k^* sensitive to the currency choice of the firm’s competitors.

³⁰We construct three Bartik-type instruments for \bar{v}_{-ikt} as follows: we use bilateral trade data at the HS6 level for 2017-18 for exports from country j to k from UN Comtrade, dropping Belgium; we then construct the shares of exports from the US, China, and other dollar-pegged countries to country k , for each industry (HS4)-destination k .

Table 4: Currency choice in imports

Dep. var.: ι_{ikt}^M	(1)	(2)	(3)	(4)	(5)	(6)	(7)
χ_i	0.106* (0.059)	0.104** (0.050)					
χ_i^E			0.007 (0.059)	0.002 (0.060)	0.013 (0.086)	-0.008 (0.070)	0.031 (0.074)
χ_i^X			0.273*** (0.095)	0.267*** (0.098)	0.377*** (0.115)	0.322*** (0.105)	0.351*** (0.121)
$\log L_i$	-0.006 (0.007)	-0.008 (0.006)	-0.011** (0.005)	-0.007 (0.010)	-0.005 (0.013)	-0.006 (0.011)	-0.003 (0.011)
S_{ijk}^M	-0.053* (0.029)	-0.154*** (0.028)	-0.152*** (0.028)	-0.149*** (0.028)	-0.089** (0.036)	-0.104*** (0.028)	-0.101*** (0.032)
out-FDI _i				0.001 (0.033)	0.001 (0.046)	0.003 (0.039)	0.005 (0.041)
in-FDI _i				-0.027 (0.034)	-0.029 (0.045)	-0.027 (0.038)	-0.025 (0.040)
$\bar{\iota}_{-ijkt}^M$					0.151*** (0.023)	0.042** (0.019)	0.791*** (0.219)
# obs.	270,477	267,009	267,009	267,009	235,062	235,022	223,991
R_{adj}^2	0.261	0.456	0.458	0.459	0.275	0.340	—
Fixed Effects:							
country (source)	✓				✓	✓	✓
industry (HS4)						✓	✓
industry × country		✓	✓	✓			
month × year	✓	✓	✓	✓	✓	✓	✓

Notes: The observations are at the firm-product (CN8)-source country-month level for all ex-EU source countries from February 2017 to March 2019. The dependent variable is $\iota_{ikt}^M = 0$ for import transactions invoiced in euros and 1 otherwise. Standard errors are clustered at the firm level. Columns 1–6 are estimated with OLS; column 7 with IV (the instrument set is constructed analogously to the one in the export regression, and it also passes the weak IV test with a Cragg-Donald F -stat of 465.9 and the over-id Hansen J -test with a p -value of 0.73).

pass-through. The quantitative magnitude of the effect is also comparable, albeit somewhat weaker (compare columns 1–3 in Tables 4 and 3).

Furthermore, strategic complementarities in import currency choice also play a large role, just like in exports (see columns 5–7). Firms with competitors that import in non-euros are themselves more likely to import in foreign currencies. We confirm this using OLS in columns 5 and 6, and with instrumental variable estimation in column 7. The IV specification results in a much larger coefficient on the competitor currency choice variable relative to OLS, like it did for exports. If all of a firm's competitors switch from euros to foreign currency in importing, that firm is 79 percentage points more likely to also use the foreign currency (controlling for industry and source country fixed effects).

Surprisingly, 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. 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. Finally, and perhaps also surprising, neither the inward nor the outward FDI dummies correlate with import currency invoicing, unlike they do for exports: being a more global firm, in terms of cross-border ownership, does not appear to affect the incidence of foreign-currency invoicing of imports.

Dominant currency in exports 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 (recall Lemma 3). Similarly, strong strategic complementarities can favor either dominant or local currency pricing, depending on the composition of competitors and their pricing decisions in the foreign market. Nonetheless, we expect foreign-currency-sourced inputs, which in practice are typically in dollars, to favor the use of the dominant currency, while strong strategic complementarities are likely to favor the use of local currency, as many competitors are local firms pricing in local currency.

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, limiting the empirical variation needed for identification. Indeed, under pegs to the dollar, the differential benefit of using the dollar versus the local currency is minimal, and hence difficult to robustly link to firm characteristics. Furthermore, in cases of hard pegs, it is not even clear how to classify the use of the dollar versus the destination currency into the vehicle and local categories: in the limit, for the United States and fully dollarized economies, such a distinction is altogether impossible.

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 floating exchange rate with the dollar.³¹ 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 specifications in Table 3. Specifically, we define a dummy $\iota_{ikt}^D = 1$ 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 two columns show that the choice between local and vehicle currency is not affected by the overall ex-eurozone 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

³¹This subsample also drops observations where the currency choice is other than the dollar or the destination currency, which occurs in 4% of non-euro observations (or around 1% of all observations). Including these observations and classifying any third-currency use as vehicle does not change the results reported in Table 5.

Table 5: Vehicle currency choice in exports

Dep. var.: ι_{ikt}^D	(1)	(2)	(3)	(4)	(5)	(6)
φ_i	-0.204 (0.168)	-0.027 (0.109)				
φ_i^E			-0.106 (0.134)	-0.108 (0.135)	-0.070 (0.121)	-0.127 (0.161)
φ_i^X			0.457*** (0.156)		0.504*** (0.146)	0.729*** (0.216)
φ_i^D				0.490*** (0.163)		
$\log L_i$	-0.092*** (0.012)	-0.088*** (0.010)	-0.079*** (0.010)	-0.077*** (0.010)	-0.093*** (0.017)	-0.095*** (0.022)
S_{ik}	0.061* (0.037)	0.049 (0.051)	0.012 (0.044)	0.009 (0.044)	0.012 (0.044)	0.113 (0.069)
out-FDI _{<i>i</i>}					0.051 (0.042)	0.107* (0.060)
in-FDI _{<i>i</i>}					0.026 (0.034)	-0.022 (0.061)
$\bar{\iota}_{ikt}^D$						1.516** (0.697)
# obs.	113,327	111,606	111,606	111,606	111,606	104,584
R_{adj}^2	0.650	0.878	0.882	0.882	0.883	—
Fixed Effects:						
destination	✓					✓
industry (HS4)						✓
industry × destination		✓	✓	✓	✓	
month × year	✓	✓	✓	✓	✓	✓

Notes: The observations are for exports at the firm-product (CN8)-destination-month level for the sample of non-pegged destinations only (i.e., excluding the US and dollar-pegged countries) from February 2017 to March 2019. The dependent variable is $\iota_{ikt}^D = 1$ for exports invoiced in dollar (DCP) and 0 in destination currency (LCP). Standard errors are clustered at the firm level. Columns 1–5 are estimated with OLS; column 6 with IV (instruments as in Table 3, and again pass the weak IV test with a Cragg-Donald F -stat of 100.9 and the over-id Hasen J -test with a p -value of 0.824).

in particular in dollars (φ_i^D), favors the use of the dominant currency in exporting, and the effect is both strong and economically sizable.³²

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.³³ Note, 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, as we discuss in Section 2.2. 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.

³²We also split import intensity by the country of origin (not reported in the table), and find no additional effect of import intensity from dollar-pegged countries, as a lot of the imports from floating countries are also denominated in dollars.

³³Just like for the choice of producer versus foreign currency, we find that, controlling for the absolute size, the relative size of the firm in the destination market does not robustly correlate with the choice between local and vehicle currency.

We illustrate the relationship between firm size and the export currency choice in Figure 2, where the left panel shows the results for all ex-eurozone destinations, while the right panel focuses on the subset of destinations excluding the United States and the dollar-pegged countries. Indeed, a much clearer pattern emerges from the subsample of non-pegged countries, where the distinction between LCP and DCP can be clearly identified. The incidence of use of foreign currencies robustly increases with firm size, and this pattern is particularly pronounced for the use of LCP, which is negligible for the smallest firms, yet covers almost 30% of export revenues for the largest firms, exceeding the incidence of the dollar use in this bin (for the non-pegged destinations).³⁴

In addition, the (outward) FDI variable, arguably proxying for the international nature of the firm and its role in the global value chains, also positively correlates with the dollar use (DCP) in exporting (albeit with a low t -stat of 1.78). Finally, we also find evidence of strong strategic complementarities, yet imprecisely estimated, in the dominant currency choice across Belgian exporters.

Summary Our evidence on the currency use in exports and imports is consistent with the theory of currency choice presented in Section 2. For exports, it is the firms that source intermediate inputs in foreign currencies that are likely to use foreign currency for exports, especially the dollar. Larger firms are also more likely to price in foreign currencies, especially in the destination currency, as we expect them to have low desired pass-through and pricing complementarities with the local competitors. Furthermore, our evidence is consistent with the view that export currency choice is a more active firm-level decision than the import currency choice.³⁵ In particular, firm size, which tends to correlate with many firm-level characteristics, does not show an association with import currency choice, while it strongly predicts export currency choice (compare Figures 2 and A1). Finally, we find evidence of pronounced strategic complementarities in currency choice across firms, in both exports and imports, which likely propagate the currency choice equilibrium over time. In addition to the variables in the theory, we find that a firm’s cross-border ownership (FDI) also predicts a greater likelihood of foreign currency (especially dollar) use in export pricing, perhaps proxying for the firm being part of a global supply chain.

5 Exchange rate pass-through

Having established the firm-level determinants of currency choice, we now turn to the analysis of exchange rate pass-through into prices and quantities. We start with a firm-level specification of exchange rate pass-through into export prices, following [Amiti, Itskhoki, and Konings \(2014\)](#), which emphasizes firm size and import intensity as the key determinants of incomplete pass-through, operating through the markup and marginal cost channels respectively. We augment this specification with the firm’s currency choice, which mechanically affects ERPT during the period of sticky price duration, differentially depending on the currency of pricing. We start with the projection of price changes on the

³⁴Appendix Figure A1 reports analogous figures for imports; consistent with Table 4, there is no clear pattern in import currency use (euro, dollar or other) across size bins, whether we consider all source countries or only non-pegged ones.

³⁵The baseline models of currency choice, as presented in Section 2, typically focus on the supplier making the currency-choice and price-setting decisions, while the downstream firms choosing quantities given the realized prices.

euro-destination exchange rate, as a benchmark in the flexible-price pass-through literature. However, such specifications are misspecified in the presence of dominant-currency price stickiness, and therefore, following the theory in Section 2, we augment these specifications with the dollar-destination exchange rate as well. Finally, we consider the response of quantities to price changes, which we instrument with the firm-level determinants of ERPT.

Producer-destination ERPT In Table 6, we show how firm-product-destination prices, at the annual frequency, respond to movements in the euro-destination exchange rate. We interact the exchange rate with various flexible-price determinants of the desired pass-through, as well as with a currency choice dummy to capture the pass-through implications during the period of price stickiness. Specifically, we estimate the following regression:

$$\Delta p_{ikt}^* = [\alpha + \beta\varphi_i + \gamma S_{ik} + \delta \iota_{ik}] \Delta e_{kt} + \text{fixed effects and controls} + \epsilon_{ikt}, \quad (19)$$

where the dependent variable Δp_{ikt}^* is the change in the firm's export price in the destination currency, and an increase in Δe_{kt} measures the depreciation of the destination currency against the euro. We use the firm's import intensity φ_i to proxy for the marginal cost channel of ERPT and its industry-destination market share S_{ik} to proxy for the markup channel, as well as the foreign-currency dummy ι_{ik} equal to one if the firm prices in non-euros (that is, in local or dominant currency).

Note that specification (19) is a special case of the theoretical equation (12), which implicitly imposes $\iota_i^D = \varphi_i^D = \gamma_i^D = 0$, ruling out the effect of the dollar-destination exchange rate. The coefficient α measures the ERPT of a counterfactual small Belgian exporter, with zero destination market share, using no foreign intermediate inputs, and setting its export price in euros. We expect β , γ and δ to be negative, reflecting incomplete pass-through due to foreign intermediates, variable markups, and foreign-currency price stickiness, respectively. In our previous work, we showed that β and γ are negative without controlling for the currency of export pricing. We now are able to estimate these coefficients controlling for the currency choice of the firm, in order to establish whether the flexible-price variables continue to be significant determinants of ERPT. Furthermore, we are interested in whether δ is significant, conditional on the flexible-price determinants, as a negative δ provides evidence for the consequences of the foreign-currencies price stickiness. The absolute magnitude of δ reflects the extent of price stickiness over the annual horizon (recall (12)).

The first column of Table 6 does not include the currency choice variable, reproducing our specification from [Amiti, Itskhoki, and Konings \(2014\)](#), with the dependent variable now expressed in the destination currency. We use the full sample of ex-EU destinations and include year and destination-industry (HS4) fixed effects. As in that paper, we find that a counterfactual small Belgian exporter with no foreign inputs exhibits complete ($\approx 100\%$) exchange rate pass-through into the destination prices. Firms that rely on foreign inputs and/or are large — in either absolute employment size L_i or in terms of their destination market share S_{ik} — exhibit incomplete pass-through, captured by the negative significant coefficients on the interaction terms. This is consistent with the theoretical determinants of the desired pass-through in (11).

Table 6: Exchange rate pass-through

Dep. var.: Δp_{ikt}^*	All countries				OECD	US only
	(1)	(2)	(3)	(4)	(5)	(6)
Δe_{kt}	1.111*** (0.031)	1.075*** (0.029)	1.075*** (0.029)	—	1.047*** (0.037)	—
$\Delta e_{kt} \cdot \varphi_i$	-0.272*** (0.087)	-0.173** (0.077)				
$\Delta e_{kt} \cdot \varphi_i^E$			-0.081 (0.139)	0.125 (0.174)	-0.418 (0.354)	0.328 (0.269)
$\Delta e_{kt} \cdot \varphi_i^X$			-0.227** (0.106)	-0.306** (0.122)	-0.416*** (0.147)	-0.533* (0.221)
$\Delta e_{kt} \cdot S_{ik}$	-0.061** (0.028)	-0.061** (0.028)	-0.061** (0.028)	-0.058 (0.046)	-0.146* (0.082)	-0.174** (0.067)
$\Delta e_{kt} \cdot \log L_i$	-0.017*** (0.006)	-0.003 (0.006)	-0.003 (0.006)	-0.007 (0.006)	0.005 (0.006)	-0.010 (0.012)
$\Delta e_{kt} \cdot l_{ik}$		-0.207*** (0.038)	-0.206*** (0.037)	-0.148*** (0.043)	-0.300*** (0.042)	-0.240** (0.082)
# obs.	262,043	262,043	262,043	221,702	88,144	21,635
R_{adj}^2	0.056	0.057	0.057	0.078	0.019	0.020
Fixed Effects:						
year	✓	✓	✓		✓	✓
industry × destination	✓	✓	✓		✓	✓
industry × destination × year				✓		

Notes: The observations are at the firm-product (CN8)-destination-year level from 2012 to 2018. The dependent variable is the log change in export price in the destination currency; l_{ik} is a time-invariant indicator of foreign-currency (non-euro) pricing based on the 2017-2019 currency use data; e_{kt} is the bilateral euro-destination exchange rate. All interaction terms are also included separately in levels (not reported). Standard errors are clustered at the destination-year level.

In the remaining columns of the table, we include the exchange rate interaction with the currency choice l_{ik} , which is the novel ingredient of this study. We expect the coefficient on this interaction to reflect the extent of nominal price duration (stickiness) — a period during which the ERPT is fully determined by the currency choice of the firm. Column 2 represents our benchmark specification. Indeed, we find that a firm that prices its exports in non-euros has a significantly lower ERPT at the annual frequency. The estimated coefficient suggests that roughly 20% of prices remain unchanged at the annual horizon. Conditional on the currency choice, the flexible-price determinants of ERPT are still important — both greater import intensity and larger destination market share reduce the estimated ERPT at the annual frequency, after controlling for currency choice. Note that the absolute size of the firm no longer affects ERPT after controlling for currency choice, with the coefficient on the employment interaction becoming virtually zero.³⁶ Finally, we still find that a small non-importing firm that prices its exports in euros exhibits complete ERPT at annual horizon.

³⁶Recall from Table 3 that employment was one of the main determinants of the currency choice whereas the destination market share was not. This suggests an interesting exclusion restriction for the currency choice and ERPT regressions, whereby the absolute size of the firm shapes its currency choice, while the destination-specific market share determines its flexible-price pass-through.

Column 3 estimates a similar specification, additionally splitting the ex-eurozone import intensity of the firm φ_i into its components that are imported in euros φ_i^E and those imported in other currencies φ_i^X . As in the currency choice regressions, we find that it is the non-euro import intensity that drives the qualitative and quantitative results for the marginal cost channel, consistent with the theory.

In column 4, we verify that all the results hold when we include extremely detailed time-destination-industry fixed effects, which in particular fully absorb the bilateral euro-destination exchange rate fluctuations. In this specification, which includes over 40,000 fixed effects, 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. We find largely the same patterns, as in columns 2 and 3, with a mildly attenuated (yet not statistically different) coefficient on the currency choice variable.

Finally, we re-estimate the main specification from column 3 for a subsample of destinations – the developed OECD countries in column 5 and the US only in column 6. One reason to limit the sample to non-eurozone OECD countries, which represent around a third of export observations in our sample, is so we can focus on a subset of relatively homogenous destinations for which the patterns are arguably more comparable (see [Amiti, Itskhoki, and Konings 2014](#)). Indeed, we find that in this subsample we identify the same patterns as for all countries, but with larger estimated coefficients on interaction terms. In particular, we still find complete pass-through for small non-importing firms that price their exports in euros, and a more pronounced reduction in pass-through driven by both the flexible-price and the sticky-price (currency choice) determinants. The same patterns emerge when we focus exclusively on Belgian firm exports to the United States.

Dominant currency pass-through In all of the specifications in Table 6, we have only included the euro-destination exchange rate; however, the dollar-destination exchange rate is also relevant in cases when firms use DCP in their export pricing. As a result, the specifications estimated in Table 6 may suffer from an omitted variable bias, a concern that we address next. We use theory introduced in Section 2.2 to guide the correct empirical specification with multiple currencies.

Before we proceed, it is instructive to note that column 6 of Table 6, where we focus on exports to the US only, does not suffer from this potential bias from the omission of the dominant exchange rate. Indeed, the choice of the US dollar in this case simultaneously corresponds to local and dominant currency invoicing. A similar argument applies for the dollar-pegged destinations, for which there is also little distinction between LCP and DCP, as the two are nearly equivalent, and exactly so in the limit of a perfect peg. In the context of theoretical relationship (12), this corresponds to the case of $\Delta e_{kt}^D \equiv 0$, as the dollar-destination exchange rate is fixed/pegged, and thus the empirical specification (19) does not suffer from omitted variable bias.

In column 1 of Table 7, we start by re-estimating the baseline specification from column 2 of Table 6 for the subset of destinations (both inside and outside of OECD) that peg their exchange rate to the US dollar, including the United States (the results are nearly identical if we exclude the US).³⁷ We

³⁷To keep the number of exchange rate interaction variables from expanding too much, the specifications in Table 7 do not include the insignificant interactions with the firm employment size, and only use the overall import intensity of the firm φ_i without splitting it by currency of imports.

Table 7: Exchange rate pass-through: Vehicle currency

Dep. var.: Δp_{ikt}^*	USD/Pegs	Non-pegged		All countries	
	(1)	(2)	(3)	(4)	(5)
Δe_{kt}	1.130*** (0.075)	1.064*** (0.032)	1.006*** (0.015)	1.011*** (0.015)	—
$\Delta e_{kt} \cdot \varphi_i$	-0.514*** (0.136)	-0.058 (0.090)	-0.339*** (0.100)	-0.392*** (0.077)	-0.354*** (0.100)
$\Delta e_{kt}^D \cdot \varphi_i$			0.414*** (0.086)	0.435*** (0.076)	0.386*** (0.113)
$\Delta e_{kt} \cdot S_{ik}$	-0.101* (0.058)	-0.049 (0.032)	-0.031 (0.049)	-0.047 (0.035)	-0.058 (0.072)
$\Delta e_{kt}^D \cdot S_{ik}$			0.023 (0.042)	-0.011 (0.035)	0.006 (0.068)
$\Delta e_{kt} \cdot l_{ik}$	-0.358*** (0.038)	-0.133*** (0.042)	-0.330*** (0.057)	-0.342*** (0.036)	-0.235*** (0.047)
$\Delta e_{kt}^D \cdot l_{ik}^D$			0.306*** (0.051)	0.321*** (0.042)	0.235*** (0.050)
# obs.	99,025	163,018	150,659	240,440	200,888
R_{adj}^2	0.016	0.074	0.078	0.062	0.086
Fixed Effects:					
year	✓	✓	✓	✓	
industry × destination	✓	✓	✓	✓	
industry × destination × year					✓

Notes: The specifications are as in Table 6, additionally including interactions with the dollar-destination exchange rate, e_{kt}^D ; l_{ik}^D is a time-invariant indicator of US dollar invoicing based on the 2017-2019 currency use data. Standard errors are clustered at the destination-year level.

find similar quantitative and qualitative results, as in the case of the US-only exports in column 6 of Table 6. In column 2, we estimate the same specification for the subsample of *non-dollar-pegged* destinations (excluding the US), in which case we find considerably weaker patterns, both statistically and economically. This is to be expected, as the specification for the non-pegged countries is more likely to suffer from the omitted variable bias.

The dominant currency literature following [Gopinath et al. \(2020\)](#) has emphasized the role of the dollar-destination exchange rate as a key determinant of pass-through into export prices, yet the specifications we considered so far do not control for this. Therefore, in the remaining specifications, in columns 3–5 of Table 7, we include the interaction terms with both the euro-destination e_{kt} and the dollar-destination e_{kt}^D exchange rates. We follow the theoretical ERPT relationship (12), for which we estimate an empirical counterpart given by:

$$\Delta p_{ikt}^* = [\alpha + \beta\varphi_i + \gamma S_{ik} + \delta l_{ik}] \Delta e_{kt} + [\beta^D \varphi_i + \gamma^D S_{ik} + \delta^D l_{ik}^D] \Delta e_{kt}^D + \text{F.E./controls} + \epsilon_{ikt}. \quad (20)$$

The δ and δ^D terms capture the sticky-price determinants of the exchange rate pass-through, respectively for products priced in any foreign currency ($l_{ik} = 1$) and in dollars specifically ($l_{ik}^D = 1$). The magnitudes of δ and δ^D measure the extent of price stickiness at the annual horizon. The other

terms in (20) correspond to the flexible-price determinants of ERPT. To the extent that prices are flexible at the annual horizon, the firm’s pass-through does not depend on the currency of pricing, but does depend on the exposure to foreign inputs φ_i and strategic complementarities in price setting, as we discussed in Section 2.2. We expect $\alpha \approx 1$, and $\beta, \gamma, \delta < 0$, resulting in incomplete pass-through of the euro-destination exchange rate for firms with $\varphi_i, S_{ik}, \iota_{ik} > 0$. Additionally, we expect $\beta^D, \gamma^D, \delta^D > 0$, so that firms with $\varphi_i, S_{ik}, \iota_{ik}^D > 0$ exhibit a positive pass-through of the dollar-destination exchange rate.

In column 3 of Table 7, we test these theoretical predictions using the export price data for the subsample of Belgian firm exports to non-dollar-pegged destinations invoiced in euros, dollars or the destination (local) currency. We estimate the regression with year and destination-industry (HS4) fixed effects. Note that the year fixed effect absorbs the euro-dollar exchange rate, and so we cannot simultaneously include in the regression the euro-destination and the dollar-destination exchange rates, however we can include their interactions with the firm-level characteristics.

The results are consistent with the theory, and in particular correct the omitted variable bias present in the previous specification. Indeed, comparing the coefficients in columns 3 and 2, we see that controlling for the dollar-destination exchange rate interactions increases substantially (in absolute value) the coefficients on the euro-destination exchange rate interactions, both with import intensity and with the foreign-currency dummy. Thus, we now estimate the sticky price coefficients δ and δ^D to be about 0.3 in absolute value (similar to δ in column 1 for pegged destinations), which roughly corresponds to 30% of prices still being sticky at the annual horizon in the currency of pricing.

Furthermore, unlike in column 2, we recover a large and significant effect of the imported inputs φ_i on ERPT via the marginal cost mechanism. Consistent with theory, imported inputs reduce pass-through on the euro-destination exchange rate and increase it on the dollar-destination exchange rate, with the elasticity around 0.4 in both cases. If we take a value of $\delta = 0.3$, then an extra 10 percentage points cost share on foreign intermediates reduces flexible-price pass-through of the euro-destination exchange rate and increases it for the dollar-destination exchange rate by about 6 percentage points ($\approx 0.1 \cdot 0.4 / (1 - \delta) \approx 0.06$). These estimates are again consistent with those in column 1 of Table 7 for the pegged destinations, and are considerably larger than those we found in column 2 of Table 6 for all countries.

Lastly, we estimate the same dominant-currency specification (20) from column 3 of Table 7 on the full sample of destination countries, some of which have a pegged exchange rate, with year and destination-industry fixed effects in columns 4 and the extremely detailed destination-industry-year fixed effects in column 5. The specification in (20) applies generally to any destination, whether dollar-pegged or not, however identification of the DCP coefficients requires destinations with sufficiently varying exchange rates against the dollar. The results are consistent with those in columns 1 and 3 of Table 7, which also feature specifications without omitted dominant currency interactions.

To summarize, small Belgian exporters with no exposure to foreign inputs and pricing in euros (PCP) exhibit complete pass-through. The same exporters that set prices in local or vehicle currency exhibit a 34% lower pass-through of the euro-destination exchange rate at the annual horizon, and a 32% pass-through of the dollar-destination exchange rate if pricing in dollars, in line with the sticky-

price mechanism. Greater exposure to foreign inputs substantially reduces (increases) pass-through of the euro-destination (dollar-destination) exchange rate, after controlling for the currency choice of the firms – consistent with the flexible-price determinants of exchange rate pass-through conditional on price adjustment. Lastly, exporters with larger destination market shares exhibit somewhat lower pass-through of the euro-destination exchange rate, consistent with strategic complementarities in price setting conditional on price adjustment.

The response of quantities We now turn to the effects of exchange rate movements on quantities, in order to establish the consequences of currency choice and incomplete pass-through into prices for real allocations. Indeed, even if prices are sticky, they may not necessarily be allocative, that is, they may have no effect on quantities, which are themselves fixed in contracts or negotiated separately from prices. We test this using IV estimation and find that quantities do have a pronounced response to prices, and in particular respond to the components of price variation, which correspond to both the flexible-price and the sticky-price determinants of ERPT studied above.

In Table 8, we report the second-stage regression of changes in log export quantities Δq_{ikt}^* on changes in log export prices Δp_{ikt}^* in destination currency. In the first stage, we instrument the change in export prices with the exchange rates interacted with the firm-level flexible-price and sticky-price determinants of incomplete pass-through, as in (20). Different columns of the table correspond to different first-stage specifications, namely different fixed effects and instrument sets, which correspond to various ERPT specifications from Tables 6 and 7.³⁸ We report the result for the full set of ex-EU destinations, as in columns 4–5 of Table 7.

In all cases, we find a significant and negative effect of export prices on export quantities. The first column includes time and destination-industry (HS4) fixed effects separately, and the remaining columns of Table 8 include over 40,000 extremely detailed time-destination-industry fixed effects. In column 1, the main variation in prices and quantities comes from the time-series changes in the euro-destination exchange rates (as can be seen from the reduced-form regressions in Table A3). In the other columns, that variation is absorbed into the fixed effects, and all inference comes from the cross-sectional differences in price and quantity responses to the exchange rates for firms with different characteristics within a given time-destination-industry. Therefore, if product demand at the sectoral level is correlated with exchange rate movements, we expect a possible endogeneity bias in the first specification, which we control for in the subsequent specifications with detailed fixed effects.

Indeed, we find a precisely-estimated elasticity below 1 in absolute value in the first specification. In contrast, in all other specifications, we recover an elasticity greater than 1 in absolute value, yet much less precisely estimated, as these specifications include detailed fixed effects, which absorb the bulk of the aggregate exchange rate variation used for estimation in column 1. The point estimates for this elasticity range from -1.1 to -1.7 , depending on the first stage used. Specifically, column 2 uses the baseline specification from column 5 of Table 7 with the full set of flexible-price and sticky-price

³⁸ In all cases, we additionally include over 2,000 firm fixed effects to avoid the need to control for firm variables in levels. Inclusion of firm fixed effects does not have a material effect on the other coefficient estimates, either in the first or the second stage. Appendix Table A3 reports the corresponding first stages and reduced forms.

Table 8: Quantity response, IV

Dep.var: Δq_{ikt}^*	(1)	(2)	(3)	(4)
Δp_{ikt}^*	- 0.446*** (0.076)	- 1.098** (0.524)	- 1.255** (0.549)	- 1.709* (0.880)
# obs.	240,188	200,595	200,595	221,564
First stage	(4) in Table 7	(5) in Table 7	(5) [†] in Table 7	(4) [†] in Table 6
Over-ID J -test χ^2 [p -value]	15.62 [0.02]	13.90 [0.02]	6.35 [0.10]	0.30 [0.58]
Weak IV F -test	1,403.8	10.6	14.9	7.0
Fixed Effects:				
firm	✓	✓	✓	✓
industry \times destination & year	✓			
industry \times destination \times year		✓	✓	✓

Note: The observations are at the firm-product (CN8)-destination-year level from 2012 to 2018. The dependent variable is the log change in export quantities. All columns are estimated with IV, with the first stages based on different ERPT specifications from Tables 6 and 7, as noted ([†] means that the specification drops the insignificant market share interactions; all specifications additionally feature firm fixed effects). See first stages and reduced forms in Appendix Table A3.

determinants of ERPT, using both euro-destination and dollar-destination exchange rates. In column 3, we drop the insignificant interaction terms with the destination market-shares, which leads to a larger point estimate (in absolute value) of the quantity elasticity. Also, in this case, the instrument set is both strong and passes the over-identification test. Finally, in column 4 we drop the dollar-destination exchange rate interaction terms from the set of instruments, which further increases the estimated quantity elasticity (in absolute value), yet results in a weak instrument set.³⁹

Interestingly, both the flexible-price (import intensity) and the sticky-price (currency choice) determinants of exchange rate pass-through contribute significantly to the instrument set, and we do not reject the over-identification test for the two types of instruments (in columns 3 and 4 of Table 8). This suggests that incomplete pass-through into export prices – whether due to the limited marginal cost exposure to the exchange rate because of imported inputs or due to price stickiness in foreign currencies – both have important allocative effects on export quantities, at the annual frequency.

The quantity elasticity that we estimate is greater than 1 in absolute value, consistent with the time-series macro literature (Feenstra, Luck, Obstfeld, and Russ 2018), 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 exporter 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.

³⁹The movement in the dollar-destination exchange rate interacted with firm characteristics, while having a significant effect on prices in the first stage, does not have a statistically pronounced effect on quantities, as can be seen from the reduced form regression in Appendix Table A3.

6 Pass-through Dynamics

So far, we have focused on exchange rate pass-through at the annual frequency. We now study the dynamics of exchange rate pass-through by re-estimating (20) using monthly data for the period January 2012 to March 2019, 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 (20) 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 (see Section 2.3).

Concretely, we estimate the following specification for each regression horizon h :

$$\Delta_h p_{ikt}^* = [\alpha_h + \beta_h \varphi_i + \delta_h \iota_{ik}] \Delta_h e_{kt} + [\beta_h^D \varphi_i + \delta_h^D \iota_{ik}^D] \Delta_h e_{kt}^D + \text{fixed effects} + \epsilon_{ikt}^h, \quad (21)$$

where Δ_h is the h -month difference, e.g. $\Delta_h e_{kt} = e_{kt} - e_{k,t-h}$, and the other variables are as in the benchmark specification (20) above. The estimates at one-month horizon are very noisy due to the standard timing issue of the shock and price adjustment, and therefore, we report the results starting from a four-month horizon and up to 24 months, $h \in \{4, \dots, 24\}$, where the timing issue no longer results in such noisy ERPT estimates. Specification (21) is the same as in column 4 of Table 7, but dropping the insignificant market share interaction terms.⁴⁰ We also run a similar pass-through specification for quantities, $\Delta_h q_{ikt}^*$, including the detailed time-industry-destination fixed effects, exactly as in column 3 of Table A3, and thus necessarily omitting the first exchange rate term, $\alpha_h \Delta_h e_{kt}$ – that is, estimating only the *differential* effect of foreign currency pricing on quantities.

We are interested in how the sticky-price (δ_h, δ_h^D) and the flexible-price (β_h, β_h^D) coefficients in (21) evolve with the regression horizon h . For the flexible-price determinants of ERPT, theory predicts that $\beta_h < 0 < \beta_h^D$, as firms with higher exposure to foreign intermediates φ_i should have a lower flexible-price pass-through of the euro-destination exchange rate, and a higher one of the dollar-destination exchange rate. In the short-run, we expect $\beta_h, \beta_h^D \approx 0$, when prices are mostly sticky, with both coefficients gradually increasing in absolute value with the regression horizon h (recall (12) and (13)).

In turn, for the sticky price determinants of ERPT, theory predicts $\delta_h < 0 < \delta_h^D$, with δ_h^D capturing the pass-through of the dollar-destination exchange rate by the DCP firms, and δ_h capturing the gap in the pass-through of the euro-destination exchange rate between the foreign-currency (LCP or DCP) invoicing and PCP invoicing. Since PCP firms have the highest pass-through in the short run, δ_h is expected to be negative.⁴¹ We expect both δ_h and δ_h^D to decline over time in absolute value, as firms adjust prices and the effects of the price stickiness dissipate.

Indeed, these are exactly the patterns we find in the data. We report the results in Figures 3 and 4. The left panel of Figure 3 plots the dynamics of exchange rate pass-through for PCP, LCP and DCP firms respectively, conditional on the flexible-price determinants of ERPT. The first thing to note is that a counterfactual PCP firm that uses no foreign intermediate inputs has a complete pass-through of the euro-destination exchange rate into destination prices, with $\alpha_h \approx 1$ at all horizons h . In contrast, if the

⁴⁰We also include firm fixed effects, as in column 3 of Table A3, which does not affect the coefficient estimates in (21).

⁴¹Note that α_h estimates the pass-through of the PCP firms, while $\alpha_h + \delta_h$, estimates the pass-through of the foreign-currency pricing firms, and we expect $\alpha_h + \delta_h < \alpha_h$ (that is, $\delta_h < 0$).

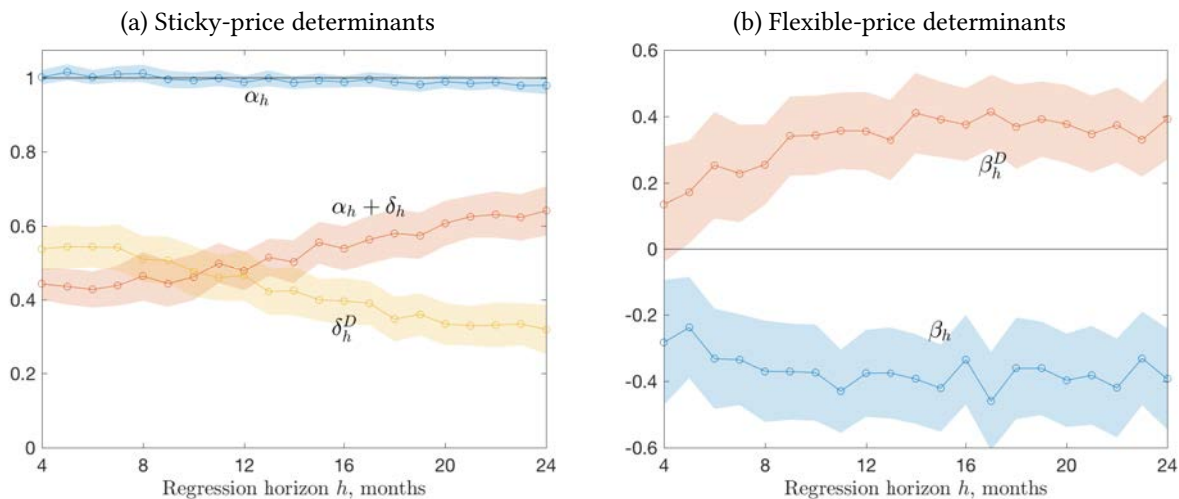


Figure 3: Exchange rate pass-through dynamics

Note: coefficient estimates from the ERPT specification (21), 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 for further details. The right panel plots the flexible-price coefficients: β_h and β_h^D depict the euro-destination and the dollar-destination ERPT, respectively, per unit of the firm's imported input intensity φ_i .

same firm were to price its exports in foreign currencies (LCP or DCP), it would have an incomplete pass-through of the euro-destination exchange rate, $\alpha_h + \delta_h < 1$, which gradually increases from 45% at the 4-month horizon to 65% at the 24-month horizon. This closes over a third of the gap with the complete pass-through of the PCP firms. The DCP firms, in addition, exhibit a high, nearly 55%, pass-through of the dollar-destination exchange rate at the 4-month horizon, which gradually decreases to about 30% at the 24-month horizon.

The right panel of Figure 3 plots the dynamic contribution of the flexible-price determinants, namely the imported intermediate inputs φ_i , conditional on the currency of pricing. The exposure to foreign intermediates reduces the pass-through of the euro-destination exchange rate, $\beta_h < 0$, and increases the pass-through of the dollar-destination exchange rate, $\beta_h^D > 0$. These effects are small, or even insignificant, in the short run, and build up gradually over the regression horizon h , in line with the theory. The magnitude of estimated effects continues to increase beyond the one-year horizon, $h = 12$, which was our benchmark in the analysis in Section 5.

Figure 4 compares the dynamic patterns of foreign-currency price stickiness to a theoretical benchmark, both for prices and quantities. Towards this end, we enhance specification (21) with highly detailed industry-destination-time fixed effects. This is the theoretically desirable specification for both prices and quantities, as it controls for all dynamic industry-destination-level shocks, but it is at the cost of absorbing the levels of pass-through, captured by α_h in Figure 3. Hence, the coefficients reflect the dynamic estimates of the differential pass-through for PCP and DCP firms relative to LCP firms, as captured by δ_h and δ_h^D , respectively. Two striking results emerge. First, $\delta_h^D \approx -\delta_h$ at all horizons,

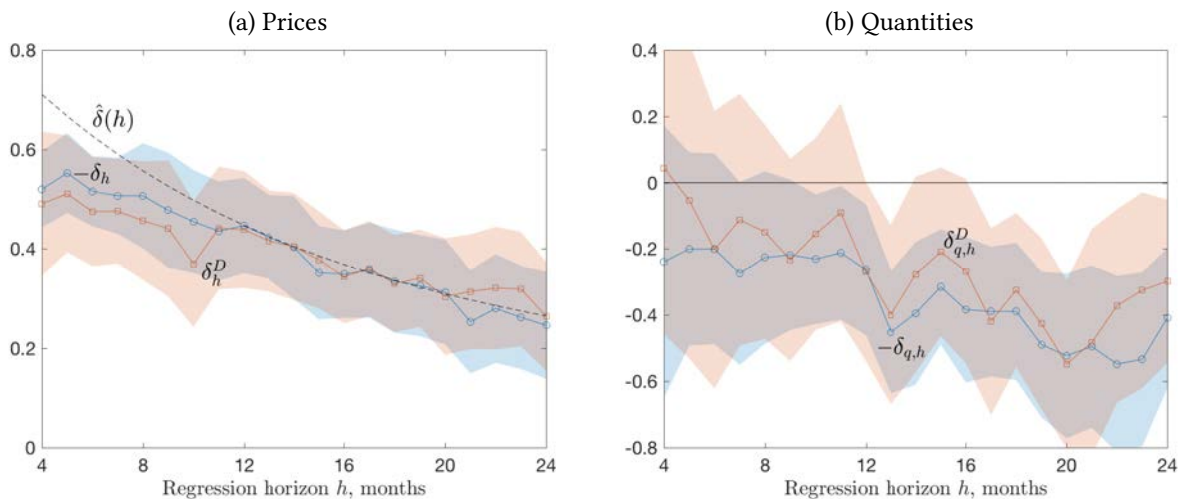


Figure 4: The dynamic effect of foreign-currency price stickiness

Note: left (right) panel estimates (21) for prices (quantities) for different h , with firm and industry-destination-time fixed effects; shaded areas are 95% confidence intervals. Coefficients δ_h and $\delta_{q,h}$ estimate the differential responses of prices and quantities to the euro-destination exchange rate for PCP relative to LCP firms; δ_h^D and $\delta_{q,h}^D$ estimate the differential responses of prices and quantities to the dollar-destination exchange rate for DCP relative to LCP firms. The dashed line in the left panel is $\hat{\delta}(h)$ from (13) evaluated for $\delta = 0.88$.

which suggests the extent of price stickiness for firms pricing in different currencies is symmetric. This is exactly the prediction from a simple Calvo model with a common price stickiness parameter δ , which implies $\delta_h^D = -\delta_h = \hat{\delta}(h)$, as given by (13). This is evident in the left panel of Figure 4, which plots δ_h^D alongside the negative of δ_h , to facilitate the comparison of the estimates. Consistent with the theory, the impact of currency of pricing is large in the short run and gradually decreases over time.

Second, we find that $\hat{\delta}(h) \equiv \frac{1}{h} \frac{\delta}{1-\delta} (1 - \delta^h)$, derived in Section 2.3, and plotted with a dashed line in the figure for the parameter value $\delta = 0.88$, approximates the dynamics of both δ_h^D and $-\delta_h$ very accurately for $h \in [12, 24]$ months.⁴² This suggests that a Calvo model with a single parameter $\delta = 0.88$, corresponding to a $1/(1-\delta) = 8.3$ months price duration, provides a good fit to the medium-run dynamics of pass-through in the data. Note that at the 12-month horizon, $\delta^{12} = 0.22$, which means that 22% of firms have yet to adjust their prices after 12 months, consistent with our back-of-the-envelope calculations in Section 5. This fraction at 24 months is $\delta^{24} = 0.05$, suggesting that the effect of sticky prices nearly washes out at this horizon.⁴³ This provides new evidence for the long-run convergence in exchange rate pass-through across currency bins of firms, conditional on the underlying firm characteristics.

Finally, we turn to the dynamic response of quantities. In the right panel of Figure 4, we plot $-\delta_{q,h}$

⁴²We calibrated δ to match the 12-month pass-through estimate, that is $\hat{\delta}(h) = -\delta_h$ for $h = 12$. Note that for this value of δ , $\hat{\delta}(h)$ overstates the extent of pass-through for $h < 12$, which could suggest either the presence in the data of a subset of more flexible price setters or the downward bias in our estimates over short horizons due to the timing issue discussed above.

⁴³As we show in Appendix B, the Calvo model with parameter δ implies that δ^h is the direct causal effect of price stickiness on ERPT at horizon h . At the same time, the estimates in specification (21), $\delta_h^D = -\delta_h = \hat{\delta}(h)$, can be considerably larger for large h , as this regression uses variation over all horizons up to h , which explains the hyperbolic rather than geometric decline in $\hat{\delta}(h)$, with $\hat{\delta}(h) > \delta^h$ for $h > 1$. For small h , the gap between $\hat{\delta}(h)$ and δ^h is small.

and $\delta_{q,h}^D$, which are estimates of the differential impact of the exchange rates (euro-destination and dollar-destination, respectively) on quantities at various horizons for euro- and dollar-pricing firms (relative to LCP firms), respectively. Recall that an increase in both exchange rates corresponds to a depreciation of the destination currency, and hence results in a (partial) increase in the destination-currency prices ($-\delta_h, \delta_h^D > 0$). In turn, we expect a reduction in quantities in response to these shocks, especially for firms pricing their exports in euros or in dollars, as captured by $-\delta_{q,h}, \delta_{q,h}^D < 0$, respectively.⁴⁴ These coefficients reflect the direct causal impact of foreign-currency price stickiness on the exchange rate pass-through into real economic outcomes. According to the theory, these effects should be particularly pronounced in the short run, gradually dissipating over time as prices become flexible.

As expected, we find negative point estimates for the response of quantities to both exchange rates at almost all horizons. Although the estimates are noisy, we still see that they become larger in absolute value over time and become statistically significant around the one-year horizon. On the one hand, this is consistent with the allocative effects of price stickiness in alternative currencies of pricing, yet on the other hand, it suggests a presence of some additional frictions limiting the response of quantities on impact and in the short run (*cf.* the *J*-curve literature).

7 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 same firm characteristics that determine flexible pricing also determine the currency choice, namely the firm size and the share of imported inputs. Large exporters that rely intensively on imported intermediate inputs are more likely to invoice in foreign currencies, especially in the US dollar, while the smaller firms tend to use the euro. A firm's currency choice is also influenced by the decisions of its competitors in a given market, due to strategic complementarities. We find that the currency choice matters for exchange rate pass-through, even after controlling for the flexible price characteristics, providing evidence for the role of price stickiness. The cross-currency pass-through differentials persist beyond a one-year horizon, generating allocative expenditure-switching effects on foreign import quantities.

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 two 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

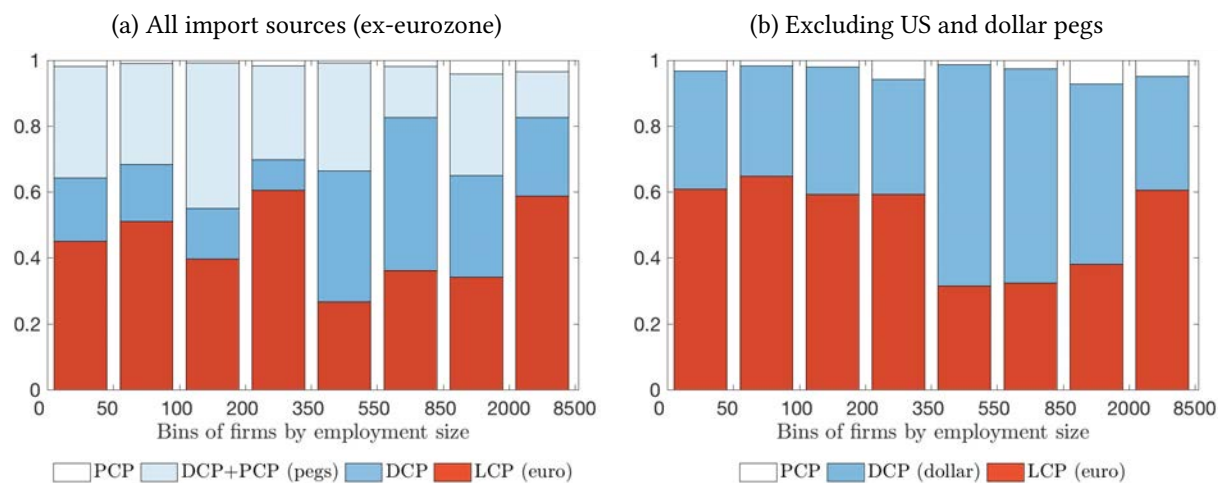
⁴⁴To clarify, $\delta_{q,h}$ corresponds to the relative response of quantities for LCP vs PCP firms, and thus $-\delta_{q,h} < 0$ is the negative relative response of quantities for PCP firms, as we expect. Similarly, $\delta_{q,h}^D < 0$ is the negative response of quantities for DCP firms relative to LCP firms.

to a multiple-regional-currencies equilibrium, with more intensive trade within the regions and greater barriers to cross-regional trade. This, in turn, may increase the expenditure-switching role of bilateral exchange rate movements, yet with a lower volume of long-distance trade.

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 pricing system.

A Additional Figures and Tables

Figure A1: Firm size and import currency invoicing



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

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	1,948	299	246	115	60	36	23	12
Share in total exports	6%	7%	11%	10%	7%	10%	13%	35%
Share in total imports	5%	3%	8%	9%	7%	10%	8%	50%

Note: We sort firms by employment into 8 size bins, roughly corresponding to the first 7 deciles of export revenues and the last one combining the top three deciles (containing only 12 firms, which together account for 35% of Belgian manufacturing exports and 50% of imports).

Table A2: Summary statistics

Variable	Mean	St Dev.	5 pctl	Median	95 pctl	Count
Currency choice (Tables 2 and 3–5)						
l_{ikt}	0.316	0.465	0	0	1	741,570
φ_i	0.139	0.133	0.003	0.099	0.439	741,570
φ_i^X	0.052	0.080	0.000	0.034	0.217	741,570
$\log L_i$	5.678	1.799	2.651	5.730	7.874	741,570
S_{ik}	0.268	0.327	0.001	0.090	0.985	741,570
out-FDI _i	0.498	0.500	0	0	1	741,570
in-FDI _i	0.469	0.499	0	0	1	741,570
l_{ikt}^M	0.632	0.482	0	1	1	270,490
χ_i	0.266	0.219	0.000	0.225	0.676	270,490
χ_i^X	0.081	0.130	0	0.017	0.383	270,490
S_{ijk}^M	0.137	0.270	0.000	0.007	0.909	270,490
l_{ikt}^D	0.545	0.498	0	1	1	113,337
Exchange rate pass-through (Tables 6–7 and 8)						
Δp_{ikt}^*	0.043	0.364	−0.613	0.034	0.712	265,841
Δq_{ikt}^*	0.031	1.319	−2.055	0.012	2.118	265,841
Δe_{kt}	0.033	0.098	−0.130	0.025	0.193	265,841
Δe_{kt}^D	0.043	0.096	−0.046	0.006	0.213	265,841

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 February 2017 to March 2019; the lower panel for the ERPT regressions at the firm-product-destination-year level for 2012 to 2018.

Table A3: ERPT into prices and quantities, reduced form

Dep. var.:	(1)		(2)		(3)		(4)	
	Δp_{ikt}^*	Δq_{ikt}^*	Δp_{ikt}^*	Δq_{ikt}^*	Δp_{ikt}^*	Δq_{ikt}^*	Δp_{ikt}^*	Δq_{ikt}^*
Δe_{kt}	1.016*** (0.014)	−0.527*** (0.096)	—	—	—	—	—	—
$\Delta e_{kt} \cdot \varphi_i$	−0.350*** (0.081)	0.270 (0.429)	−0.284*** (0.106)	−0.023 (0.641)	−0.293*** (0.105)	−0.026 (0.636)	−0.114 (0.091)	0.412 (0.405)
$\Delta e_{kt}^D \cdot \varphi_i$	0.391*** (0.075)	0.426 (0.455)	0.319*** (0.112)	0.822 (0.675)	0.320*** (0.111)	0.766 (0.668)	—	—
$\Delta e_{kt} \cdot S_{ik}$	−0.051 (0.036)	−0.006 (0.129)	−0.065 (0.074)	−0.141 (0.258)	—	—	—	—
$\Delta e_{kt}^D \cdot S_{ik}$	−0.010 (0.035)	−0.169 (0.139)	0.006 (0.068)	−0.317 (0.237)	—	—	—	—
$\Delta e_{kt} \cdot l_{ikt}$	−0.359*** (0.037)	0.466*** (0.121)	−0.259*** (0.050)	0.464*** (0.165)	−0.262*** (0.049)	0.453*** (0.163)	−0.166*** (0.045)	0.257* (0.133)
$\Delta e_{kt}^D \cdot l_{ikt}^D$	0.324*** (0.041)	−0.253 (0.167)	0.234*** (0.050)	−0.201 (0.223)	0.234*** (0.049)	−0.202 (0.222)	—	—
# obs.	240,188	240,188	200,595	200,595	200,595	200,595	221,564	221,564
Fixed Effects:								
firm	✓	✓	✓	✓	✓	✓	✓	✓
destination	✓	✓						
industry×destination	✓	✓						
industry×destination×year			✓	✓	✓	✓	✓	✓

Notes: Each column reports (a) the first stage regression of the corresponding column in Table 8, where the dependent variable is the log change in destination price Δp_{ikt}^* ; and (b) the reduced form OLS specification where the dependent variable is the log change in export quantity Δq_{ikt}^* . The observations are at the firm-CN8 product-destination-year level for 2012–2018. The explanatory variables are as described in Tables 6 and 7. All regressions are clustered at the destination-year level.

B Dynamic of Pass-through

Consider a simple dynamic Calvo model of price setting with a desired price in the destination currency that follows:

$$\tilde{p}_{it}^* = \alpha_i e_t,$$

where e_t is the producer-destination exchange rate (following a random walk), and $\alpha_i = 1 - \varphi_i - \gamma_i$, as a special case of Lemma 3. The desired price in producer currency is thus $\tilde{p}_{it} = (\alpha_i - 1)e_t$.

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

$$\begin{aligned}\bar{p}_{it}^* &= (1 - \beta\delta) \sum_{j=0}^{\infty} (\beta\delta)^j \mathbb{E}_t \tilde{p}_{t+j}^* = \alpha_i e_t, \\ \bar{p}_{it} &= (1 - \beta\delta) \sum_{j=0}^{\infty} (\beta\delta)^j \mathbb{E}_t \tilde{p}_{t+j} = (\alpha_i - 1)e_t,\end{aligned}$$

for the LCP and PCP cases respectively, where we use the assumption of a random walk in exchange rate, namely that $\mathbb{E}_t e_{t+j} = e_t$. For an LCP firm, the realized destination-currency price is given by $p_{it}^{L*} = p_{i,t-1}^{L*}$ with probability δ and $p_{it}^{L*} = \bar{p}_{it}^*$ with probability $1 - \delta$. For a PCP firm, the realized destination-currency price is $p_{it}^{P*} = p_{it}^P + e_t$, with $p_{it}^P = p_{i,t-1}^P$ with probability δ and $p_{it}^P = \bar{p}_{it}$ with probability $1 - \delta$.

Observing a large number of symmetric firms with α_i , some of which adjust prices on a given date, while others do not, we record an average price $p_t^{L*} = \delta p_{t-1}^{L*} + (1 - \delta)\bar{p}_{it}^*$ and $p_t^{P*} = p_t^P + e_t$ with $p_t^P = \delta p_{t-1}^P + (1 - \delta)\bar{p}_{it}$, for LCP and PCP subsets of firms respectively. With this, we have that Δp_t^{L*} and Δp_t^{P*} both follow an AR(1) process with persistence δ and *iid* innovations $(1 - \delta)\alpha_i \Delta e_t$ and $(1 - \delta)(\alpha_i - 1)\Delta e_t$ respectively.

We are interested in the regression coefficients of $\Delta_h p_t^{L*} = p_t^{L*} - p_{t-h}^{L*}$ and $\Delta_h p_t^{P*} = p_t^{P*} - p_{t-h}^{P*}$ on $\Delta_h e_t = e_t - e_{t-h}$, which we denote $\hat{\delta}_h^L$ and $\hat{\delta}_h^P$ respectively. We calculate (see the Proof in the end of this appendix):

$$\hat{\delta}_h^L = \frac{\text{cov}(p_t^{L*} - p_{t-h}^{L*}, e_t - e_{t-h})}{\text{var}(e_t - e_{t-h})} = \alpha_i \left[1 - \frac{1}{h} \frac{\delta}{1 - \delta} (1 - \delta^h) \right], \quad (\text{A1})$$

$$\hat{\delta}_h^P = \frac{\text{cov}(p_t^P + e_t - p_{t-h}^P - e_{t-h}, e_t - e_{t-h})}{\text{var}(e_t - e_{t-h})} = 1 + (\alpha_i - 1) \left[1 - \frac{1}{h} \frac{\delta}{1 - \delta} (1 - \delta^h) \right]. \quad (\text{A2})$$

Note that at $h = 1$, $\hat{\delta}_1^L = \alpha_i(1 - \delta)$ and $\hat{\delta}_1^P = 1 - (1 - \delta)(1 - \alpha_i)$, with $\hat{\delta}_1^P - \hat{\delta}_1^L = \delta$, reflecting the fraction of firms that do not adjust on impact (in the first month). Over time, the gap between the two pass-through elasticities closes:

$$\hat{\delta}(h) \equiv \hat{\delta}_h^L - \hat{\delta}_h^P = \frac{1}{h} \frac{\delta}{1 - \delta} (1 - \delta^h) \rightarrow 0 \quad \text{as } h \rightarrow \infty.$$

At $h = \infty$, we have $\hat{\delta}_\infty^P = \hat{\delta}_\infty^L = \alpha_i$, that is both elasticities converge to the desired-price pass-through.

Note that at each horizon h , the fraction of prices that have not yet adjusted is δ^h , and $1 - \delta^h$ is

respectively the fraction of prices that adjusted at least once. The impulse response of prices to the exchange rate shock (theoretical pass-through elasticity) is (see the Proof below):

$$\psi_h^L = \frac{\partial p_{t+h}^{L*}}{\partial(\Delta e_t)} = \alpha_i(1 - \delta) \sum_{j=0}^{h-1} \delta^j = \alpha_i(1 - \delta^h), \quad (\text{A3})$$

$$\psi_h^P = \frac{\partial p_{t+h}^{P*}}{\partial(\Delta e_t)} = 1 + (\alpha_i - 1)(1 - \delta^h) = \alpha_i + \delta^h(1 - \alpha_i), \quad (\text{A4})$$

so that $\hat{\psi}(h) \equiv \psi_h^L - \psi_h^P = \delta^h$.

Note that for $h = 1$, $\hat{\psi}(1) = \hat{\delta}(1) = \delta$, while for any $h > 1$ we have $\hat{\delta}(h) > \hat{\psi}(h) = \delta^h$. This is because the empirical pass-through regression has to aggregate both short-run and long-run responses to estimate a *medium-run* response, and therefore estimates a larger gap in ERPT (or equivalently, a slower decline in this gap) than exhibited by the theoretical impulse response.

Lastly, we discuss the role of α_i . The currency choice between LCP and PCP is endogenous to α_i , and firms with a higher α_i are more likely to select into PCP. Therefore, in the regressions, we control for the flexible-price determinants of pass-through, which proxy for α_i . With a perfect measure of α_i , one fully controls for selection by including the interaction term $(1 - \hat{\delta}(h))(1 - \alpha_i)\Delta_h e_t$ in the pass-through regression (recall (12)), and still recovers $\hat{\delta}_h^L$ and $\hat{\delta}_h^P$, and thus $\hat{\delta}(h)$, which captures the causal effect of foreign-currency price stickiness.

Proof: For the calculations, note that $e_t - e_{t-h} = \sum_{j=0}^{h-1} \varepsilon_{t-j}$, where ε_t is the iid exchange rate innovation. Furthermore, prices $p_t^{L*} - p_{t-h}^{L*} = \sum_{j=0}^{h-1} \Delta p_{t-j}^{L*}$ with

$$\Delta p_{t-j}^{L*} = \delta^{h-j} \Delta p_{t-h}^{L*} + (1 - \delta) \alpha_i \sum_{\ell=0}^{h-j-1} \delta^\ell \varepsilon_{t-j-\ell}.$$

Therefore:

$$\begin{aligned} \text{cov}(p_t^{L*} - p_{t-h}^{L*}, e_t - e_{t-h}) &= \text{cov} \left(\sum_{j=0}^{h-1} \varepsilon_{t-j}, \sum_{j=0}^{h-1} (1 - \delta) \alpha_i \sum_{\ell=0}^{h-j-1} \delta^\ell \varepsilon_{t-j-\ell} \right) \\ &= \alpha_i \text{cov} \left(\sum_{j=0}^{h-1} \varepsilon_{t-j}, \sum_{j=0}^{h-1} (1 - \delta^{j+1}) \varepsilon_{t-j} \right) = \alpha_i \left[h - \frac{\delta(1 - \delta^h)}{1 - \delta} \right] \sigma_e^2, \end{aligned}$$

where $\sigma_e^2 = \text{var}(\varepsilon_t) = \text{var}(\Delta e_t)$. Using the fact that $\text{var}(e_t - e_{t-h}) = h\sigma_e^2$ results in (A1), and a similar calculation applies in the PCP case to obtain (A2).

Finally, (A3) follows directly from the expansion for Δp_{t-j}^{L*} after noticing that $\Delta e_t = \varepsilon_t$ is an iid innovation, and similarly for (A4). ■

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