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# Dominant currency dynamics:
## Evidence on dollar-invoicing from UK exporters

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# Abstract

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# 1 Introduction

The majority of international trade transactions are invoiced in a small number of currencies, with the US dollar being the dominant currency globally.[1] The last century witnessed the rise of the dollar as the globe's dominant currency, eclipsing the prior dominance of the British pound sterling.[2] A rich literature has sought to explain the factors contributing to the dollar's dominance in world trade; early contributions pointed to the relative macroeconomic stability of the US and its currency (Devereux and Engel (2002)), while more recent papers have focused on the importance of strategic complementarities in price-setting by firms in foreign markets (Goldberg and Tille (2008, 2016)) and hedging against the risk of changes to marginal cost due to imported inputs priced in foreign currencies (Chung (2016), Amiti, Itskhoki and Konings (2020), and Lyonnet, Martin and Mejean (2021)). However, due to limited data on invoicing over time, the mechanism by which a particular currency comes to dominate the invoicing of world trade flows has remained something of a mystery.

While survey data from many countries suggests that the aggregate shares of invoicing currencies are relatively stable over time, this is not always the case.[3] In the space of just ten years, the share of British (extra-EU) exports invoiced in dollars rose 52.9%, from just under a third of (extra-EU) export value in 2010, to nearly half in 2019.[4] The large depreciation of the pound against the dollar in 2016 undoubtedly contributed to this shift, but does not tell the full story. Crucially, there was a steady and distinct rise in the use of the dollar for invoicing Britain's (extra-EU) exports *before* the sterling's 2016 depreciation; this rise is apparent not only in the share of (extra-EU) export *value* invoiced in dollars, which rose 16.9% over 2010-2015, but also in the share of (extra-EU) export *transactions* invoiced in dollars, which rose

[1] Gopinath (2015) documents the dollar's share in global invoicing of trade was 4.7 (3.1) times its share in world imports (exports) for a sample of 43 (44) countries over 1999-2014.

[2] Eichengreen and Flandreau (2009) argue this shift took place as early at the 1920s; Chinn and Frankel (2008) discuss the evidence that the transition to dollar dominance was completed by 1945.

[3] See Ito and Chinn (2015), Ito and Kawai (2016), and Maggiori, Neiman and Schreger (2019) for a discussion of changing shares of invoicing currencies for international trade, all of which build upon earlier work by Goldberg and Tille (2008).

[4] The dollar-invoiced share of the UK's (extra-EU) exports was 31.0% (48.0%) in 2010 (2019). See Her Majesty's Revenue and Customs (2012, 2020). Notably, the dramatic ten-year shift in dollar-invoicing is not mirrored in Britain's (extra-EU) imports whose dollar share rose by a much more modest 5.7% over 2010-2019. Because the UK did not record the currency of invoice for its trade with the EU over this period, our analysis of invoicing currencies is limited to Britain's trade with non-EU countries.

18.7% between 2010 and 2015.[5]

This paper investigates the dynamic mechanisms behind the rise of a dominant currency. Our empirical analysis focuses on the previously unexplored choice of an invoicing currency to a new foreign market by firms with varying levels of tenure as exporters. Using the universe of export transactions from Her Majesty's Revenue and Customs (HMRC) Overseas Trade in Goods Database over 2010-2016, we document that a British firm's choice to invoice its exports to a *new* foreign market in dollars is *increasing* in its previous experience with dollar-invoicing to *other* foreign markets. We exploit this newly-identified feature of *extensive margin* invoicing patterns, in conjunction with evidence of strategic complementarities in British export pricing, to guide the development of a general framework of a firm's dynamic invoicing behaviour.

Our theoretical contribution is to introduce fixed costs associated with the management of foreign invoicing currencies into the firm's profit function. Intuitively, a firm that is strategically motivated to invoice in dollars in order to better maintain price stability relative to its (dollar-invoicing) competitors in one foreign market gains experience with dollar-invoicing; this experience, which is captured as increasing returns to scale deriving from the fixed costs of currency management, feeds into a higher likelihood of using the dollar in a firm's new foreign markets in subsequent periods. In this way, the two mechanisms of strategic complementarities and increasing returns to scale in currency management reinforce each other dynamically and strengthen the dominance of the dollar in global trade.

Understanding how and why a currency comes to dominate global trade is important from three perspectives. First, as recent research documents a close link between the currency in which a transaction is invoiced and the degree to which firms pass through exchange rate movements into import and domestic prices,[6] firms' invoicing choices are clearly a key to deciphering the global transmission of monetary and pro-

[5]Authors' calculations based on Britain's (extra-EU) export value with a declared currency of invoice; the dollar share stood at 31.1% (36.7%) in 2010 (2015). See Her Majesty's Revenue and Customs (2012, 2016). The dollar share of Britain's extra-EU export transactions (among transactions with a declared currency of invoice) was 20.3% (24.1%) in 2010 (2015) (Calculated from data presented in Figure A1 in Corsetti, Crowley and Han (2020)).

[6]See Gopinath, Itskhoki and Rigobon (2010), Boz, Gopinath and Plagborg-Møller (2019), Bonadio, Fischer and Saure (2019), Auer, Burstein, Erhardt and Lein (2019), Chen, Chung and Novy (2019), Amiti, Itskhoki and Konings (2020), Barbiero (2020), Corsetti, Crowley and Han (2020), Drenik and Perez (2020) and Auer, Burstein and Lein (2021).

ductivity shocks and to the setting of optimal policies.[7] Second, the path-breaking work of Gopinath et al. (2020) highlights the importance of dollar dominance as the source of asymmetric exchange rate pass-through across countries; investigating the dynamic roots of the 'Dominant Currency Paradigm' could help predict the rise of other dominant currencies. Third, a study of the dynamics of firms' invoicing choices sheds new light on the long-run effects of major policy changes or economic events, such as Brexit or Covid. Despite the importance of dominant currency dynamics, little progress has been made on the dynamics of invoicing choices due to data limitations.[8]

The UK presents an interesting case to study because its own currency, the pound sterling, was used for invoicing over 60% of British exports to extra-EU destinations in 2010, but this share had fallen dramatically to 41% by 2019 (see Her Majesty's Revenue and Customs (2012, 2020)). Previous work from Corsetti, Crowley and Han (2020) has documented interesting and important patterns in the use of invoicing currencies by British exporters; most notably, 99% of the UK's extra-EU export value originates from firms that use at least two currencies, 50% of export value originates from UK exporters that are using at least two different currencies to invoice sales of the same product to the same foreign destination within a calendar year, and finally, British exporters actively switch the currencies used to invoice exports over time. Altogether, this information tells us that invoicing currency is an active margin of choice for British exporters and examining the static and dynamic factors that influence British firms' choices could be informative about changes in the use of currencies around the globe and over time.

Empirically, we document two novel facts that are essential to understanding the dynamics of invoicing currency choices and the formation of a dominant currency. First, we analyse and document the role that previous successful experience with dollar-invoicing plays in future choices, focusing on a firm's choice of an invoicing currency when it enters a new foreign market. One year of dollar-invoicing in any of a firm's existing markets increases the probability of dollar invoicing in a new

[7] The transmission of shocks in a open macroeconomic model depends on the currency in which the price is stable. For example, a stable local currency price would insulate a local economy against foreign shocks. See Goldberg and Knetter (1997), Corsetti and Pesenti (2005) and Burstein and Gopinath (2014) for more details.

[8] US data is not well-suited for this type of analysis as one cannot distinguish between producer versus vehicle currency invoicing by US exporters that invoice in dollars. Many countries' administrative datasets, such as the Belgium data used in Amiti, Itskhoki and Konings (2020), have recorded invoicing choices for only a limited time-span of one to two years.

market by 4 percentage points relative to those firms that have never used the dollar in any market. Importantly, the probability of dollar invoicing in a new market is increasing in a firm's experience with the dollar – a firm with 6 years of dollar-invoicing experience is 14 percentage points more likely to invoice in dollars in a new market relative to those firms which have never invoiced in dollars. This evidence suggests the existence of a positive feedback channel of dollar invoicing that cannot be explained by existing models of invoicing currency choice.

Second, we document micro evidence on the role of complementarity in firms' invoicing choices. We find a one standard deviation increase in the dollar-invoicing share of a firm's competitors from the UK raises the probability of dollar-invoicing by 2.1 percentage points, corresponding to a 9.45% increase from the mean dollar invoicing probability in our estimation sample. Moreover, we estimate that the quantitative importance of strategic complementarity as a factor underpinning dollar invoicing is more pronounced for large firms and for less differentiated products, consistent with theoretical models of oligopolistic competition.

Consistent with findings in Chung (2016) and Amiti, Itskhoki and Konings (2020), we confirm a significant role of imported inputs in determining the invoicing currency for exports. A higher share of *imports* invoiced in dollars is associated with a higher likelihood of invoicing *exports* in dollars. In contrast, imports invoiced in other currencies – the euro in particular – reduce the probability of dollar-invoicing. This pattern is consistent with a practice in which firms hedge their exchange rate risk in dollars by aligning their export currency with their import currency.

Our novel theoretical contribution is a framework that incorporates the dynamics of invoicing currency choices and characterizes the necessary conditions under which the model can reproduce our newly documented empirical patterns. We show our framework of invoicing dynamics can be easily integrated with existing invoicing currency choice models through the dynamics of managerial costs. For example, if the cost of using dollars can be shared across the firm's dollar-invoiced destinations, the managerial cost of using dollars will be a decreasing function of a firm's dollar invoicing share in the past. Therefore, firms with a larger number of dollar-invoiced foreign export markets will be more likely to invoice in dollars in any new markets. More importantly, we show how the firm's invoicing choices change over time as a firm grows and how invoicing dynamics interact with entry dynamics to jointly determine the evolution of a dominant currency.

Altogether, our analysis identifies a firm's experience with dollars as an important channel contributing to the dollar's dominance. At the same time, it lends strong empirical support to theoretical works that have emphasized strategic complementarity and dollar-invoiced imported inputs as important factors associated with vehicle currency pricing (VCP).[9] The role of a firm's past experience with dollar-invoicing as a driver behind future choices has not been previously considered in the literature which, due to data limitations, has focused primarily on cross-sectional variation. Our results open up a new line of research exploring the evolution of invoicing choices over time and across destinations. This highlights the importance of the dynamic paths of individual firms' choices in the formation of a dominant currency.

**Related literature.** This paper builds on a rich theoretical and empirical literature on endogenous currency choices and their implications [Friberg (1998), Bacchetta and van Wincoop (2005), Engel (2006), Goldberg and Tille (2008, 2016), Mukhin (2018), Devereux, Dong and Tomlin (2017) and Lyonnet, Martin and Mejean (2021)]. An early contribution from Goldberg and Tille (2008) uses cross-country data on the aggregate shares of different invoicing currencies to analyse a theoretical model of a firm's strategic incentive to choose the same currency as other exporters.[10] More recent work has used large firm-level datasets to study the use of different invoicing currencies by firms. Amiti, Itskhoki and Konings (2020) study Belgian firms' trade with extra-EU destinations and document that larger firms are more likely to invoice in dollars while smaller, less import-intensive firms invoice in euros (i.e., producer currency pricing) and exhibit almost complete exchange rate pass-through into foreign import prices. To further this line of research, we present a framework for invoicing currency choice and examine both the existing channels of strategic complementarity and operational hedging as well as a novel dynamic channel that arises from the managerial cost of using a foreign currency.

The rest of the paper is organized as follows. Section 2 describes our data and

[9]Theoretical models emphasizing strategic complementarity in invoicing currency choices include Bacchetta and van Wincoop (2005), Goldberg and Tille (2008), Mukhin (2018) and Gopinath et al. (2020). Additional papers focusing on strategic complementarities in pricing and exchange rate pass through include Gopinath and Itskhoki (2010, 2011), Auer and Schoenle (2016), and Pennings (2017).

[10]Their analysis emphasizes the prevalence of dollar pricing in homogeneous goods sectors as indirect evidence of a form of strategic complementarity that they refer to as the "coalescing motive"; that is, because demand for homogeneous products is more price-elastic than that for heterogeneous goods, the firms selling homogeneous goods have stronger incentives to stabilize their relative prices vis-a-vis their competitors and, hence, are more likely to price in dollars.

presents new stylized facts on firm and transaction level invoicing choices. Section 3 outlines a theoretical framework. Section 4 discusses our empirical strategy. Section 5 presents our main estimation results. Section 6 discusses the aggregate implications of our findings. Section 7 concludes.

## 2 The evolution of invoicing currency use

In this section, we highlight the key features of our data and present three stylized facts on invoicing currency dynamics. The data used in our analysis, a seven year panel of transaction-level customs data from Her Majesty's Revenue and Customs (HMRC) Overseas Trade in Goods Database, enables us to document a series of important facts about a firm's use of different invoicing currencies *over time.* We exploit the long panel dimension to identify: (1) the role of export tenure in invoicing currency diversity; (2) the persistence of invoicing currency choices over time; and (3) the relationship between export tenure and a firm's dollar-invoicing share. These facts complement previous cross-sectional work that has examined within-period factors associated with invoicing currency usage, but adds important new features about the evolution of invoicing currency patterns over a firm's life-cycle.

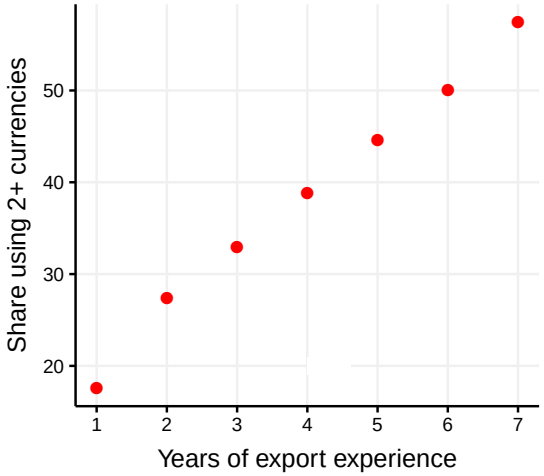
HMRC has recorded the invoicing currency for extra-EU trade transactions since January 2010. All importers must report their currency of invoicing for every transaction. Exporters whose annual exports exceed a value of £100,000 must report their invoicing currency for each transaction. For each transaction, the invoicing currency is recorded alongside an anonymous trader identifier, product and industry codes, country of origin and destination, and customs variables including values and quantities.[11] Given data availability, our analysis focuses on export transactions to extra-EU destinations over 2010-2016.[12]

Our first stylized fact is that experience in exporting is associated with the use of more currencies by UK firms. In figure 1, we present statistics that document that

[11] Products are defined by an 8-digit Combined Nomenclature (CN) code.

[12] Approximately fifty-three percent of UK goods exports were sent to extra-EU destinations over 2010-2016 (Calculated by the authors from HMRC Overseas Trade Statistics available at: https://www.uktradeinfo.com/trade-data/overseas/). When the currency of invoicing is not reported, we drop the corresponding observation. For instance, in 2015, the share of extra-EU exports from the UK which did not report the invoicing currency accounts for around 7.5% of export value and 31.0% of transactions. For extra-EU imports, observations for which no invoicing currency is reported account for a small fraction of transactions (less than 5%) and a trivial share of import value (0.1% or lower).

Figure 1: Share of firms using 2 or more currencies given $t$ years of exporting experience

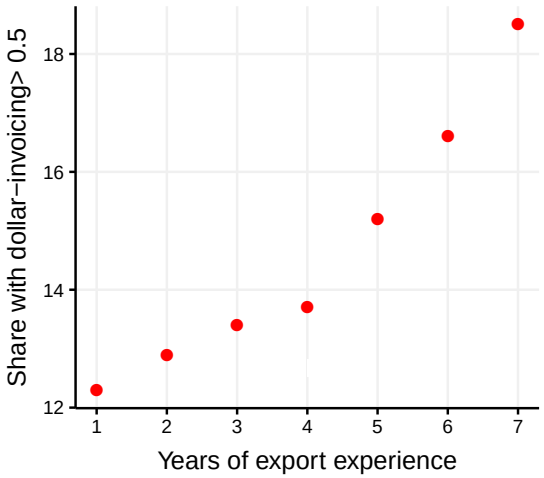



Notes: Each point represents the share of firm-year dyads using 2 or more currencies in a firm's $t$th year of exporting, given the the firm has $t$ years of export experience over 2010-2016. The underlying data are reported in appendix table C1, panel (a). Data source: HMRC Overseas Trade in Goods Statistics, UK's extra-EU export transactions, 2010-2016.

firms with more years of exporting experience tend to invoice their extra-EU exports in a larger number of currencies. For each firm, we calculate the joint distribution of years in which it is observed exporting and the number of currencies it uses in the $t$th year of exporting. Figure 1 presents the share of firms with $t$ years of export experience that use two or more currencies in the $t$th year of exporting. The steady increase from 17.6% for firms with only one year of recorded exports over 2010-2016 to 57.4% for firms that exported in every year of the sample period indicates an important change over the lifespan of a firm. The statistics hint at the possibility that success in identifying valuable export markets increases the likelihood of success with using more currencies or, alternatively, that firms that know how to hedge risk via the use of multiple currencies are better able to survive as exporters. Our econometric analysis will tease out the factors behind this intriguing correlation.

The second stylized fact, depicted in figure 2, is that firms with more years of exporting experience tend to have a higher reliance on a specific currency – the US dollar – in invoicing their exports. For each firm, we plot the joint distribution of years in which it is observed exporting and the fraction of firms that invoice over 50% of their extra-EU exports in US dollars. Only 12.3% of firms with one year of

Figure 2: Share of firms invoicing over 50% of extra-EU exports in dollars given $t$ years of exporting



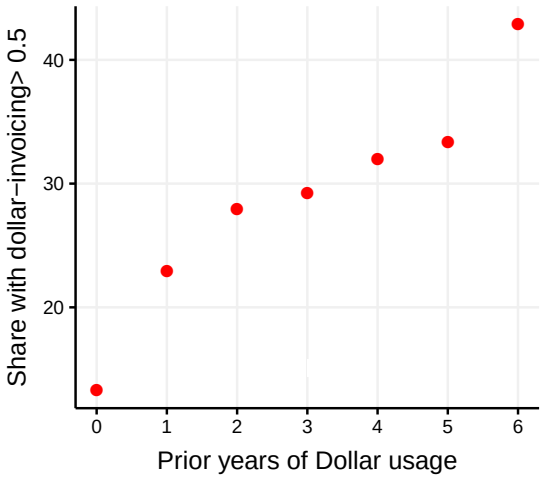

Notes: Each point represents the share of firm-year dyads invoicing more than one-half of extra-EU export value in dollars in a firm's $t$th year of exporting given the firm has $t$ years of export experience over 2010-2016. The underlying data are reported in appendix table C2, panel (a). Data source: HMRC Overseas Trade in Goods Statistics, UK's extra-EU export transactions, 2010-2016.

export experience use dollars to invoice more than one-half of their exports. But the share of 'heavy dollar users' rises with exporting experience such that 18.5% of firms which report 7 years of dollar use over 2010-2016 invoice more than one-half of their extra-EU exports in dollars. The fact that the share of firms which predominantly invoice in US dollars increases with exporting experience suggests the presence of firm-level economies of scale in the use of a currency which increase with a firm's duration of experience with the dollar.

Our final stylized fact relates the duration of dollar invoicing experience to a firm's dollar invoicing share. Figure 3 depicts a firm's prior years of dollar experience as of $t-1$ on the x-axis against the corresponding share of firm-year dyads which invoice over 50% of export value in dollars in year $t$. A substantial 42.8% of firms with 6 years of prior dollar-invoicing experience invoice over one-half of their exports in dollars. This is in stark contrast to the mere 13.3% of firms which predominantly use dollars even though they had no prior experience with dollar invoicing during our sample period.

To summarize, an exploration of the panel dimension of UK export transactions has revealed that firms with more years of export experience use a larger variety of

Figure 3: Share of firms invoicing over 50% of extra-EU exports in dollars in year $t$ given prior years of dollar invoicing




Notes: Each point represents the share of firm-year dyads invoicing more than one-half of extra-EU export value in dollars in year $t$ given $k$ years of dollar invoicing at $t-1$. The underlying data can be obtained from appendix table C3, by dividing statistics in the sixth column of panel (a) by those in the seventh. Data source: HMRC Overseas Trade in Goods Statistics, UK's extra-EU export transactions, 2010-2016.

invoicing currencies. Second, the share of firms that invoice more than half of their extra-EU exports in dollars increases in the firm's tenure as an exporter. Finally, the share of firms invoicing more than half of their extra-EU sales in dollars is increasing in the duration of a firm's previous experience with invoicing in dollars. Altogether, these facts paint a picture of how the use of a dominant currency grows with firm tenure in exporting, and more specifically, with tenure in dollar invoicing.

# 3 A model of currency choice

In this section, we propose a framework that incorporates the key elements of invoicing currency choices from the existing literature and captures the dynamic features of invoicing currency choices observed among the British firms in our data. The environment for currency choice is characterized by nominal rigidities in the spirit of previous contributions from Engel (2006), Goldberg and Tille (2008), Gopinath, Itskhoki and Rigobon (2010) and Mukhin (2018). Our novel contribution is the introduction of a managerial cost associated with the use of any currency other than

the firm's own producer's currency for invoicing exports.

## 3.1 Optimal flexible price

We begin with a firm's optimal pricing under flexible prices. On the production side, a firm uses labour and intermediate inputs from home and foreign countries to produce its output with a Cobb-Douglas production technology:

$$Y_f = A_f L_f^{1-\phi_f} \prod_{j=1}^{J} (M_{fj}^{\alpha_{fj}})^{\phi_f} \tag{1}$$

where $Y_f$ denotes output, $A_f$ is the exogenously given firm productivity, $L_f$ is labour and $M_{fj}$ are firm $f$'s imports of intermediates invoiced in currency $j$. Constant returns to scale imply $\sum_{j=1}^{J} \alpha_{fj} = 1$. $J$ denotes the set of currencies in which intermediate inputs are invoiced.

The firm faces a market structure featuring oligopolistic competition à la Atkeson and Burstein (2008) and Amiti, Itskhoki and Konings (2019). Specifically, each firm $f$ produces a differentiated good in each industry and exports it to destination market $d$. Consumers in each destination have a nested CES demand over the varieties of goods. The elasticity of substitution within and across industries are $\rho$ and $\eta$, respectively, with $\rho > \eta \geq 1$. The demand faced by a firm $f$ in destination $d$ is

$$Q_{fd} = P_{fd}^{-\rho} P_d^{\eta-\rho} D_d \tag{2}$$

where $D_d$ is the exogenous demand shifter, $P_{fd}$ is firm $f$'s price in local (i.e., destination) currency and $P_d \equiv \left(\sum_f P_{fd}^{1-\rho}\right)^{\frac{1}{1-\rho}}$ is the aggregate price index in the destination. The firm's profit-maximizing price in local currency for each destination $d$ is derived as

$$P_{fd} = \frac{\varepsilon(S_{fd})}{\varepsilon(S_{fd}) - 1} \frac{MC_f}{\xi_d} \tag{3}$$

where $MC_f$ denotes the marginal cost derived from the firm's cost minimization problem and $\xi_d$ is the level of the nominal exchange rate in units of producer currency relative to one unit of destination $d$ currency. Note that the multiplicative markup ($\frac{\varepsilon_{fd}}{\varepsilon_{fd}-1}$) depends on the market share of individual firms ($S_{fd}$). Assuming that exchange rate movements are the only source of uncertainty, we can obtain the first-order approximation for the log optimal price $p_{fd}$ around the non-stochastic

steady-state as

$$p_{fd} \approx \frac{\Gamma_{fd}}{1+\Gamma_{fd}} p_{(-f)d} + \frac{1}{1+\Gamma_{fd}} \left( \sum_{j}^{J} \psi_f^j e_j - e_d \right) + \overline{C}_{fd} \tag{4}$$

where $p_{(-f)d} \equiv \sum_{k \neq f} \frac{S_{kd}}{1-S_{fd}} p_{kd}$ is the log of competitors' prices in local currency and $\Gamma_{fd} \equiv \Gamma(S_{fd}; \rho, \eta)$ denotes the markup elasticity with respect to prices. $\psi_f^j (= \alpha_{fj}\phi_f)$ is the share of imported inputs invoiced in each currency $j$ which enters into firm $f$'s production costs. $e_d$ and $e_j$ are the log exchange rates in units of producer currency relative to one unit of destination currency $d$ and origin currency $j$, respectively. $\overline{C}_{fd}$ is a collection of non-stochastic terms.

## 3.2 Currency choice under nominal rigidities

We start by assuming the firm makes separate invoicing choices in each destination. Let $\mathbb{E}[\Pi_{fd}^c]$ denote firm $f$'s expected profit in destination $d$ if it has chosen currency $c$ as its invoicing currency. For a given invoicing currency, the firm chooses its optimal one-period ahead pre-set price $\bar{p}_{fd}^c$ to maximize its expected operating profit $\mathbb{E}[\pi_{fd}(.)]$ denominated in its own home currency. The new element we introduce relative to a standard model in the literature is a managerial cost of using a foreign currency $F_f^c$.[13] The invoicing currency choice problem can be written formally as[14]

$$c = \underset{c}{\text{argmax}}\, \mathbb{E}[\Pi_{fd}^c] = \underset{c}{\text{argmax}} \left\{ \max_{\bar{p}_{fd}^c} \mathbb{E}\left[\pi_{fd}(\bar{p}_{fd}^c - e_d^c)\right] - F_f^c \right\} \tag{5}$$

where $e_d^c$ is the log of the exchange rate in units of invoicing currency $c$ relative to one unit of the destination currency $d$. The solution of the problem is characterized by a well-known theoretical result in the literature: the firm chooses the invoicing currency that most closely mimics its optimal flexible price and implements its desired degree of exchange rate pass through.[15]

Under a set of simplifying conditions detailed in appendix A and using the optimal

[13] Several articles suggest the relevance of a managerial cost associated with invoicing in a foreign currency (Gopinath (2015) and Goldberg and Tille (2016)). Also see Lyonnet, Martin and Mejean (2021) for recent empirical evidence and a theoretical model for invoicing currency choices with financial hedging.

[14] We assume that there is no managerial cost of using the firm's own producer currency for invoicing. We also implicitly assume that the managerial cost of an invoicing currency is small enough such that it does not affect the firm's entry decision for each destination.

[15] See e.g., Engel (2006), Mukhin (2018) and Amiti, Itskhoki and Konings (2020).

price expression (4), it can be shown that the expected profit of firm $f$ exporting to destination $d$ from using currency $v$ relative to that from any arbitrary currency $b$ has the following relationship:

$$\mathbb{E}[\Pi^v_{fd}] - \mathbb{E}[\Pi^b_{fd}] \propto \lambda_{fd}\Bigg[\underbrace{\frac{\Gamma_{fd}}{1+\Gamma_{fd}}(\zeta^v_{(-f)d} - \zeta^b_{(-f)d})}_{\text{Strategic complementarity}} + \underbrace{\frac{1}{1+\Gamma_{fd}}(\psi^v_f - \psi^b_f)}_{\text{Operational hedging}}\Bigg] - \underbrace{(F^v_f - F^b_f)}_{\text{Managerial cost}} \tag{6}$$

where $\Gamma_{fd}$ is the markup elasticity with respect to the firm's own price; $\zeta^c_{(-f)d}$ is firm $f$'s competitors' invoicing share of currency $c$ in destination $d$; $\psi^c_f$ is the firm's share of imports invoiced in currency $c$; and $\lambda_{fd} > 0$ is a non-stochastic term related to the second derivative of the operational profit function detailed in appendix A. The firm will choose currency $v$ over currency $b$ if the difference in expected profits is positive.

Equation (6) highlights three key mechanisms behind invoicing choices. The first element in the square brackets of equation (6) is related to strategic complementarities in pricing. Under nominal rigidities, the firm chooses the invoicing currency that is predominantly used by its competitors in order to keep its relative prices, and thereby its market shares, stable in the presence of exchange rate shocks. Note that the strength of the strategic complementarity in invoicing is governed by the markup elasticity ($\Gamma_{fd}$) which encapsulates two sources of heterogeneity to this strategic motive. The first heterogeneity is related to the firm's size. Since the markup elasticity ($\Gamma_{fd}$) has a hump-shaped relationship with the firm's market share ($S_{fd}$) for given parameters $\rho$ and $\eta$, so does the extent of the strategic complementarity. Empirically, for realistic market shares (i.e., market shares below 80%), the markup elasticity monotonically increases with the market share. The second heterogeneity is related to the level product differentiation, which, in turn, is governed by the elasticity of substitution within an industry ($\rho$). If a product is less differentiated and thus demand is more price-elastic, changes in relative prices due to exchange rate movements induce larger profit changes. This, in turn, implies that firms exporting less differentiated goods would have a stronger incentive to stabilize their relative prices against exchange rate shocks by matching the invoicing currency of their competitors in the destination.

The second element in square brackets of equation (6) captures a firm's operational hedging motive. All else equal, firms would prefer to match their export currency with that of their imported inputs since this would provide an 'effective

hedge' on exchange rate risk from importing inputs.

The third factor determining the choice of an invoicing currency is the managerial cost of using a particular currency; a higher managerial cost is associated with a lower probability of choosing the currency. The managerial cost captures various costs of managing exchange rate risk and writing contracts for delivery in foreign currencies; it could include hiring staff or services of a currency management firm.

## 3.3 Invoicing dynamics arising from entry dynamics and managerial costs

In this section, we explain how invoicing choices evolve under different assumptions about the functional form of the managerial cost given an assumed process of firm entry into new markets.

To keep our model as tractable as possible, we assume firms start with no exporting experience. Each firm adds one foreign market in each period.[16] We further assume, after controlling for the observable factors of strategic complementarity $\boldsymbol{\zeta}_{(-f)d}$, and operational hedging $\boldsymbol{\psi}_{fd}$, expected operational profit of using the US dollar (the local currency) relative to the producer's currency is uniformly distributed for each destination:[17]

$$\begin{aligned} \mathbb{E}[\pi_{fd}^{\text{USD}} - \pi_{fd}^{\text{PCI}} | \boldsymbol{\zeta}_{(-f)d}, \boldsymbol{\psi}_{fd}] \sim U(0,1) \\ \mathbb{E}[\pi_{fd}^{\text{LCI}} - \pi_{fd}^{\text{PCI}} | \boldsymbol{\zeta}_{(-f)d}, \boldsymbol{\psi}_{fd}] \sim U(0,1) \end{aligned} \tag{7}$$

If the firm makes its invoicing choice in each market without regard for its choice in other markets, then it will use dollars in a new destination $d$ if the expected benefit of using the dollar is larger than the benefit of (1) using the producer's currency and (2) the local currency:

$$\begin{aligned} \mathbb{E}(\Pi_{fd}^{\text{USD}}) - \mathbb{E}(\Pi_{fd}^{\text{PCI}}) = \mathbb{E}[\pi_{fd}^{\text{USD}} - \pi_{fd}^{\text{PCI}} | \boldsymbol{\zeta}_{(-f)d}, \boldsymbol{\psi}_{fd}] - (F_f^{USD} - 0) > 0 \quad \text{and} \\ \mathbb{E}(\Pi_{fd}^{\text{USD}}) - \mathbb{E}(\Pi_{fd}^{\text{LCI}}) = \mathbb{E}[\pi_{fd}^{\text{USD}} - \pi_{fd}^{\text{LCI}} | \boldsymbol{\zeta}_{(-f)d}, \boldsymbol{\psi}_{fd}] - (F_f^{USD} - F_f^{LCI}) > 0 \end{aligned} \tag{8}$$

A direct implication of (8) is that, if the managerial cost is fixed and paid separately

[16] This assumption is useful for deriving the theoretical relationships. Our quantitative simulation results hold with alternative entry and exit patterns.

[17] We have assumed a 0-1 uniform distribution for simplicity and convenience. Our discussions and key results hold for alternative normal distributions or uniform distributions with a different support. We can always adjust the level of the managerial cost to match the empirical statistics. For example, the assumption of a $U(-0.5, 0.5)$ distribution with a managerial cost of 0.5 is equivalent to the assumption of a $U(0,1)$ distribution with a managerial cost of 0.

in each destination, there will be no time or path dependency in the choice of an invoicing currency. For example, if $F_f^{USD} = F_f^{LCI} = \kappa_0$, then the probability of using the dollar in a new market is the same as the probability of using the local currency, which is equal to $1/2[1 - (\kappa_0)^2]$. A constant probability means that, controlling for the observable factors of strategic complementarity and operational hedging, the firm's invoicing currency decision in a new market is independent from the firm's previous invoicing choices in its existing markets. Note that this conclusion relies on the assumption that the fixed cost of currency management is specific to each individual foreign market; there are no cross-market returns to scale.

We believe it is more realistic to assume that the managerial cost of using a currency is firm-specific, rather than firm and destination-specific. This would imply the fixed cost of currency management could be shared across destinations. Once the cost is paid, then the firm can use the currency in any of its markets in the period. In this case, the actual managerial cost incurred in each destination is a function of the number of destinations using that currency. That is,

$$F_{ft}^c = \frac{\kappa_0}{\sum_d \mathbb{1}_{fdt}^c} \tag{9}$$

where $\mathbb{1}_{fdt}^c$ equals one if the firm uses currency $c$ in destination $d$ at time $t$. In this specification, the fixed cost of using currency $c$ in period $t$ in each foreign destination declines with each additional market in which the firm uses currency $c$. The shared managerial cost provides an incentive by which the firm's optimal choice of a currency in destination $d$ is linked to its choices of currencies in all other destinations. That is, the firm chooses to use the dollar in a set of markets $\mathcal{D}_{ft}$ if $F_{ft}^{\text{USD}} = \kappa_0 / \sum_{d \in \mathcal{D}_{ft}} \mathbb{1}_{fdt}^{\text{USD}}$ and

$$\begin{aligned} &\mathbb{E}(\Pi_{fd}^{\text{USD}}) - \mathbb{E}(\Pi_{fd}^{\text{PCI}}) > 0 \quad \text{and} \quad \mathbb{E}(\Pi_{fd}^{\text{USD}}) - \mathbb{E}(\Pi_{fd}^{\text{LCI}}) > 0 \quad \forall d \in \mathcal{D}_{ft} \\ &\mathbb{E}(\Pi_{fd}^{\text{USD}}) - \mathbb{E}(\Pi_{fd}^{\text{PCI}}) \leq 0 \quad \text{or} \quad \mathbb{E}(\Pi_{fd}^{\text{USD}}) - \mathbb{E}(\Pi_{fd}^{\text{LCI}}) \leq 0 \quad \forall d \notin \mathcal{D}_{ft} \end{aligned} \tag{10}$$

Under this set-up, an interesting dynamic pattern of invoicing choices arises when the firm expands by adding new markets. First, as the number of markets that it serves increases, the firm is more likely to use dollars. Second, the firm is more likely to use dollars in a new market if it has lots of existing dollar markets. This means, if we trace the invoicing choices of the same firm over time, we will see interesting path dependence in the firm's invoicing choices. The firm that happened to enter a dollar heavy market in the earlier stage of its life will be more likely to use dollars

in all of the subsequent markets it enters.

While the model gives interesting dynamics of invoicing choices, the joint invoicing decision problem can be only solved computationally rather than analytically. Supported by the simulation results, we proxy the theoretical evolution of the managerial costs suggested by (9) and (10) with the following reduced-form representation:

$$F(\omega^c_{ft-1}) = \kappa_1 - \kappa_2 \cdot \omega^c_{ft-1} \tag{11}$$

where $\omega^c_{ft-1}$ is the invoicing share of currency $c$ in firm $f$ global exports in period $t-1$; $\kappa_1$ such that $0 < \kappa_1 < 1$ represents the initial cost invoicing in currency $c$; and $\kappa_2$ such that $0 < \kappa_2 < \kappa_1$ represents the degree of cost reduction due to prior usage. This cost reduction could be due to effective cost sharing across destinations or more generally a result of accumulated know-how of conducting a foreign currency transaction and/or managing foreign exchange risk. Similar to (9), as the firm adds more dollar markets, $\omega^{\text{USD}}_{ft-1}$ would tend to rise, which subsequently reduces the cost of dollar invoicing in a new market.

Using equations (7), (8) and (11), the probability of dollar invoicing in a new market can be derived analytically as:

$$T(\omega^{\text{USD}}_{ft-1}) = \frac{1}{2}(1 + \kappa_2 \omega^{\text{USD}}_{ft-1})^2 - \frac{1}{2}(\kappa_1)^2 \tag{12}$$

Figure 4: Dollar transition function

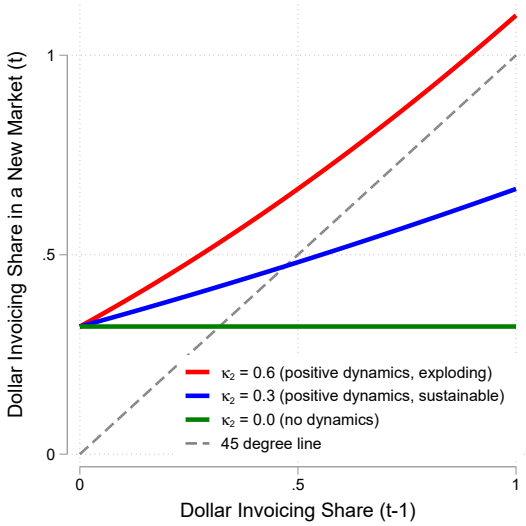


Figure 4 gives an illustration of this simple function when the initial cost parameter $\kappa_1$ is set to 0.6. As shown by the dark green horizontal line, when $\kappa_2 = 0$, the dollar invoicing probability in the new market is constant and does not depend on the firm's dollar invoicing share in the last period. Interesting dynamics which relate the choice of an invoicing currency for a new market to a firm's prior share of exports invoiced in dollars arises when $\kappa_2 > 0$. Figure 4 depicts two important cases in which $\kappa_2$ is greater than zero. In the first case, represented by the blue line, the dollar invoicing share will be sustained at a particular level. As can be seen from the blue line of figure 4, the firm's dollar invoicing share will increase (decrease) if its last period's dollar invoicing share was low (high). The dollar invoicing share will eventually stabilize around the interaction between the blue line and the 45 degree line.[18] The second important case occurs when the cost reduction ($\kappa_2$) is large relative to the fixed component $\kappa_1$ (i.e., $\kappa_2 > -1 + \sqrt{2 + (\kappa_1)^2}$). As shown in the red line, the model converges into a dollar only equilibrium, where all firms use dollars in all destinations. The dollar transition function (12) directly governs the relationship between the probability of dollar invoicing in a new market and the firm's prior dollar experience, which we discuss next.

### 3.3.1 Dollar invoicing probability in a new market and the firm's dollar invoicing experience

In this subsection, we characterize the relationship between the firm's probability of dollar invoicing in a new market and its prior dollar invoicing experience and compare the predictions of models with different managerial cost structures through Monte Carlo simulations. We present a general theoretical framework in Appendix A.4.

Specifically, we present the simulation predictions of the relationship between the dollar invoicing probability in a new market and a firm's prior dollar experience from four different models. The first model takes our reduced form assumption of the managerial cost in equation (11), where we calibrate $\kappa_1 = 0.6$ and $\kappa_2 = 0.18$.[19] The second model uses the shared global managerial cost setting in (9), where we calibrate $\kappa_0$ such that the model gives a similar cost function of the reduced form

[18] The steady-state dollar share is given by $\overline{\omega}^{\text{USD}} = \frac{1-\kappa_2-\sqrt{(\kappa_1\kappa_2)^2-2\kappa_2+1}}{(\kappa_2)^2}$.

[19] As it will be clear in the later sections, this calibration matches our empirical estimates reasonably well.

managerial cost model. The third model considers a one-off global sunk cost of using a currency. For example, the company may encounter a small fee in setting up a US dollar account. The cost of using a currency assumed to be 0 if the firm has used this currency in any of its existing markets in the past and $\kappa_0$ otherwise.[20] Finally, the fourth model assumes a fixed transaction cost – the firm pays a fixed cost for each destination that uses a foreign currency. Notably, the fixed transaction cost model can be thought of as a special case of our reduced form model where $\kappa_2 = 0$.

For each model, we simulate 200,000 firms with 10 destinations over 10 time periods according to the data generating process specified in (7). All firms start with no exporting market, add one foreign market in each period and end up with exporting to 10 destinations in period 10. We drop the first 3 periods of the simulated data to reflect the fact that we do not observe the full dynamics of firms in our empirical data.[21]

Figure 5 shows the predicted relationships between the dollar invoicing probability in a new market and the firm's prior dollar experience measured by the "Dollar Spell Length", which is defined as the number of years the firm has invoiced any foreign sales in dollars prior to its entry into the new market. We can see the probability of dollar invoicing is increasing in the dollar spell length for models A and B. As the firm adds more dollar markets and becomes more experienced in dollar-invoicing, the cost of using the dollar goes down and the firm is more likely to use dollars in the new market. In contrast, in models C and D, the probability of dollar-invoicing is constant and does not depend on the firm's prior dollar experience. Especially, in model C with the one time global sunk cost, the dollar invoicing probability jumps to $\kappa_0 = 0.05$ once the firm has used the dollar in any of its existing markets but this probability does not change over time as the firm becomes more experienced in dollar invoicing. As shown in section 5.2, our empirical results show a clear positive relationship between the dollar invoicing probability in the new market and the dollar spell length and thus rejects models of C and D.

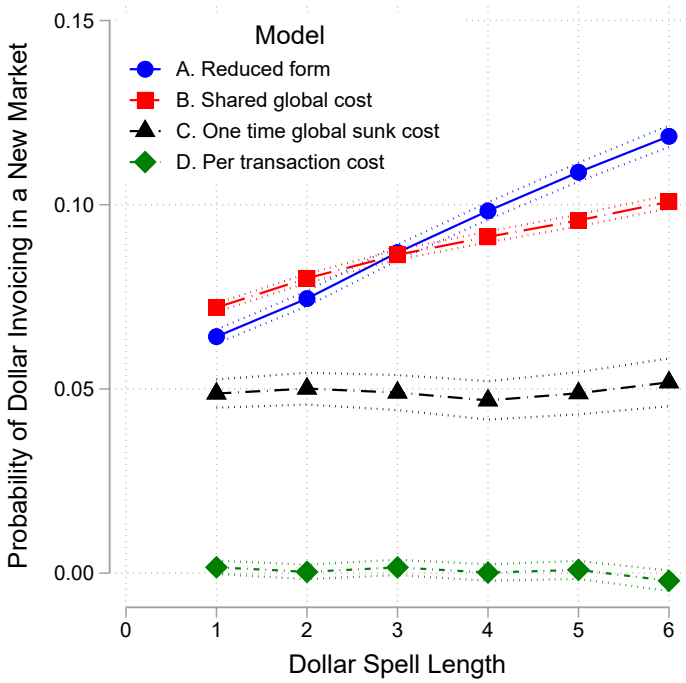
Figure 6 shows the predicted relationship between the dollar invoicing probabil-

[20] More formally,

$$F^c_{fdt} = \begin{cases} \kappa_0 & \text{if} \quad \sum_{\tau=0}^{t-1} \sum_d \mathbb{1}^c_{fd\tau} = 0 \\ 0 & \text{if} \quad \sum_{\tau=0}^{t-1} \sum_d \mathbb{1}^c_{fd\tau} > 0 \end{cases}$$

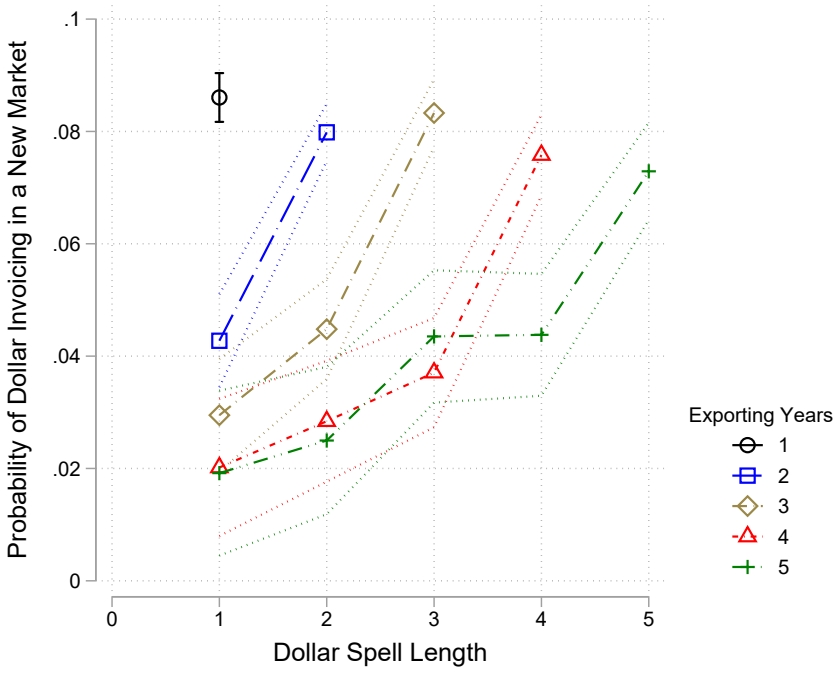
[21] HMRC only started collecting the detailed information on invoicing currency of transactions in 2010. We therefore do not observe the full dynamics of invoicing currency choices for firms started exporting before 2010.

Figure 5: Comparison of predictions: Dollar invoicing probability in a new market and prior dollar experience




Notes: This figure compares the relationship between the dollar invoicing probability in a new market and the prior years of dollar experience at a firm ("Dollar Spell Length") of the four managerial cost models described in the text. The dashed lines indicate the 90% confidence interval of the estimates.

Figure 6: Dollar invoicing probability and prior dollar experience by exporting year cohort




Notes: This figure presents estimates by the number of exporting years from simulated data of our reduced form model. We calibrate $\kappa_1 = 0.6$ and $\kappa_2 = 0.18$. The dashed lines indicate the 90% confidence interval of the estimates.

ity in a new market and the dollar spell length by the number of exporting year cohort from the model with the reduced form managerial cost.[22] Firstly, we can see the positive relationship between the dollar invoicing probability and dollar spell length holds within each exporting year cohort, suggesting the positive relationship predicted in models A and B of figure 5 is not entirely driven by mixtures of firms of different ages. Secondly, comparing the estimates vertically, we can see the effect of one additional year of dollar experience decreases in the number of exporting years.[23] Intuitively, for a firm that has been exporting for many years but only used dollar for one or two years, the realized benefit of using the dollar must be very low in the firm's existing markets. Therefore, the probability that the dollar cost in a new market can be shared with the existing markets is relatively low for the firm.

# 4 Empirical strategy

To test the predictions laid out in the previous section, we exploit the invoicing currency information of UK exports to extra-EU countries over 2010-2016 and estimate the probability of invoicing in dollars at the firm-product-destination-year level. Throughout our analysis, we report estimates of linear probability models.

## 4.1 Strategic complementarities and operational hedging

We start by testing the importance of the two static determinants of invoicing currency: strategic complementarities and operational hedging. Specifically, we estimate:

$$\mathbb{1}^{\text{USD}}_{fhdt} = \beta_1 \zeta^{\text{USD}}_{(-f)idt} + \beta_2 \psi^{\text{USD}}_{ft} + \beta_3 \psi^{\text{Euro}}_{ft} + \beta_4 \psi^{\text{LCI}}_{ft} + \gamma \text{TOTEXP}_{ft} + \text{FEs} + \nu_{fhdt} \quad (13)$$

where the subscripts $f$, $h$, $i$, $d$ and $t$ denote a firm, an 8-digit CN product, a more aggregated 6-digit industry (to which the product $h$ belongs), a destination market, and a transaction year, respectively. $\mathbb{1}^{\text{USD}}_{fhdt}$ is a dummy variable equal to one if the invoicing currency is US dollars and zero otherwise. Subscript $(-f)$ indicates all other UK firms excluding firm $f$. The explanatory variable related to strategic complementarity is $\zeta^{\text{USD}}_{(-f)idt}$, defined as the dollar invoicing share of firm $f$'s competitors

[22] The figure for the shared global cost model is very similar to the one presented here.
[23] See equations (A15)-(A17) in Appendix A.4 for the theoretical relationships.

*from the UK* in destination $d$ in year $t$ at the 6-digit industry $i$ level:

$$\zeta^{\text{USD}}_{(-f)idt} = \frac{\sum_{k \neq f} \text{Export}^{\text{USD}}_{kidt}}{\sum_c \sum_{k \neq f} \text{Export}^{c}_{kidt}}$$

where $\text{Export}^{c}_{fidt}$ is firm $f$'s export value invoiced in currency $c$ (measured in sterling) in 6-digit industry $i$ to country $d$ in year $t$. The operational hedging motive is captured by $\psi^{c}_{ft}$ which is the share of currency $c \in \{\text{USD}, \text{Euro}, \text{LCI}\}$ in firm $f$'s imports in year $t$ (measured in sterling):[24]

$$\psi^{c}_{ft} = \frac{\text{Import}^{c}_{ft}}{\sum_c \text{Import}^{c}_{ft}}$$

where $\text{Import}^{c}_{ft}$ is firm $f$'s total import value invoiced in currency $c$ (measured in sterling) in year $t$. In addition to these main variables of interest, we control for firm size ($\text{TOTEXP}_{ft}$) with the logarithm of the total export value of firm $f$ at time $t$ across all destinations. This is based on the argument that, irrespective of the factors above, large exporters would be more likely to use a foreign currency as they are better able to handle exchange rate risk (Lyonnet, Martin and Mejean, 2021). We also include 8-digit product-year fixed effects and destination-year fixed effects to control for any time-invariant product and country characteristics as well as product- and country-specific demand changes that could separately affect a firm's currency choice.

## 4.2 The endogeneity of competitors' currency choices

One concern regarding the baseline specification is the potential endogeneity of the UK competitors' dollar invoicing share ($\zeta^{\text{USD}}_{(-f)idt}$). If strategic complementarity indeed exists, firm $f$'s decision to invoice in dollars likely affects other UK firms' currency choices. To address this issue, we construct two instruments to isolate the variation in the competitors' currency choices that are due to the competitors' own existing characteristics and are unlikely to be affected by the current invoicing choices of firm $f$. In particular, we exploit differences in competitors' cost structures and construct

[24]Note that the term $\psi^{c}_{ft}$ in the model indicates the imported inputs in each currency as a share of total production costs. But the variable $\psi^{c}_{ft}$ in our empirical analysis does not exactly match the theory as it is measured as a share of total imported inputs because firm-level data on the total wage bill and total materials costs is not available in our dataset. This variable captures the (relative) importance of a certain currency in a firm's importing of inputs.

measures of the UK competitors' dollar import share ($\psi^{\text{USD}}_{(-f)idt}$).[25] We also include the UK competitors' average firm size ($\text{TOTEXP}_{(-f)idt}$) as an additional instrument. Thus, our two instruments are:

$$\begin{aligned}\psi^{\text{USD}}_{(-f)idt} = &\sum_{k\neq f}\frac{S_{kidt}}{1-S_{fidt}}\times\psi^{\text{USD}}_{kt}\\ \text{TOTEXP}_{(-f)idt} = &\sum_{k\neq f}\frac{S_{kidt}}{1-S_{fidt}}\times\text{TOTEXP}_{kt}\end{aligned}$$

where $S_{fidt}$ denotes firm $f$'s export share in a 6-digit industry $i$ to destination $d$ in year $t$ among all UK firms:

$$S_{fidt}=\frac{\text{Export}_{fidt}}{\sum_i \text{Export}_{fidt}}.$$

## 4.3 Dynamics: Dollar invoicing in new destinations

Lastly, we examine whether the managerial cost of using a particular currency depends on a firm's past experience of using that currency. We introduce two firm-level measures to investigate how previous invoicing behaviour in existing markets impacts the invoicing choices in a new destination, i.e., (1) the total number of years that a firm has invoiced any export sales in dollars before it enters a new destination and (2) the dollar invoicing share in the firm's total exports in the year before entering a new destination. To distinguish the dynamic impact of the previous dollar invoicing experience from simple inertia caused by, for example, long-term contracts, we focus our analysis on a firm's exports to a *new* destination. We control for potential confounding factors such as competitors' dollar invoicing share, the currency of imports, and firm size, as in the baseline case. The new entry specification is then given by:

$$\begin{aligned}\mathbb{1}^{\text{USD}}_{fhdt} = &\beta_1\zeta^{\text{USD}}_{(-f)idt}+\beta_2\psi^{\text{USD}}_{ft}+\beta_3\psi^{\text{Euro}}_{ft}+\beta_4\psi^{\text{LCI}}_{ft}\\ &+\left(\sum_{l=0}^{6}\eta_l Spell^{\text{USD},l}_{ft-1}\text{ or }\delta\omega^{\text{USD}}_{ft-1}\right)+\gamma\text{TOTEXP}_{ft}+\text{FEs}+\nu_{fhdt}\end{aligned}\tag{14}$$

where $Spell^{\text{USD},l}_{ft-1}$ is a dummy variable equal to one if the firm used dollars for $l$ years

[25] This IV strategy is conceptually similar to the work of Amiti, Itskhoki and Konings (2019) on Belgian firms' domestic pricing that exploits the competitor's marginal cost as an instrument for the competitor's price.

prior to entering the new market (and zero otherwise) and $\omega_{ft-1}^{\text{USD}}$ is the dollar export share of firm $f$ in the year before entering the new market.

# 5 Estimation Results

Our analysis documents that strategic complementarity and operational hedging are important factors driving the choices of invoicing currencies for exports among British firms. We also document our novel findings on the important role that a firm's previous dollar invoicing has on its currency choice in a new destination.[26]

## 5.1 Strategic complementarities and operational hedging

Table 1 reports the benchmark results for the dollar invoicing probability of UK exporters. Columns 1 to 3 are based on simple OLS regressions. Column 1 includes the dollar invoicing share of a firm's British competitors as an explanatory variable with no fixed effects, while column 2 adds firm-product-year and destination-year fixed effects. Both regressions show a significant positive effect of the UK competitors' dollar invoicing share. These indicate that firms are more likely to invoice in dollars if more UK competitors use dollars in the destination. Column 3 includes the shares of each invoicing currency in a firm's imports to capture the hedging motive and firm size as well as product-year and destination-year fixed effects. The influence of the competitors' currency choices becomes smaller but still remains significant.

A concern with these OLS results is that they do not account for potential endogeneity of the competitors' dollar invoicing which would bias the estimates. In column 4, we adopt the same specification as in column 3, but implement 2SLS using the competitors' average dollar import share and the competitors' average firm size as instruments for the competitors' dollar invoicing share for exports.[27] Column 4 confirms the significant influence of the competitors' dollar invoicing. In comparison to the OLS result in column 3, the coefficient becomes larger, signalling a downward bias when endogeneity is not controlled for. To quantify the magnitude,

[26] Summary statistics of variables used in our estimation sample are reported in appendix table B1.

[27] The first-stage regression result is reported in table B2 in the appendix. Both instruments are strongly and positively correlated with the competitors' dollar invoicing shares. Regarding the validity of our instruments, a Hansen J-test does not reject the null of over-identification at a conventional level while the null of a weak instrument is strongly rejected.

Table 1: Dollar invoicing probability: Baseline

| | (1) OLS | (2) OLS | (3) OLS | (4) IV |
|---|---|---|---|---|
| UK competitors' dollar invoicing share | 0.319*** | 0.041*** | 0.026*** | 0.076*** |
| | (0.001) | (0.001) | (0.001) | (0.004) |
| Dollar import share | | | 0.164*** | 0.164*** |
| | | | (0.000) | (0.000) |
| Euro import share | | | -0.009*** | -0.009*** |
| | | | (0.001) | (0.001) |
| Destination currency import share | | | -0.018*** | -0.018*** |
| | | | (0.001) | (0.001) |
| Firm size | | | 0.016*** | 0.016*** |
| | | | (0.000) | (0.000) |
| Observations | 4,719,628 | 3,052,546 | 4,719,628 | 4,719,628 |
| Adjusted $R^2$ | 0.0468 | 0.288 | 0.149 | - |
| Firm-Product-Year FE | | ✓ | | |
| Country-Year FE | | ✓ | ✓ | ✓ |
| Product-Year FE | | | ✓ | ✓ |
| Hansen J-stat [p-value] | - | - | - | 0.156 [0.693] |
| Weak IV F-stat | - | - | - | 69,591 |

Notes: The dependent variable is the dollar invoicing probability at the firm-product-destination-year level. Columns 1-3 present OLS results while column 4 is the result using 2SLS. Weak IV F-statistic denotes Kleibergen-Paap Wald rk F-statistic. Robust standard errors in parentheses. Significance: *** p<0.01, ** p<0.05, * p<0.1. Data source: HMRC Overseas Trade in Goods Statistics, UK's extra-EU export transactions, 2010-2016.

a one standard deviation rise in the UK competitors' dollar invoicing share leads to an increase in the firm's own dollar invoicing probability of 2.1 percentage points (=0.285*0.076). This magnitude corresponds to 9.45% increases (0.229→0.250) from the mean dollar invoicing probability in the sample. To sum up, these results lend support to the hypothesis that strategic complementarity influences firms' currency choices; that is, firms keep their relative prices stable vis-a-vis their competitors by picking the same invoicing currency as the majority of their competitors in the market.

Turning to operational hedging, the firm's import currency composition also plays a significant role in determining its invoicing currency for exports. In all specifications, a higher share of imports invoiced in dollars is associated with a higher chance of invoicing exports in dollars. In column 4, a one standard deviation rise in a firm's dollar import share is associated with an increase in their dollar invoicing probability

for exports of 6.4 percentage points (=0.164*0.391). On the other hand, a higher share of imported inputs in alternative currencies – euros or a destination currency – decreases the dollar invoicing probability, which is also in line with the prediction.

Finally, we find that firm size – measured by a firm's total export value – is an important driver for dollar invoicing. Regarding the fact that the majority of UK firms invoice their exports in sterling (i.e., the producer's currency in the UK), this result is consistent with the prior literature that large firms are more likely to use foreign currencies.

### 5.1.1 Heterogeneity in strategic complementarity: market share and product differentiation

We highlight two sources of heterogeneity in strategic complementarity. First, firms with larger market shares in a destination have a stronger strategic motive to invoice in the same currency as their competitors. To see this, we split our sample into 'large' and 'small' firms at the median of firms' market shares among UK exporters within an industry and a foreign destination and implement 2SLS in each sub-sample (see table 2). Column 1 gives the baseline results previously reported in column 4 of table 1. Columns 2 and 3 report the results from the sub-samples for large and small firms, respectively. Consistent with the theory, larger firms exhibit a stronger tendency to align their currency with their competitors relative to smaller firms (0.100 vs 0.046).[28]

In table 3, we examine whether the strength of strategic complementarity varies with the extent of product differentiation. Columns 1 and 2 split our dataset into sub-samples according to the product classification system of Rauch (1999). Homogeneous goods which are 'traded on an organized exchange' exhibit stronger strategic complementarities (0.198) relative to goods that Rauch classifies as 'differentiated' (0.075).[29] This leads us to employ the new product classification introduced by

[28] One might argue that if we follow the theoretical relationship in equation (6) more strictly, we should expect the coefficients on imported inputs – particularly dollar-invoiced imports – to be larger for small market share firms. But as noted in footnote 24, our measure of imported inputs in each currency does not fully correspond to $\psi^c_{ft}$ in the model since it is measured as a share of total imported inputs rather than a share of total production costs.

[29] An alternative interpretation is that goods 'traded on an organized exchange' are highly concentrated in commodities such as petroleum where the dollar's prevalence in these goods is not directly related to product homogeneity. Instead, as Eichengreen, Chiţu and Mehl (2016) argue, the dollar's prevalence would be simply due to the fact that the US is among the largest suppliers of oil-related products and most of the US firms price in dollars.

Table 2: Dollar invoicing probability: Market share heterogeneity

| | (1) Baseline | (2) Large | (3) Small |
|---|---|---|---|
| UK competitors' dollar invoicing share | 0.076*** | 0.100*** | 0.046*** |
| | (0.004) | (0.005) | (0.006) |
| Dollar import share | 0.164*** | 0.163*** | 0.160*** |
| | (0.000) | (0.001) | (0.001) |
| Euro import share | -0.009*** | -0.012*** | -0.012*** |
| | (0.001) | (0.001) | (0.002) |
| Destination currency import share | -0.018*** | -0.042*** | -0.010*** |
| | (0.001) | (0.002) | (0.001) |
| Firm size | 0.016*** | 0.013*** | 0.018*** |
| | (0.000) | (0.000) | (0.000) |
| Observations | 4,719,628 | 2,359,085 | 2,354,927 |
| Country-Year FE | ✓ | ✓ | ✓ |
| Product-Year FE | ✓ | ✓ | ✓ |
| Hansen J-stat [p-value] | 0.156 [0.693] | 0.003 [0.956] | 2.389 [0.122] |
| Weak IV F-stat | 69,591 | 36,632 | 39,551 |

Notes: The dependent variable is the dollar invoicing probability at the firm-product-destination-year level. All the results are based on 2SLS. Column 1 shows the baseline results from column 4 of table 1. Columns 2 and 3 are the results using the sub-samples for large and small firms according to the median of firms' market share within an industry, destination, and year. Robust standard errors in parentheses. Significance: *** p<0.01, ** p<0.05, * p<0.1. Data source: HMRC Overseas Trade in Goods Statistics, UK's extra-EU export transactions, 2010-2016.

Corsetti, Crowley, Han and Song (2018) which is constructed from the use of different types of Chinese measure words in Chinese customs data. Column 3 reports results for a subsample of less differentiated manufactured goods that are identified by the use of continuous measures such as kilograms on customs forms. In column 4, estimates for products that use measure words that indicate that they are discrete items, such as televisions or motorcycles, are reported. Under this classification, the analysis shows strategic complementarities are stronger when goods are less differentiated. We estimate firms selling less differentiated products (0.091) are more responsive to competitors' dollar invoicing than those selling highly differentiated products (0.043).

Table 3: Dollar invoicing probability by product differentiation

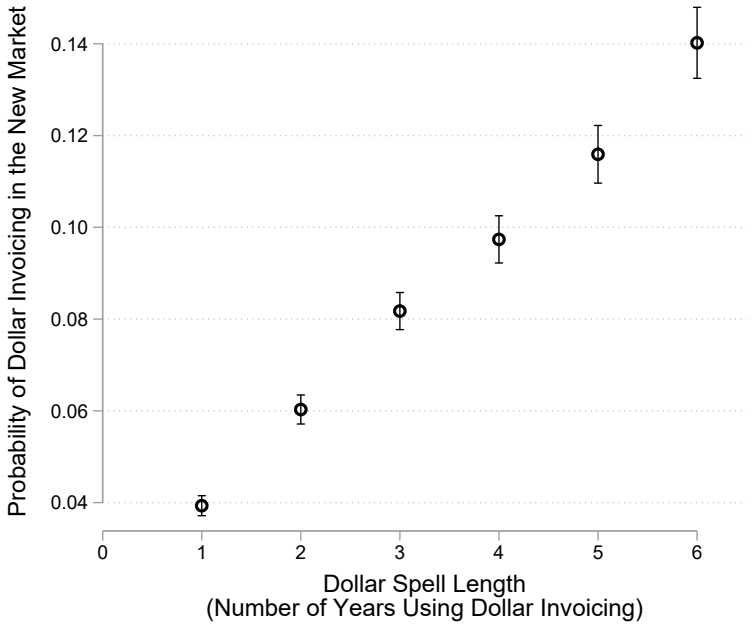
| | (1) Homog. (Rauch) | (2) Diff. (Rauch) | (3) Low diff. (CCHS) | (4) High diff. (CCHS) |
|---|---|---|---|---|
| UK competitors' dollar invoicing share | 0.198** | 0.075*** | 0.091*** | 0.043*** |
| | (0.092) | (0.004) | (0.005) | (0.006) |
| Dollar import share | 0.102*** | 0.164*** | 0.150*** | 0.182*** |
| | (0.011) | (0.000) | (0.001) | (0.001) |
| Euro import share | -0.015 | -0.009*** | -0.010*** | -0.010*** |
| | (0.035) | (0.001) | (0.001) | (0.002) |
| Destination currency import share | 0.081*** | -0.019*** | -0.011*** | -0.029*** |
| | (0.030) | (0.001) | (0.002) | (0.002) |
| Firm size | 0.007*** | 0.016*** | 0.017*** | 0.015*** |
| | (0.001) | (0.000) | (0.000) | (0.000) |
| Observations | 10,663 | 4,708,964 | 2,611,076 | 1,883,102 |
| Country-Year FE | ✓ | ✓ | ✓ | ✓ |
| Product-Year FE | ✓ | ✓ | ✓ | ✓ |
| Hansen J-stat | 0.179 | 0.154 | 0.245 | 0.0368 |
| [p-value] | [0.672] | [0.695] | [0.621] | [0.848] |
| Weak IV F-stat | 89 | 69,553 | 35,952 | 29,562 |

Notes: The dependent variable is the dollar invoicing probability at the firm-product-destination-year level. All the results are based on 2SLS. Columns 1 and 2 are the results from the sub-samples for "traded on organized exchange" ('Homog') and "differentiated goods" ('Diff') based on Rauch (1999), respectively. Columns 3 to 4 are the results from the sub-samples according to the differentiation measure of Corsetti, Crowley, Han and Song (2018) in which 'Low diff.' denotes less differentiated goods and 'High diff.' denotes highly differentiated goods. Robust standard errors in parentheses. Significance: *** p<0.01, ** p<0.05, * p<0.1. Data source: HMRC Overseas Trade in Goods Statistics, UK's extra-EU export transactions, 2010-2016.

## 5.2 Dynamic evolution in currency choice

In this subsection, we explore whether a firm's previous dollar invoicing intensity in existing markets affects its currency choice in a new destination using a sample of entrants into new destinations. Figure 7 illustrates a key finding: firms which have more historical experience with dollar-invoicing are more likely to invoice in dollars in a new destination. As seen in the figure, the probability of invoicing in dollars in a new destination market in year $t$ increases with the number of years of dollar-invoicing experience in existing markets as of time $t-1$, the last period before entry.

Figure 7: Impact of dollar invoicing experience on dollar invoicing in new markets




Notes: The figure plots the trajectory of the coefficients of dummies for the number of previous dollar invoicing years (column 3, table 4). Top and bottom horizontal bars around each point estimate represent 90% confidence intervals. Data source: HMRC Overseas Trade in Goods Statistics, UK's extra-EU export transactions, 2010-2016.

We present estimates from our empirical model of new market entry (14) in table 4. With entry into a new destination, we find evidence of strategic complementarities and operational hedging in the choice of an invoicing currency for exports. Interestingly, one exception is operational hedging in relation to imported inputs invoiced

in the local currency of the export destination (in the fourth row of table 4). That is, firms entering a new destination are less prone to invoicing in local currency even when they use that currency for invoicing a share of their imports. In this case, they are more inclined to choose dollars for their initial transactions in the new destination.

Turning to the role of historical dollar-invoicing, the sixth row of column 1 indicates that a ten percentage point rise in a firm's previous dollar invoicing share is associated with a 2.9 percentage point increase in the probability of dollar invoicing in a new destination. Similarly, the seventh row of column 2 shows that firms with one additional year of dollar invoicing experience, prior to entry, are 2.5 percentage points more likely to choose dollars in their new destinations. Column 3 experiments with a full set of dummies indicating the specific number of years a firm has used dollars prior to entry – from one to six years (the excluded category is firms with no prior experience with dollar-invoicing). We again find a strictly monotonic relationship between a firm's previous dollar invoicing experience and its probability of choosing dollars for invoicing in new markets.

One might be concerned that these results could be driven simply by a positive association between firms' dollar invoicing years and their exporting tenure (as in figure 2). To address this concern, we test an additional layer of heterogeneity, i.e., whether the effect of previous dollar invoicing on dollar invoicing in a new destination depends on a firm's export tenure. We introduce a full set of interaction terms between dummies for years of dollar-invoicing and dummies for the years of exporting. Figure 8 displays the trajectories of dollar-invoicing by exporting-year cohort. A key finding is that, across all exporting-year cohorts, the probability of dollar-invoicing in a new destination rises with previous dollar experience. It is worth noting that the marginal impact of additional experience becomes smaller for older exporters, as shown in the flatter trajectories for cohorts with longer export tenure.[30]

What is interesting about the estimates in figures 7 and 8 is that the impact of previous dollar invoicing experience intensifies with the number of years beyond the first year. This means that the simple 'fixed' component of the cost of using a new currency alone is not sufficient to generate this empirical pattern. While it is

[30]Additionally, we break down our sample by firms' total export size in the last period before entry and estimate the specification in column 3 from table 4 for each sub-sample. As reported in appendix table B3, the influence of the number of years of dollar-invoicing on dollar-invoicing in a new destination is less pronounced for large exporters compared to medium and small exporters.

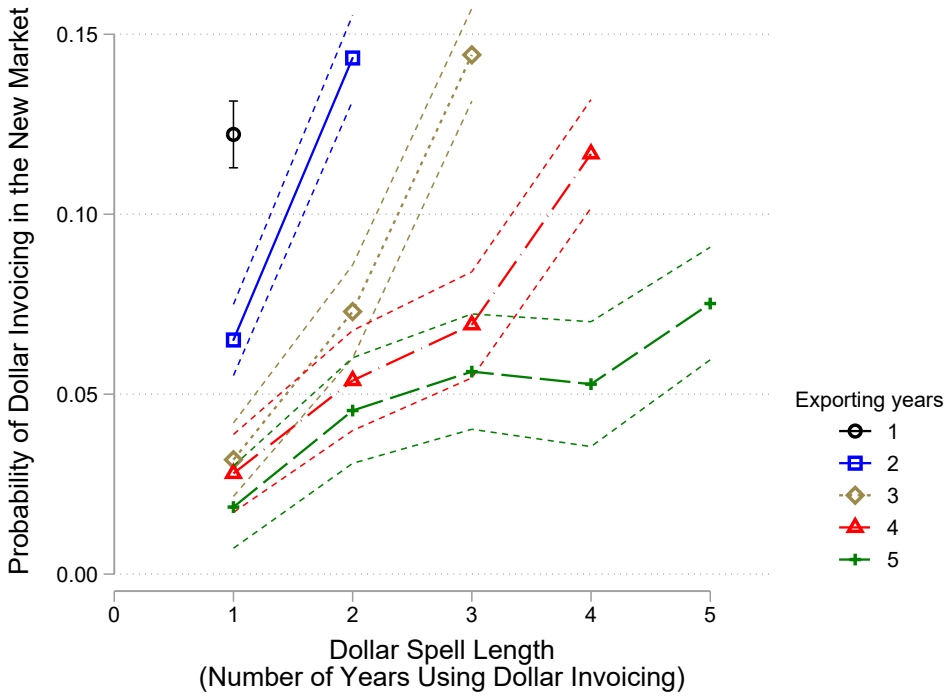
Table 4: Dollar invoicing probability at entry year

| | (1) | (2) | (3) |
|---|---|---|---|
| UK competitors' dollar invoicing share | 0.069*** | 0.071*** | 0.071*** |
| | (0.007) | (0.007) | (0.007) |
| Dollar import share | 0.093*** | 0.103*** | 0.103*** |
| | (0.001) | (0.001) | (0.001) |
| Euro import share | -0.014*** | -0.017*** | -0.017*** |
| | (0.002) | (0.002) | (0.002) |
| Destination currency import share | 0.022*** | 0.014*** | 0.015*** |
| | (0.002) | (0.002) | (0.002) |
| Firm size | 0.013*** | 0.013*** | 0.013*** |
| | (0.000) | (0.000) | (0.000) |
| Dollar share in total export (t-1) | 0.292*** | | |
| | (0.002) | | |
| Dollar invoicing years (t-1) | | 0.025*** | |
| | | (0.000) | |
| Dollar invoicing years (t-1) = 1 | | | 0.039*** |
| | | | (0.001) |
| Dollar invoicing years (t-1) = 2 | | | 0.060*** |
| | | | (0.002) |
| Dollar invoicing years (t-1) = 3 | | | 0.082*** |
| | | | (0.002) |
| Dollar invoicing years (t-1) = 4 | | | 0.097*** |
| | | | (0.003) |
| Dollar invoicing years (t-1) = 5 | | | 0.116*** |
| | | | (0.004) |
| Dollar invoicing years (t-1) = 6 | | | 0.140*** |
| | | | (0.005) |
| Observations | 1,181,074 | 1,181,074 | 1,181,074 |
| Country-Year FE | ✓ | ✓ | ✓ |
| Product-Year FE | ✓ | ✓ | ✓ |
| Hansen J-stat [p-value] | 0.020 [0.886] | 0.009 [0.922] | 0.008 [0.926] |
| Weak IV F-stat | 15,143 | 15,143 | 15,142 |

Notes: The dependent variable is the dollar invoicing probability at the firm-product-destination-year level. Observations are of the first-year of exporting in each firm-destination pair. All results are based on 2SLS. Robust standard errors in parentheses. Significance: *** p<0.01, ** p<0.05, * p<0.1. Data source: HMRC Overseas Trade in Goods Statistics, UK's extra-EU export transactions, 2010-2016.

true that the one-off fixed cost of adopting dollars would imply that the probability of dollar-invoicing in a new destination is higher for existing dollar users, it cannot generate the further dynamics of dollar invoicing beyond the first year. That is, once

Figure 8: Impact of dollar invoicing years by exporting year cohort




Notes: The figure plots the trajectories of the coefficients on dummies for the number of previous dollar invoicing years by each exporting year cohort. Dotted lines are 90% confidence intervals. Data source: HMRC Overseas Trade in Goods Statistics, UK's extra-EU export transactions, 2010-2016.

the fixed cost is paid, any later years of dollar usage should not matter, contradictory to what is documented in figures 7 and 8.

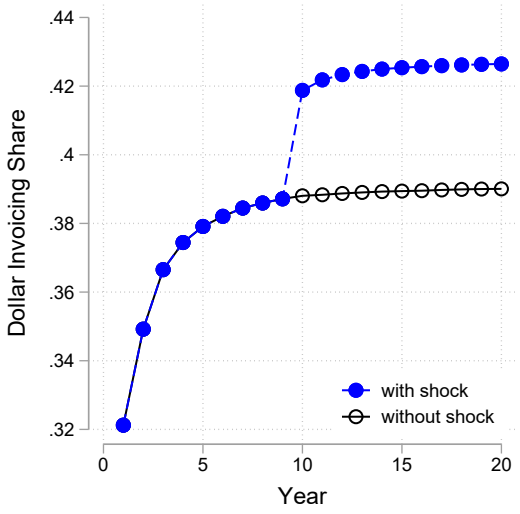
# 6 Aggregate implications

To quantify the aggregate importance of the empirical channels driving currency choices, we conduct a partial equilibrium analysis. In particular, we study the effect of the positive feedback of prior dollar invoicing in the propagation of shocks and in sustaining a high dollar invoicing share.

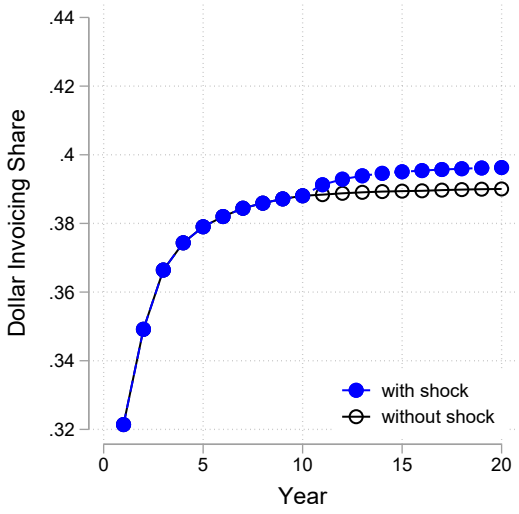
We first investigate how a destination-specific shock propagates and affects the dollar-invoicing choices in other destinations not hit by the shock. We simulate the model for 20 years. For the first 10 periods, the model reaches its steady state. We then introduce a positive permanent shock to the profitability of using dollars in

Figure 9: Propagation of destination-specific shocks

(a) All destinations

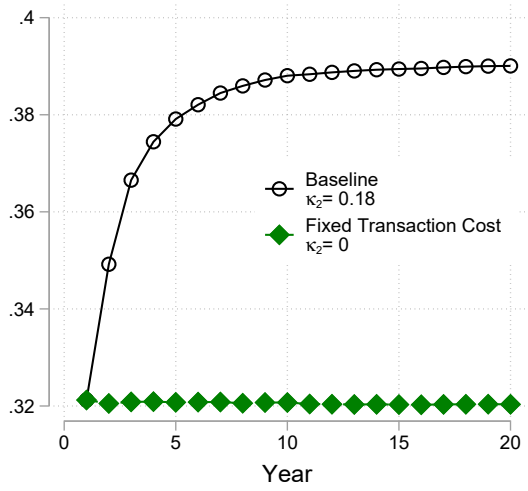



(b) Non-shocked destinations




Notes: These two figures show the evolution of the aggregate dollar invoicing share in the simulated model with reduced form managerial costs of 200,000 firms, 20 destinations and 20 years. The left figure compares the dollar invoicing share for all destinations (black circles) versus the same statistic in a counterfactual environment where a destination-specific shock to the profitability of dollar invoicing was given in destination 1 at year 10 (blue dots). The right figure compares the dollar invoicing share for those other destinations (2-20) not hit by the shock.

Figure 10: Evolution of aggregate dollar invoicing share with and without cost dynamics




Notes: This figure shows the evolution of the aggregate dollar invoicing share in two distinct versions of the simulated model. The black dots represent the aggregate dollar invoicing shares from the reduced form managerial cost model with positive feedback from prior dollar invoicing, i.e., $F(\omega_{ft-1}^{\text{USD}}) = \kappa_1 - \kappa_2\omega_{ft-1}^{\text{USD}}$ and $\kappa_1 = 0.6$, whereas the blue squares represent evolution in per transaction managerial cost model without positive feedback, i.e., $F = \kappa_1$.

destination 1 at year 10.[31] Figure 9 shows the path of the aggregate dollar invoicing share across all destinations over time (left) and that for other destinations not hit by the shock (right). An immediate effect is an increase in the dollar-invoicing share in destination 1 as firms switch to dollar invoicing in response to the shock. This, in turn, increases the firms' overall dollar-invoicing share and thus the probability of dollar invoicing when entering other destinations. As a result, figure 9(b) shows that the dollar invoicing share in all other destinations rises gradually over time.

We conclude with an investigation of the role of dollar invoicing dynamics in sustaining a high dollar-invoicing share. Figure 10 shows the evolution of aggregate dollar-invoicing shares across all destinations. The model without the positive feedback from prior dollar use suggests that the dollar invoicing share would be 18% [(0.39-0.32)/0.39] lower compared to the model with the positive feedback.

[31]This captures events such as a destination country suddenly pegging its own currency to the dollar or forming a currency union. This could strengthen the exporters' incentives to invoice in dollars through, say, strategic complementarity.

# 7 Conclusions

A key feature of today's global macroeconomic environment is the dominance of the US dollar in the world's trade transactions. Since import prices tend to be stable in the currency of invoicing, the outsized role of the dollar in global trade has important implications for firms' responses to international and country-specific shocks, shedding light on the transmission of economic shocks internationally. Despite the importance of dollar dominance, there is little empirical evidence on the underlying mechanisms driving and sustaining the high dollar-invoicing share in global trade.

Using transaction level data on UK exports to extra-EU destinations, we document evidence on two key channels behind the dominance of the dollar. First, we find strong evidence of strategic complementarity in currency choices: UK exporters are more likely to use dollars if more UK competitors use dollars in the destination. This strategic motive is stronger for firms with larger market shares and for those selling less differentiated goods. Second, we document a significant role played by prior experience: firms entering a new destination are more likely to adopt dollars if they have used dollars more intensively and persistently in their existing markets.

We argue that the strategic complementarity and prior experience channels reinforce each other to sustain dollar dominance in international trade. Attentiveness to strategic complementarity seems to lead UK exporters to choose the US dollar in those foreign markets such as the US or Canada where the dollar dominates. Once a firm initiates dollar-invoicing for strategic reasons, a successful experience with dollar-invoicing in one market can propagate forward in time to the firm's other foreign markets, raising the share of dollar-invoicing to widely-dispersed locations.

We extend the standard theoretical framework of invoicing currency choice by introducing simple dynamics via the managerial cost of adopting an additional currency. Despite its simplicity, the structure we employ can successfully match the empirically documented firm-level dynamics of dollar invoicing. Counterfactual analysis of the model suggests the prior experience channel plays an important role in the propagation of destination-specific shocks and sustaining the high share of the US dollar in invoicing global trade.

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# A Theoretical appendix

This appendix provides a detailed description of our conceptual framework that incorporates oligopolistic competition and a firm's use of multiple imported inputs into a model of currency choice under nominal rigidities. We further allow for the presence of a managerial cost that varies with the firm's prior dollar invoicing experience.

## A.1 Production with multiple imported inputs

A firm uses labour and imported intermediate inputs to produce its output in the following production function

$$Y_f = A_f L_f^{1-\phi_f} \prod_{j=1}^{J} (M_{fj}^{\alpha_{fj}})^{\phi_f} \tag{A1}$$

where $Y_f$ denotes output, $A_f$ is the exogenously given firm productivity, $L_f$ is labour and $M_{fj}$ is imports of intermediates in currency $j$. Constant returns to scale imply $\sum_{j=1}^{J} \alpha_{fj} = 1$. $J$ denotes the set of currencies in which intermediate inputs are invoiced. The firm's total production cost is expressed as

$$TC_f = WL_f + \sum_{j=1}^{J} \xi_{fj} P_{mj} M_{fj} \tag{A2}$$

where $W$ is the nominal wage and $P_{mj}$ is the price of foreign intermediate inputs invoiced in currency $j$. $\xi_j$ is the nominal exchange rate expressed in units of producer currency per one unit of origin currency $j$. Cost minimization over labour and each intermediate input for a given level of output yields marginal cost as

$$MC_f = \frac{W^{1-\phi_f} P_M^{\phi_f}}{{A_f}^*} \tag{A3}$$

where ${A_f}^* = (1-\phi_f)^{1-\phi_f} {\phi_f}^{\phi_f} A_f$ and $P_M = \prod_{j=1}^{J_f} (\frac{\xi_{fj} P_{mj}}{\alpha_{fj}})^{\alpha_{fj}}$ is the price index of the intermediate input bundle. The share of imported inputs invoiced in currency $j$ in the firm $f$'s production cost, denoted by $\psi_f^j$, is equal to $\phi_f \alpha_{fj}$.

## A.2 Optimal flexible price under oligopolistic competition

Firms entering a new destination $d$ face a market structure featuring oligopolistic competition à la Atkeson and Burstein (2008) and Amiti, Itskhoki and Konings (2019). Each firm $f$ produces a differentiated good in each industry and exports it to destination market $d$. Consumers in each destination have a nested CES (constant elasticity of substitution) demand over the varieties of goods. The elasticity of substitution within and across industries are $\rho$ and $\eta$, respectively, with $\rho > \eta \geq 1$. The demand faced by a firm $f$ in destination $d$ is

$$Q_{id} = P_{fd}^{-\rho} P_d^{\eta-\rho} D_d \tag{A4}$$

where $D_d$ is the exogenous demand shifter, $P_{fd}$ is the firm $f$'s price in local currency and $P_d \equiv \left(\sum_f P_{fd}^{1-\rho}\right)^{\frac{1}{1-\rho}}$ is the aggregate price index in the destination. The effective demand elasticity is a function of the market share of the firm with large firms having a less elastic demand, i.e.,

$$\varepsilon_{fd} \equiv -\frac{d\log(Q_{fd})}{d\log(P_{fd})} = \rho(1-S_{fd}) + \eta S_{fd} \tag{A5}$$

where $S_{fd} \equiv \frac{P_{fd}Q_{fd}}{\sum_f P_{fd}Q_{fd}} = \left(\frac{P_{fd}}{P_d}\right)^{1-\rho}$ is the firm's destination-specific market share. If the firm is able to set its price flexibly in response to exchange rate shocks, its profit-maximizing price in local currency in the new destination $d$ is

$$P_{fd} = \frac{\varepsilon(S_{fd})}{\varepsilon(S_{fd})-1}\frac{MC_f}{\xi_d}. \tag{A6}$$

Note that, unlike in monopolistic competition, the multiplicative markup ($\frac{\varepsilon_{fd}}{\varepsilon_{fd}-1}$) depends on the market share of individual firms ($S_{fd}$). The markup elasticity with respect to prices $\Gamma_{fd}$ is expressed as

$$\Gamma_{fd} \equiv -\frac{d\log\left(\frac{\varepsilon_{fd}}{\varepsilon_{fd}-1}\right)}{d\log(P_{fd})} = \frac{(\rho-\eta)(\rho-1)S_{fd}(1-S_{fd})}{(\rho-(\rho-\eta)S_{fd})(\rho-1-(\rho-\eta)S_{fd})} \tag{A7}$$

Assuming that exchange rate movements are the only source of uncertainty, we can obtain the expression for the log of the optimal price $p_{fd}$ by a first-order approx-

imation of (A6) around the non-stochastic steady-state

$$p_{fd} \approx \frac{\Gamma_{fd}}{1+\Gamma_{fd}} p_{-fd} + \frac{1}{1+\Gamma_{fd}} \left( \sum_{j}^{J} \psi_f^j e_j - e_d \right) + \overline{C_{fd}} \tag{A8}$$

which is (4) in the text.

## A.3 Optimal currency choice under nominal rigidities

To solve the problem (5), we adopt the lemma established in Engel (2006), Gopinath, Itskhoki and Rigobon (2010) and Mukhin (2018):

$$\bar{p}_{fd}^c = \mathbb{E}\big[p_{fd} + e_d^c\big]. \tag{A9}$$

This lemma indicates that the firm's optimal preset price $\bar{p}_{fd}^c$ is equal to the *expected* value of the optimal flexible price in invoicing currency $c$. An important implication of this is that the invoicing currency is relevant only if the firm considers the second-order moment of its expected profits. If the firm maximizes its expected profit up to the first-order approximation, the choice of invoicing currency is irrelevant as all the invoicing currencies yield the same expected value of *ex-post* price, $\mathbb{E}[\bar{p}_{fd}^c - e_d^c]$, which is simply the "average" of optimal price $\mathbb{E}\big[p_{fd}\big]$. Instead, if the firm targets up to the second-order moment of its expected profit, the invoicing currency helps to bring the *ex post* price $(\bar{p}_{fd}^c - e_d^c)$ closer to its actual optimal flexible price $(p_{fd})$ contingent on any exchange rate movements.

With lemma (A9), the currency choice problem can be written as[32]

$$\max_c \mathbb{E}\left\{ \pi_{fd}(p_{fd}) + \frac{\partial^2 \pi_{fd}}{\partial p^2}|_{p=p_{fd}} (\bar{p}_{fd}^c - e_d^c - p_{fd})^2 - F_f^c \right\} \tag{A10}$$

$$\Leftrightarrow \max_c \left\{ \frac{\partial^2 \pi_{fd}}{\partial p^2}|_{p=\widetilde{p}_{fd}} * \mathrm{Var}[p_{fd} + e_d - e_c] - F_f^c \right\} \tag{A11}$$

where $\widetilde{p}_{fd}$ is the deterministic steady-state value of optimal price $p_{fd}$. $c = o, d, v, u$ corresponds to producer currency invoicing (PCI), local currency invoicing (LCI) and invoicing in the US dollar as a vehicle currency (VCI) and invoicing in euros as a

[32] The transformation from (A10) to (A11) involves the following two steps; First, as in Mukhin (2018), we assume $\frac{\partial^2 \pi_{fd}}{\partial p^2}|_{p=p_{fd}} = \frac{\partial^2 \pi_{fd}}{\partial p^2}|_{p=\widetilde{p}_{fd}} < 0$ to the zero-order approximation. Second, it holds that $\mathbb{E}[(\bar{p}_{fd}^c - e_d^c) - p_{fd}]^2 = \mathbb{E}[\mathbb{E}(p_{fd} + e_d^c) - (p_{fd} + e_d^c)]^2 = \mathrm{Var}[p_{fd} + e_d^c] = \mathrm{Var}[p_{fd} + e_d - e_c]$.

vehicle currency (VCI2), respectively.[33] The optimal invoicing problem is therefore to choose currency $c$ in which the variance of the optimal price plus the managerial cost $F_f^c$ of adopting the currency are jointly *minimized*.

While simpler than before, the problem (A11) is still complicated. Specifically, as the firm chooses over multiple currencies, it considers various elements of exchange rate volatility in each currency ($\text{Var}(e_d)$, $\text{Var}(e_v)$, $\text{Var}(e_u)$) and the covariances for each pair of currencies ($\text{Cov}(e_d e_v)$, $\text{Cov}(e_d e_u)$, $\text{Cov}(e_v e_u)$).[34] To limit our attention to the three key determinants – strategic complementarity, imported inputs and managerial cost –, we introduce a set of simplifying assumptions:

- Similarly to Goldberg and Tille (2008), the log exchange rate is shaped by the differential of independent country-specific shocks; $e_c = \varsigma_o - \varsigma_c$, $e_c^{c'} \equiv e_c - e_{c'} = \varsigma_{c'} - \varsigma_c$ with a zero mean ($\mathbb{E}(\varsigma_o) = \mathbb{E}(\varsigma_c) = 0$) and an identical variance ($\sigma_o^2 = \sigma_c^2 = \sigma^2$) where $\varsigma_o$ denotes the home country shock. Then, $\mathbb{E}(e_c^2) = 2\sigma^2$ and $\mathbb{E}(e_c e_{c' \neq c}) = \sigma^2$ for any $c$ and $c'$.[35]

- Again following Goldberg and Tille (2008), we express the log price index of firm $f$'s competitors in destination $d$ that is pertinent to the currency choice problem as[36]

$$p_{-fd} = -\sum_c \zeta_{(-f)d}^c (e_d - e_c) \tag{A12}$$

  where $\zeta_{(-f)d}^c$ denotes the total market share of the competitors which are invoicing in currency $c$ in destination $d$, which satisfies $\sum_c \zeta_{(-f)d}^c = 1$. In our partial equilibrium setting, we assume these competitors' average invoicing shares as exogenously given.

- The set of currencies used for imported inputs is identical to that of export currencies: $J = \{o, d, v, u\}$.

Now we can derive the expected profit differences for each pair of currencies. Plugging the equations (A8) and (A12) into the variance expression (A11) and ap-

[33] For convenience, we introduce a separate notation $o$ for the choice of sterling, or producer currency invoicing (PCI). Note that $e_d^o = e_d$ and $e_o = 0$.

[34] Novy (2006) explores how the variances of each currency and covariances would affect the currency choice in a three-currency environment.

[35] We initially assume the exchange rate as $\xi_c = \bar{\xi} * \exp(e_c)$ where $\bar{\xi}$ is the steady-state exchange rate and $e_c$ is a mean zero innovation. To simplify, let $\bar{\xi} = 1$ and thus $\log \xi_c = e_c$.

[36] This is due to our assumption that exchange rates are the only stochastic elements.

plying the above set of simplifying assumptions yields the variance term as:

$$
\begin{aligned}
&\mathrm{Var}[p_{fd} + e_d - e_c] \\
&= \mathrm{Var}\left[\frac{\Gamma_{fd}}{1+\Gamma_{fd}}(-\zeta^d_{(-f)d}e_d - \zeta^v_{(-f)d}e_d + \zeta^v_{(-f)d}e_v - \zeta^u_{(-f)d}e_d + \zeta^u_{(-f)d}e_u + e_d)\right. \\
&\quad \left. + \frac{1}{1+\Gamma_d}\sum_j^J \psi_j e_j - e_c\right] \\
&= \mathrm{Var}\left[\frac{\Gamma_{fd}}{1+\Gamma_{fd}}(\zeta^d_{(-f)d}e_d + \zeta^v_{(-f)d}e_v + \zeta^u_{(-f)d}e_u) + \frac{1}{1+\Gamma_{fd}}\sum_j^J \psi_{fj} e_j - e_c\right] \\
&= -\frac{2\Gamma_{fd}}{1+\Gamma_{fd}}(\zeta^d_{(-f)d}\mathbb{E}(e_d e_c) + \zeta^v_{(-f)d}\mathbb{E}(e_v e_c) + \zeta^u_{(-f)d}\mathbb{E}(e_u e_c)) \\
&\quad - \frac{2}{1+\Gamma_{fd}}\sum_j^J \psi_{fj}\mathbb{E}(e_j e_c) + \mathbb{E}(e_c^2) + ..
\end{aligned}
$$

The third line uses $\sum_c \zeta^c_{(-f)d} = 1$ and the fourth line displays only the terms involving $e_c$ as all other terms will be cancelled out when differencing the variances across currencies. Then, for each pair of invoicing currencies,

$$\textbf{(VCI vs PCI)} \quad \Delta_{v,o}\,\mathrm{Var}_{fd} = -\left[\frac{2\sigma^2\Gamma_{fd}}{1+\Gamma_{fd}}(\zeta^v_{(-f)d} - \zeta^o_{(-f)d}) + \frac{2\sigma^2}{1+\Gamma_{fd}}(\psi^v_f - \psi^o_f - 1)\right]$$

$$\textbf{(VCI vs LCI)} \quad \Delta_{v,d}\,\mathrm{Var}_{fd} = -\left[\frac{2\sigma^2\Gamma_{fd}}{1+\Gamma_{fd}}(\zeta^v_{(-f)d} - \zeta^d_{(-f)d}) + \frac{2\sigma^2}{1+\Gamma_{fd}}(\psi^v_f - \psi^d_f)\right]$$

$$\textbf{(VCI vs VCI2)} \quad \Delta_{v,u}\,\mathrm{Var}_{fd} = -\left[\frac{2\sigma^2\Gamma_{fd}}{1+\Gamma_{fd}}(\zeta^v_{(-f)d} - \zeta^u_{(-f)d}) + \frac{2\sigma^2}{1+\Gamma_{fd}}(\psi^v_f - \psi^u_f)\right]$$

where $\Delta_{v,b}\,\mathrm{Var}_{fd} \equiv \mathrm{Var}[p_{fd} + e_d - e_v] - \mathrm{Var}[p_{fd} + e_d - e_b]$. The expected profit difference over currency $v$ and $b$ is summarized as

$$\mathbb{E}[\Pi^v_{fd}] - \mathbb{E}[\Pi^b_{fd}] \propto \lambda_{fd}\left[\underbrace{\frac{\Gamma_{fd}}{1+\Gamma_{fd}}(\zeta^v_{(-f)d} - \zeta^b_{(-f)d})}_{\text{Strategic complementarity}} + \underbrace{\frac{1}{1+\Gamma_{fd}}(\psi^v_f - \psi^b_f)}_{\text{Operational hedging}}\right] - \underbrace{(F^v_f - F^b_f)}_{\text{Managerial cost}}$$

where $\lambda_{fd} \equiv -2\sigma^2\frac{\partial^2\pi_{fd}}{\partial p^2}|_{p=\widetilde{p}_{fd}} > 0$. The likelihood of choosing currency $v$ relative to any other arbitrary currency $b$ increases with the difference of the expected profits

in the last equation.

## A.4 A general framework for invoicing dynamics

In this section, we discuss a general framework of invoicing currency dynamics. We start by considering a transition function $T(.)$ that maps a firm's dollar invoicing share $\omega_{ft-1}^{USD}$ into the probability of dollar invoicing when a new destination is added. That is, when the dollar invoicing share of firm $f$ takes the value of $x$, the probability of choosing dollar invoicing in a new destination $d$ in period $t$ is given by $T(x)$:

$$T(x) \equiv Pr(\mathbb{1}_{fdt}^{\text{USD}} = 1 | \omega_{ft-1}^{USD} = x) \tag{A13}$$

In principle, the exact functional form of $T(x)$ can depend on the distribution of a bunch of factors, such as share of dollar invoicing competitors and the dollar share of imported inputs predicted by a conventional static model. We abstract from the exact functional form of (A13) for the moment and focus on discussing the general properties of $T(x)$ and its relationship with the key variable of our interest, the dollar spell length, $Spell_{ft}^{USD}$.

Using the transition function (A13), it can be shown that the dollar invoicing probability in a new destination conditional on a specific dollar spell length depends on two elements: (1) the distribution of dollar invoicing shares conditional on the dollar spell length[37] and (2) the transition function $T(x)$. More specifically, the conditional probability of dollar invoicing in a new destination for a firm with dollar spell length $l$ can be written as:

$$\begin{aligned} Pr(\mathbb{1}_{fdt}^{\text{USD}} = 1 | Spell_{ft-1}^{USD} = l) &= \sum_x Pr(\omega_{ft-1}^{USD} = x | Spell_{ft-1}^{USD} = l) T(x) \\ &= \frac{\sum_x Pr(\omega_{ft-1}^{USD} = x \bigcap Spell_{ft-1}^{USD} = l) T(x)}{\sum_x Pr(\omega_{ft-1}^{USD} = x \bigcap Spell_{ft-1}^{USD} = l)} \end{aligned} \tag{A14}$$

If the transition function $T(.)$ does not depend on the dollar share, then the probability of using dollar invoicing in the new destination is independent of the dollar spell length, i.e., $Pr(\mathbb{1}_{it}^{\text{USD}} = 1 | Spell_{it-1}^{USD} = l)$ is a constant for all $l$.[38]

[37] For example, given a firm has used dollar invoicing for two years, $Spell_{ft-1}^{USD} = 2$, what is the probability that its dollar invoicing share is $x$, e.g., $x = 0, 0.5, 1$, etc.

[38] It is worth stressing that this result does not depend on the dynamic process of firm distributions. An important case in which $T(.)$ does not depend on the dollar share is when the dollar

To further characterize the dynamics of invoicing currency choices, we specify on how firms grow by extending their markets and how these firms make invoicing choices in their existing and new markets. Specifically, to keep the model tractable, we make the two simplifying assumptions as following:

(1) A firm enters a new market in each period and the size of each market is normalized to one in all periods

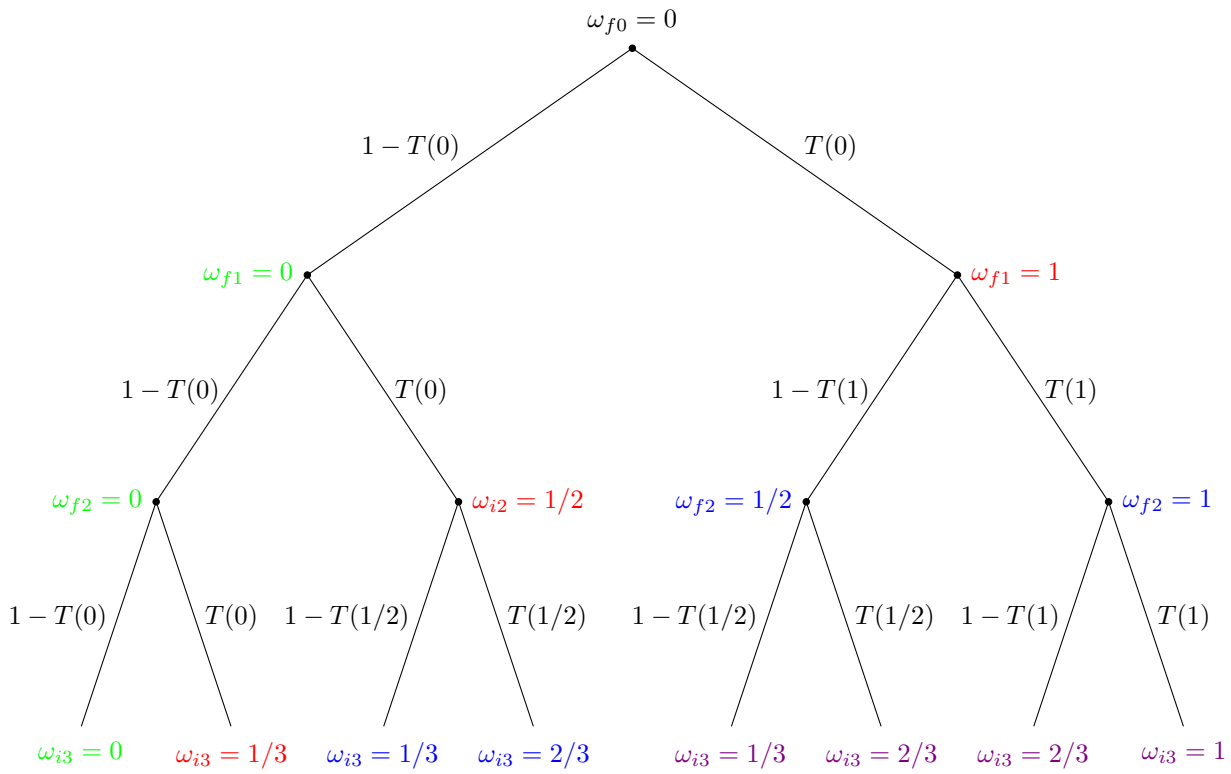
(2) A firm sticks to the currency selected upon entry for each of its existing markets.[39]

Figure A1 illustrates the evolution of the dollar spell and dollar invoicing share for the first 3 periods. In the initial period $t = 0$, all firms start with zero foreign markets and therefore a zero dollar invoicing share. In period 1, each firm enters one foreign market. For a given transition function $T(x)$, the probability of dollar invoicing in the foreign market is $T(0)$. As shown in figure A1, there is a probability of $T(0)$ that the firm chooses to invoice in dollars and has a dollar export share of $\omega_{f1} = 1$ and $1 - T(0)$ probability of invoicing in other currencies with a dollar trade share of $\omega_{f1} = 0$. In period 2, each firm adds one more new destination and the dollar invoicing share will change according to the existing dollar share $\omega_{f1}$ and the transition function $T(\omega_{f1})$. As illustrated in the third row of figure A1, there is a probability $[1 - T(0)]^2$ that the firm does not use dollars in any of the two markets in period 2 and has a dollar spell of zero (i.e., $Spell_{f2}^{USD} = 0$). With probability $[1 - T(0)]T(0)$, the firm uses dollar in the newly added market and has a dollar spell of one, i.e., $Spell_{f2}^{USD} = 1$. There is a probability $T(0)[1 - T(1)]$ that the firm uses dollar only in the previously added markets and a probability $[T(1)]^2$ that the firm uses dollars in both markets. In both cases, the firm has a dollar spell of two, i.e., $Spell_{f2}^{USD} = 2$. The distributions of the dollar invoicing choices and the dollar spell in later periods can be obtained by continutously iterating the process outlined in figure A1.

invoicing probability in a new destination is firm-specific but time invariant, e.g., firms that need to constantly import lots of dollar invoiced inputs are more likely to invoice their exports in dollars. Therefore, this property rules out this case as a possible explanation for the empirical facts documented in figures 7 and 8.

[39] We add this assumption for the sake of analytical convenience. Removing this assumption will strengthen the mechanism. We discuss the spillover effect of the invoicing choices in the new destination on existing destinations in the next subsection.

Figure A1: Illustrating the relationship between dollar spell and dollar invoicing share




Notes: This figure shows the evolution of the dollar spell and the dollar invoicing share of a firm beginning to export under the following three assumptions: (1) the firm enters one new market in each period and (2) the firm sticks to the invoicing currency of its initial choice for the existing markets. $T(x)$ represents the probability of invoicing in dollar in a new destination given the dollar invoicing share at the firm level. $\omega_{ft}$ represents the firm's dollar invoicing share in period $t$, where $t = 0, 1, 2, 3$. Different colors highlight positions identified with different dollar spell lengths. Green, red, blue and violet indicate a dollar spell length of zero, one, two and three years, respectively.

The key challenge, as can be seen in figure A1, is to characterize the relationship between firms' dollar spell lengths and the distribution of dollar invoicing shares. The tricky part is that the dollar invoicing share, the key variable in the transition function, is only indirectly linked to the dollar spell length. A firm is characterized as a dollar user (and therefore the dollar spell length will be increased by 1 year) if the firm used dollars at least once in any of its export destinations previously. Therefore, for a given dollar spell length, the dollar invoicing share can differ substantially across firms. Under our assumption 1, the dollar invoicing probability in a new destination

conditional on the spell length $Spell_{ft-1}^{USD}$ and the exporting age of the firm $age_t$ depends on the distribution of dollar invoicing in the last period (i.e., the values of $\omega_{ft-1}$) and the transition function $T(x)$. With assumption 2, the conditional probability of dollar invoicing in a new destination can be solved explicitly and is given by[40]

$$Pr(\mathbb{1}_{fdt}^{\text{USD}} = 1 | Spell_{ft-1}^{USD} = 0 \bigcap age_{ft} = \tau) = T(0) \tag{A15}$$

$$Pr(\mathbb{1}_{fdt}^{\text{USD}} = 1 | Spell_{ft-1}^{USD} = 1 \bigcap age_{ft} = \tau) = T\left(\frac{1}{\tau}\right) \tag{A16}$$

$$Pr(\mathbb{1}_{fdt}^{\text{USD}} = 1 | Spell_{ft-1}^{USD} = 2 \bigcap age_{ft} = \tau) = \left[1 - T\left(\frac{1}{\tau - 1}\right)\right] T\left(\frac{1}{\tau}\right) + T\left(\frac{1}{\tau - 1}\right) T\left(\frac{2}{\tau}\right) \tag{A17}$$

As can be seen from equations (A15)-(A17), a sufficient condition to get our empirical results of dollar invoicing dynamics (i.e., figures 7 and 8) is that $T(x)$ is an increasing function of $x$.[41] An increasing transition function of $T(x)$ ensures a positive reinforcement loop as it means firms starting with a high dollar invoicing share are also more likely to use dollars in a new destination. This implies that firms with a dollar spell length of one year are more likely to use dollars in a new destination in the next period than those firms with a dollar spell length of zero; hence these firms are more likely to end up with high dollar shares which in turn increases the dollar invoicing probability in a new destination in the following period. Notably, the condition that $T(x)$ is an increasing function of $x$ also naturally generates the pattern documented in figure 8. As shown in (A16) and (A17), for a given dollar spell length, the dollar invoicing probability in a new destination decreases in the exporting age of the firm $\tau$.

# B Further estimation results

[40] $Pr(\mathbb{1}_{fdt}^{\text{USD}} = 1 | Spell_{ft-1}^{USD} = 3 \bigcap age_t = \tau) = a_1(\tau) T\left(\frac{1}{\tau}\right) + a_2(\tau) T\left(\frac{2}{\tau}\right) + a_3(\tau) T\left(\frac{3}{\tau}\right)$ where $a_1(\tau) = [1 - T\left(\frac{1}{\tau-2}\right)][1 - T\left(\frac{1}{\tau-1}\right)]$; $a_2(\tau) = [1 - T\left(\frac{1}{\tau-2}\right)] T\left(\frac{1}{\tau-1}\right) + T(1)[1 - T(1)]$; $a_3(\tau) = T^2(1)$. More generally, when the total number of years is greater than 3, we have $a_1(\tau) = [1 - T\left(\frac{1}{\tau-2}\right)][1 - T\left(\frac{1}{\tau-1}\right)]$; $a_2(\tau) = [1 - T\left(\frac{1}{\tau-2}\right)] T\left(\frac{1}{\tau-1}\right) + T\left(\frac{1}{\tau-2}\right)[1 - T\left(\frac{2}{\tau-1}\right)]$; $a_3(\tau) = T\left(\frac{1}{\tau-2}\right) T\left(\frac{2}{\tau-1}\right)$.

[41] Given $T(x)$ is an increasing in $x$, it is straightforward to see the dollar invoicing probability in a new destination is higher for any firm age $\tau$ as the dollar spell length increases.

Table B1: Summary statistics of estimation sample

| | | Unweighted | | Weighted | |
|---|---|---|---|---|---|
| | Obs | Mean | Std | Mean | Std |
| Dollar invoicing probability | 4,719,628 | 0.229 | 0.420 | 0.362 | 0.480 |
| Dollar import share | 4,719,628 | 0.571 | 0.391 | 0.603 | 0.365 |
| Euro import share | 4,719,628 | 0.055 | 0.158 | 0.054 | 0.159 |
| Destination currency import share | 4,719,628 | 0.113 | 0.287 | 0.199 | 0.346 |
| Firm size (log) | 4,719,628 | 14.559 | 3.231 | 19.181 | 2.774 |
| UK competitors' dollar invoicing share | 4,719,628 | 0.254 | 0.285 | 0.359 | 0.336 |
| UK competitor's dollar import share | 4,719,628 | 0.578 | 0.246 | 0.594 | 0.272 |
| UK competitors' firm size (log) | 4,719,628 | 15.748 | 2.093 | 18.307 | 2.529 |

Notes: 'Weighted' indicates that the variables are weighted by export values at the firm-product-destination-year level. Data source: HMRC Overseas Trade in Goods Statistics, UK's extra-EU export transactions, 2010-2016.

Table B2: First-stage regression for UK competitors' dollar invoicing share

| | |
|---|---|
| UK competitors' dollar import share | 0.202*** |
| | (0.000) |
| UK competitors' firm size | 0.013*** |
| | (0.000) |
| Observations | 4,719,628 |
| Adjusted $R^2$ | 0.435 |
| Country-Year FE | ✓ |
| Product-Year FE | ✓ |

Notes: The first-stage regression for 2SLS in columns 4 from table 1. The dependent variable is UK competitors' dollar invoicing share at the firm-industry-destination-year level for which industry is defined at 6-digit level. Robust standard errors in parentheses. Significance: *** p<0.01, ** p<0.05, * p<0.1. Data source: HMRC Overseas Trade in Goods Statistics, UK's extra-EU export transactions, 2010-2016.

Table B3: Dollar invoicing probability at entry year: By firm size in year t-1

| | (1) Baseline | (2) 0-5p | (3) 5-25p | (4) 25-50p | (5) 50-75p | (6) 75-95p | (7) 95-100p |
|---|---|---|---|---|---|---|---|
| UK competitors' dollar invoicing share | 0.071*** | 0.009 | 0.019 | -0.000 | 0.048** | 0.081*** | 0.075 |
| | (0.007) | (0.055) | (0.024) | (0.023) | (0.022) | (0.024) | (0.054) |
| Dollar import share | 0.103*** | 0.040*** | 0.042*** | 0.051*** | 0.087*** | 0.140*** | 0.218*** |
| | (0.001) | (0.006) | (0.003) | (0.003) | (0.003) | (0.005) | (0.015) |
| Euro import share | -0.017*** | 0.017 | -0.006 | -0.019*** | 0.007 | -0.047*** | 0.010 |
| | (0.002) | (0.017) | (0.007) | (0.006) | (0.007) | (0.009) | (0.028) |
| Destination currency import share | 0.015*** | 0.039** | 0.053*** | 0.011 | -0.018 | -0.044* | 0.008 |
| | (0.002) | (0.015) | (0.009) | (0.011) | (0.016) | (0.027) | (0.134) |
| Firm size | 0.013*** | 0.015*** | 0.009*** | 0.012*** | 0.009*** | 0.005*** | 0.016*** |
| | (0.000) | (0.002) | (0.001) | (0.001) | (0.001) | (0.002) | (0.004) |
| Dollar invoicing years (t-1) = 1 | 0.039*** | 0.122*** | 0.113*** | 0.093*** | 0.082*** | 0.076*** | 0.082*** |
| | (0.001) | (0.011) | (0.004) | (0.003) | (0.003) | (0.005) | (0.020) |
| Dollar invoicing years (t-1) = 2 | 0.060*** | 0.103*** | 0.166*** | 0.134*** | 0.114*** | 0.099*** | 0.099*** |
| | (0.002) | (0.022) | (0.007) | (0.004) | (0.004) | (0.006) | (0.023) |
| Dollar invoicing years (t-1) = 3 | 0.082*** | 0.209*** | 0.223*** | 0.168*** | 0.152*** | 0.125*** | 0.134*** |
| | (0.002) | (0.040) | (0.011) | (0.006) | (0.005) | (0.007) | (0.025) |
| Dollar invoicing years (t-1) = 4 | 0.097*** | 0.168** | 0.237*** | 0.199*** | 0.181*** | 0.167*** | 0.120*** |
| | (0.003) | (0.068) | (0.016) | (0.009) | (0.006) | (0.008) | (0.030) |
| Dollar invoicing years (t-1) = 5 | 0.116*** | 0.138 | 0.328*** | 0.244*** | 0.193*** | 0.188*** | 0.095*** |
| | (0.004) | (0.140) | (0.023) | (0.011) | (0.008) | (0.010) | (0.031) |
| Dollar invoicing years (t-1) = 6 | 0.140*** | - | 0.387*** | 0.251*** | 0.256*** | 0.212*** | 0.134*** |
| | (0.005) | (-) | (0.041) | (0.015) | (0.010) | (0.011) | (0.035) |
| Observations | 1,181,074 | 16,232 | 77,208 | 97,942 | 98,036 | 77,735 | 17,544 |
| Country-Year FE | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Product-Year FE | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Hansen J-stat | 0.008 | 0.073 | 6.431 | 0.004 | 2.036 | 0.024 | 0.429 |
| [P-value] | [0.926] | [0.787] | [0.011] | [0.946] | [0.154] | [0.875] | [0.512] |
| Weak IV F-stat | 15,142 | 225 | 1,122 | 1,471 | 1,545 | 1,448 | 298 |

Notes: The dependent variable is the dollar invoicing probability as the firm-product-destination-year level. Column 1 presents the baseline results from column 1 in table 4. Columns 2 to 7 show the results for sub-samples based on the firms' total export values in the previous year. '0-5p' indicates firms with previous export values less than the bottom five percentile in the sample and so on. Robust standard errors in parentheses. Significance: *** p<0.01, ** p<0.05, * p<0.1. Data source:HMRC Overseas Trade in Goods Statistics, UK's extra-EU export transactions, 2010-2016.

# C Distributional statistics on invoicing currency

Table C1: Years of Exporting & Number of Invoicing Currencies

| Years of Exporting | Number of Invoicing Currencies | | | | | Share using 2+ currencies |
|---|---|---|---|---|---|---|
| | 1 | 2-5 | 6-10 | 10+ | Total | given export experience |
| (a) by Share of Firm-Year Units | | | | | | |
| 1 | 26.1 | 5.5 | 0.1 | 0.0 | 31.7 | 17.6 |
| 2 | 14.6 | 5.4 | 0.1 | 0.0 | 20.1 | 27.4 |
| 3 | 9.9 | 4.8 | 0.1 | 0.0 | 14.9 | 32.9 |
| 4 | 7.1 | 4.4 | 0.1 | 0.0 | 11.6 | 38.8 |
| 5 | 5.1 | 4.0 | 0.1 | 0.0 | 9.2 | 44.6 |
| 6 | 3.6 | 3.5 | 0.1 | 0.0 | 7.2 | 50.0 |
| 7 | 2.3 | 3.0 | 0.1 | 0.0 | 5.4 | 57.4 |
| Total | 68.8 | 30.7 | 0.4 | 0.1 | 100.0 | |
| (b) by Share of Trade Values | | | | | | |
| 1 | 1.8 | 7.9 | 2.1 | 1.6 | 13.5 | 86.7 |
| 2 | 1.4 | 8.2 | 2.7 | 1.8 | 14.2 | 90.1 |
| 3 | 1.1 | 8.4 | 2.4 | 2.3 | 14.2 | 92.3 |
| 4 | 1.0 | 8.0 | 3.1 | 1.7 | 13.8 | 92.7 |
| 5 | 0.7 | 10.2 | 2.0 | 2.2 | 15.1 | 95.4 |
| 6 | 0.4 | 9.6 | 2.8 | 2.6 | 15.5 | 97.4 |
| 7 | 0.5 | 7.8 | 2.9 | 2.6 | 13.8 | 96.4 |
| Total | 7.0 | 60.2 | 17.9 | 14.9 | 100.0 | |
| (c) by Share of Transactions | | | | | | |
| 1 | 4.9 | 9.2 | 1.0 | 0.7 | 15.8 | 69.0 |
| 2 | 3.7 | 9.4 | 1.1 | 0.7 | 14.9 | 75.2 |
| 3 | 3.1 | 9.4 | 1.1 | 0.8 | 14.4 | 78.5 |
| 4 | 2.7 | 9.7 | 1.2 | 0.9 | 14.5 | 81.4 |
| 5 | 2.2 | 9.5 | 1.1 | 1.1 | 13.8 | 84.1 |
| 6 | 1.8 | 9.4 | 1.3 | 1.0 | 13.5 | 86.7 |
| 7 | 1.4 | 9.2 | 1.3 | 1.2 | 13.2 | 89.4 |
| Total | 19.7 | 65.7 | 8.1 | 6.5 | 100.0 | |

Notes: The raw data have five panel dimensions, namely firm, product, invoicing currency, origin/destination, and date. We aggregate data and calculate the dollar invoicing share at the firm-year level. To construct the table, we split the data into different bins as defined by the row and column categories. For stastistics in panel (a), we count the number of firm-years that fall into each bin. For stastistics in panels (b) and (c), we calculate the total trade value (denominated in sterling) and the number of annual transactions of firm-year units that fall into each bin. Data source: HMRC Overseas Trade in Goods Statistics, UK's extra-EU export transactions, 2010-2016.

Table C2: Years of Exporting & Dollar Invoicing Share

| Years of Exporting | Dollar Invoicing Share | | | | | | Share with |
|---|---|---|---|---|---|---|---|
| | 0 | (0, 0.05] | (0.05, 0.15] | (0.15, 0.5] | (0.5, 1] | Total | dollar-invoicing> 0.5 |
| (a) by Share of Firm-Year Units | | | | | | | |
| 1 | 24.9 | 0.8 | 1.4 | 0.7 | 3.9 | 31.7 | 12.3 |
| 2 | 14.5 | 0.8 | 1.4 | 0.8 | 2.6 | 20.1 | 12.9 |
| 3 | 10.1 | 0.8 | 1.3 | 0.7 | 2.0 | 14.9 | 13.4 |
| 4 | 7.4 | 0.8 | 1.2 | 0.6 | 1.6 | 11.6 | 13.7 |
| 5 | 5.4 | 0.7 | 1.1 | 0.6 | 1.4 | 9.2 | 15.2 |
| 6 | 3.9 | 0.7 | 1.0 | 0.5 | 1.2 | 7.2 | 16.6 |
| 7 | 2.5 | 0.6 | 0.8 | 0.5 | 1.0 | 5.4 | 18.5 |
| Total | 68.7 | 5.2 | 8.1 | 4.4 | 13.6 | 100.0 | |
| (b) by Share of Trade Values | | | | | | | |
| 1 | 1.8 | 3.2 | 3.0 | 1.4 | 4.1 | 13.5 | 30.4 |
| 2 | 1.7 | 3.6 | 3.5 | 0.8 | 4.6 | 14.2 | 32.4 |
| 3 | 1.5 | 3.0 | 3.1 | 1.5 | 5.0 | 14.2 | 35.2 |
| 4 | 1.3 | 3.0 | 3.4 | 1.4 | 4.7 | 13.8 | 34.0 |
| 5 | 1.0 | 2.8 | 4.9 | 1.4 | 5.0 | 15.1 | 33.1 |
| 6 | 0.6 | 3.4 | 5.2 | 1.1 | 5.1 | 15.5 | 32.9 |
| 7 | 0.6 | 3.2 | 3.8 | 1.4 | 4.8 | 13.8 | 34.8 |
| Total | 8.5 | 22.2 | 26.9 | 9.0 | 33.4 | 100.0 | |
| (c) by Share of Transactions | | | | | | | |
| 1 | 5.4 | 2.4 | 3.7 | 1.5 | 2.8 | 15.8 | 17.7 |
| 2 | 4.3 | 2.4 | 3.7 | 1.6 | 2.9 | 14.9 | 19.5 |
| 3 | 3.7 | 2.3 | 3.4 | 1.7 | 3.3 | 14.4 | 22.9 |
| 4 | 3.3 | 2.5 | 3.9 | 1.7 | 3.1 | 14.5 | 21.4 |
| 5 | 2.7 | 2.5 | 3.8 | 1.7 | 3.2 | 13.8 | 23.2 |
| 6 | 2.3 | 2.5 | 3.8 | 1.6 | 3.3 | 13.5 | 24.4 |
| 7 | 1.8 | 2.3 | 3.9 | 1.8 | 3.3 | 13.2 | 25.0 |
| Total | 23.5 | 16.8 | 26.1 | 11.7 | 21.9 | 100.0 | |

Notes: The raw data have five panel dimensions, namely firm, product, invoicing currency, origin/destination, and date. We aggregate data and calculate the dollar invoicing share at the firm-year level. To construct the table, we split the data into different bins as defined by the row and column categories. For stastistics in panel (a), we count the number of firm-years that fall into each bin. For stastistics in panels (b) and (c), we calculate the total trade value (denominated in sterling) and the number of annual transactions of firm-year units that fall into each bin. Data source: HMRC Overseas Trade in Goods Statistics, UK's extra-EU export transactions, 2010-2016.

Table C3: Prior Years of Dollar Invoicing vs. Dollar Invoicing Share

| Prior Years of Dollar Invoicing | Dollar Invoicing Share | | | | | |
|---|---|---|---|---|---|---|
| | 0 | (0, 0.05] | (0.05, 0.15] | (0.15, 0.5] | (0.5, 1] | Total |
| (a) by Share of Firm-Year Units | | | | | | |
| 0 | 49.0 | 3.8 | 5.8 | 3.2 | 9.5 | 71.3 |
| 1 | 3.8 | 1.8 | 2.8 | 1.6 | 3.0 | 13.1 |
| 2 | 1.1 | 1.1 | 1.8 | 1.0 | 1.9 | 6.8 |
| 3 | 0.4 | 0.6 | 1.2 | 0.6 | 1.2 | 4.1 |
| 4 | 0.2 | 0.4 | 0.8 | 0.4 | 0.8 | 2.5 |
| 5 | 0.1 | 0.2 | 0.5 | 0.2 | 0.5 | 1.5 |
| 6 | 0.0 | 0.1 | 0.2 | 0.1 | 0.3 | 0.7 |
| Total | 54.7 | 7.9 | 13.2 | 7.0 | 17.2 | 100.0 |
| (b) by Share of Trade Values | | | | | | |
| 0 | 8.0 | 20.5 | 24.7 | 8.2 | 31.6 | 93.1 |
| 1 | 0.3 | 0.7 | 0.7 | 0.4 | 1.0 | 3.0 |
| 2 | 0.1 | 0.4 | 0.3 | 0.3 | 0.4 | 1.4 |
| 3 | 0.0 | 0.4 | 1.0 | 0.1 | 0.2 | 1.7 |
| 4 | 0.0 | 0.1 | 0.2 | 0.1 | 0.1 | 0.4 |
| 5 | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 | 0.2 |
| 6 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 |
| Total | 8.5 | 22.2 | 26.9 | 9.0 | 33.4 | 100.0 |
| (c) by Share of Transactions | | | | | | |
| 0 | 21.7 | 14.3 | 22.0 | 9.5 | 18.1 | 85.6 |
| 1 | 1.3 | 1.2 | 2.0 | 1.1 | 1.7 | 7.4 |
| 2 | 0.3 | 0.7 | 0.9 | 0.5 | 0.9 | 3.4 |
| 3 | 0.1 | 0.3 | 0.5 | 0.3 | 0.6 | 1.8 |
| 4 | 0.0 | 0.2 | 0.3 | 0.2 | 0.3 | 1.0 |
| 5 | 0.0 | 0.1 | 0.2 | 0.1 | 0.2 | 0.6 |
| 6 | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 | 0.3 |
| Total | 23.5 | 16.8 | 26.1 | 11.7 | 21.9 | 100.0 |

Notes: The raw data have five panel dimensions, namely firm, product, invoicing currency, origin/destination, and date. Prior years of dollar invoicing indicates the total number of years that each firm used invoiced in dollars up to $t-1$ and dollar invoicing share is measured at $t$. We aggregate data and calculate the dollar invoicing share at the firm-year level. To construct the table, we split the data into different bins as defined by the row and column categories. For stastistics in panel (a), we count the number of firm-years that fall into each bin. For stastistics in panels (b) and (c), we calculate the total trade value (denominated in sterling) and the number of annual transactions of firm-year units that fall into each bin. Data source: HMRC Overseas Trade in Goods Statistics, UK's extra-EU export transactions, 2010-2016.

Table C4: Years of Exporting vs. Number of Exported Products

| | Number of Exported Products | | | | |
|---|---|---|---|---|---|
| Years of Exporting | 1 | 2-5 | 6-10 | 10+ | Total |
| (a) by Share of Firm-Year Units | | | | | |
| 1 | 18.2 | 9.7 | 2.0 | 1.8 | 31.7 |
| 2 | 8.2 | 7.9 | 2.1 | 1.8 | 20.1 |
| 3 | 4.8 | 6.3 | 2.0 | 1.8 | 14.9 |
| 4 | 3.0 | 4.9 | 1.8 | 1.8 | 11.6 |
| 5 | 2.0 | 3.9 | 1.6 | 1.7 | 9.2 |
| 6 | 1.2 | 3.0 | 1.4 | 1.6 | 7.2 |
| 7 | 0.7 | 2.0 | 1.1 | 1.6 | 5.4 |
| Total | 38.1 | 37.8 | 11.9 | 12.2 | 100.0 |
| (b) by Share of Trade Values | | | | | |
| 1 | 0.8 | 2.1 | 1.2 | 9.4 | 13.5 |
| 2 | 0.4 | 1.7 | 1.3 | 10.8 | 14.2 |
| 3 | 0.3 | 1.4 | 1.7 | 10.7 | 14.2 |
| 4 | 0.4 | 1.4 | 1.2 | 10.8 | 13.8 |
| 5 | 0.2 | 1.2 | 1.4 | 12.3 | 15.1 |
| 6 | 0.1 | 1.0 | 1.1 | 13.3 | 15.5 |
| 7 | 0.1 | 0.8 | 1.1 | 11.8 | 13.8 |
| Total | 2.4 | 9.6 | 9.0 | 79.0 | 100.0 |
| (c) by Share of Transactions | | | | | |
| 1 | 1.6 | 2.9 | 2.0 | 9.2 | 15.8 |
| 2 | 0.8 | 2.6 | 2.2 | 9.3 | 14.9 |
| 3 | 0.5 | 2.2 | 2.1 | 9.6 | 14.4 |
| 4 | 0.3 | 1.9 | 2.0 | 10.2 | 14.5 |
| 5 | 0.2 | 1.6 | 1.8 | 10.2 | 13.8 |
| 6 | 0.2 | 1.4 | 1.7 | 10.3 | 13.5 |
| 7 | 0.1 | 1.0 | 1.4 | 10.6 | 13.2 |
| Total | 3.8 | 13.7 | 13.1 | 69.4 | 100.0 |

Notes: The raw data have five panel dimensions, namely firm, product, invoicing currency, origin/destination, and date. We aggregate data and calculate the number of products exported at the firm-year level. To construct the table, we split the data into different bins as defined by the row and column categories. For stastistics in panel (a), we count the number of firm-years that fall into each bin. For stastistics in panels (b) and (c), we calculate the total trade value (denominated in sterling) and the number of annual transactions of firm-year units that fall into each bin. Data source: HMRC Overseas Trade in Goods Statistics, UK's extra-EU export transactions, 2010-2016.

Table C5: Years of Exporting vs. Number of Exporting Destinations

| | Number of Exporting Destinations | | | | |
|---|---|---|---|---|---|
| Years of Exporting | 1 | 2-5 | 6-10 | 10+ | Total |
| (a) by Share of Firm-Year Units | | | | | |
| 1 | 21.1 | 7.9 | 1.5 | 1.2 | 31.7 |
| 2 | 10.1 | 7.1 | 1.5 | 1.3 | 20.1 |
| 3 | 6.1 | 5.9 | 1.5 | 1.3 | 14.9 |
| 4 | 3.9 | 4.8 | 1.5 | 1.3 | 11.6 |
| 5 | 2.6 | 3.9 | 1.4 | 1.3 | 9.2 |
| 6 | 1.6 | 3.1 | 1.3 | 1.3 | 7.2 |
| 7 | 0.8 | 2.2 | 1.1 | 1.2 | 5.4 |
| Total | 46.2 | 35.0 | 9.8 | 9.0 | 100.0 |
| (b) by Share of Trade Values | | | | | |
| 1 | 1.0 | 1.5 | 1.5 | 9.5 | 13.5 |
| 2 | 0.5 | 1.7 | 1.2 | 10.8 | 14.2 |
| 3 | 0.4 | 1.5 | 1.1 | 11.2 | 14.2 |
| 4 | 0.2 | 1.4 | 1.1 | 11.1 | 13.8 |
| 5 | 0.3 | 1.1 | 1.3 | 12.3 | 15.1 |
| 6 | 0.2 | 0.9 | 1.4 | 13.1 | 15.5 |
| 7 | 0.2 | 0.6 | 1.0 | 12.0 | 13.8 |
| Total | 2.8 | 8.7 | 8.5 | 80.1 | 100.0 |
| (c) by Share of Transactions | | | | | |
| 1 | 2.5 | 3.1 | 2.1 | 8.1 | 15.8 |
| 2 | 1.4 | 3.1 | 2.2 | 8.2 | 14.9 |
| 3 | 0.9 | 2.7 | 2.2 | 8.5 | 14.4 |
| 4 | 0.7 | 2.4 | 2.2 | 9.3 | 14.5 |
| 5 | 0.5 | 2.1 | 2.0 | 9.3 | 13.8 |
| 6 | 0.3 | 1.7 | 2.0 | 9.5 | 13.5 |
| 7 | 0.2 | 1.3 | 1.8 | 9.8 | 13.2 |
| Total | 6.4 | 16.5 | 14.4 | 62.7 | 100.0 |

Notes: The raw data have five panel dimensions, namely firm, product, invoicing currency, origin/destination, and date. We aggregate data and calculate the number of destinations at the firm-year level. To construct the table, we split the data into different bins as defined by the row and column categories. For stastistics in panel (a), we count the number of firm-years that fall into each bin. For stastistics in panels (b) and (c), we calculate the total trade value (denominated in sterling) and the number of annual transactions of firm-year units that fall into each bin. Data source: HMRC Overseas Trade in Goods Statistics, UK's extra-EU export transactions, 2010-2016.