How Does a Dominant Currency Replace Another? Evidence from European Trade*

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Abstract

We assess why a dominant currency in international trade invoicing can be replaced with another by contrasting two hypotheses stressed in recent theory: increased trade and reduced exchange rate volatility vis-à-vis the emergent dominant currency area. Our study focuses on 13 European economies that saw marked increases in the use of the euro at the expense of the US dollar for trade invoicing. We show how theory maps itself into a network which links together invoicing currency decisions across countries and develop a fitting Panel-Vector autoregression to jointly model invoicing, trade and exchange rate volatility dynamics across countries, while allowing for cross-country effects emphasized in theory. We identify for each country a "trade shock" and an "exchange rate volatility shock", finding significant evidence in support of the increased trade hypothesis. Our estimates suggest that in countries where trade with the euro area increased, higher trade explains almost 40% of the rise in euro invoicing from 1999 to 2019. In contrast, the impact of greater exchange rate stability against the euro is found to be insignificant. Importantly, a country's invoicing decision is significantly influenced by those of other countries within the regional trade network. We find that this effect operates mainly via bilateral trade linkages rather than strategic complementarities in export price setting, which points to the relevance of changes to input-output linkages in making or breaking dominant currencies.

Keywords: Dominant Currencies, Trade Invoicing, Structural VAR, Panel VAR, Cross-Sectional Dynamics, Network Effects.

JEL Codes: F3, F44, C13, C3

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1 Introduction

The global dominance of a few currencies for international trade invoicing—the leading currencies in which international trade prices are set—is central to our understanding of the international propagation of shocks, the stability of the global financial system and optimal policy in open economies. Theory predicts that an equilibrium with one globally dominant currency (DC) is stable and self-perpetuating. This prediction is rooted in models where international currency status is characterized by network externalities giving rise to strong lock-in and inertia effects that benefit the incumbent (Krugman (1980), Krugman (1984), Rey (2001)), (Matsuyama et al. (1993), Zhou (1997)). It fits the historical record well[1] and remains valid today—the US dollar continues to reign supreme in global trade and finance (Maggiori et al. (2019), Ilzetzki et al. (2019), Boz et al. (2022)).[2]

The euro area (EA)'s neighborhood is a noteworthy exception, however. Countries that joined the EA or the European Union (EU) after the euro's creation in 1999, EU candidate countries and other European countries have experienced marked increases in the use of the euro as an invoicing currency for international trade at the expense of the US dollar. As Figure 1 shows, for these countries, the share of the euro increased on average by more than 20 percentage points (left panel),[3] which contrasts with broad stability in global patterns of trade invoicing (right panel). Importantly, the rise in euro invoicing is not just a mechanical implication of euro adoption by a few of these countries.[4] This suggests that, under certain circumstances, a DC can be replaced—or dwarfed in importance—by another. Why did the equilibrium shift to the benefit of the euro? How

[1]The traditional account is that it took between 30 to 70 years, depending on the aspects of economic and international currency status considered, from when the United States overtook Britain as the leading economic and commercial power in the 19th century to when the dollar overtook sterling as the DC in the 20th (Eichengreen et al. (2017)).

[2]The US dollar accounts for between 50% and 90% of global trade and financial transactions, depending on the metric considered, far more than the US's global economic and financial weight. This is the case notwithstanding earlier claims that the euro (EUR) (Chinn and Frankel (2008)) or the renminbi (Subramanian (2011)) would dethrone the USD.

[3]Figure 2 shows that patterns across countries are heterogeneous. The euro either strengthened its lead (as in Hungary, Croatia and the Czech Republic), caught-up (as in Norway) or replaced the US dollar as main invoicing unit (as in Bulgaria, Lithuania and Poland). See Figure B.1 for related evidence on imports.

[4]These countries joined several years after the euro share of invoicing increased; Slovenia joined in 2007, Slovakia in 2009, Estonia in 2011, Latvia in 2014, Lithuania in 2015 and Croatia in 2023. Moreover, prior to euro adoption, invoicing in legacy currencies of the countries in question was limited, while invoicing in major global currencies was widespread.

does one dominant currency replace another? We examine these questions empirically in the context of European trade.

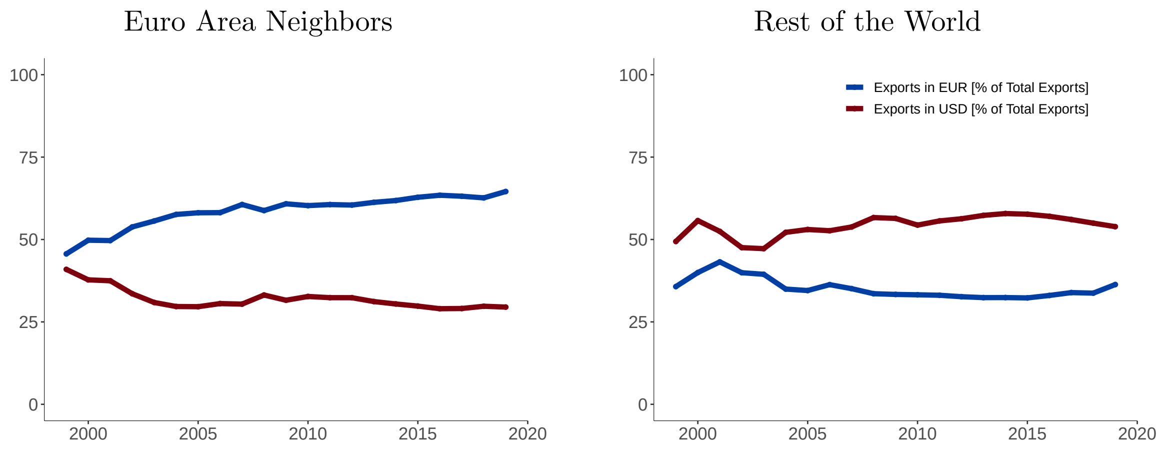

Figure 1: Invoicing Currency Patterns in Exports

Notes: The figure plots shares of exports invoiced in euros ($EX^{€}_{it}$, blue line) and in US dollars ($EX^{\$}_{it}$, red line) from 1999 to 2019. The left panel reports averages across European countries which are not inaugural members of the EA. The right panel shows averages across the remaining countries. Missing values are imputed using linear interpolation. Data: Boz et al. (2022).

Recent theory (Gopinath and Stein (2021), Mukhin (2022), Amiti et al. (2022)) points primarily to two hypotheses. The first emphasizes growing importance of the challenger-dominant currency area—in our case the EA—in international trade. The second stresses the relevance of lower exchange rate volatility vis-à-vis the challenger currency. Accordingly, a switch from US dollar to euro invoicing requires enough central banks to shift their exchange rate anchor from the US dollar to the euro. Thereby, both recent and earlier theoretical contributions underline the importance of network effects. These include bilateral trade links between countries in the form of input-output linkages, strategic complementarities in price setting among competitors and suppliers, and economies of scope in alternative uses of a currency, all of which link together invoicing currency choices of different firms, both within and across countries. The resulting cross-country effects suggest that a switch in DCs is a joint—rather than a unilateral—phenomenon affecting multiple countries, in line with the empirical evidence of Figures 2 and B.1.

We take these hypotheses to the data. As we show, theory maps itself into a network which links together invoicing currency choices across countries. In line with that, we develop a Panel-Vector autoregression (Panel-VAR) to jointly model invoicing currency choices, exchange rate volatility and trade developments of 13 EA neighbors between 1999 and 2019. This setup allows us to explicitly model cross-country effects empha-

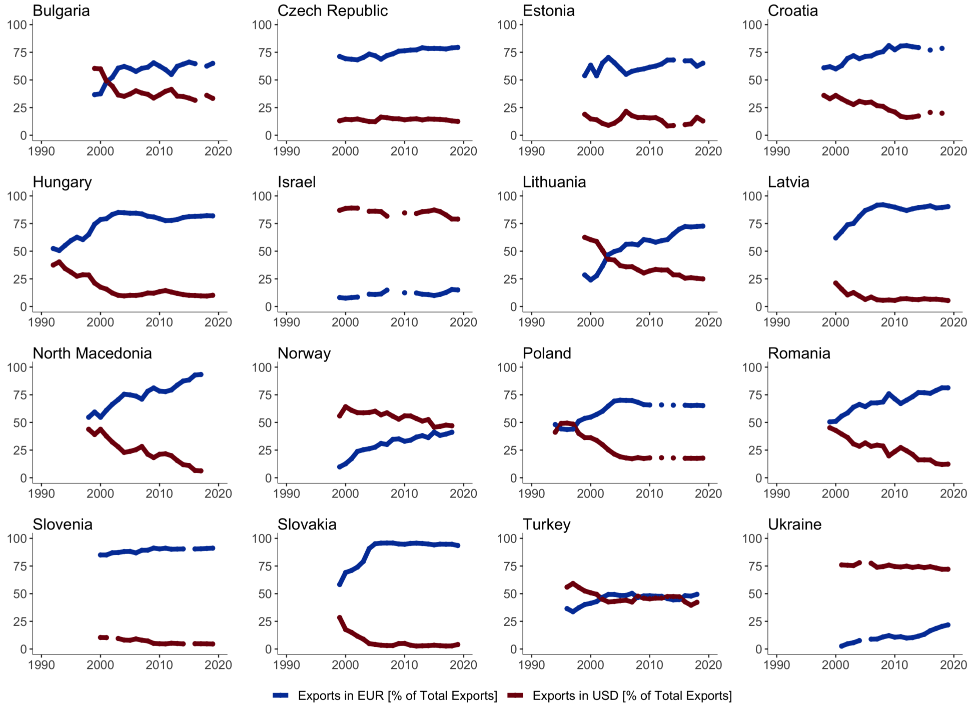

Figure 2: Invoicing Currency Shares in Exports

Notes: The figure shows the evolution of the share of exports invoiced in euro ($EX_{it}^{€}$, blue lines) and in US dollars ($EX_{it}^{\$}$, red lines) across countries in our sample. Data: Boz et al. (2020).

sized in theory and thereby account for network effects: a country's invoicing currency choice is not only impacted by its own fundamentals—trade patterns and exchange rate volatility—but also those of its trade partners and competitors, those of the trade partners and competitors of the latter, etc. Moreover, it allows us to investigate the dynamics underlying invoicing currency choices rather than just their static determinants, which is relevant in view of the significant cross-country heterogeneity in the timing, speed and extent of increases in euro invoicing (see Figure 2). In this framework, we identify a "trade shock" and an "exchange rate volatility shock" and quantify their respective contributions to the increases in euro invoicing across countries. Identification is achieved by using the exchange rate disconnect—the lack of correlation between the exchange rate and other macroeconomic fundamentals, a well-known puzzle of the international finance literature[5]—and by limiting cross-country effects to those emphasized in theory.[6]

Our estimates provide significant evidence in support of the increased trade hypoth-

[5]See e.g. Obstfeld and Rogoff (2000), Itskhoki and Mukhin (2021)

[6]Although not required for identification, in our baseline specification, we add the additional restriction that there is no feedback loop from invoicing currency choices to trade and exchange rate volatility. This allows us to identify shocks to the latter which occurred prior to the start of our invoicing data sample (in 1999). This is crucial because the most pronounced changes to trade and exchange rate volatility patterns in the sample occurred in the 1990s.

esis. Stronger trade with the EA relative to trade with the US leads to a significant and persistent rise in euro invoicing. This result is robust to a range of different specifications. The effect of the trade shock is economically important: in countries where trade with the EA increased, the latter explains almost 40% of the rise in the share of exports invoiced in euro.[7] In contrast, the impact of greater exchange rate stability against the euro is found to be insignificant. Although domestic shocks play a predominant role, a country's euro share of exports is significantly influenced by those of other countries in the regional trade network. Cross-country effect operate mainly via bilateral trade linkages rather than strategic complementarities in export price setting, which point to the relevance of changes to input-output linkages in making or breaking DCs.

Our work draws on theoretical contributions, such as Engel (2006), Gopinath et al. (2010), Gopinath and Stein (2021), Mukhin (2022) and Amiti et al. (2022), which recently proposed mechanisms through which switches in DCs occur. We provide an empirical test of these mechanisms using a rare episode during which such a switch happened, thereby filling a gap in this active research area (Gopinath and Itskhoki (2021)).[8] Other related empirical work documented the use of DCs across countries and uncovered its potential determinants with static panel data regressions (Kamps (2006), Goldberg and Tille (2008), Ito and Chinn (2014), Gopinath (2015), Goldberg and Tille (2016), Boz et al. (2022), Amiti et al. (2022), Georgiadis et al. (2021)). The framework we develop allows us to go one step further and to analyze whether such determinants can explain the dynamics of observed invoicing currency patterns. Moreover, in contrast with firm-level analyses (Chung (2016), Goldberg and Tille (2016), Devereux et al. (2017), Auer et al. (2021) and Amiti et al. (2022)), we use country-level data, which provides us with much broader cross-sectional coverage, and allows to explicitly account for network effects. As a result, our analysis acknowledges that the invoicing choices of a firm's suppliers and competitors are endogenous to that firm's own invoicing decisions, though at the aggregated level of countries. Other studies ignore this aspect of endogeneity by arguing that firms are small enough and have only negligible influence on other firms' invoicing behavior, which may be plausible for some firms and industries, but leads to

[7] Henceforth, to simplify notation: euro share of exports. Similarly for US dollar and/or imports.

[8] In their recent survey of the theoretical and empirical literature that documents patterns of currency use in global trade and the implications of DCs, Gopinath and Itskhoki stress indeed that "what it will take for new currency equilibria to emerge" is one of the main questions to explore in future research (Gopinath and Itskhoki (2021), p. 47).

larger estimation biases for others. Moreover, network effects are an important feature of theoretical models and their estimation is of interest on its own. Our estimates at the country-level in the context of a shift in DC usage complement the firm-level estimates in an environment with stable invoicing patterns from Amiti et al. (2022).[9] Another related study is Benguria and Wagner (2022) who study the euro's introduction as a natural experiment triggering shifts in invoicing currency patterns of one country (Chile).

We also contribute to the literature on networks in econometrics by providing an example of inference through shock identification in a Panel-VAR with multiple variables per cross-sectional unit and multiple types of cross-sectional connections. As stressed above, we motivate this framework by showing that theory maps itself into a network which links together invoicing currency choices across countries and is akin to networks discussed in other areas of economics (Acemoglu et al. (2012), Elliott et al. (2014), Bramoullé et al. (2016)) and econometrics (Manski (1993), Pesaran et al. (2004), Lee (2007), Bramoullé et al. (2009), Graham (2020)). The literature on networks in econometrics is predominantly concerned with identifying network effects in a static framework of contemporaneous connections, which is ill-suited for our purpose. We build on Mlikota (2023) and model lagged along with contemporaneous interactions. As a result, rather than materializing instantaneously, higher-order network effects can take time to accumulate, which is a necessary feature in empirical work with time series data. As opposed to Mlikota (2023), we have several variables and connection-types per cross-sectional unit—a multi-layer network. Also, we are concerned with shock identification, and we show that limiting the contemporaneous interactions between variables from different countries to the few relationships emphasized in theory can provide an identification assumption by itself.[10] We estimate these links by interacting a low-dimensional vector of parameters with the relevant metric of observed bilateral trade connections. Also, given limited data availability, we assume that the same parameters govern the dynamics in all countries. The resulting parsimony allows us to estimate the system as a whole rather than separate country-level VARs under the conditional exogeneity assumption as done for the Global

[9] In their study of invoicing behavior of Belgian firms, Amiti et al. (2022) use firm size as a proxy for the extent of strategic complementarities a firm faces with local competitors. They find that firm size is one of the key determinants of currency choice (together with the cost share of imported inputs): larger and more import-intensive firms are more likely to deviate from producer currency pricing and choose foreign-currency invoicing in exports.

[10] Another approach for achieving shock identification by relying on networks is discussed in Dahlhaus et al. (2021).

VAR of Pesaran et al. (2004).

The rest of the paper is set out as follows. Section 2 discusses the relevant theory in greater detail, which motivates the setup of our empirical framework, presented in Section 3. In Section 4, we discuss our results. Finally, Section 5 concludes and draws implications for research and policy.

2 Testable Predictions from Theory

Recent theoretical studies (e.g. Gopinath and Stein (2021), Mukhin (2022), Amiti et al. (2022)) provide conceptual frameworks for understanding why a DC can be replaced by another. They point to two major candidate hypotheses, on which we focus in our empirical setup below: reduced exchange rate volatility and stronger trade vis-à-vis the emerging DC area. Moreover, they emphasize cross-country effects—the fact that countries' invoicing currency choices are not just impacted by their own trade patterns and exchange rate volatilities but also by those of their trade partners and competitors, and hence also those of the trade partners and competitors of the latter, etc. Other hypotheses exist, such as a significant deterioration in the fundamentals of the DC issuer (as discussed by e.g. Mukhin (2022)), geopolitical considerations (as discussed by e.g. Eichengreen et al. (2019)), or active policy support (e.g. the availability of currency swap lines in the challenger currency, as discussed in Bahaj and Reis (2020)), but they play a more subordinated role.

2.1 Two Hypotheses

A first major hypothesis as to how a DC can replace another is reduced exchange rate volatility vis-à-vis the emerging DC area. Mukhin (2022) develops a quantitative general equilibrium model with endogenous currency choice, where complementarities in price setting and input-output linkages across firms generate complementarities in invoicing currency decisions, which make exporters coordinate on the same unit of account. Widespread exchange rate pegs to the US dollar explain its central role in world trade. Since many countries try to stabilize their exchange rates vis-à-vis the dollar, it becomes the best substitute for many currencies, in turn increasing the probability that it is also used for invoicing.[11] Given that price linkages give rise to path dependence and inertia, switches in DCs can occur only if a sufficiently large number of countries abandon their exchange rate pegs vis-à-vis the dollar in favor of a peg vis-à-vis the challenger.[12] A similar mechanism is echoed in Amiti et al. (2022) who conclude that if an emerging DC economy, like China, abandoned its peg vis-à-vis the incumbent DC, like the US dollar, for a float, Chinese exporters would be encouraged to increase invoicing in their own currency. This move, as they stress, would impact the dynamics of prices in input markets and the competitive environment in output markets across multiple industries and change the equilibrium environment for exporting firms around the world towards the emerging DC economy.[13]

Another major hypothesis emphasized in recent theory as to how a DC can replace another is stronger trade with the emerging DC area. Gopinath and Stein (2021) propose a theory on DCs that highlights complementarities between a currency's role as a unit of account for invoicing and its role as a safe store of value.[14] In absence of complementarities, use of a currency in trade invoicing would be proportional to the corresponding economy's share of international trade. However, complementarities can lead to the emergence of a single DC for invoicing of trade and global banking even when multiple candidate countries share similarly strong economic fundamentals. A direct implication of this result is that a major shock to the size of the emerging DC economy is required to change the equilibrium. For instance, as the authors point out, if China (or the EA) took up a sufficiently large share of global exports relative to the US, dynamics would eventually get to a point where a renminbi-dominant (or euro-dominant) equilibrium would become inevitable. Size also matters in the model of Mukhin (2022): globally, firms use many intermediate goods and compete with a large number of firms from the US, because it is

[11]The fact that many emerging economies have high inflation amplifies the mechanism, insofar as their own currencies are ill-suited for invoicing.

[12]Mukhin considers a counterfactual simulation where China abandons its peg to the dollar and several emerging economies follow suit to use the renminbi as a new anchor currency. In the counterfactual, while path dependence prevents the renminbi from becoming the new DC, it is not strong enough for the dollar to keep its dominant role. Therefore, the global economy moves to a new equilibrium with multiple regional currencies, where both the dollar and the renminbi play consequential roles.

[13]In line with this, their empirical estimates suggest that the currency in which a firm's imports are invoiced and the currency in which its competitors price are important determinants of exporters' invoicing currency choices.

[14]In a nutshell, under sticky prices, households and importing firms tend to prefer deposits denominated in the currency in which imports are invoiced. This in turn creates an incentive for private financial intermediaries to create deposits and offer loans in the same currency. With more debt the currency in question, domestic exporters will prefer to use it for export pricing.

a large economy. This makes prices sensitive to the dollar's exchange rate and increases the odds that they choose to price in US dollars. This said, counterfactual simulations from the model point to a stronger role of the exchange rate volatility shock in switches from one DC to another—a substantial increase in China' share in world manufacturing exports would not lead the US dollar to lose its DC role, unless China and other emerging markets also abandon their pegs vis-à-vis the greenback.[15]

Both the models of Mukhin (2022) and Gopinath and Stein (2021) emphasize cross-country effects. In Mukhin's model, owing to price linkages, each exporting firm wants to synchronize its price with the prices of suppliers on the import side and with the prices of competitors on the export side. In Gopinath and Stein's model, the fact that a country's import invoicing currency is given by other countries' export invoicing currencies is crucial for their complementarity mechanism—which operates within a country—to lead to the emergence of a single DC across countries. In our empirical setup below, we model cross-country effects in the spirit of these models in three ways. First, a country's euro share of imports is mechanically related to the euro share of exports of its import partners; second, a country's euro share of exports is affected by the euro and US dollar exchange rate volatilities of its export destination markets' local currencies; and third, there is a direct effect of a country's euro share of exports on another's, on top of the indirect one mentioned above operating via the latter's euro share of imports.

2.2 Preliminary Evidence

Descriptive evidence suggests that there is merit in considering both hypotheses in explaining the ascent of the euro at the expense of the dollar in European trade in the past decades. The left panel of Figure 3 shows that the average EA neighbor's share of exports destined to EA countries increased significantly between the early 1990s and the mid-2000s, which is consistent with the trade shock hypothesis. In parallel, the share of exports to the United States declined somewhat since the early 1990s. Trade

[15] Although this is not modeled explicitly, it is safe to assume that reduced exchange rate volatility would increase the likelihood that a currency becomes dominant in the model of Gopinath and Stein (2021). This is because this would facilitate feedback mechanisms between a currency's role as a unit of account for invoicing and its role as a safe store of value. At the very least, if households' consumption baskets include goods priced in local currency, households are more likely to hold deposits in the foreign currency with the least volatile bilateral exchange rate against the domestic currency. A similar reasoning could apply for banks' incentives to provide deposits and loans—and local firms to demand loans—in the foreign currency in question.

developments since 1999 are more stable.[16]

The right panel of Figure 3 shows that exchange rate volatility against the euro declined significantly throughout the 1990s as exchange rate policies in many EA neighbors turned to the euro as a nominal anchor. At the same time, exchange rate volatility against the US dollar declined as well, albeit to a lesser extent. These developments are consistent with the exchange rate volatility hypothesis.[17] The fact that the most pronounced changes in export destinations and exchange rate volatility occurred in the 1990s suggests that we need to identify shocks that occurred prior to the start of our invoicing currency data (i.e. 1999). Section 3.4 explains how we achieve this.

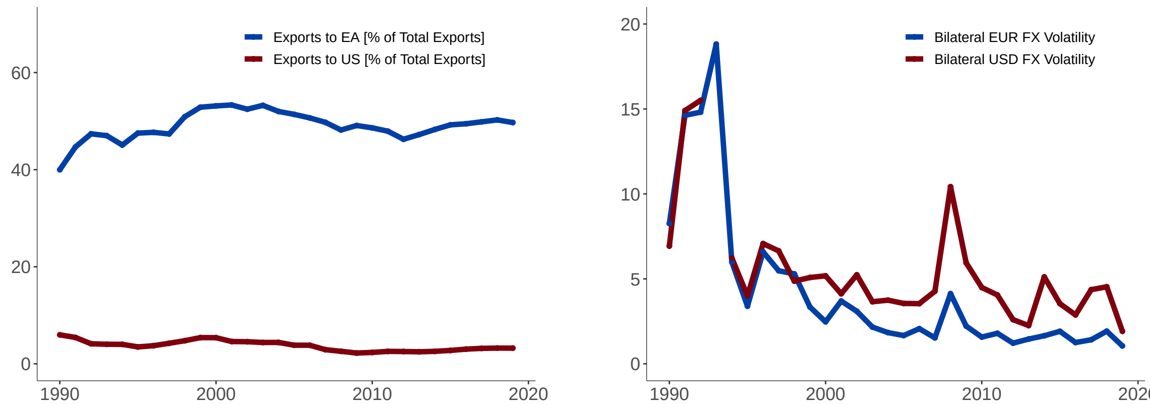

Figure 3: Evolution of Cross-Country Averages of Exchange Rate Volatilities and Share of Exports (by Base Currency/Destination)

Notes: The figure plots the shares of exports destined to the Euro Area and the US, respectively, EX_{it}^{EA} and EX_{it}^{US} (left panel) and bilateral exchange rate volatilities against the euro and US dollar, $FX_{it}^{€}$ and $FX_{it}^{\$}$ (right panel), both averaged across countries in the sample.

Prima facie evidence across countries is favorable to the increased trade-hypothesis, but not the reduced exchange rate volatility-hypothesis. Figure 4 plots changes in the share of exports invoiced in euro in each country over the sample period against changes in the share of exports destined to the EA relative to the US (in the left panel), and against changes in bilateral exchange rate volatility against the euro relative to the US dollar (in the right panel). Euro invoicing increases are larger in countries with higher increases in relative exports to the EA. The correlation with changes in (relative) exchange rate volatility is more tenuous, in contrast, which might point to a stronger role for the trade

[16] Figure B.2 shows the evolution separately for each country in our sample. In all countries, the share of exports to the US has been remarkably stable in the past 30 years for most countries. There was presumably no “US trade shock”, in other words. In contrast, developments in the share of exports destined to the EA have been more varied. Figure B.3 shows the equivalent data for imports.

[17] Figure B.4 shows the corresponding developments by country.

shock hypothesis than for the exchange rate volatility shock hypothesis. We now turn to explaining how we test formally for the two hypotheses.

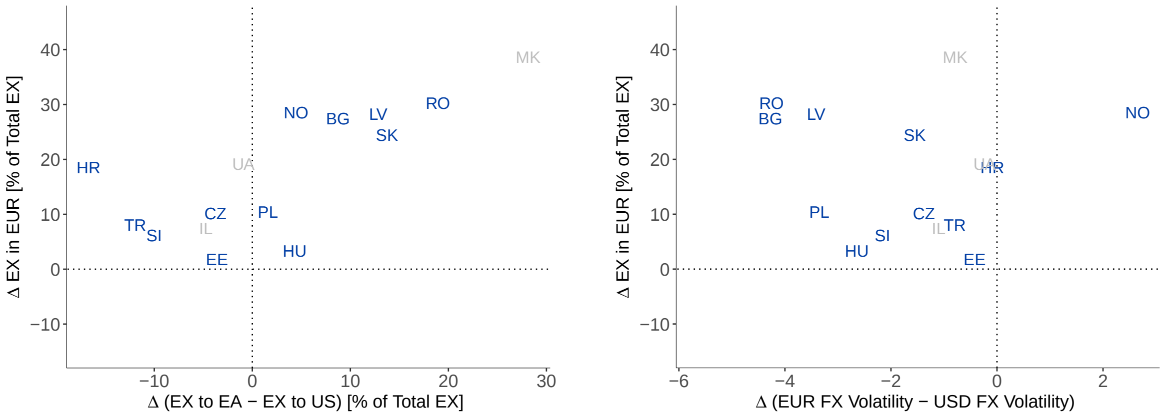

Figure 4: Long-Term Changes in Euro Shares of Exports and Potential Determinants

Notes: The figure plots overall changes in the euro share of exports, $EX^{€}_{it}$, from 2000 to 2019 in each country against changes in the share of exports destined to the Euro Area relative to the US, $EX^{EA}_{it} - EX^{US}_{it}$ (left panel) and against changes in bilateral exchange rate volatility against the euro relative to the US dollar, $FX^{€}_{it} - FX^{\$}_{it}$ (right panel). The latter two are computed as changes in mean values from 1990-1995 to 2015-2020. Countries in gray are included only in the broader sample (see Section 3.1).

3 A Panel-SVAR with Cross-Country Effects

As Section 2 makes clear, a country's euro share of exports depends on several variables, both domestic and foreign. Mirroring this, we build a Panel-VAR to capture the dynamics of invoicing currency choices, trade and exchange rate volatilities for multiple countries. In turn, we identify (country-level) shocks to trade and exchange rate volatility, and determine their contributions to the observed increases in euro shares of exports (across countries) using a historical decomposition. In contrast to static panel data regressions, this setup enables us to not only identify the determinants of invoicing currency choice levels at a given point in time, but to also analyze the dynamic aspects of any such relationships. In addition, the setup permits us to model cross-country connections emphasized in theory, which ultimately link a country's invoicing currency choice to developments in other countries with which it interacts in the global trade network. After presenting the Panel-VAR in Section 3.1, we discuss cross-country effects in Section 3.2. We then review our cointegration assumptions in Section 3.3 and finally discuss shock identification and further parameter restrictions in Section 3.4.

3.1 Panel-VAR

Let $y_{it} = [EX_{it}^{€}, IM_{it}^{€}, FX_{it}^{€-\$}, EX_{it}^{EA-US}]'$ be a 4×1 vector which contains country i's euro share of exports $EX_{it}^{€}$, euro share of imports $IM_{it}^{€}$, the difference between its bilateral euro and US dollar exchange rate volatilities, $FX_{it}^{€-\$} = FX_{it}^{€} - FX_{it}^{\$}$, and the difference between the shares of exports destined to the euro area (EA) and the US, $EX_{it}^{EA-US} = EX_{it}^{EA} - EX_{it}^{US}$. In turn, let $y_t = [y'_{1t}, ..., y'_{nt}]$ be a $4n \times 1$ vector that stacks y_{it} for all n countries in our sample. Analogously, let $\varepsilon_t = [\varepsilon'_{1t}, ..., \varepsilon'_{nt}]'$, whereby $\varepsilon_{it} = [\varepsilon_{i1t}, ..., \varepsilon_{i4t}]'$ and $\varepsilon_{ivt} \overset{iid}{\sim} N(0, \sigma_{iv}^2)$ is the shock to variable $v \in 1:4$ of country i.[18]

We use annual data on the currency denomination of exports and imports in value gathered by Boz et al. (2022). For most European countries, these series start only in 1999, which is why we focus on the period 1999-2019.[19] Our sample includes countries which are non-inaugural members of the EA and for which there is satisfactory invoicing data over this period. This leads to $n = 13$ in the baseline sample.[20] Exchange rate data are obtained from the BIS database, while bilateral trade data come from the IMF's Direction of Trade Statistics.[21] These series are available earlier than 1999 and for a much wider set of countries. For the setup below it is convenient to denote by $\mathcal{C}$ the set of sample countries, by $\mathcal{W}$ the set of countries for which we have trade and exchange rate data and by $\mathcal{E} = \mathcal{W} \backslash \mathcal{C}$ the set of countries excluded from our sample.

We can write the structural form representation of our Panel-VAR as follows:

$$\mathbf{A}_t y_t = \mathbf{k} + \sum_{l=1}^{p} \mathbf{B}_t^l y_{t-l} + \sum_{l=0}^{p} \mathbf{C}_l z_{t-l} + \varepsilon_t \ . \tag{3.1}$$

The vector $\mathbf{k} = [k'_1, ..., k'_n]'$ stacks the intercepts k_i for each country i. The $4n \times 4n$ matrices $\mathbf{A}_t$ and $\{\mathbf{B}_t^l\}_{l=1}^p$ can be partitioned into 4×4 blocks. The diagonal blocks A_{ii}

[18] Whenever convenient to simplify notation, we write $a : b$ for the set of integers $a, a+1, ..., b$, $a \leq b$.

[19] Only for Hungary and Poland do the series start significantly before 1999. North Macedonia starts in 1998.

[20] Our baseline sample consists of countries without missing observations for several years in a row. Such occasional missing observations can be seen in Figures 2 and B.1. Missing observations are imputed using linear interpolation and constant extrapolation. In addition, we do not consider countries with less than 0.5 million inhabitants. This leads to $n = 13$ countries: Bulgaria (BG), Czech Republic (CZ), Estonia (EE), Croatia (HR), Hungary (HU), Lithuania (LT), Latvia (LV), Norway (NO), Poland (PL), Romania (RO), Slovenia (SI), Slovakia (SK) and Turkey (TK). In a robustness exercise, we add Israel (IL), North Macedonia (MK) and Ukraine (UA), which have at most three consecutive years missing.

[21] We compute $FX_{it}^{€}$ as the percentage standard deviation of the daily exchange rate between country i's currency and the euro in year t, and analogously for $FX_{it}^{\$}$. None of the results change when we use weekly exchange rates instead.

and B^l_{ii} contain the responses of country i's variables, y_{it}, to its own contemporaneous and lagged movements, respectively. The off-diagonal blocks A_{ijt} and B^l_{ijt} contain the responses of y_{it} to contemporaneous and lagged movements of country j's variables, y_{jt}. The matrices $\{\mathbf{C}_l\}_{l=0}^p$ capture the impact of variables of countries outside our sample, included in z_t.

Under $A_{ijt} = 0$, $B^l_{ijt} = 0$ and $\mathbf{C}_l = 0 \ \forall \ i, j, l$, this framework yields a set of (independent) country-level VARs:

$$Ay_{it} = k_i + \sum_{l=0}^{p} B^l y_{i,t-l} + \varepsilon_{it} \ . \tag{3.2}$$

To achieve the necessary parsimony under limited data availability, we assume that the dynamic relationships among y_{it} are the same for all countries i: $A_{ii} = A$ and $B^l_{ii} = B^l$ $\forall \ i$. However, we allow for cross-country heterogeneity in levels and shock volatilities. The restrictions on A, $\{B^l\}_{l=1}^p$ and k_i are discussed in Sections 3.3 and 3.4. But first, in Section 3.2, we discuss the extent to which our framework augments the above country-level VARs, i.e. we discuss the cross-country effects captured by A_{ijt}, $\{B^l_{ijt}\}_{l=1}^p$ and $\{\mathbf{C}_l z_{t-l}\}_{l=0}^p$.

3.2 Cross-Country (Network) Effects

Theory points to three relationships that a country's euro share of exports depends on developments in other countries. First, a country's euro share of imports is mechanically related to the euro share of exports of its import partners. Specifically, we have

$$IM^{€}_{it} = \sum_{j \in \mathcal{W}} m_{ijt} IM^{€}_{ijt} = \sum_{j \in \mathcal{W}} m_{ijt} EX^{€}_{jit} \ , \tag{3.3}$$

where $m_{ijt} = IM_{ijt}/IM_{it}$ denotes country j's share in the imports of country i and $IM^{€}_{ijt} = EX^{€}_{jit}$ is the share of this trade invoiced in euro. In turn, $EX^{€}_{jit}$ appears in $EX^{€}_{jt}$:

$$EX^{€}_{jt} = \sum_{k \in \mathcal{W}} x_{jkt} EX^{€}_{jkt} \ ,$$

where $x_{jkt} = EX_{jkt}/EX_{jt}$ denotes the share of country j's exports destined to country k. In the absence of bilateral invoicing data, we capture the resulting effect of $EX^{€}_{jt}$ on $IM^{€}_{it}$

by assuming that any change in $EX_{jt}^{€}$ is equally reflected in j's exports to all countries k, i.e. we assume $\partial EX_{jkt}^{€}/\partial EX_{jt}^{€} = 1 \; \forall \; k$. This implies

$$\partial IM_{it}^{€}/\partial EX_{jt}^{€} = m_{ijt} \; .^{22} \tag{3.4}$$

Provided that $IM_{it}^{€}$ affects $EX_{it}^{€}$—be it through the use of imported goods in export good production, as emphasized in Mukhin (2022), or through a financial channel operating via households' deposit and banks' lending currency choices, as emphasized in Gopinath and Stein (2021)—this mechanical cross-country effect leads to a channel by which $EX_{jt}^{€}$ affects $EX_{it}^{€}$.

Second, a country's euro share of exports is affected by the euro and US dollar exchange rate volatilities of its export destination markets' local currencies. As discussed in Mukhin (2022), under the presence of nominal rigidities, firms choose to invoice in the currency in which their desired, flexible price is most stable. If there are strategic compelementarities in price setting, the prices of local competitors at their export destination markets—assumed to invoice in their local currency—enter this calculation. Therefore, we would expect firms in country i to use more the euro (as opposed to the US dollar) in their exports to country j if the volatility of the local currency in j vis-à-vis the euro decreases relative to its volatility vis-à-vis the US dollar. In our model, we allow for both contemporaneous and lagged such effects, parameterized by $\{\gamma_l\}_{l=0}^{p}$, which we estimate. More specifically, we let

$$\partial EX_{ijt}^{€}/\partial FX_{j,t-l}^{€-\$} = \gamma_l \; ,$$

which implies

$$\partial EX_{it}^{€}/\partial FX_{j,t-l}^{€-\$} = x_{ijt}\gamma_l \; . \tag{3.5}$$

Third, there is a direct effect of a country's euro share of exports on another's, on top of the indirect one mentioned above. Just as local competitors enter firms' invoicing

[22] As Equation (3.3) makes clear, if we had bilateral invoicing data to break up $EX_{jt}^{€}$ into $\{EX_{jkt}^{€}\}_{k\in\mathcal{W}}$ for all j, we could perfectly construct $IM_{it}^{€}$ without any error. In our analysis, we do have an error because of our approximation of $EX_{jkt}^{€}$ by $EX_{jt}^{€}$ and due to the fact that not all import partners of i are included in the analysis.

currency decisions under strategic complementarities, so do exporters from other countries which compete in the same local markets. Therefore, we would expect firms in country i to use more the euro (as opposed to the US dollar) in their exports to country k if the firms from another country j use more the euro in their exports to country k, even more so if the firms from j have a high market share in k. Again we model this effect to be both contemporaneous and lagged, parameterized by $\{q_l\}_{l=0}^{p}$. Also, we approximate said market share by the share of country k's imports coming from country j. This leads to

$$\partial EX_{ikt}^{€}/\partial EX_{jk,t-l}^{€} = m_{kj,t-l}\, q_l \ .$$

Together with the previous assumption that $\partial EX_{jkt}^{€}/\partial EX_{jt}^{€} = 1\ \forall\ k$, this implies

$$\partial EX_{it}^{€}/\partial EX_{j,t-l}^{€} = \sum_{k\in\mathcal{W}} x_{ikt} m_{kj,t-l} q_l \ . \tag{3.6}$$

In this expression, $\chi_{ijt}^{l} \equiv \sum_{k\in\mathcal{W}} x_{ikt} m_{kj,t-l}$ is a measure of the importance of competitor-country j for the invoicing currency choice of country i at different lags l. It reflects the expectation that country i's invoicing currency decision is impacted by that of country j to the extent that country j is present as an exporter in country i's export destination market k.

In sum, the cross-country effects in equations 3.4, 3.5 and 3.6 imply the following parameterization of A_{ijt} and B_{ijt}^{l}, $i, j \in \mathcal{C}$:

$$A_{ijt} = \begin{bmatrix} -q_0\chi_{ijt}^{0} & 0 & -\gamma_0 x_{ijt} & 0 \\ -m_{ijt} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} , \quad B_{ijt}^{l} = \begin{bmatrix} q_l\chi_{ijt}^{l} & 0 & \gamma_l x_{ijt} & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} , \quad l = 1:p \ , \tag{3.7}$$

recalling that $y_{it} = [EX_{it}^{€}, IM_{it}^{€}, FX_{it}^{€-\$}, EX_{it}^{EA-US}]'$. Because we have data on exchange rate volatilities also for countries which are excluded from the sample (due to lack of invoicing data availability), we can let $EX_{it}^{€}$ be affected by $FX_{j,t-l}^{€-\$}$ not only for $j \in \mathcal{C}$, but for $j \in \mathcal{W} \supset \mathcal{C}$. While element (1,3) in the matrices A_{ijt} and B_{ijt}^{l} above takes care of this effect for $j \in \mathcal{C}$, the terms $\{\mathbf{C}_l z_{t-l}\}_{l=0}^{p}$ add the effect for $j \in \mathcal{E} = \mathcal{W} \backslash \mathcal{C}$:

$$\mathbf{C}_l z_{t-l} = \left[\gamma_l \sum_{j \in \mathcal{E}} x_{ijt} FX_{jt-l}^{€-\$} \; , \quad 0 \; , \quad 0 \; , \quad 0 \right]' \; , \quad l = 0 : p \; .$$

These terms are plausibly exogenous because the small open economies in our sample are unlikely to influence the exchange rate volatilites of their major export partners.

Owing to cross-country effects, $\mathbf{A}_t$ and $\{\mathbf{B}_t^l\}_{l=1}^{p}$ can be interpreted as network-adjacency matrices, which summarize the contemporaneous and lagged relationships, respectively, between the variables y_{it} of different countries i. The variables of every country are linked to their own current and past values via the diagonal elements A and $\{B^l\}_{l=1}^{p}$, just as would be the case under (independent) country-level VARs. In addition, there are directed and weighted links from country j's variables to country i's variables, contained in A_{ijt} and $\{B_{ijt}^l\}_{l=1}^{p}$. These matrices summarize the direct effects of $\{y_{jt-l}\}_{l=0}^{p}$ on y_{it}—and in particular on $EX_{it}^{€}$—which are the result of the direct interaction of countries i and j in international trade. This interaction can happen contemporaneously or with a lag, and it takes several forms, as captured by the three cross-country effects discussed above. A standard result from network science is that these direct links give rise to higher-order connections between countries. Correspondingly, our framework captures the insight from theory that a country's euro share of exports is not only impacted by its own fundamentals ($FX_{it}^{€-\$}$ and EX_{it}^{EA-US}), but also those of its trade partners (and competitors), the trade partners of its trade partners, etc. The extent to which all these higher-order effects play out contemporaneously is determined by the cross-country effects A_{ijt} in $\mathbf{A}_t$, while the extent to which these higher-order effects take time to unfold is given by the cross-country effects B_{ijt}^l in $\mathbf{B}_t^l$ (see Mlikota (2023)).

3.3 Cointegration

The variables in y_t are non-stationary. In fact, their pronounced changes over the sample are the very object of analysis; our focus is on understanding to what extent increases in $EX_{it}^{€}$ and $IM_{it}^{€}$ are due to decreases in $\{FX_{jt}^{€-\$}\}_{j \in \mathcal{C}}$ and increases in $\{EX_{jt}^{EA-US}\}_{j \in \mathcal{C}}$.

As a result, the common procedure in applied time series analysis of working with detrended variables is not suitable. Modeling all variables in first differences is not appealing either, as it removes too much information and presupposes a separate stochastic trend in each variable. Instead, in the spirit of Phillips (1991), we combine equations in levels for $\{EX_{it}^{€}, IM_{it}^{€}\}_{i\in\mathcal{C}}$ with equations in first differences for $\{FX_{it}^{€-\$}, EX_{it}^{EA-US}\}_{i\in\mathcal{C}}$. This means that we assume stochastic trends in the explanatory variables, $\{FX_{it}^{€-\$}\}_{i\in\mathcal{C}}$ and $\{EX_{it}^{EA-US}\}_{i\in\mathcal{C}}$, while allowing for the possibility of additional (own) stochastic trends in the invoicing variables, $\{EX_{it}^{€}\}_{i\in\mathcal{C}}$ and $\{IM_{it}^{€}\}_{i\in\mathcal{C}}$, by estimating the coefficients in front of their lags in an unrestricted way. As a result, our setup can accommodate other causes besides decreases in exchange rate volatilities and increases in trade as determinants of countries' increases in euro shares of exports. In a nutshell, our analysis is about estimating to what extent the stochastic trend in the invoicing variables is due to the stochastic trend in exchange rate volatility, the stochastic trend in trade, or a third stochastic trend inherent in the invoicing variables as well as identifying which shocks drive these stochastic trends.

To accommodate this setup, we reparameterize our model as follows. Partition $y_{it} = [y_{it}^{1\prime}, y_{it}^{2\prime}]'$ into the 2×1 vectors $y_{it}^1 = [EX_{it}^{€}, IM_{it}^{€}]'$ and $y_{it}^1 = [FX_{it}^{€-\$}, EX_{it}^{EA-US}]'$, and analogously for $k_i = [k_i^{1\prime}, k_i^{2\prime}]'$ and $\varepsilon_{it} = [\varepsilon_{it}^{1\prime}, \varepsilon_{it}^{2\prime}]'$. Correspondingly, partition A and B^l into four 2×2 blocks, respectively: $A_{11}, A_{12}, A_{21}, A_{22}$ and $B_{11}^l, B_{12}^l, B_{21}^l, B_{22}^l$. We have

$$A_{22}y_{it}^2 + A_{21}y_{it}^1 = k_i^2 + \sum_{l=1}^{p}\left\{B_{22}^l y_{i,t-l}^2 + B_{21}^l y_{i,t-l}^1\right\} + \varepsilon_{it}^2 \ .$$

Note that, following the analysis in Section 3.2, there are no cross-country effects in the equations for y_{it}^2. We model y_{it}^2 in first differences as

$$\tilde{A}_{22}\Delta y_{it}^2 + A_{21}y_{it}^1 = k_i^2 + \sum_{l=1}^{p-1}\left\{\tilde{B}_{22}^l \Delta y_{i,t-l}^2 + B_{21}^l y_{i,t-l}^1\right\} + \varepsilon_{it}^2 \ ,$$

which is equivalent to the above for $\tilde{A}_{22}$ and $\{\tilde{B}_{22}^l\}_{l=1}^{p-1}$ given by the following relations:

$$A_{22} = \tilde{A}_{22} \ , \qquad B_{22}^1 = \tilde{B}_{22}^1 + \tilde{A}_{22} \ ,$$
$$B_{22}^l = \tilde{B}_{22}^l - \tilde{B}_{22}^{l-1} \ , \quad l = 2:p-1 \ , \qquad B_{22}^p = \tilde{B}_{22}^{p-1} \ .$$

3.4 Shock Identification and Parameter Restrictions

Following the discussion in Sections 3.1 and 3.3, our parameters of interest are

$$A_{1\cdot}, A_{21}, \tilde{A}_{22}, \{B^l_{1\cdot}, B^l_{21}\}^p_{l=1}, \{\tilde{B}^l_{22}\}^{p-1}_{l=1}, \{k_i\}_{i\in\mathcal{C}}, \{q_l, \gamma_l\}^p_{l=0}, \{\sigma_{iv}\}_{i\in\mathcal{C},v=1:4}\,.^{23} \tag{3.8}$$

In this section, we discuss the restrictions we impose on them. To avoid confusion with the notation from Section 3.3, we denote element (g,h) of the matrix X by $X_{(g,h)}$.

In our baseline specification, we set:

1. $A_{(3,4)} = 0:$ $FX^{€-\$}_{it}$ is not impacted contemporaneously by EX^{EA-US}_{it}. We motivate this with the exchange rate disconnect, the well-documented lack of empirical correlation between exchange rates and fundamentals in the short run (see e.g. Obstfeld and Rogoff (2000), Itskhoki and Mukhin (2021)).[24] This restriction is crucial as it allows us to separate shocks to these two variables.

2. $A_{21} = 0,\ B^l_{21} = 0,\ l = 1:p:$ $FX^{€-\$}_{it}$ and EX^{EA-US}_{it} are not impacted by $EX^{€}_{it}$ and $IM^{€}_{it}$. We impose this restriction in our baseline specification because it allows us to identify exchange rate volatility and trade shocks prior to the start of our invoicing sample in 1999 (see Appendix A). This is crucial as the most pronounced movements in these variables happened prior to 1999.

   We relax this assumption in robustness checks below. Specifically, although theory posits that the choice of trade partners precedes the choice of currency denomination of trade, we allow EX^{EA-US}_{it} to be impacted by $EX^{€}_{it}$ and $IM^{€}_{it}$. We also allow $FX^{€-\$}_{it}$ to be impacted by $IM^{€}_{it}$, but not by $EX^{€}_{it}$, following standard theory which assumes that exchange rate policies are chosen so as to stabilize domestic prices.

Shock identification across countries is the result of restrictions imposed on $\{A_{ijt}\}_{i,j\in\mathcal{C}}$, i.e. the limitation of cross-country effects to the ones emphasized in theory and discussed in Section 3.2. The assumption is that, conditional on the contemporaneous cross-country effects we include, shocks are uncorrelated across countries. The identification of shocks $\{\varepsilon_{ivt}\}_{v=1:n}$ to different variables within a country is the result of restrictions imposed

[23] With the understanding that under $p = 1$, $\{\tilde{B}^l_{22}\}^{p-1}_{l=1} = \emptyset$. By $A_{1\cdot}$ we denote the matrix containing both upper blocks in $A - A_{1\cdot} = [A_{11}A_{12}]$—and analogously for $B^l_{1\cdot}$.

[24] With our reparameterization, we implement this restriction on $\tilde{A}_{22}$. Setting $A_{(3,4)} = 0$ is equivalent to setting element (1,2) in the 2×2 matrix $\tilde{A}_{22}$ to zero because $A_{22} = \tilde{A}_{22}$.

both on A and $\{A_{ijt}\}_{i,j\in\mathcal{C}}$. As a result of the particular parameterization of A_{ijt} in Equation (3.7), the restriction $A_{(3,4)} = 0$ is sufficient to achieve point identification because it ensures that every row of $\mathbf{A}_t$ has a different set of non-zero elements (all while the number of free parameters in $\mathbf{A}_t$ is $\ll 4n(4n+1)/2$, the number of non-redundant elements in the variance of reduced form errors, which can be identified from the data).

In addition to these restrictions, we set $k_i^2 = 0 \ \forall \ i$, which excludes trends in first differences of $FX_{it}^{€-\$}$ and EX_{it}^{EA-US}. By definition, EX_{it}^{EA-US} is bounded to $[0, 100]$ and therefore cannot have a long-term trend. Similarly, $FX_{it}^{€-\$} \geq 0$ cannot have a long-term downward trend, while an upward trend would imply exploding exchange rate volatility.[25]

4 Results

In this section, we discuss the empirical importance of shocks to exchange rate volatility and trade for the increase in the euro share of exports in our set of 13 European countries. We estimate our Panel-VAR model using Maximum Likelihood, implemented via numerical optimization with supplied gradient. In our baseline specification, we consider one lag, i.e. $p = 1$, in order not to exclude important data from the earlier part of our sample when most of the increase in euro invoicing occurred while also minimizing the number of estimated parameters.[26] Estimation shows that the cointegration setup performs well as the estimated shocks are white noise as illustrated in Figure B.5, hence indicating that spurious correlation is not a concern.

In what follows, Section Section 4.1 discusses the estimated impulse response functions, Section 4.2 decomposes the historical rise in the euro share of exports in its estimated components and Section 4.3 evaluates through which channel network effects arise. Finally, Section 4.4 discusses the robustness of the results.

[25]Also, we normalize the diagonal of A (i.e. the diagonals of A_{11} and $\tilde{A}_{22}$) to ones. This is without loss of generality as we allow for shock variances different from unity: $\varepsilon_{ivt} \sim N(0, \sigma_{iv}^2)$.

[26]Under $p = 1$, we have 97 parameters to estimate from 1,040 observations ($4nT = 4 \cdot 13 \cdot 20$), resulting in a observations-parameters ratio of 10.72. Under $p = 2$, the numbers are 988 and 111, respectively, leading to a rather low ratio of 8.9. As discussed in Section 4.4, taking instead $p = 2$ has only negligible effects on impulse responses.

4.1 Impulse Responses: Which Hypothesis Matters?

Figure 5 shows the estimated response of the fraction of exports invoiced in euro to one standard deviation shocks to relative euro and US dollar exchange rate volatilities and the share of exports to the EA relative to the US. We consider both domestic and foreign shocks, with the latter being implemented as a simultaneous one standard deviation shock to all other sample countries. As the coefficient matrices are time-varying due to variation in the trade shares scaling the cross-country effects, we show the estimated dynamics at the start of our sample, in the year 2000 (i.e. $t = 1$), which is when most of the movements in the shocked variables happened.[27] In the figures, the thick blue line represents the estimated average response across countries, along with the corresponding 95% confidence interval. The thin lines show country-specific dynamics, which can differ depending on the size of the shock (in case of a domestic and foreign shock) and bilateral trade exposures (in case of a foreign shock).[28] The full set of estimated impulse response functions is depicted in Figures B.6 and B.7 in the appendix.

For our set of European countries, there is no evidence that lower exchange rate volatility significantly affects the fraction of a country's exports invoiced in euro (see left column in Figure 5). This holds for domestic exchange rate volatility and for when the exchange rates of a country's trading partners become less volatile. This result contrasts with the literature that emphasizes the importance of exchange rate anchoring for how a DC can replace another, as illustrated in the calibrated model simulations of Mukhin (2022) for example. In the case of Europe, it appears that the substantial gains in exchange rate stability against the euro did little to foster the use of the euro in trade invoicing.

This finding is intuitive. It is consistent with what the scatter plot in Figure 4 suggests. As Figure B.4 further shows, the notable decline in exchange rate volatility of our countries' exchange rates against the euro went mostly hand-in-hand with a comparably strong decline in exchange rate volatility against the US dollar. Euro area neighbours that started to peg their currency to the euro, or those which eventually adopted the euro,

[27] As discussed in Appendix A, the exogeneity of bilateral trade shares is likely to be violated. However, conditioning on their evolution arguably underestimates the effects of our two shocks of interest as it ignores their indirect effects on countries' euro share of exports through increasing bilateral trade (i.e. more potent cross-country effects over time).

[28] Note that the impulse response functions do not revert back to zero because of non-stationarity.

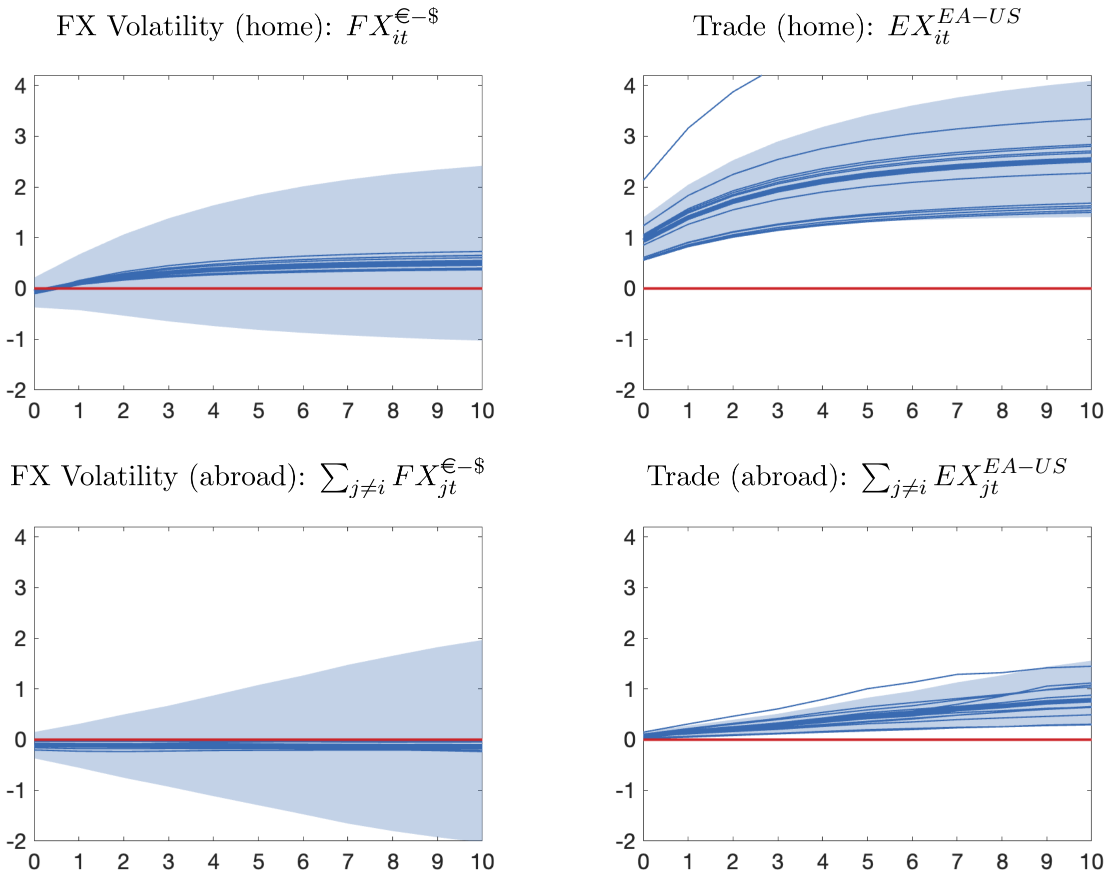

Figure 5: Impulse Responses of Euro Share of Exports

Notes: The plots show the impulse responses of the euro share of exports, $EX_{it}^{€}$, to a one-standard deviation increase in $FX_{it}^{€-\$}$ (left column) and EX_{it}^{EA-US} (right column) in the year 2000. The top row refers to a shock in the corresponding variable in country i itself, while the bottom row illustrates the responses to a simultaneous increase in the corresponding series for all other countries but country i. The thick blue line shows the average response across countries, whereas the thin lines show country-specific responses.

did experience a more pronounced reduction in volatility against the euro than relative to the US dollar. But even for these countries, such as Bulgaria and Latvia, the difference is not that large from a long-term perspective when considering how high volatility was historically against both currencies. To explain switches between two currencies with the exchange rate volatility hypothesis, it is *relative* exchange rate volatility against the euro versus the US dollar that matters. And the latter has changed much less in our sample countries compared with the decline in volatility against the euro in isolation.

By contrast, shocks to EA trade are found to be important determinants of euro invoicing. On average, a one standard deviation shock to a country's share of exports to the EA relative to the US is found to significantly increase the euro share of exports by 1 percent on impact (see upper right chart in Figure 5). The effect is persistent, and increases over time to reach twice its initial size after about 5 years. Interestingly, not only trade shocks at home, but also higher EA trade of trading partners drive domestic use of the euro for export invoicing (see the lower right chart). The effect takes time to unfold but is significant, persistent and economically meaningful in size. After an increase in exports to the EA (relative to US) by about 1 pp. in all 12 other countries in the sample, a country's euro share of exports is estimated to increase by 0.5 pp. after 5 years. It underlines the importance of accounting for cross-country linkages in analyzing switches in DCs.

The relevance of trade shocks in our estimates corroborates the literature emphasizing that large, positive shocks to the challenger's role in global trade are needed for a DC to replace another, as discussed in Section 2. It underpins the positive correlation between changes in trade patterns and changes in EUR invoicing shown in Figure 4 using structural empirical analysis. In some European countries, the share of exports destined to the EA has risen remarkably int the past decades, which contributed to explain the rise in the use of the euro for trade invoicing in these countries. But in other countries euro invoicing rose although exports to the EA relative to the US remained stable, or even declined relative, as shown in Figure B.2. We turn in the next section to quantifying how much of the rise in the euro share of exports can be explained by changes in trade patterns relative to other factors.

4.2 Historical Decomposition: Why Did Euro Invoicing Rise?

Figure 6 shows the estimated historical contributions of the two identified shocks to the overall increases in the euro shares of exports from 2000 ($t = 1$) to 2019 across countries. As discussed in Section 3.4, the shocks pertain to the period 1995-2019, with dark (light) shaded bars indicating the contribution of domestic (foreign) shocks. Several results stand out.

First, the results confirm that—of the two hypothesis tested in our empirical framework–trade shocks have been dominant in explaining the rise in the euro share of exports in our set of European countries, rather than shocks to exchange rate volatility. The effect of trade is economically relevant. In countries where trade links with the EA increased, the shock explains on average almost 40% of the rise in the share of exports invoiced in

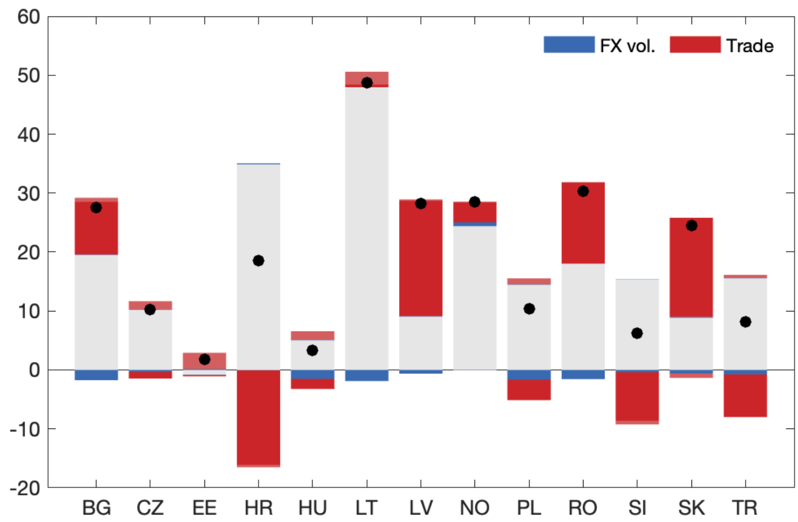

Figure 6: Historical Decomposition of Euro Share of Exports Increases Across Countries
Notes: For each country, the black dot indicates the increase in the euro share of exports, $EX_{it}^{€}$, from 2000 to 2019. The blue and red bars, respectively, show the estimated contributions of shocks to $FX_{it}^{€-\$}$ and EX_{it}^{EA-US} which occurred during 1995-2019.

euro between 2000 and 2019.[29]

However, the importance of the trade shock differs across countries. For some countries, such as Bulgaria, Latvia, Romania and Slovakia, between one-third to two-thirds of the increase in the share of the euro for export invoicing can be ascribed to stronger export orientation towards the EA. It is these countries that experienced the strongest increases in export shares to the euro area relative to the US, as shown in Figure 4, and some of the largest increases in euro invoicing in turn. Moreover, there is evidence that cross-country effects are relevant. For instance, in countries where the share of the EA in total exports remained more stable, such as Estonia, stronger trade links between the euro area and the trade partners of the countries in question resulted in a slight rise of the share of the euro for export invoicing. Finally, in countries where the share of the euro area in total exports declined to the benefit of the US, such as Croatia, Slovenia and Turkey, the model estimates pick up the fact that weaker trade linkages discouraged use of the euro for export invoicing. However, residual factors more than offset these effects, thereby leading to an increase in euro invoicing even in these economies.

A second finding is that most of the dynamics in euro trade invoicing have been driven by domestic shocks. The impulse responses in Section 4.1 show that foreign trade shocks are significant determinants of invoicing currency choices. However, there was no *general*

[29]The mean increase in the euro share of exports is around 31 percentage points.

re-orientation of trade towards the EA across countries in the sample but rather mixed developments, as mentioned before. Increases in export shares to the EA of some trading partners were counterbalanced by lower or stagnant shares of other trading partners. This dampened the overall importance of foreign shocks as determinants of the rise in the euro share of exports among our sample countries, notwithstanding the fact that cross-country linkages matter, as Figure 5 shows.

Finally, it is evident that other factors besides exchange rate volatility and trade patterns contributed to the increase in the use of the euro for export invoicing at the expense of the US dollar. On average, trade shocks explain close to 40% of the observed rise in the euro share of exports in countries where trade links with the EA increased, but the remaining part is left unexplained. Of course, this part is much higher for countries where exports to the EA either stalled or declined in relative terms. The residual component encapsulates other important determinants of invoicing currency choice, such as changes to the economic fundamentals of the DC issuer (e.g. much higher inflation, as discussed in Mukhin (2022)), geopolitical shocks (Eichengreen et al. (2019)) or policy support (e.g. the availability of currency swap lines in the challenger currency, as discussed in Bahaj and Reis (2020)).

4.3 Cross-Country Effects: How Do They Matter?

Cross-county linkages matter when analyzing why one DC can replace another. This is emphasized in the literature and is reflected in our results. What might be less empirically clear is through which channels these network effects operate. A country's decision to invoice its exports in euros can arise through "mechanical" bilateral trade linkages, meaning that when imports are priced more in euros, a higher share of exports tends to be priced in euros. This can be due to the use of imported goods in export good production, as emphasized in Mukhin (2022), or to a financial channel involving households' deposit and banks' lending currency choices, as emphasized in Gopinath and Stein (2021). Another channel of cross-country linkages emphasized in the literature is strategic complementarities arising arise when firms want to align their price with the prices of competitors (Mukhin (2022)).

Our empirical setup allows to test the strengths of these two channels, as both effects are modeled separately. On the one hand, we can assess how much of the impact of shocks to euro invoicing abroad on domestic euro invoicing operates through bilateral trade links, captured by elements m_{ijt} in the matrix A_{ijt} (see Equation (3.7) and Equation (3.4)). These elements capture the mechanical effects of increases in euro shares of foreign exports on increases in the euro share of domestic imports, which in turn might lead to an increase in the euro share of domestic exports. On the other hand, the components $q_0\chi^0_{ijt}$ and $\{q_l\chi^l_{ijt}\}^p_{l=1}$ as well as $\gamma_0 x_{ijt}$ and $\{\gamma_l x_{ijt}\}^p_{l=1}$ in the matrices A_{ijt} and $\{B^l_{ijt}\}^p_{l=1}$ proxy the transmission that arises through strategic complementarities. They link the euro share of domestic exports to changes in the euro share of exports and exchange rate volatility in foreign countries, respectively.

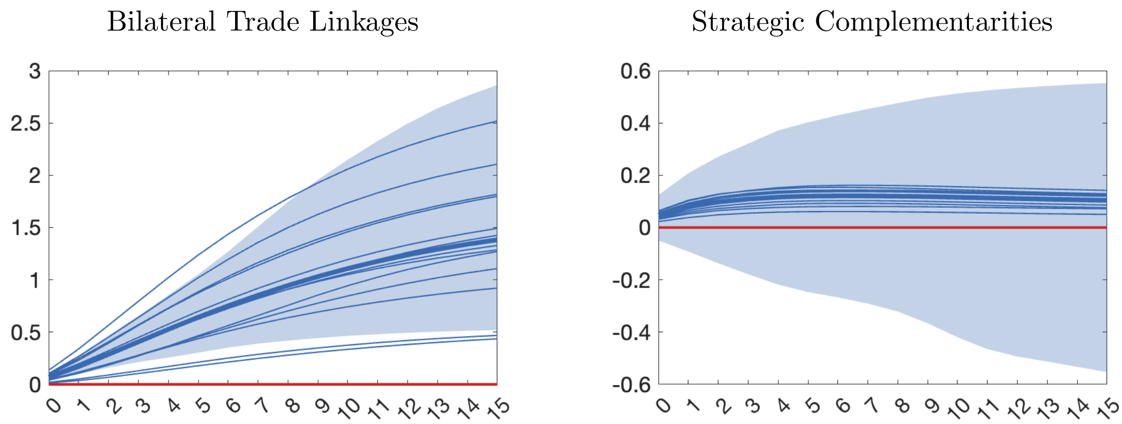

Figure 7: Euro Share of Exports' Domestic Response to Increases Abroad

Notes: The plots show the impulse responses of the euro share of exports in country i, $EX^{€}_{it}$, to a simultaneous and persistent increase in the euro share of exports in all countries but country i, $\sum_{j\neq i} EX^{€}_{jt}$, in the year 2000 by one percentage point. The left plot shows the part of the response due to mechanical trade links (element (2,1) in A_{ijt}), the right part shows the part due to strategic complementarities in currency choice (elements (1,1) and (1,3) in A_{ijt} and $\{B^l_{ijt}\}^p_{l=1}$). The thick blue line shows the average response across countries, whereas the thin lines show country-specific responses.

Figure 7 provides evidence on the strength of these two channels. It shows the effect of a joint and persistent one percentage point increase in the euro share of exports in all other sample countries on a country's domestic euro share of exports. The left plot shows the part due to bilateral trade links and the right plots the part due to strategic complementarities. The estimates underscore the relevance of bilateral trade linkages. Owing to them, the increase in euro invoicing in all sample countries abroad is met by a matching 1 pp. increase in domestic euro invoicing after about 8 years. The response stabilizes at 1.5 pp. in the long-run. By comparison, we do not find evidence for the importance of strategic complementarities. On impact, their estimated contribution is only negligibly smaller than the effect via bilateral trade linkages, but it is less persistent and not significantly different from zero over the impulse response horizon. This might seem to stand in contrast with other studies which found evidence in favour an important role of strategic complementarities for invoicing currency choice (such as Amiti et al. (2022)). However, it is important to recall that we consider strategic complementarities at the country- rather than firm-level and that we explicitly model them as bilateral effects rather than using proxies to determine to what extent a firm or a country is affected by strategic complementarities. As a result, our estimates are informed by spillover and spillback effects in the form of higher-order network linkages (see Section 3.2) although they are also necessarily more crude since they are based on aggregate data. Yet our results indicate that, at this aggregate level, trade linkages seem to dominate strategic complementarities in driving a country‘s choice of invoicing currency, which point to the relevance of changes to input-output linkages in making or breaking DCs.

4.4 Robustness of Results

Our results are robust to various changes in the empirical setup. We highlight four tests in this section, of which the figures are provided in Appendix B. First, and most importantly, we relax the assumption that there is no feedback loop from invoicing currency choices to trade and exchange rate volatility. This assumption is imposed in the baseline model to allow us to identify shocks prior to the start of our invoicing data sample in 1999, although it is not needed to disentangle shocks to these two variables (see also Section 3.4). Figure B.10 shows that relaxing this assumption only negligibly alters the estimated impulse response functions. Second, as shown in Figure B.9, increasing the lag length in the Panel-VAR from 1 to 2 slightly decreases the effects of trade shocks, but does not change the insignificance of exchange rate volatility shocks' impacts.[30] Third, plotting the impulse response functions for another point in time, for example $t = 2010$ (instead of $t = 2000$) shows that both the shocks to exchange rate volatility and trade became stronger over time, as shown in Figure B.8. This is because countries traded more among themselves. Nevertheless, the effect of exchange rate volatility shock abroad on the domestic euro share of exports remains insignificant. As a final test, we widen our set of countries to include those which have at most two consecutive years missing, i.e.

[30]With $p = 1$, we have 97 parameters to estimate from 1040 observations ($n \times 4 \times 20$, whereas with $p = 2$ we have 111 parameters which comes down to 8.9 observations per estimated parameter).

Israel, North Macedonia and Ukraine. Including these leaves the estimated historical contributions of the trade and exchange rate volatility shocks to the euro share of exports unaffected for our baseline set of countries, as shown in Figure B.11.

5 Conclusion

This paper assesses why a dominant currency in international trade invoicing can be replaced with another using a rare episode during which such a switch happened: the rise in euro invoicing in international trade of euro area neighbors of the past 20 years. It discusses two competing hypotheses that may explain these developments: a trade shock—that stronger trade links with the euro area tilts invoicing towards the euro—and an exchange rate volatility shock—that growing use of the euro as an exchange rate anchor spills over to invoicing. It takes these hypotheses to the data using a Panel-Vector autoregression to jointly model invoicing, trade and exchange rate volatility dynamics across countries, while allowing for cross-country effects emphasized in theory. The estimates give support to a trade shock as a key determinant of the stronger role of the euro for invoicing of international trade of euro area neighbours. Moreover, they point to significant cross-country effects operating mainly via bilateral trade linkages rather than strategic complementarities in export price setting, which underscores the relevance of changes to input-output linkages as determinants of invoicing currency patterns.

These findings have implications for the international propagation of shocks, the international monetary system and macroeconomic policies going forward. They suggest that, in response to the pandemic and the war in Ukraine, reshoring or friendshoring of production chains could lead to stronger regional trade, notably on the European continent. That in turn could strengthen the future role of the euro for export invoicing and its importance for the international transmission of shocks and pass-through of exchange rate movements to global output and inflation.

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Appendix

A Additional Details on the Panel-SVAR

Historical Decomposition We are interested in the contribution of $\{\varepsilon_{j3t}\}_{j\in\mathcal{C}}$ and $\{\varepsilon_{j4t}\}_{j\in\mathcal{C}}$ to $EX^{€}_{i,T} - EX^{€}_{i,1}$, whereby ε_{j3t} and ε_{j4t} are shocks to $FX^{€-\$}_{jt}$ and EX^{EA-US}_{jt}, respectively, and, for our baseline specification with $p = 1$ lags, $t = 1$ and $t = T$ refer to the years 2000 and 2019, respectively. In the following we show that under the restrictions $A_{21} = 0$ and $B^{l}_{21} = 0$, $l = 1 : p$ (see Section 3.4), we can identify not only the contribution of such shocks which occurred in the period 2000-2019, but even ones that occurred before 2000. This is crucial for our analysis because the most pronounced movements in $FX^{€-\$}_{jt}$ and EX^{EA-US}_{jt} happened during 1995 - 2000, before invoicing data becomes available in 1999 ($t = 0$).

Any time series y_t is a function of past shocks ε_{t-j}, $j = 0, 1, 2, ...$ (and initial conditions y_0). For expositional simplicity, let $p = 1$, ignore the exogenous variables z_t and the time-variation of $\mathbf{A}_t$ and $\mathbf{B}^1_t$. We can write our PVAR from equation 3.1 as

$$y_t = \Phi_c + \Phi_1 y_{t-1} + \Phi_\varepsilon \varepsilon_t \ ,$$

where $\Phi_c = \mathbf{A}^{-1}\mathbf{k}$, $\Phi_1 = \mathbf{A}^{-1}\mathbf{B}^1$ and $\Phi_\varepsilon = \mathbf{A}^{-1}$. Repeatedly inserting for lagged y_t on the right-hand side, we get

$$y_T = \sum_{j=0}^{T-1} \Phi_1^j \Phi_c + \sum_{j=0}^{T-1} \Phi_1^j \Phi_\varepsilon \varepsilon_{t-j} + \Phi_1^T y_0 \ ,$$

i.e. y_T is a function of i) a constant, ii) the shocks ε_t that occurred in the sample period $t = 1 : T$, and iii) the initial condition y_0.

Without further assumptions we can only determine the contributions of shocks that occurred in this time frame. However, if $A_{21} = 0$ and $B^l_{21} = 0$, $l = 1 : p$, then $[FX^{€-\$}_{it}, EX^{EA-US}_{it}]$ do not depend on (neither contemporaneously nor lagged) invoicing variables $[EX^{€}_{it}, IM^{€}_{it}]$, and we obtain a triangular system; $\{FX^{€-\$}_{it}, EX^{EA-US}_{it}\}_{i\in\mathcal{C}}$ follow a separate (panel-)VAR and are driven exclusively by their own past shocks, $\{\varepsilon_{j3t}, \varepsilon_{j4t}\}_{j \in \mathcal{C}}$. Using data for these series, available from 1994,[31] we can identify these shocks from $1994+p$ to 1999 and determine their contribution to y_0 and therefore on y_T. Neither the presence of more lags, nor exogenous variables z_t, nor time-variation in $\mathbf{A}_t$ and $\mathbf{B}_t$ affects this result.

Time Variation of Dynamics Our historical decomposition and impulse response analysis take as given the evolution of z_t, $\mathbf{A}_t$ and $\mathbf{B}_t$. With regard to z_t, the assumption is that exchange rate volatilities in countries excluded from the analysis are unaffected by developments in sample countries. This is reasonable as the latter are small open economies (see Section 3.2). Regarding $\mathbf{A}_t$ and $\mathbf{B}_t$, the assumption is that the evolution of bilateral trade shares among sample countries is unaffected by the evolution of y_t, the variables included in the analysis. It is likely to be violated. However, note that conditioning on this time-variation in $\mathbf{A}_t$ and $\mathbf{B}_t$ works against our hypotheses, as we ignore the extent to which reduced euro exchange rate volatility and increased trade with the Euro Area (arguably) led to increased trade among sample countries, which renders the cross-country effects in $\mathbf{A}_t$ and $\mathbf{B}_t$ more potent over time and implies an additional, indirect effect on countries' euro shares of exports.

[31] Dictated by data availability for CZ, HR, RO (and MK).

B Additional Figures

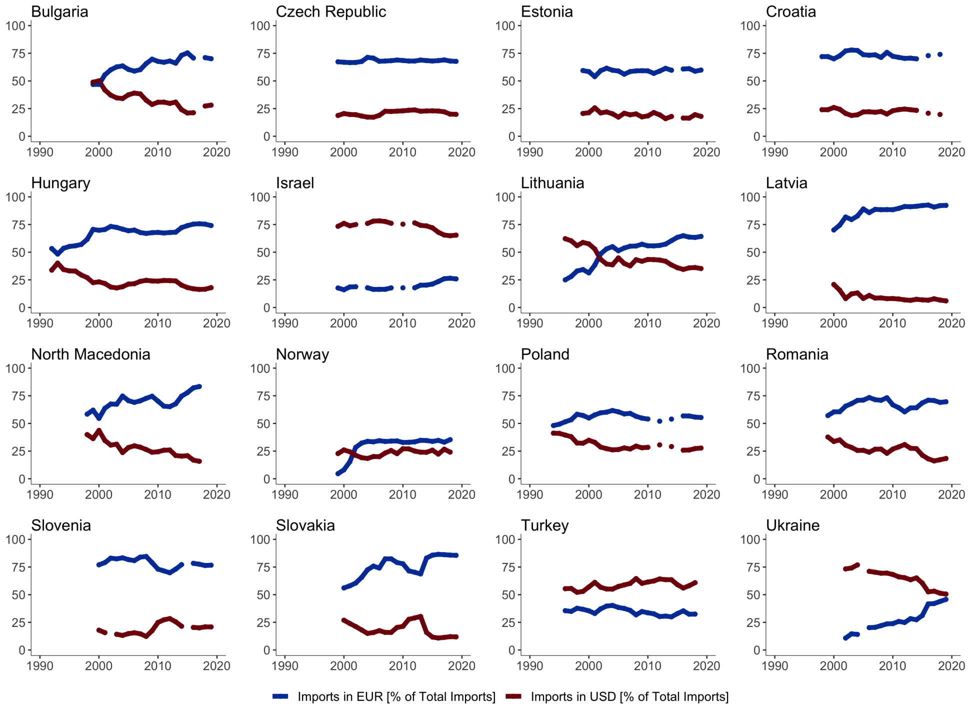

Figure B.1: Invoicing Currency Shares in Imports

Notes: The figure shows the evolution of the share of imports invoiced in euro ($IM^{€}_{it}$, blue lines) and in US dollars ($IM^{\$}_{it}$, red lines) across countries in our sample. Data: Boz et al. (2022).

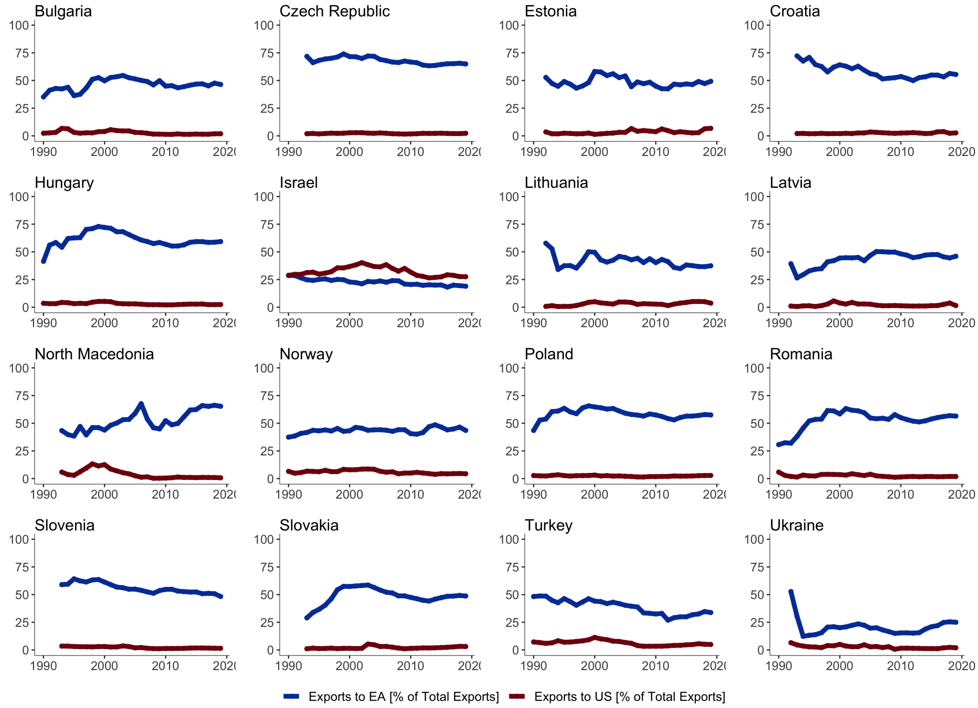

Figure B.2: Export Shares by Destination Market

Notes: The figure shows the evolution of the share of exports destined to the Euro Area (EX_{it}^{EA}, blue lines) and to the US (EX_{it}^{US}, red lines) across the countries of our sample. Data: IMF.

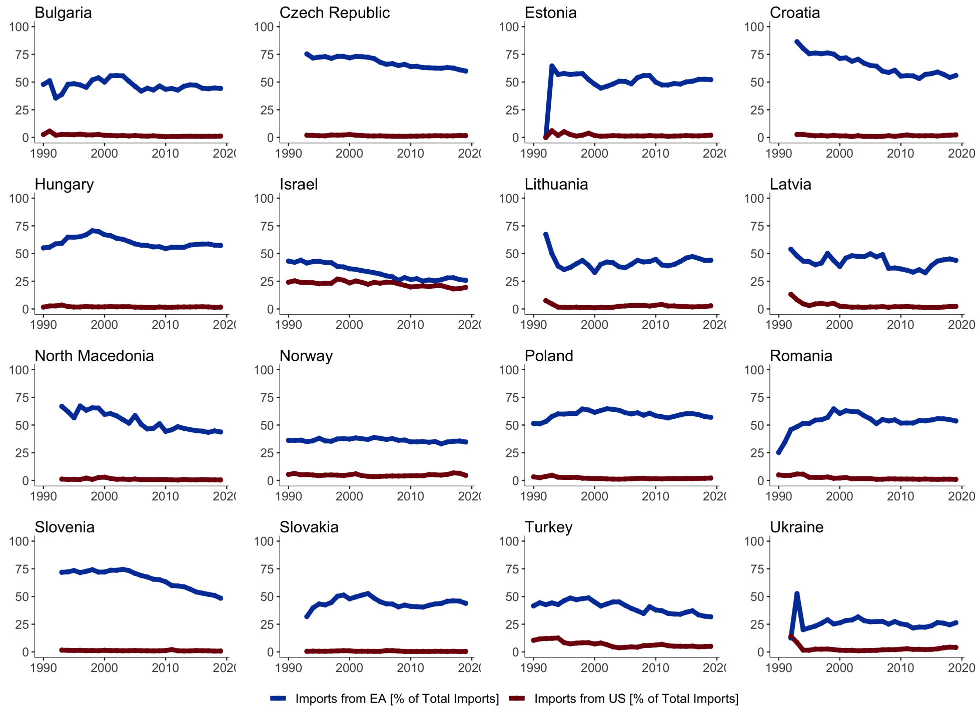

Figure B.3: Import Shares by Source Market

Notes: The figure shows the evolution of the share of imports from the euro area (IM_{it}^{EA}, blue lines) and the US (IM_{it}^{US}, red lines) across countries in our sample. Data: IMF.

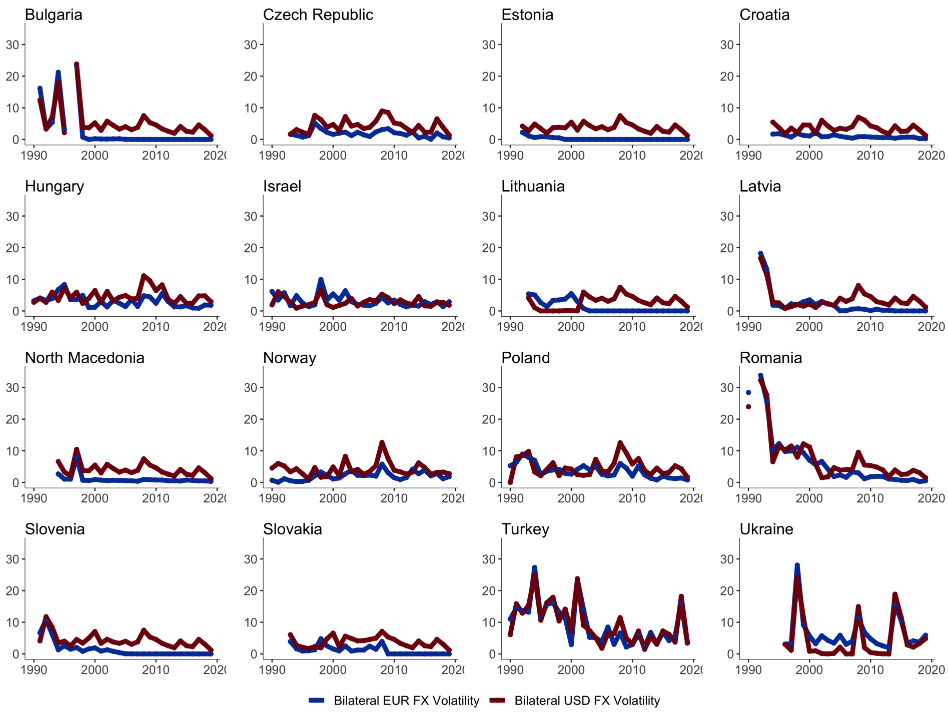

Figure B.4: Exchange Rate Volatility Against the Euro and the US Dollar

Notes: The figure shows the evolution of bilateral exchange rate volatility against the euro ($FX^{€}_{it}$, blue lines) and the dollar ($FX^{\$}_{it}$, red lines) across countries in our sample, both calculated as percentage standard deviations of the respective daily exchange rates. For some countries, observations in early 1990s vastly exceed 35%, chosen as the truncation point for visualization purposes. Data: BIS.

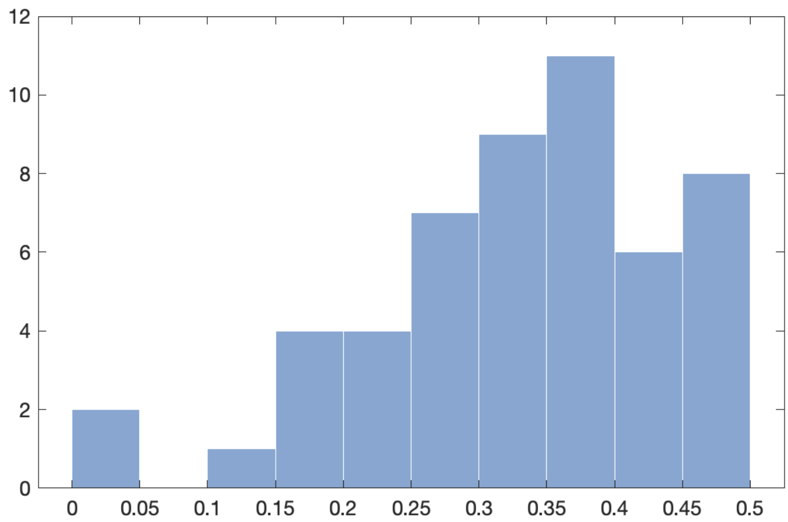

Figure B.5: P-Values of Estimated Shocks' Autocorrelations

Notes: The plot shows a histogram of p-values (Normal) of estimated autocorrelations for each shock series. Speicifcally, we fit an AR(1) for each estimated shock $\{\varepsilon_{ivt}\}_{i\in\mathcal{C},v=1:4}$ and compute the p-value of the estimated coefficient.

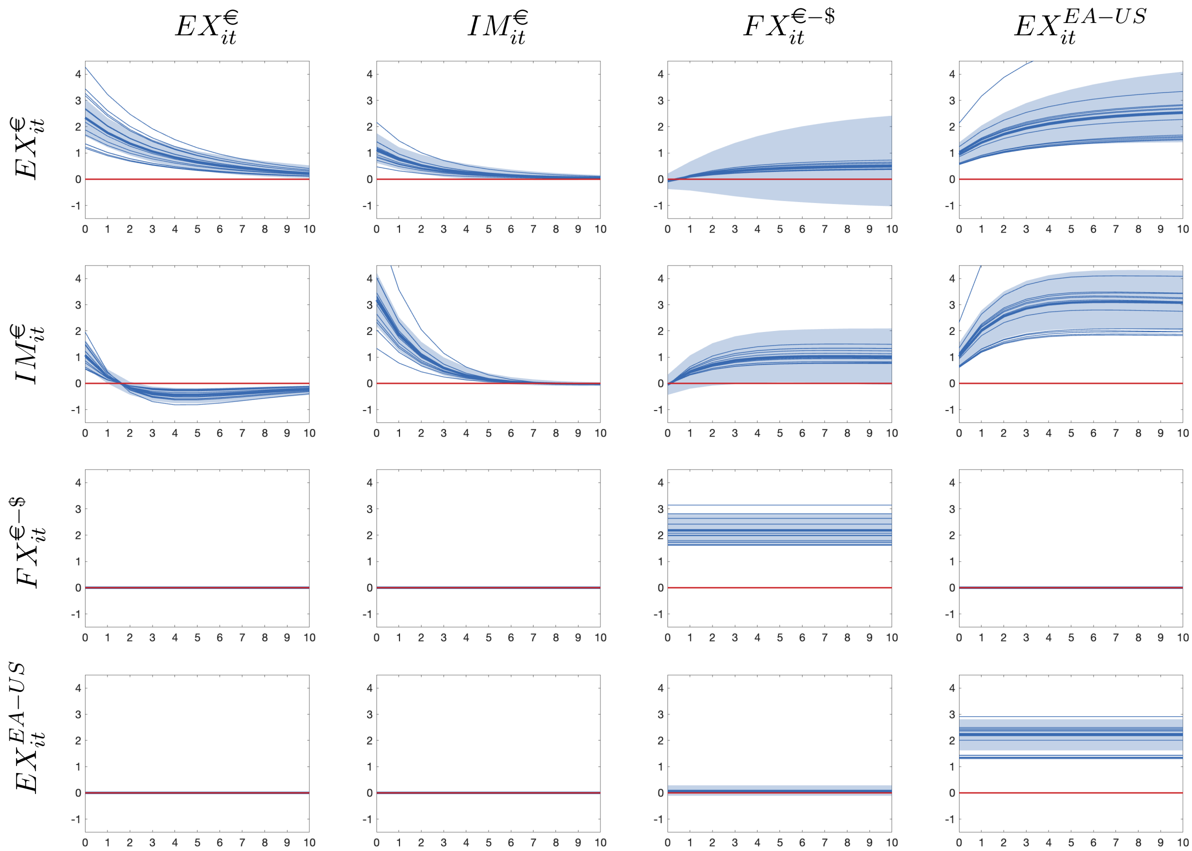

Figure B.6: Impulse Responses: Own Shocks

Notes: The figures show the whole set of impulse responses of a country's variables to one standard deviation shocks to a given variable in the same country in the year 2000. The thick blue lines shows the average response across countries, whereas the thin lines show country-specific responses.

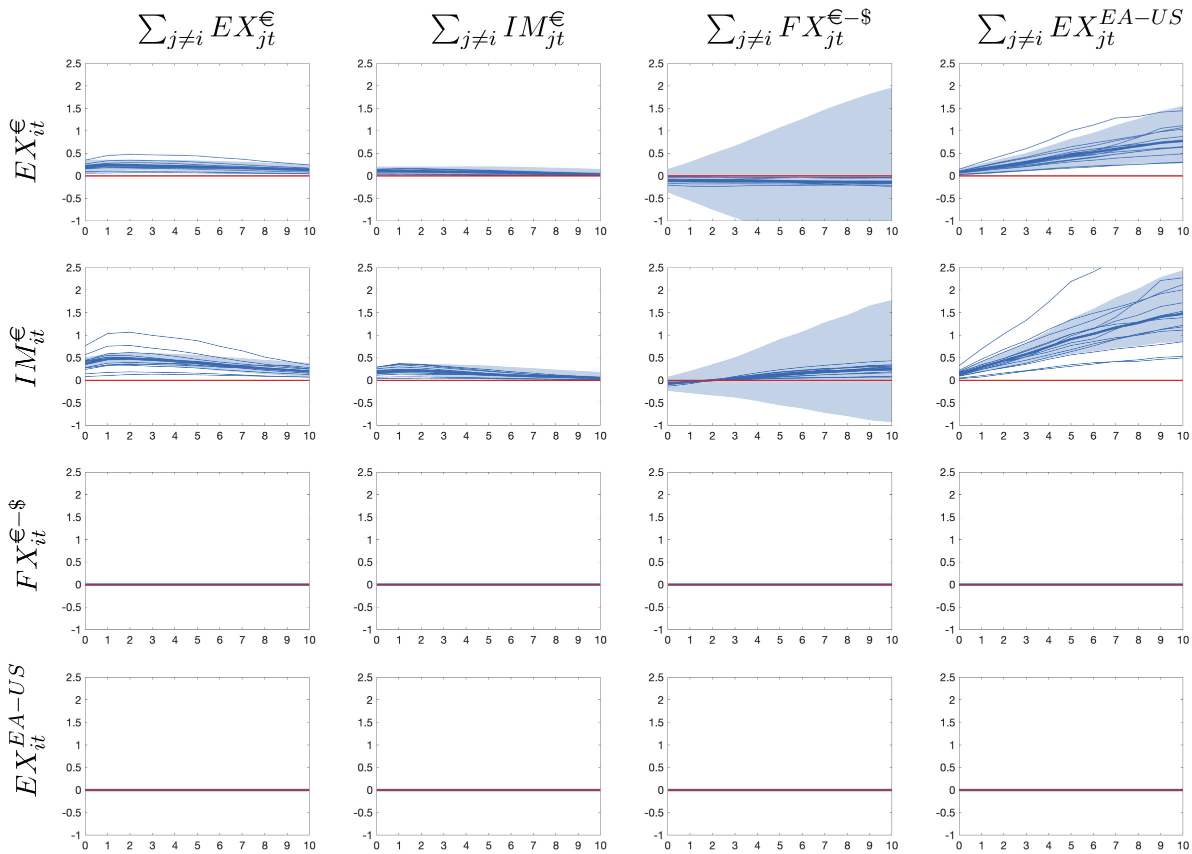

Figure B.7: Impulse Responses: Shocks Abroad

Notes: The figures show the whole set of impulse responses of a country's variables to simultaneous one-standard deviation shocks to a given variable in all other countries in the year 2000. The thick blue lines shows the average response across countries, whereas the thin lines show country-specific responses.

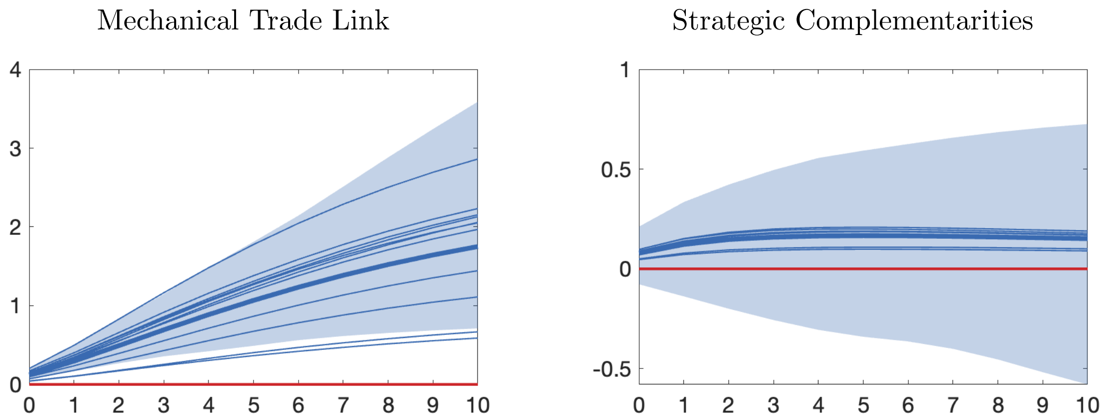

Figure B.8: Euro Share of Exports' Domestic Response to Increases Abroad: Year 2010

Notes: The plots show the impulse responses of the euro share of exports in country i, $EX^{€}_{it}$, to a simultaneous and persistent increase in the euro share of exports in all countries but country i, $\sum_{j\neq i} EX^{€}_{jt}$, in the year 2010 by one percentage point. The left plot shows the part of the response due to mechanical trade links (element (2,1) in A_{ijt}), the right part shows the part due to strategic complementarities in currency choice (elements (1,1) and (1,3) in A_{ijt} and $\{B^{l}_{ijt}\}^{p}_{l=1}$). The thick blue line shows the average response across countries, whereas the thin lines show country-specific responses.

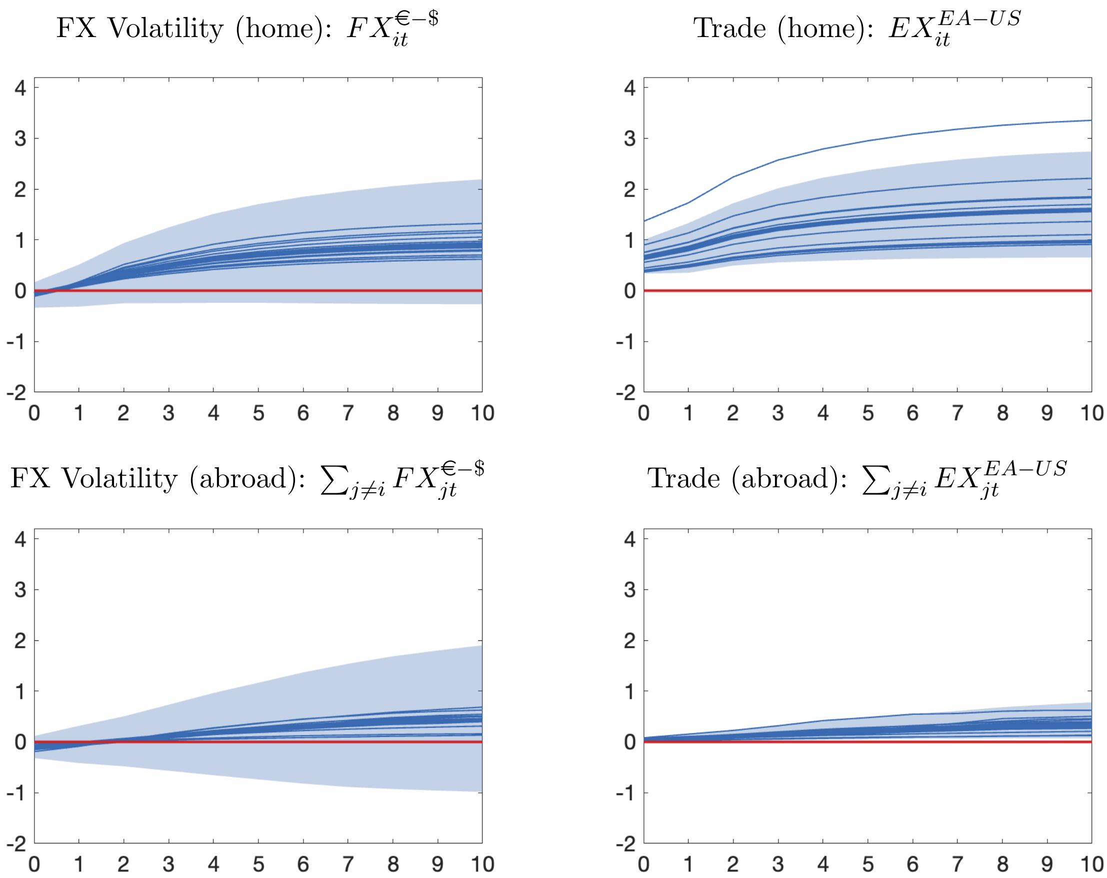

Figure B.9: Impulse Responses of Euro Share of Exports: $p = 2$ lags

Notes: The plots show the impulse responses of the euro share of exports, $EX_{it}^{€}$, to a one-standard deviation increase in $FX_{it}^{€-\$}$ (left column) and EX_{it}^{EA-US} (right column) in the year 2000. The top row refers to a shock in the corresponding variable in country i itself, while the bottom row illustrates the responses to a simultaneous increase in the corresponding series for all other countries but country i. The thick blue line shows the average response across countries, whereas the thin lines show country-specific responses.

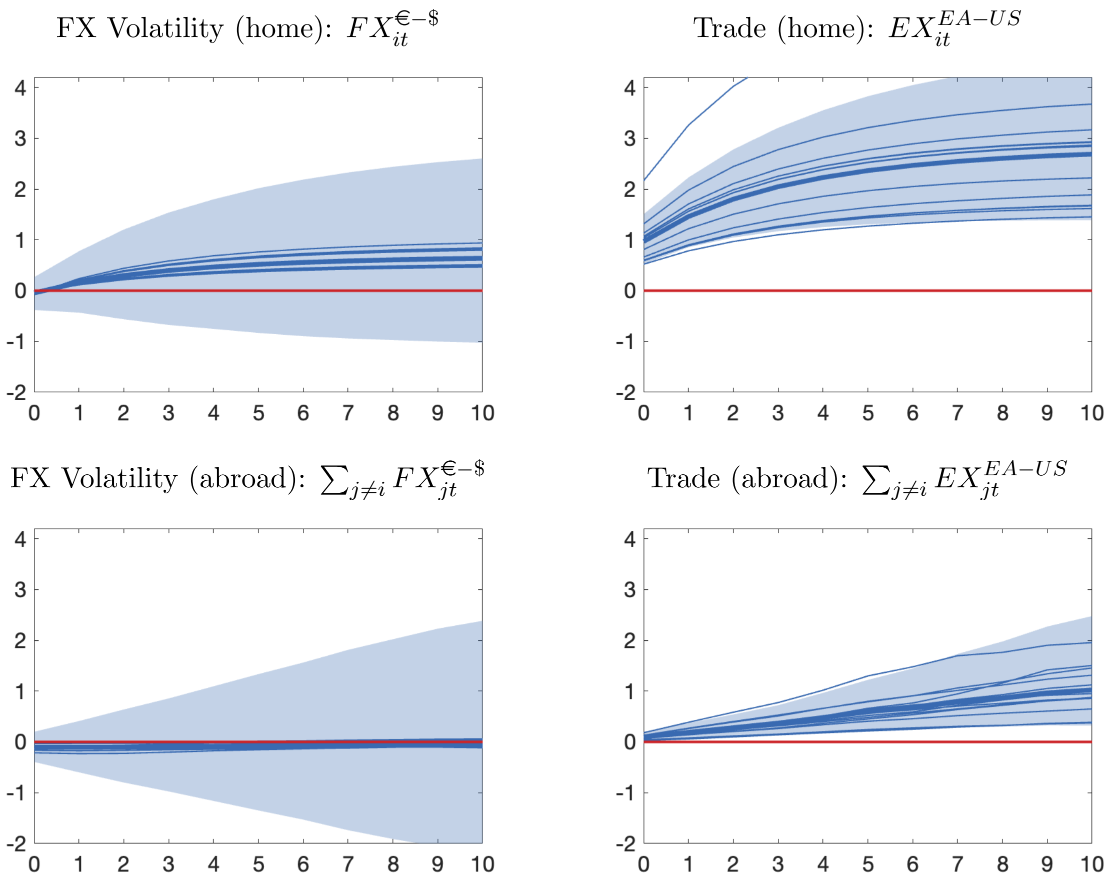

Figure B.10: Impulse Responses of Euro Share of Exports: Non-Triangularity

Notes: The plots show the impulse responses of the euro share of exports, $EX_{it}^{€}$, to a one-standard deviation increase in $FX_{it}^{€-\$}$ (left column) and EX_{it}^{EA-US} (right column) in the year 2000. The top row refers to a shock in the corresponding variable in country i itself, while the bottom row illustrates the responses to a simultaneous increase in the corresponding series for all other countries but country i. The thick blue line shows the average response across countries, whereas the thin lines show country-specific responses.

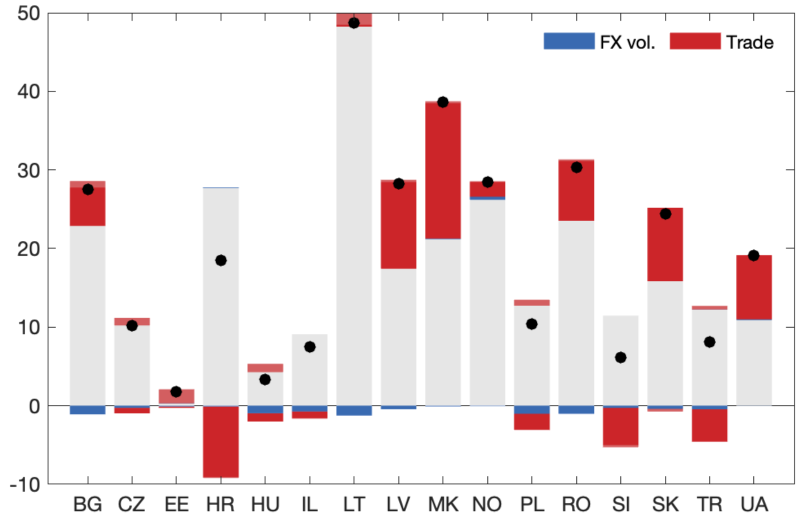

Figure B.11: Historical Decomposition of Euro Share of Exports Increases: Wider Sample

Notes: For each country, the black dot indicates the increase in the euro share of exports, $EX_{it}^{€}$ from 2000 to 2019. The blue and red bars, respectively, show the estimated contribution of shocks to $FX_{it}^{€-\$}$ and EX_{it}^{EA-US} which occurred during 1995-2019.