
Bought, Sold and Bought Again

The Impact of Complex Value Chains on Export Elasticities

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Global value chain participation affects the exchange rate pass-through to export prices and export volumes. The paper develops a partial equilibrium model of international trade with cross-border production and shows that higher participation in global value chains reduces the elasticities. Specifically, a higher share of foreign value added in exports reduces the exchange rate pass-through to export prices and export volumes. A greater share of exports that return as imports also reduces the responsiveness of export volumes to changes in bilateral exchange rates. Finally, exports of inputs that are further re-exported increase the responsiveness to the trading partner’s effective exchange rate. Using a novel sector-level panel dataset with 40 countries, the analysis tests and finds strong empirical support for the theoretical predictions. The paper further shows that some sectors in some countries can even experience a decline in gross exports when their currency depreciates.
Bought, Sold and Bought Again:
The Impact of Complex Value Chains on Export Elasticities

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Non-technical summary

International trade is characterized by the operation of global value chains. In this paper we show in a partial equilibrium model of international trade in which different production networks have different impacts on both the exchange rate pass-through to export prices and to exports volumes. Upstream linkages via a higher share of foreign value added, $FV$, reduces the exchange rate pass-through to export prices through the supply-chain channel. The exchange rate elasticity of export volumes is also reduced by a greater share of $FV$. But, export volumes are also impacted by downstream conditions in the supply chain. A larger share of domestic value added that returns as imports, $RDV$, reduces the exchange rate elasticity of export volumes in our model, whereas a greater share of exports of inputs that are re-exported further, $IV$, makes trade flows sensitive to a forward-looking exchange rate, computed between the origin country and the country of final absorption.

To test the predictions of the model, we construct bilateral country-sector-by-destination indices of global value chain participation from global input-output tables, following Wang et al. (2013). Differently from the literature however, we base these measures on currencies and not countries. This is important because it is arguably only supply chain links with countries of different currencies that will matter for the respective exchange rate elasticities.

With these new measures we find strong support for the theoretical predictions with our empirical estimates: a higher share of $FV$ (from a destination country with a different currency) reduces the exchange rate pass-through to export prices. A greater share of $FV$ as well as a higher $RDV$ weakens the responsiveness of export volumes to bilateral exchange rate movements. Exports of inputs that are re-exported further by the direct trading partner, $IV$, do not seem to change the price elasticity of export volumes. These exports however tend to increase the responsiveness to the direct trading partner’s nominal effective exchange rate. Some sectors in some countries with both high $FV$ and high $RDV$ can even experience a decline in gross exports when their currency depreciates.

The main contribution of this paper is that it considers precisely defined bilateral indices of global value chain participation - based on currencies instead of countries - that capture all the important links (upstream and downstream) embedded in global value chains. This allows us to outline the importance of currency unions for the estimation of different effects of production networks on the export elasticities.
1 Introduction

The production processes for goods and services became increasingly fragmented across countries over the past decades. The value-added ratio in global trade, defined as the domestic value-added in gross exports divided by total gross exports, fell sharply from 87% in 1970 to 77% in 2009 (Johnson and Noguera, 2017). More comprehensive measures of global value chain integration indicates that the expansion seems to have slowed since the 2008/2009 Great Recession (Timmer et al., 2016) but still accounts for a large share of global trade and more than half of gross exports of the euro area (ECB, 2017).

The international fragmentation of production can be split into two parts (Koopman et al., 2014): firms are integrated “upstream” in the value chain, where domestic inputs are replaced by imported inputs. Firms also have “downstream” linkages and sell inputs that are used in further production processes. This means that some proportion of exports are re-exported further by its first trading partner, either to another final destination or back to the origin country.

The expansion of these complex production networks might reduce two key elasticities in macroeconomics: (i) the exchange rate pass-through to trade prices (Amiti et al., 2014) and (ii) exchange rate elasticity of export volumes (Ahmed et al., 2015), and thus weaken the transmission of monetary policy through the exchange rate channel and hamper external rebalancing (Leigh et al., 2017).

In tandem with global value chain expansion, many European countries intensified their regional economic integration in large currency areas such as the Economic and Monetary Union of the European Union (EMU). Firms within such areas share the same currency and movements of nominal exchange rates do not impact relative prices across borders within such unions. When assessing the impact of global value chains on export elasticities, it is therefore imperative to also take into account that some trade flows are within currency unions.

In this paper, we outline a partial equilibrium model of international trade with cross-border production. From the model, we derive a set of quantitative predictions on the impact of integration in global value chains on the exchange rate pass-through to export prices and export volumes. Differently from much of the literature (Amiti et al. 2014, Fauceglia et al. 2014, Ahmed et al. 2015 and Arbatli and Hong 2016) we consider several precisely defined bilateral indices of global value chain participation, similar to Wang et al.
foreign value added in exports that originate in destination countries with different currencies (foreign value added - $FV$), value added in exports that are re-exported by the trading partners (indirect value added - $IV$) and value added that are re-imported at a later stage (re-imported domestic value added - $RDV$).

The results suggest that for export prices, only $FV$ should reduce the exchange rate pass-through through a price-effect. For export volumes, both $FV$ and $RDV$ should decrease the price elasticity of bilateral exports, whereas $IV$ should make trade flows sensitive to a forward-looking exchange rate, computed as the nominal effective exchange rate of the trading partner.

To evaluate the theoretical predictions, we construct the three indices of global value chain participation bilaterally at the country-sector-by-destination level from the World Input-Output tables. We estimate their role in shaping the export elasticities in a interacted panel fixed-effects regressions for sectoral export prices and export volumes in a dataset that covers 85% of world GDP from 1995-2009.

The results strongly corroborate the predictions. A higher $FV$ (from a country with a different currency) reduces the exchange rate pass-through to export prices (similar to the findings in Amiti et al. 2014). For export volumes, higher shares of $FV$, or $RDV$ weakens the exchange rate responsiveness. Higher shares of $IV$ do not have any impact on bilateral export elasticities. At the same time, a higher $IV$ with a trading partner increases the responsiveness of gross exports to that trading partner’s nominal effective exchange rate. This is intuitive: it is the trading partner’s trading relationships and price competitiveness that determine the demand for the $IV$ exports.

Sectors with combined high shares of $FV$ and $RDV$ (above the 99th percentile) might actually see their exports decline when their currency depreciates (which normally should make their exports more competitive). This is not just a "exchange rate disconnect": it reverses the sign of the elasticity, see Figure (1) which highlights one of our main empirical results.

Our results confirm earlier studies on the impact of global value chains on export elasticities (Amiti et al. 2014, Fauche glia et al. 2014, Ahmed et al. 2015 and Arbatli and Hong 2016). However we add a couple of crucial dimensions. We develop a simple model of international trade which we use to gain some intuition on how upstream and downstream linkages matter differently for the exchange rate elasticities of export prices and export volumes. We also acknowledge that although the “global” part of the value chain has
grown over time, value chains are still in fact largely regional and often involve countries within currency areas. This feature is taken into consideration when we construct our three measures of global value chain integration, that are based on currencies and not countries, and are thus more suitable for assessing the impact of global value chains on exchange rate elasticities. From where value added is sourced and in which currency the trade is taking place, or where its final destination is, has implications for how participation in global value chains affects the elasticities.

The outline of the paper is as follows: Section 2 gives a brief description of the literature related to this paper. Section 3 outlines the theoretical framework and provides numerical predictions about the impact of global value chain participation on the exchange rate pass-through to export prices and the price elasticity of export volumes. Section 4 presents the main data sources, by outlining the difference between our currency-based global value chain indices and those produced by Wang et al. (2013). Section 5 introduces the econometric methodology and presents the results. Section 6 concludes.
2 Related literature

Currency movements are generally thought to strongly affect trade prices and volumes. However, some prominent arguments for a reduced exchange rate sensitivity of export prices and export volumes relate to the operation of global value chains. A secular increase in the use of imported inputs in the production of exports could for example reduce the competitiveness gains following a depreciation through an offsetting impact on the marginal costs of exporting firms.

On the theoretical side, our work relates to papers modeling cross-border production and the associated consequences for trade elasticities, such as Yi (2003). More recently, Bems and Johnson (2017) examine how cross-border input linkages shape the response of demand for value added to international relative price changes. While they emphasize the role of relative elasticities in production versus consumption and condition their theoretical results on the value of model primitives, we take the direction of assuming Cobb-Douglas aggregation to derive more easily our predictions, which are then validated by our empirical exercise.\footnote{We also share with Bems and Johnson (2017) the partial equilibrium nature of our theoretical exercise.}

By considering spending shares in the input-output matrix as constant in the short run (a natural consequence of our Cobb-Douglas assumptions), our work can be compared to Wang et al. (2013) and Koopman et al. (2014). Those papers pioneered the investigation of global value chains and created the decomposition of gross trade flows that is at the heart of the mechanisms we study. They derive the indices used in this paper (FV, RDV and IV) by manipulating input-output, value added and demand shares in a framework with many sectors and countries, and assuming that those coefficients are constant. Our model with Cobb-Douglas production and demand follows a similar logic and additionally provides new predictions regarding the association between GVCs and exchange rate pass through, which are then validated using international data.

On the empirical side, Ahmed et al. (2015) find that participation in global value chains lowers the elasticity of manufacturing exports in OECD countries to the real effective exchange rate (REER) by 22 percent on average and by close to 30 percent for countries with the highest participation rates. Fauceglia et al. (2014) also explore how a decrease in relative prices of imported intermediate inputs may mitigate or even offset the negative effects of an exchange rate appreciation in Switzerland. Arbatli and Hong (2016) find that
growing participation in global production chains and rising export complexity are important determinants of Singapore’s export elasticities and Imbs and Mejean (2017) confirm that trade elasticities can differ because of the specialization of consumption and production, or because of international differences in sector-level trade elasticities. Moreover, the value of bilateral exchange rates might not be what matters for determining trade flows. Boz et al. (2017) for example find that the US dollar is disproportionately important for determining global trade prices and volumes which could be due to invoicing practices.

Other factors that could reduce the responsiveness of exports to exchange rate movements relate to the use of pricing-to-market strategies among large exporters that tend to keep their export prices stable and absorb any variability in the exchange rate in their mark-ups. Based on Belgian firm-product-level data, Amiti et al. (2014) find that import intensity and market share are key determinants of the exchange rate pass-through to export prices.

Although these studies have generally documented a lower exchange rate pass-through to export prices or reduced export elasticity to the exchange rate from increasing global value chain participation, they have not taken into consideration the full set of global production linkages (upstream and downstream), nor the origin of the import content in exports, or the final destination of value added. Our contribution to this literature is that we consider precisely defined bilateral participation in upstream- and downstream value chains that capture all the important links. This allows us to distinguish between different types of production networks and how they affect export elasticities. Moreover, we construct bilateral measures of global value chain participation based on currencies, and not countries, which improves the identification of the impact of global value chain participation on the export elasticities.

3 Theoretical framework

In this section we build a simple theoretical framework that illustrates how participation in global value chains impacts both the exchange rate pass-through to export prices and the price elasticity of export volumes. By taking into account firms’ engagement in global value chains both through imports and exports within a multi-country (multi-currency) world, we see our model as a first step towards the development of general equilibrium frameworks that can usefully be applied to the analysis of exchange rate movements. Using simple
examples of specific production structures, we show that both upstream and downstream linkages play a significant role in shaping the sensitivity of exports to devaluations.

As discussed in Amiti et al. (2014), firms importing a large share of inputs to produce exports experience a lower exchange rate pass-through, due to offsetting exchange rate effects on their marginal cost. As a result, the change in export volumes associated with a devaluation is also reduced. Note that this channel is only effective when imported inputs are made of foreign value added. Indeed, inputs imported from any country can contain a significant share of value added that originated from home, or in any country sharing the same currency.

The reaction of export volumes to changes in the exchange rates is also a function of downstream linkages in global value chains. As we will see in this section, the effectiveness of currency changes in affecting exports depends on the country of final absorption for those exports. Inputs sold to a destination could for example be re-exported by the trading partner to countries with different currencies, or re-imported as final products after transformation abroad. These downstream linkages necessitates the full consideration of global input-output linkages in order to account for the consequences for the elasticities.

While we recognize that the elasticity of exports to currency changes can be impacted by a variety of channels including, for example, the endogenous responses of mark-ups or different reaction of firms along the productivity distribution, our goal here is to focus on the specific impact of global value chains. As a result, the model developed below abstracts from elements such as strategic pricing, fixed exporting costs or firms’ heterogeneity.

3.1 Production

Consider an economy with $N$ countries indexed by $k$. In each country, there is a single sector with a representative firm producing with domestic labour and imported inputs according to a Cobb-Douglas technology:

$$Y_k = L_k^\gamma \times \prod_{k'=1}^{N} m_{k,k'}^\alpha \quad \text{with} \quad \gamma_k + \sum_{k'=1}^{N} \alpha_{k,k'} = 1$$

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2See Amiti et al. (2014).
3See Demian and di Mauro (2017).
4Another assumption is that exports are priced in either of the two countries’ currency and not some third currency, as in Boz et al. (2017).
where $\gamma_k$ is the labour share in production in country $k$, while $\alpha_{k,k'}$ is the share of output from country $k'$ in the total production of country $k$. Note that $Y_k$ is the gross output produced by country $k$, which is not equal to value added. $\varepsilon_{i,j}$ is the exchange rate faced by country $i$ vis-a-vis country $j$, that is: the units of country $i$ currency per unit of country $j$ currency.\footnote{One should keep in mind that with this definition, a depreciation of country $i$’s currency (compared to the one of country $j$) corresponds to an increase in $\varepsilon_{i,j}$ and a decrease in $\varepsilon_{j,i}$} Firms are perfectly competitive, price at marginal cost and buy all their inputs in their domestic currency.\footnote{In a static environment with perfect competition where prices are equal to marginal costs, firms’ pricing strategy is not affected by the currency in which such price is set. The equations presented here can be interpreted as if firms set the price in their own currency (so called “Producer Currency Pricing”).} In the absence of trade costs and taxes, standard cost minimization in each country leads to the following pricing system:

$$p_k = c_k \times w_k^{\gamma_k} \times \prod_{k'=1}^N (\varepsilon_{k,k'}p_{k'})^{\alpha_{k,k'}} \quad \text{for all } k$$

With $c_k$ a constant depending only on parameters.\footnote{$c_k$ is defined as: $c_k = \gamma_k^{-\gamma_k} \prod_{k'} \alpha_{k,k'}^{-\alpha_{k,k'}}$} Taking the log and noting $k_k = \log(c_k)$ and $\Omega$ the cross-country input-output matrix of the economy (with $\Omega_{i,j} = \alpha_{i,j}$), country-specific prices are the solution of:

$$\begin{pmatrix}
\log(p_1) \\
\vdots \\
\log(p_N)
\end{pmatrix} = (I_N - \Omega)^{-1} \begin{pmatrix}
(k_1 + (\gamma_1) \log(w_1)) \\
\vdots \\
(k_N + (\gamma_N) \log(w_N))
\end{pmatrix} + \Omega \circ \log(E) \begin{pmatrix} 1 \\
\vdots \\
1 \end{pmatrix}$$

where $E$ is an $N$-by-$N$ matrix of nominal exchange rate defined by $E_{i,j} = \varepsilon_{i,j}$, the symbol $\circ$ represents the element-wise (Hadamard) product and the log operator on $E$ is applied element-wise. As is standard in the literature, matrix $(I_N - \Omega)^{-1}$ is the Leontief inverse and captures all direct and indirect input-output linkages and naturally appears in the pricing equation. It is worth noting here that the price of a firm in any country is a function of the price of all its direct and indirect suppliers and all associated exchange rates. If country 1 exports inputs to country 2 that are used in production and re-exported to country 3, then the price level in country 3 is naturally a function of the exchange rate with its direct suppliers $\varepsilon_{3,2}$ as well as the exchange rate relative to upstream production steps such as $\varepsilon_{2,1}$.

As discussed extensively in the literature, gross trade data can be deeply misleading
in the presence of complex production networks. With global production patterns, it is becoming increasingly important to use value-added flows. We illustrate this phenomenon by considering a simple case with only three countries and a specific input-output structure without domestic intermediates (zeros along the diagonal) as follows:\(^8\)

\[
\Omega = \begin{pmatrix}
0 & \alpha_{1,2} & \alpha_{1,3} \\
\alpha_{2,1} & 0 & \alpha_{2,3} \\
\alpha_{3,1} & \alpha_{3,2} & 0 \\
\end{pmatrix}
\]

In such a case, it is useful to write a closed form solution for \(\log(p_1)\) to gain some intuition for the impact of different elements on firms’ pricing behaviour:

\[
\log(p_1) = \frac{1}{\det(I_3 - \Omega)} \left[ (1 - \alpha_{3,2}\alpha_{2,3})(k_1 + \gamma_1 \log(w_1) + \alpha_{1,2} \log(\varepsilon_{1,2}) + \alpha_{1,3} \log(\varepsilon_{1,3})) \\
+ (\alpha_{1,2} + \alpha_{1,3}\alpha_{2,3})(k_2 + \gamma_2 \log(w_2) + \alpha_{2,1} \log(\varepsilon_{2,1}) + \alpha_{2,3} \log(\varepsilon_{2,3})) \\
+ (\alpha_{1,3} + \alpha_{1,2}\alpha_{2,3})(k_3 + \gamma_3 \log(w_3) + \alpha_{3,1} \log(\varepsilon_{3,1}) + \alpha_{3,2} \log(\varepsilon_{3,2})) \right]
\]

Note that this expression of prices is independent of the demand side of the economy which will be described in the next section. From equation 3, the exchange rate pass-through to export prices can be computed from the above system. In order to do so, one must specify the exact currency movement for all country pairs. To gain intuition, we start with a particularly simple example and consider the case of depreciation in country 1 \textit{vis-à-vis} the other two countries and assume that both countries do not alter the value of their own currency. In such a case, we have:

\[
\begin{align*}
1 &= \Delta \log(\varepsilon_{1,2}) = \Delta \log(\varepsilon_{1,3}) \\
-1 &= \Delta \log(\varepsilon_{2,1}) = \Delta \log(\varepsilon_{3,1}) \\
0 &= \Delta \log(\varepsilon_{2,3}) = \Delta \log(\varepsilon_{3,2})
\end{align*}
\]

Generally, a depreciation of country 1’s currency could also impact the wage rates in all countries.\(^9\) For simplicity, we abstract from these general equilibrium effects here.

\(^8\)This structure is also used for example in Duval et al. (2016).

\(^9\)The consequence of a depreciation on the labour market can be twofold: if there are some unemployed resources, depreciation can increase employment and output by stimulating foreign demand. If factors of production are fixed, it can increase wages. See Krugman and Taylor (1978) for a theoretical discussion of the possible contractionary effects of devaluation.
Using the above result, we can compute the elasticity on country 1 price (in its domestic currency) with respect to a one percent depreciation of its own currency, everything else being constant with $\lambda = \text{det}(I_3 - \Omega)^{-1}$:

$$\Delta \log(p_1) \mid _{1 \text{% devaluation in } 1} = \lambda \left[ \left( \alpha_{1,2} + \alpha_{1,3} - (\alpha_{1,2} + \alpha_{1,3} \alpha_{3,1}) \right) \right.$$ 

$$\left. - \alpha_{1,2} (\alpha_{2,3} + \alpha_{3,2} + \alpha_{3,2} \alpha_{2,3}) - \alpha_{1,3} (\alpha_{3,2} + \alpha_{3,2} \alpha_{2,3}) \right] \tag{5}$$

Equation 5 provides us with some intuitions regarding the role of global value chains for the exchange rate pass-through: as a first order effect, a depreciation of country 1’s currency makes its imports relatively more expensive, which increases its price (in its own currency, but obviously not in foreign currency) as shown by the first term in the bracket, $\alpha_{1,2} + \alpha_{1,3}$. Such an effect has been studied extensively and has been tested in the data for example in Amiti et al. (2014).

The importance of imported inputs for the pass-through could however be mitigated by the fact that some imported inputs are not entirely produced abroad, but are domestic value added that returns home as imports. Such value added comes from direct linkages (second term of the above equation, $(\alpha_{1,2} + \alpha_{1,3} \alpha_{3,1}$)) or indirectly through third country effects (third and fourth term). These terms, in turn, tend to reduce the first order increase due to the direct linkages. The key element of the above reasoning is the separation between gross flows and value added flows between countries. By considering gross trade flows instead of value added flows, other studies such as Amiti et al. (2014) face the risk of missing the full extent of cross-country linkages, which is an important feature of modern global production processes.

As a next step, we consider more general exchange rate movements. We denote by $\Delta$ the time difference of a given variable and use the fact that for all country pairs $\Delta \log(\varepsilon_{i,j}) = -\Delta \log(\varepsilon_{j,i})$. A total differentiation of the price equation (3) yields:

$$\Delta \log(p_{1,t}) = [\alpha_{1,2}(1 - \alpha_{3,2} \alpha_{2,3}) - \alpha_{2,1}(\alpha_{1,2} + \alpha_{1,3} \alpha_{3,2})] \lambda \Delta \log(\varepsilon_{1,2t})$$

$$+ [\alpha_{1,3}(1 - \alpha_{3,2} \alpha_{2,3}) - \alpha_{3,1}(\alpha_{1,3} + \alpha_{1,2} \alpha_{2,3})] \lambda \Delta \log(\varepsilon_{1,3t})$$

$$+ [\alpha_{2,3}(\alpha_{1,2} - \alpha_{1,3} \alpha_{3,2}) - \alpha_{3,2}(\alpha_{1,3} + \alpha_{1,2} \alpha_{2,3})] \lambda \Delta \log(\varepsilon_{2,3t})$$

$$+ u_{k,t} \tag{6}$$

where we assumed that changes in wage rates are not correlated with changes in the
exchange rate so that the residual \( u_{k,t}^{10} \) is orthogonal to other terms in the right hand side of the equation. The above expression then yields a simple, intuitive and testable prediction: the price change associated with a change in the exchange rate is increasing if the share of foreign value added in gross production increases (from countries vis-à-vis which the currency depreciates). Moreover, the last term in the equation also shows that exchange rate movements between two foreign countries also affect domestic prices when they are associated with the same value chain.

3.2 Demand

We now return to the general case with many countries. Goods produced in any country can be sold to domestic and foreign buyers as final good or as inputs. Demand stemming from consumers is derived from a reduced form utility function defined by:

\[
C_k = \prod_{k'}^N \beta_{k,k'} y_{k,k'} \quad \text{with} \quad \sum_{k'}^N \beta_{k,k'} = 1
\]

where \( \beta_{k,k'} \) captures the share of country \( k' \) in final consumption of country \( k \) and \( y_{k,k'} \) is the quantity of good produced in \( k' \) consumed in \( k \).

In order to simplify the analysis and to abstain from general equilibrium effects, we assume an exogenous mass \( L_k \) of agents in country \( k \), all employed and earning an exogenous wage rate \( w_k \). In what follows, we assume that the nominal wage is exogenously fixed and is not affected by exchange rate movements. It is important to note the partial equilibrium nature of this assumption: the wage is not determined by market clearing in the labour market and we do not model what happens to workers not employed by the domestic firm.\(^{11}\)

The Cobb-Douglas nature of aggregate preferences implies that:

\[
\begin{align*}
0_{k',k} &= \beta_{k',k} w_{k'} L_{k'} , \quad \forall \ k, k' \\
0_{k',k} &= \alpha_{k',k} p_{k'} Y_{k'} , \quad \forall \ k, k' 
\end{align*}
\]

Moreover, demand schedules coming from foreign firms are simply

\[
\begin{align*}
0_{k',k} &= (1 - \alpha_{3,2}\alpha_{2,3}) \gamma_1 \Delta \log(w_{1,t}) + (\alpha_{1,2} + \alpha_{1,3}\alpha_{3,2}) \gamma_2 \Delta \log(w_{2,t}) + (\alpha_{1,3} + \alpha_{1,2}\alpha_{2,3}) \gamma_3 \Delta \log(w_{3,t})
\end{align*}
\]

\(^{10}\)A simple micro-foundation of this would simply be to model an “outside good” sector employing labour only and which would be freely traded across countries.

\(^{11}\)A simple micro-foundation of this would simply be to model an “outside good” sector employing labour only and which would be freely traded across countries.
As a reminder, in the equations above, the exchange rate transforms country \( k \) currency into country \( k' \)’s. When country \( k \) devalues its currency vis-a-vis \( k' \), \( \varepsilon_{k',k} \) decreases so that the price of \( k \)-produced good sold in \( k' \)’s currency decreases, which leads to higher quantities exported.

### 3.3 Market Clearing

Collecting sales across all agents and equating to production, market clearing conditions are given by:

\[
Y_k = \sum_i y_{i,k} + \sum_j m_{j,k} \quad \forall k \tag{9}
\]

Using equations (7) and (8) and using the fact that \( \varepsilon_{i,j} = 1/\varepsilon_{j,i} \) we get the revenue system (in nominal terms for simplicity):

\[
\begin{pmatrix}
  p_1 Y_1 \\
  \vdots \\
  p_N Y_N \\
\end{pmatrix} = \left( I_N - \Omega^T \circ E \right)^{-1} \begin{pmatrix}
  w_1 L_1 \\
  \vdots \\
  w_N L_N \\
\end{pmatrix} \tag{10}
\]

where \( B \) is a \( N \times N \) matrix grouping the shares \( \beta_{i,j} \). For notational purposes, let us denote \( T = (I_N - \Omega^T \circ E)^{-1} \). \( T \) which is the Leontief inverse and takes into account all input-output linkages and final demand shares.

Comparing to the pricing system (2), it is interesting to note that in the revenue system (10) the input-output matrix \( \Omega \) is transposed, which stems from the fact that the revenue of a given firm depends on the revenue of its customers (downstream linkages), whereas prices depend solely on a firm’s direct and indirect suppliers (upstream linkages).\(^{12}\) For given wages, the (partial) equilibrium is then defined by optimality of pricing (system (2)) and market clearing conditions (system (10)).

### 3.4 Decomposition of gross exports

This section elaborates on the consequences of a depreciation of country 1’s currency vis-à-vis other currencies and how global value chain participation affects the export elasticities. We start by formally defining three indices of global value chain participation.

Following closely the decompositions of gross nominal trade flows from Koopman et al.\(^ {12}\)

\(^{12}\)See for example de Soyres (2017) for a discussion of this.
(2014) and Wang et al. (2013), we define three indices which are presented schematically in figure 2.

Figure 2: Decomposition of nominal export flows

![Diagram of export flows](image)

The *FV* index measures the share of foreign value added in exports and is a purely “backward looking” indicator in the sense that it does not depend on the country of final absorption of the value added. It is related to the “import content of export” used in other papers such as Amiti et al. (2014) but focuses on the value added flows rather than gross flows. The *IV* index measures the domestic value added that is exported and used by the direct trading partner for the production of their own exports to other countries. The third index, labeled *RDV*, captures the domestic value added exported abroad that then returns home where it is finally absorbed. Such an index is particularly interesting when studying the impact of currency movements on trade elasticities since it measures the value added in exports that is driven by domestic demand of the exporting country.

The general idea underlying this decomposition is to separate, in the expression of total trade flows, the embedded value added in exports by both origin and destination of final absorption. Gross exports from country 1 to country 2, $E_{1 \rightarrow 2}$, can be traced following the

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13In the global value chains literature, *FV* and *IV* are also considered measures of backward and forward participation in global value chains, respectively.
steps described in Koopman et al. (2014) and Wang et al. (2013) as:

\[ E_{1\rightarrow 2} = v_1 T_{1,1} \varepsilon_{1,2} \beta_{2,1} w_2 L_2 + v_1 T_{1,2} \beta_{2,2} w_2 L_2 \]

Absorbed by direct partner

\[ + v_1 \sum_{k \neq 1, 2} T_{1,2} \varepsilon_{2,k} \beta_{k,2} w_k L_k \]

IV

\[ + v_1 T_{1,2} \varepsilon_{2,1} \beta_{1,2} w_1 L_1 + v_1 T_{1,2} \varepsilon_{2,1} \alpha_{1,2} \frac{1}{1 - \alpha_{1,1}} \beta_{1,1} w_1 L_1 \]

RDV

\[ + \sum_{k \neq 1} v_k T_{k,1} \varepsilon_{1,2} \beta_{2,1} w_2 L_2 + \sum_{k \neq 1} v_k T_{k,1} \varepsilon_{1,2} \alpha_{2,1} \frac{1}{1 - \alpha_{2,2}} \beta_{2,2} w_2 L_2 \]

IV

\[ + v_1 T_{1,2} \varepsilon_{2,1} \alpha_{1,2} \frac{1}{1 - \alpha_{1,1}} E_{1\rightarrow s} + \sum_{k \neq 1} v_k T_{k,1} \varepsilon_{1,2} \alpha_{2,1} \frac{1}{1 - \alpha_{2,2}} E_{2\rightarrow s} \]

Double counting

(11)

where \( T_{i,j} \) are elements of the matrix \( T \) and \( v_i \) is the value added share of gross output in country \( i \), which is simply equal to the share of labour in total costs and is defined by \( v_i = 1 - \sum_{k=1}^{N} \alpha_{i,k} = \gamma_i \).\(^{14}\) Moreover, \( E_{j\rightarrow s} \) represents total gross exports from country \( j \), irrespective of the destination country.

### 3.5 Illustrative examples

Using the equilibrium structure described above, we now specify examples of network structures in order to emphasize the role of both upstream and downstream linkages in shaping the export elasticities and to derive qualitative predictions for the role of each of the three indices of GVC participation (\( FV \), \( RDV \) and \( IV \)).

#### 3.5.1 Role of upstream linkages

Let us consider the production structure depicted in figure 3 where country 1 only exports final goods to country 2 and imports intermediate inputs from both country 2 and 3. Because country 1 uses foreign value added in its export, we have \( FV \neq 0 \). But since

\[^{14}\text{As shown in Koopman et al (2014), one can decompose gross nominal trade flows into value added component by using the following equation:}\]

\[ \sum_{k=1}^{N} v_k T_{k,i} = 1 \quad \forall \ i \]
country 1 does not export any intermediate inputs, all exports are directly absorbed by the associated direct partner and we have by construction $RDV = 0$ and $IV = 0$.

Figure 3: GVC with only “upstream” linkages

The associated model parameters are:

$$\Omega = \begin{pmatrix} 0 & \alpha_{1,2} & \alpha_{1,3} \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \quad \text{and} \quad B = \begin{pmatrix} \beta_{1,1} & 0 & 0 \\ \beta_{2,1} & \beta_{2,2} & 0 \\ 0 & 0 & \beta_{3,3} \end{pmatrix}$$

Using (7), nominal exports from 1 to 2 in country 1’s currency can be expressed as $E_{1\to2} = \varepsilon_{1,2}\beta_{2,1}w_2L_2$, which can be log-differentiated as:

$$d\log(E_{1\to2}) = d\varepsilon_{1,2} \quad (12)$$

The above expression is a natural consequences of our Cobb-Douglas assumption: regardless of currency values, a fraction $\beta_{2,1}$ of country 2’s total spending in country 2 is allocated to final goods coming from country 1. Hence, a devaluation in country 1 has no impact on final demand in country 2’s currency but translates into a one-for-one increase in export values labeled in country 1’s currency. Assuming constant wages in our partial equilibrium framework, we can get a simple expression for the exchange rate pass-through. \textsuperscript{15}

$$d\log(p_1) = \alpha_{1,2}d\varepsilon_{1,2} + \alpha_{1,3}d\varepsilon_{1,3} \quad (13)$$

With (12) and (13), the impact of currency changes on real exports from country 1 to country 2 is simply:

$$d\log(y_{2,1}) = (1 - \alpha_{1,2})d\varepsilon_{1,2} - \alpha_{1,3}d\varepsilon_{1,3} \quad (14)$$

When country 1 devalues its currency vis-a-vis 2, $\varepsilon_{1,2}$ increases. As illustrated by (14), \textsuperscript{15}Note that one can use (2) to get the proportional change in country 1’s price, $p_1$, following movements in currency values.
the associated change in real exports $\log(y_{2,1})$ is impacted by the foreign value-added embedded in exports. The first term on the right hand side, governed by $\alpha_{1,2}$, relates to the foreign value added coming from the destination country, which unambiguously decreases the elasticity of real exports to exchange rate. The second term relates to value added coming from a third country. Such a linkage is a priori ambiguous since it depends on the relative currency values between 1 and 3. The direction of this channel then depends on the correlation between $\varepsilon_{1,2}$ and $\varepsilon_{1,3}$. Overall, from this simple case we can infer that the share of foreign value added in exports coming from the direct partner’s country reduces the exchange rate pass-through to export prices and export volumes.

3.5.2 Role of downstream linkages

While the literature has extensively studied the impact of imported inputs in dampening the reactivity of exports to exchange rate movements, our model also allows us to derive prediction for the role of downstream linkages. In order to illustrate this in the simplest form, we consider the supply chain presented in figure 4: In such a case, country 1 does not import any intermediate input and hence is characterized by $FV = 0$. However, it exports intermediate inputs that are used for further exports to country 3 as well as back in country 1 (so that $IV \neq 0$ and $RDV \neq 0$ respectively). The associated model parameters are:

$$\Omega = \begin{pmatrix} 
\alpha_{1,1} & 0 & 0 \\
\alpha_{2,1} & \alpha_{2,2} & 0 \\
0 & 0 & \alpha_{3,3}
\end{pmatrix} \quad \text{and} \quad 
B = \begin{pmatrix} 
\beta_{1,1} & \beta_{1,2} & 0 \\
0 & \beta_{2,2} & 0 \\
0 & \beta_{3,2} & \beta_{3,3}
\end{pmatrix}$$

Using (10), we can derive a closed-form expression of nominal output in all countries. Then, with (8), we get a closed-form expression for nominal exports from country 1 to country 2

![Figure 4: GVC with no “upstream” linkages](image-url)
in country 1’s currency:

$$E_{1 \rightarrow 2} = \frac{\alpha_{2,1} \beta_{1,2}}{1 - \alpha_{2,2}} w_1 L_1 + \varepsilon_{1,2} \frac{\alpha_{2,1} \beta_{2,2}}{1 - \alpha_{2,2}} w_2 L_2 + \varepsilon_{1,3} \frac{\alpha_{2,1} \beta_{3,2}}{1 - \alpha_{2,2} w_3 L_3}$$ (15)

When country 1 devalues its currency vis-a-vis 2, $\varepsilon_{1,2}$ increases and the associated consequences on $E_{1 \rightarrow 2}$ are strongly impacted by participation in global value chains. From looking at the decomposition in (15), we can see that the first term on the right-hand side, which is governed by the RDV index, is not affected at all by the devaluation. Intuitively, this is the case because the final demand driving this part of exports is located in country 1 and is labeled in country 1’s currency. As a result, a devaluation of country 1’s currency is simply ineffective in attracting additional demand. The larger this term, the lower the sensitivity of exports to devaluation.

The second term in (15) increases exactly one-for-one with $\varepsilon_{1,2}$. This part corresponds to the share of exports from 1 to 2 that is ultimately absorbed in country 2 and its proportional change is naturally equal to the price elasticity of demand—which is equal to one with our Cobb-Douglas assumption.

Finally, the third term is ambiguous and depends on the country 1’s currency vis-a-vis 3. This last term, which is governed by the IV index, corresponds to exports from 1 to 2 that are ultimately absorbed in country 3. Hence, the final demand driving this part of the exports is labeled in country 3’s currency, and intuitively the only exchange rate that matters for this flow relate the country of origin (country 1) to the country of absorption (country 3), leapfrogging any intermediate production step. This result of course crucially depends on the Cobb-Douglas assumption in production. For example, if we assumed that inputs were perfectly substitutable in the production function of country 2, then any appreciation of country 1’s currency vis-a-vis country 2 would result in a collapse in demand from country 1’s inputs, irrespectively of the country of final absorption.\footnote{While our Cobb-Douglas assumption can be seen as strong, one should note that it allows us to derive easily several predictions that are then tested in the data. In section 5, we find significant empirical support for those predictions.}

Note that since country 1 does not import any intermediate inputs, its domestic price is independent of the relative value of its currency so that we have $d \log(p_1) = 0$. It then follows that the proportional change in real exports (or quantity exported) is exactly equal
to the proportional change in nominal exports:

\[ d \log(m_{2,1}) = d \log(E_{1\rightarrow 2}) - d \log(p_1) = d \log(E_{1\rightarrow 2}) \]  

(16)

3.5.3 Summary of testable predictions

The illustrative examples presented above yield two sets of predictions. First, an increase in upstream integration in global value chains, as measured by the \( FV \) index, is associated with a lower exchange rate pass-through to export prices when prices are measured in destination currency. Moreover, an increase in \( FV \) is associated with a decrease in the elasticity of exports to exchange rates. Second, a high level of downstream integration, measured by \( RDV \) or \( IV \), creates a dependency between export and the exchange rate between the origin country and the final country of absorption. In the case of \( RDV \), the final country is the same as the origin country and the associated export flow is independent of the direct exchange rate, which means that an increase in \( RDV \) reduces the elasticity of exports to exchange rate. For \( IV \), the final country of absorption is neither the origin country nor the direct partner, so that the relevant exchange rate “leapfrogs” the direct partner and relates origin and final absorption.

Finally, the setup developed in this paper assumes a fixed elasticity of substitution equal to one between domestic and foreign inputs in all production functions. Such a Cobb-Douglas framework has evidently an important impact on the value of the elasticity of exports volumes and export prices to exchange rate changes which might not be in line with empirical findings in all sectors or countries. However, it is important to note that our goal is not to recover the level of those elasticities, but rather is to illustrate the impact of changes in global value chain participation. In other words, our analysis shows that for any fixed value of the sensitivity of exports volumes to changes in export prices,\(^{17}\) the participation in global value chain impacts the responsiveness of exports to movements in the exchange rate.\(^{18}\)

\(^{17}\)In general, this elasticity is a function of (i) the elasticity of substitution between domestic and foreign goods in both production and demand functions and (ii) the inter-temporal elasticity of substitution governing inter-temporal choices. In our static framework, the latter channel is not present.

\(^{18}\)While the focus of this paper is on export volumes, in the theoretical literature the effect of an exchange rate change on the trade balance is usually studied through the Marshall-Lerner condition which states that the sum of export and import elasticities of the exchange rate should be above unity in order for trade balance to improve upon currency depreciation. Our study shows that both elasticities are strongly impacted by countries’ participation in global value chains. Moreover, the empirical literature has expressed concerns regarding the validity of the Marshall-Lerner condition. See Rose (1991) or Auboin and Ruta (2013) for more comprehensive insights into the topic.
4 Data

4.1 Data sources

Testing the predictions from the previous section requires a detailed dataset that captures all the important upstream- and downstream links embedded in global value chains.

We utilise mainly two sources of data; (i) the World Input-Output Tables (WIOD) and (ii) a sectoral panel dataset from the Socio-Economic Accounts (SEA). These tables contain annual global input-output information for 35 sectors, comprising primary, durable and non-durable manufacturing as well as services sectors, including financial intermediation.

The tables are available for 40 countries of which a majority is in the European Union, but also include countries in North America, South America and Asia, as well as rest of the world (constructed as one economy) from 1995 to 2011. These tables are available in current (to 2011) and in previous years prices (to 2009). Therefore, for each year a full country-sector input-output matrix of the dimension $1 \times 1,435 \times 1,435$ is available and allows for the analysis of bilateral supply and use relationships between a sector in a specific country and all other sectors in the 39 countries.

The Socio-Economic Accounts of the WIOD contain a multi-country panel of sector data on, for example, employment, capital stocks, gross output and value added. The bilateral nominal exchange rates are provided by the WIOD, whereas we obtain the countries’ nominal effective exchange rates from the BIS. Together, these sources enable us to construct bilateral trade flows, export prices, exchange rates and indices of global value chain participation. To alleviate issues regarding possible endogeneity of export prices and volumes and bilateral exchange rates at the aggregate level, our empirical analysis will be conducted at the sector-level. Export prices and volumes at such a disaggregated level is less likely to directly impact bilateral exchange rates at the aggregate level.

Obtaining real bilateral exports flows between a sector $s$ and its destination market $d$ from the WIOD is straightforward: we calculate the gross nominal flows (both of final and intermediate products) from sector $s$ in country $o$ to other countries $d$ (where $o \neq d$).

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19 See Timmer et al. (2015) and www.wiod.org

20 The 2016 release of the World Input-Output Tables contains information for 56 sectors in 43 countries annually from 2000-2014 in nominal values. However, these tables are not yet available in both current and previous year’s prices.

21 In the rest of the empirical analysis, we drop observations relating to "Private households with employed persons" with largely zero trade flows and winsorize the sample at the 99th percentile.
Sector-level export prices to a particular destination are computed by dividing the global input-output tables in current prices with the same tables in previous year’s prices for each year. Since the WIOD is expressed in US dollars, we convert them to local currencies with bilateral exchange rates. Thereafter, we consider export prices from sector $s$ in country $o$ to destination market $d$ (recall that $o \neq d$ so intra-country prices are not included) and we use them to deflate the corresponding gross nominal export flows to obtain real values. Following the theoretical model, these prices will be expressed in the destination markets’ currency.

4.2 Currency- and country-based indices of global value chains

Our three main indices ($FV$, $IV$ and $RDV$) of global value chain participation follow the decomposition of sectoral gross exports developed by Wang et al. (2013). These measures need to be adapted to be comparable to our predictions from Section 3. Recall that in the theoretical model each country has its own currency. Since reality is more complex and countries participate in currency unions (such as the EMU) or have currency pegs, we construct indices of global value chain participation that are based on currencies instead of countries. This is important because it is arguably only those trade flows in global value chains that vary with the bilateral exchange rates that will impact the trade elasticities.

To elucidate the general concept of these indices, Figure 5 provides a graphical representation. Starting with the first index, $FV$, i.e. the "import content of exports": this measure includes all imports of an origin country from the destination that are used to produce exports to the same destination. If the destination market $d$ has the same currency as the origin (i.e. $\varepsilon_{o,d} = 1$), the import content will be nil and $FV_{o\rightarrow d} = 0$.

Figure 5: GVC participation indices
Take as an example a German firm that exports its products to the United States. Increasing the share of inputs imported from the United States would affect the German firm’s exchange rate pass-through to export prices and elasticity of export volumes to the EUR/USD exchange rate. Inputs sourced by the German firm from countries with the same currency as Germany (such as Spain) should have no impact on the bilateral export elasticities to the United States. Moreover, imported inputs from countries with different currencies than the EUR or USD would have an ambiguous impact on the elasticities and would depend on the relative exchange rate movements of the three currencies.

Our second index in panel B), \( IV \), differs from the corresponding country-based one in that it takes into consideration the currency of the country that re-exports the product. To illustrate this, we continue with the example of the German firm: it sells components to an assembly plant in Mexico, which are processed and later re-exported to the United States as a finished product. In this case, our \( IV \) measure and the country-based index coincide. If all countries (origin, assembler and final destination) are within a currency area such as the EMU however, the \( IV \) measure would not be counted at all, since the transactions are made in the same currency (without any currency effects).

If the final destination of exports is within same currency area as Germany as in panel C), we would consider that as domestic value added that returns "home" and would be counted as our third index, \( RDV \).\(^{22}\) All value added that goes through a trading partner with a different currency, but returns to a country with the same currency as the origin, will thus be counted as "returned domestic value added", \( RDV \). In the country based decomposition, this trade flow would instead be counted as \( IV \).

### 4.3 Comparing the different indices

Table 1 shows summary statistics for the various measures, computed over all country-sector exports to destination markets, based on currencies and countries in 2005, which is a mid-point in the data. As expected, the currency-based \( IV \) is smaller than the one based on countries on average, whereas \( RDV \) is larger. By construction, some exports in \( IV \) will end up in \( RDV \) when we recompute the measures on currencies instead of countries.\(^{23}\) The index values are also different across the distribution (see Figure 6). Both the \( FV \) and the

\(^{22}\)In the country based decomposition of gross exports, \( RDV \) flows would only be counted as exports of intermediate inputs that are re-imported into the same country.

\(^{23}\)To be comparable to our \( FV \) measure, the \( FV \) based on countries only considers value added from the "direct importer", which is T11 and T12 in Wang et al. (2013) terminology.
$IV$ measure based on countries is larger than measures based on currencies. Conversely, the $RDV$ measure based on currencies in the 95$^{th}$ percentile is much higher (almost 16% at the 99$^{th}$ percentile, compared to just over 6% for measures based on countries).

Table 1: Summary statistics of $FV$, $IV$ and $RDV$ based on currencies and countries

<table>
<thead>
<tr>
<th></th>
<th>based on currencies, 2005</th>
<th>based on countries, 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$FV$</td>
<td>$IV$</td>
</tr>
<tr>
<td>average</td>
<td>0.3%</td>
<td>16.0%</td>
</tr>
<tr>
<td>max</td>
<td>44.7%</td>
<td>93.8%</td>
</tr>
<tr>
<td>min</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

Figure 6: Currency- and country-based GVC participation indices across percentiles in 2005

Note: The percentiles are for nominal exports of goods and services and computed for each bilateral country-sector-to-destination observation.

The levels and the evolution over time of our indices differ from those of the country-based indices, Figure 7. The median $FV$ and $IV$ measures based on declined much more strongly during the Great Recession than the ones based on countries. The $RDV$ index has on the other hand increased strongly compared to the index based on countries.\footnote{This might indicate that extra-euro area supply chain-related flows fell more steeply during the Great Recession, suggesting that the regional chains were more resilient to the trade slowdown and the large global value chain disruption during this period.} This is unsurprising: since 1999 and over the 2000s, many countries in the sample joined the
Economic and Monetary Union of the European Union (EMU). That is also the point of our analysis: if we take the argument about global value chains and exchange rate elasticities seriously, we need to jointly take into account all links in global value chains and currency movements on the export elasticities.

One way to observe the cross-country and cross-sector differences among our global value chain participation indices is provided in Figure 8. It displays along the rows the sectors, and on the columns the origin countries. A darker shade of red indicates that a particular country-sector has, on average, a higher degree of participation.

Starting with Figure 8, it is clear that downstream sectors (transport equipment, electrical and optical equipment and manufacturing, n.e.c) in mainly Canada and Mexico stand out. These sectors are largely connected to value chains in the United States and use a large share of value added that originated there to produce final goods exports to the United States. As for IV in Figure 9, many country-sectors are highly integrated "upstream" in the value chain. These linkages are the strongest in mainly the transporting sectors (water transport and other transporting and auxiliary transport activities), sectors selling raw materials (basic and fabricated metals and mining and quarrying) and financial intermediation. The other upstream measure, RDV, is strongest for the United States in the raw materials sectors (basic and fabricated metals and mining and quarrying) and manufacturing (electrical and optical equipment and rubber and plastics). It is also quite
significant in the raw materials sectors in the Slovak Republic.  

Figure 8: FV intensity across sectors and countries

Figure 9: IV intensity across sectors and countries

25 Appendix A shows a detailed ranking among the top 100 sectors according to their average GVC indices.
5 Empirical estimates of the role of global value chains

Armed with the multi-country panel dataset and our currency-based indices of global value chain participation and our theoretical predictions, we proceed by empirically estimating the role of each index in affecting the export elasticities. Although we have dealt with one important difference between the theoretical model and the data, others remain.

First, in the model, the elasticity of substitution between domestic and foreign inputs is identical for all sectors and countries and does not vary over time. In the data, these elasticities will vary across sectors and countries. Our regressions will therefore include sector-destination-time or sector-origin-time fixed effects in order to exploit only the within sector variation.

Second, in our model, countries produce and consume the same goods for exports or for domestic consumption. This is not the case in the data and a sector’s output prices will be different from its export prices and will be specific to each destination market. To account for this, we use bilateral export prices instead of using total output prices, as outlined in Section 4.
5.1 Specification

5.1.1 Prices regression

We start by exploring the role of production linkages in reducing the exchange rate pass-through to export prices, as in equation (17). Here, $\Delta$ denotes the log-change between period $t$ and $t-1$. $\Delta p_{sodt}$ is the price - expressed in destination’s currency - of total exports produced by sector $s$ in country $o$ and sold in destination $d$. Export prices are determined by the bilateral exchange rate, $\Delta e_{xrot}$. It is zero when two countries are using the same currency. We also add other sector-specific cost measures, such as domestic labour and capital costs, $\Delta l_{sot}$ and $\Delta k_{sot}$, to control for other determinants of export prices.

$$\Delta p_{sodt} = \eta_t + \beta_{\text{exr}} \Delta e_{xrot} + \beta_{\text{exrfv}} \Delta e_{xrot} f_{v_{sodt}} + \beta_l \Delta l_{sot} + \beta_k \Delta k_{sot} + u_{sodt} \quad (17)$$

The coefficient of interest in (17) is $\beta_{\text{exrfv}}$, i.e. the coefficient of the interaction of exchange rate with $f_{v_{sodt}}$. Based on our theoretical analysis, only upstream links in the value chains should impact export prices. We expect that an exchange rate depreciation (increase in $\Delta e_{xrot}$) would make a sector $s$’ prices to destination $d$ lower. However, this effect would be (partly) outweighed if exports consists of intermediate inputs that originated in $d$. This decrease should be proportional to $f_{v_{sodt}}$. Therefore, we expect $\beta_{\text{exrfv}}$ to be positive and reduce the exchange rate pass-through.

5.1.2 Exports regression

The export volume equation is defined as in (18). Export volumes of sector $s$ in country $o$ to destination $d$, $\Delta e_{xrot}$, depend on $e_{xrot}$ (the bilateral nominal exchange rate between $o$ and $d$) and $\Delta \text{Demand}_{sdt}$, which is the import demand of the destination country for the goods produced by sectors $s$ in all countries. This measure excludes the imports of sector $s$ in country $o$. As described in Section 3, the export elasticities should, apart from being affected by upstream linkages via $FV$, also be affected by downstream linkages. Therefore, the bilateral exchange rate between $o$ and $d$ is interacted with the indices $f_{v_{sodt}}$, $r_{d_{sodt}}$ and $iv_{sodt}$ in order to test for the effect on the elasticities.

$$\Delta e_{xrot} = \eta_t + \beta_D \Delta \text{Demand}_{sdt} + \beta_{\text{exr}} \Delta e_{xrot} + \beta_{\text{exrfv}} \Delta e_{xrot} f_{v_{sodt}} + \beta_l \Delta l_{sot} + \beta_k \Delta k_{sot} + u_{sodt} \quad (18)$$
According to our predictions, $\beta_{exr}$ should be positive and $\beta_{exr \ rdv}$ and $\beta_{exr \ fv}$ should be negative. If a sector $s$ in country $o$ experiences a currency depreciation with respect to destination country $d$’s currency, it should have a positive effect on sector $s'$ exports. However, the effect is reduced as sector $s$ sources intermediate inputs from the destination market $d$ (a higher $fv_{sodt}$) and the greater the share of value added which returns back to home (to the origin country) as imports (higher $rdv_{sodt}$). By contrast, the effect of $iv_{sodt}$ on the bilateral exchange rate elasticity should instead be negligible. Intuitively, a larger share of intermediate exports should rather affect the exports elasticity to the destination country’s exchange rate vis-à-vis all its trading partners. Therefore we also regress the trading partners nominal effective exchange rate ($neer_{dt}$) on exports and its interaction with $IV$ ($\beta_{neer \ iv}$). We expect both terms to be positive.

5.2 Empirical results

5.2.1 Price pass-through

We start with results from a pooled OLS regression featuring only the exchange rate changes and changes in capital and labour costs as regressors, in order to estimate the full pass-through of exchange rate into destination prices. A currency depreciation (appreciation) of 1% leads to a decrease (increase) in export prices of about -0.7%. The coefficient does not fall dramatically when adding sector-destination (column 2) or sector-origin-destination (column 3) fixed effects and time dummies.

When the interaction between exchange rates and the $FV$ index is included, the exchange rate pass-through is diminished, as the sign of the coefficient is positive and significant in Table 2. In particular, as Figure 11 points out, for sectors falling within the 50th percentile of the $FV$ distribution, the exchange rate pass-through remains unchanged. As the share of foreign intermediate inputs in exports increases, the pass-through is reduced substantially, falling to a value of -0.39. Overall, these results are in line with those of Amiti et al. (2014) and Fauceglia et al. (2014) who also find evidence of declining exchange rate pass-through when the import content of exports increases.
<table>
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<th>(4)</th>
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<td>0.306***</td>
<td>0.081***</td>
<td>0.212***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.043)</td>
<td>(0.057)</td>
<td>(0.042)</td>
<td>(0.015)</td>
<td>(0.055)</td>
<td>(0.016)</td>
<td>(0.025)</td>
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</tr>
<tr>
<td>R-squared</td>
<td>0.565</td>
<td>0.584</td>
<td>0.614</td>
<td>0.587</td>
<td>0.742</td>
<td>0.618</td>
<td>0.757</td>
<td>0.761</td>
<td>0.875</td>
</tr>
<tr>
<td>FE</td>
<td>no S-D</td>
<td>S-D</td>
<td>S-D</td>
<td>S-D</td>
<td>O-S-D</td>
<td>O-S-D</td>
<td>S-D-Y</td>
<td>S-D-Y</td>
<td>S-O-Y</td>
</tr>
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<td>dummies</td>
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<td>Y</td>
<td>O-Y</td>
<td>no</td>
<td>no</td>
<td></td>
</tr>
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</table>

**Notes:** Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Estimation results of equation (17). Observations are at sector-origin-destination-level. \( S = \) sector, \( O = \) origin country, \( D = \) destination country and \( Y = \) year.
5.2.2 Export volume elasticities

Table 3 reports the results for the export volumes regression.\textsuperscript{26} The pooled OLS reveals a dampening effect of $FV$ on the bilateral exchange rate elasticity and the positive effect of $IV$ on the elasticity of exports to the direct partner’s nominal effective exchange rate (NEER). When we exploit the within sector-destination (second column) or the sector-origin-destination (fourth column) variability and control for common time effects, we obtain a negative and significant coefficient for the interaction terms of the bilateral exchange rate with $FV$ and $RDV$ and an insignificant effect of $IV$ on the exchange rate elasticity.

Interestingly, the coefficient of the destination’s NEER vis-à-vis its trading partners is not significant, whereas its interaction with $IV$ is positive and significant, meaning that sector $s'$ exports are more sensitive to its direct trading partners nominal effective exchange rate the higher is the quantity of exports that are intermediated by the latter. The results are confirmed even when controlling for time-varying characteristics of countries/currencies with country-time dummies, although the interaction of $IV$ with the NEER of the destination market becomes statistically insignificant, but remains of the correct sign.

\textsuperscript{26}Origin and destination country dummies take into account the formation of the EMU along the sample.
Finally, we substitute sector-origin-destination fixed effects with sector-destination-year fixed-effects, in order to control for destination characteristics varying over sector and time which might affect export elasticities, such as demand conditions, trade costs or tariffs. Overall, the results are confirmed, although the effect on $FV$ on the bilateral exchange rate elasticity of exports weakens.

As we saw in Figure 6-7 and Figure 8-10, country-sectors are differently engaged in global value chains. How their export volumes reach to the same changes in bilateral exchange rates depend on the specific nature of their global value chain linkages. Figure 12-14 plots the exchange rate elasticities computed at various percentile values of $FV$, $RDV$ and $IV$ to illustrate this heterogeneity. Sectors at or above the 25th percentile of $FV$ and $RDV$ shares, i.e. at the corresponding value of 0.011 and 0.019, respectively 27 see a dampening effect on their bilateral exchange rate elasticity of exports. Sectors which are very integrated in global value chains (those at the 95th percentile or higher, or equivalently, with shares of either $FV$ and $RDV$ greater than 1.4 and 7.7), eventually see a strong reduced impact on exports from an exchange rate depreciation. 28

As for the interactive effect of $IV$ with the destination-markets nominal effective exchange rate, we can see that sectors within the 10th percentile of the $IV$ distribution are insensitive to destination’s exchange rate movements. However, as $IV$ increases, the elasticity of sectors $s'$ exports to NEER rises until it reaches a value of 0.09, meaning that if the nominal effective exchange rate increases by 1% (i.e. sector $s'$ currency depreciates), it will stimulate sectoral exports by around 0.1 percentage point. Sectors located in this highest percentile of the $IV$ distribution are basic metals, transport, mining and quarrying and financial intermediation (Table 7 in the appendix).

---

27 The reader should remind that $FV$ and $RDV$ are bilateral measures considering the share of sector’s export of foreign value added and re-imported value added from the specific destination country.

28 The negative coefficients shown in Figure 12 and 13 are not significant at any confidence level.
Table 3: Export regression

<table>
<thead>
<tr>
<th>Dependent variable:</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
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<td>( \Delta \text{exp} )</td>
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</tr>
<tr>
<td>( \Delta \text{exr} )</td>
<td>0.243***</td>
<td>0.180***</td>
<td>0.219*</td>
<td>0.192***</td>
<td>0.256**</td>
<td>0.154**</td>
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<td>(0.015)</td>
<td>(0.062)</td>
<td>(0.125)</td>
<td>(0.055)</td>
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</tr>
<tr>
<td>( \Delta \text{Demand} )</td>
<td>0.521***</td>
<td>0.485***</td>
<td>0.485***</td>
<td>0.487***</td>
<td>0.485***</td>
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<tr>
<td></td>
<td>(0.007)</td>
<td>(0.017)</td>
<td>(0.018)</td>
<td>(0.018)</td>
<td>(0.019)</td>
<td></td>
</tr>
<tr>
<td>( \Delta \text{exr} \times iv )</td>
<td>-0.000</td>
<td>0.003</td>
<td>-0.001</td>
<td>0.001</td>
<td>-0.003</td>
<td>0.004</td>
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<tr>
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<td>(0.001)</td>
<td>(0.003)</td>
<td>(0.002)</td>
<td>(0.003)</td>
<td>(0.002)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>( \Delta \text{exr} \times rdv )</td>
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<td>-0.019**</td>
<td>-0.010</td>
<td>-0.022**</td>
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<td>(0.010)</td>
<td>(0.008)</td>
<td>(0.010)</td>
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<tr>
<td>( \Delta \text{exr} \times fv )</td>
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<td>-0.074***</td>
<td>-0.049**</td>
<td>-0.083***</td>
<td>-0.056**</td>
<td>-0.039</td>
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<tr>
<td>( \Delta \text{neer} )</td>
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<td>0.009</td>
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<td>(0.021)</td>
<td>(0.072)</td>
<td>(0.124)</td>
<td>(0.067)</td>
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<td></td>
</tr>
<tr>
<td>( \Delta \text{neer} \times iv )</td>
<td>0.003***</td>
<td>0.008**</td>
<td>0.004</td>
<td>0.008**</td>
<td>0.003</td>
<td>0.008**</td>
</tr>
<tr>
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<td>(0.001)</td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.004)</td>
</tr>
</tbody>
</table>

R-squared 0.010 0.018 0.041 0.049 0.070 0.107
FE no S-D S-D O-S-D O-S-D S-D-Y
cluster no O-Y O-Y O-Y O-Y O-Y no
dummies no Y O-Y Y O-Y no

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Estimation results of equation (18). Observations are at sector-origin-destination-level. S = sector, O = origin country, D = destination country and Y = year.
Figure 12: Effect of FV on the bilateral exchange rate elasticity

Source: World Input-Output tables (2013 release), BIS and authors’ calculations.

Note: The Figure reports percentiles of $FV$ with respective values in the second row of the x-axis and the corresponding exchange rate elasticity on the vertical axis. Elasticities are computed from the specification in column (4) of Table 3, including origin-sector-destination fixed effects and time dummies.

Figure 13: Effect of RDV on the bilateral exchange rate elasticity

Source: World Input-Output tables (2013 release), BIS and authors’ calculations.

Note: The Figure reports percentiles of $RDV$ with respective values in the second row of the x-axis and the corresponding exchange rate elasticity on the vertical axis. Elasticities are computed from the specification in column (4) of Table 3, including origin-sector-destination fixed effects and time dummies.
Figure 14: Effect of IV on destination’s exchange rate elasticity

Source: World Input-Output tables (2013 release), BIS and authors’ calculations.

Note: The Figure reports percentiles of IV with respective values in the second row of the x-axis and the corresponding exchange rate elasticity on the vertical axis. Elasticities are computed from the specification in column (4) of Table 3, including origin-sector-destination fixed effects and time dummies.

Figure 15: Effect of FV and RDV on the bilateral exchange rate elasticity

Source: World Input-Output tables (2013 release), BIS and authors’ calculations.

Note: The Figure reports the exchange rate elasticity of exports (on the vertical axis) at corresponding percentiles of both FV and RDV. The sum of the respective values of FV and RDV is reported in the second row of the x-axis. Elasticities are computed from the specification in column (4) of Table 3, including origin-sector-destination fixed effects and time dummies.

If a sector has a high FV and simultaneously has a relatively high RDV, or vice-versa, its exports would actually decline following a depreciation of its bilateral exchange rate.
This is shown in Figure 15. At the 99th percentile of both $FV$ and $RDV^{29}$, a sectors’ exports would fall following a depreciation of its bilateral exchange rate. The intuition is simple: take as a polar case a sector that imports a significant share of its inputs from abroad, sells its products abroad as intermediate and the final products are then re-imported back for domestic consumption. In such a case - due to the foreign value added part - a devaluation would increase the production price in domestic currency, and since final demand is located at home, consumers simply see an increase in the final price and hence decrease their consumption.

6 Conclusions

The exchange rate pass-through to export prices and the responsiveness of export volumes to changes in the exchange rate constitute key elements in macroeconomics. These elasticities are in turn impacted by structural changes in the global economy and particularly by international production linkages, which have expanded strongly over the past decades. These structural changes have also gone in tandem with the expansion of common currency areas such as the EMU.

In this paper, we developed a partial equilibrium, multi-country model of international trade in intermediate inputs and final goods. With the model, we derived simple predictions for the role of precisely defined indices of global value chain participation in shaping the relationship between the exchange rate, export prices and exports volumes. We validated those predictions with empirical estimates by using a comprehensive multi-country panel dataset.

The results show that the exchange rate pass-through to export prices decreases with the share of inputs bought in foreign currency and used to produce exports due to a price effect, similar to Amiti et al. (2014). For export volumes, this channel also lowers the elasticity to bilateral exchange rates. But export volumes are also impacted by downstream conditions in the value chain. The share of a sector’s exports that returns to the origin country - or in another country within the same currency area as the exporting country - also reduces the exchange rate elasticity of export volumes. In fact, some sectors that are both highly integrated “downstream” and “upstream” in the value chain actually see their exports decline when their exchange rate depreciates against the destination country. Moreover,

\footnote{Sectors with highest percentiles of $FV$ and $RDV$ are reported in Table 6 in Appendix A.}
the share of intermediate exports used to produce products that are further exported to a third currency zone by the trading partner makes bilateral trade flows sensitive to the trading partner's exchange rate.

To precisely assess the consequences of international input-output linkages on exchange rate elasticities, we have emphasized the importance of defining indices of global value chain participation based on currencies rather than countries. In our sample, the share of exports that are re-imported tends to decrease over time when based on countries, whereas it actually increases when we compute it based on currencies. On the other hand, the fall in the share of foreign value added in exports in recent years seems more pronounced when we take into account the fact that many countries share the same currency (in particular in the EMU).

These additional elements are important since they imply that participation in global value chains as defined in the literature is not necessarily associated with a decrease in the responsiveness of exports to exchange rates: if international linkages are regional and with countries sharing the same currency, they might not significantly lessen the responsiveness of exports to changes in exchange rates. Future developments in international production fragmentation and their impact on export elasticities will therefore also depend on the future scope of common currency areas.
Appendices

A Further descriptive evidence

Table 4: Ranking of sectors according to the currency-based FV index

<table>
<thead>
<tr>
<th>country</th>
<th>sector name</th>
<th>country</th>
<th>sector name</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAN</td>
<td>Transport Equipment</td>
<td>MEX</td>
<td>Other Non-Metallic Mineral</td>
</tr>
<tr>
<td>MEX</td>
<td>Electrical and Optical Equipment</td>
<td>MEX</td>
<td>Machinery, N.e.</td>
</tr>
<tr>
<td>MEX</td>
<td>Manufacturing, Nec. Recycling</td>
<td>DEU</td>
<td>Ship Building and Repair of Motor Vehicles</td>
</tr>
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<td>MEX</td>
<td>Textiles and Textile Products</td>
<td>ITA</td>
<td>Leather, Leather and Footwear</td>
</tr>
<tr>
<td>MEX</td>
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<td>ITA</td>
<td>Leather, Leather and Footwear</td>
</tr>
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<td>Electrical and Optical Equipment</td>
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<td>Printing and Publishing</td>
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<td>Chemicals and Chemical Products</td>
<td>CZE</td>
<td>Printing and Publishing</td>
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<td>Printing and Publishing</td>
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<td>CZE</td>
<td>Printing and Publishing</td>
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<td>Printing and Publishing</td>
</tr>
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<td>Printing and Publishing</td>
</tr>
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<td>Printing and Publishing</td>
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<td>Fishing and Fishing</td>
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<td>Fishing and Fishing</td>
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<td>Fishing and Fishing</td>
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<td>ITA</td>
<td>Leather, Leather and Footwear</td>
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</table>

Notes: The table shows the first 100 sectors with the highest value of the currency-based FV index. The index is calculated as a weighted average of destination specific indices, where the weight is the share of each destination over total gross exports.
Table 5: Ranking of sectors according to the currency-based RDV index

<table>
<thead>
<tr>
<th>Country</th>
<th>Sector Name</th>
<th>Country</th>
<th>Sector Name</th>
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<td>USA</td>
<td>Electricity, Gas and Water Supply</td>
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<td>USA</td>
<td>Rubber and Plastics</td>
<td>SVK</td>
<td>Other Non-Metallic Mineral</td>
</tr>
<tr>
<td>USA</td>
<td>Medical and Scientific</td>
<td>MLT</td>
<td>Inland Transport</td>
</tr>
<tr>
<td>SWK</td>
<td>Basic Metals and Fabricated Metal</td>
<td>SVK</td>
<td>Air Transport</td>
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<tr>
<td>SVK</td>
<td>Financial Interests</td>
<td>CYF</td>
<td>Sales, Maintenance and Repair of Motor Vehicles</td>
</tr>
<tr>
<td>USA</td>
<td>Electrical and Optical Equipment</td>
<td>MLT</td>
<td>Postal and Telecommunications</td>
</tr>
<tr>
<td>SVK</td>
<td>Wood and Products of Wood and Cork</td>
<td>FIN</td>
<td>Basic Metals and Fabricated Metal</td>
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<td>JPN</td>
<td>Island Transport</td>
</tr>
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<td>JPN</td>
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<td>GRC</td>
<td>Basic Metals and Fabricated Metal</td>
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<tr>
<td>USA</td>
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<td>SVK</td>
<td>Electricity, Gas and Water Supply</td>
</tr>
<tr>
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<td>Chemicals and Chemical Products</td>
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<td>Air Transport</td>
</tr>
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</tr>
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<td>Railways, except of Motor Vehicles</td>
</tr>
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<td>Chemicals and Chemical Products</td>
</tr>
<tr>
<td>SVK</td>
<td>Pulp, Paper, Paper, Printing and Publishing</td>
<td>FRA</td>
<td>Basic Metals and Fabricated Metal</td>
</tr>
<tr>
<td>SVK</td>
<td>Other Supporting and Auxiliary Transport Activities</td>
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<td>Electrical and Optical Equipment</td>
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<td>Textiles and Textile Products</td>
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<td>Rail, Maintenance and Repair of Motor Vehicles</td>
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</table>

Notes: The table shows the first 100 sectors with the highest value of the currency-based RDV index. The index is calculated as a weighted average of destination specific indices, where the weight is the share of each destination over total gross exports.
Table 6: Ranking of sectors according to the currency-based FV and RDV indices

<table>
<thead>
<tr>
<th>Country</th>
<th>Sector Name</th>
<th>Country</th>
<th>Sector Name</th>
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<tr>
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<td>MLT</td>
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<td>SVK</td>
<td>Other Supporting and Auxiliary Transport Activities</td>
</tr>
<tr>
<td>USA</td>
<td>Paper and Paper-based Products</td>
<td>BGR</td>
<td>Leather, Leather and Footwear</td>
</tr>
<tr>
<td>USA</td>
<td>Plastic and Rubber</td>
<td>BGR</td>
<td>Other Supporting and Auxiliary Transport Activities</td>
</tr>
<tr>
<td>MEX</td>
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<td>SVK</td>
<td>Hospital and Medical Equipment</td>
</tr>
<tr>
<td>MEX</td>
<td>Textiles and Textile Products</td>
<td>MEX</td>
<td>Food and Beverages and Tobacco</td>
</tr>
<tr>
<td>SVK</td>
<td>Financial Intermediation</td>
<td>MLT</td>
<td>Electrical, Gas and Water Supply</td>
</tr>
<tr>
<td>MEX</td>
<td>Basic Metals and Fabricated Metal</td>
<td>FIN</td>
<td>Rubber and Plastics</td>
</tr>
<tr>
<td>MEX</td>
<td>Telecommunication</td>
<td>SVK</td>
<td>Coal, Nondeductible and Nuclear Fuel</td>
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<td>Wood and Products of Wood and Cork</td>
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<td>Air Transport</td>
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</tr>
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<td>Pulp, Paper, Paper-based Products</td>
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<td>Wood and Products of Wood and Cork</td>
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<td>Electrical and Optical Equipment</td>
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<td>Textiles and Textile Products</td>
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<td>Electrical, Gas and Water Supply</td>
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<td>Chemicals and Chemical Products</td>
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</tr>
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<td>USA</td>
<td>Agriculture, Forestry and Mining</td>
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<td>Pulp, Paper, Paper-based Products</td>
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<td>Wood and Products of Wood and Cork</td>
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<td>Basic Metals and Fabricated Metal</td>
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<td>Chemicals and Chemical Products</td>
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<td>Basic Metals and Fabricated Metal</td>
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<tr>
<td>USA</td>
<td>Public Administration, Compulsory Social Security</td>
<td>SVK</td>
<td>Pulp, Paper, Paper-based Products</td>
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<td>IRL</td>
<td>Other Non-Metals and Minerals</td>
<td>SVK</td>
<td>Pulp, Paper, Paper-based Products</td>
</tr>
<tr>
<td>CAN</td>
<td>Leather, Leather and Footwear</td>
<td>SVK</td>
<td>Pulp, Paper, Paper-based Products</td>
</tr>
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<td>IRL</td>
<td>Hotel and Restaurants</td>
<td>SVK</td>
<td>Pulp, Paper, Paper-based Products</td>
</tr>
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<td>SVK</td>
<td>Pulp, Paper, Paper-based Products</td>
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<td>MEX</td>
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<td>SVK</td>
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<td>Financial Intermediation</td>
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<td>USA</td>
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<td>MEX</td>
<td>Textiles and Textile Products</td>
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<tr>
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<td>Leather, Leather and Footwear</td>
<td>SVK</td>
<td>Pulp, Paper, Paper-based Products</td>
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Notes: The table shows the first 100 sectors with the highest value of the sum of the currency-based FV and RDV indices. Both indices are calculated as a weighted average of destination-specific indices, where the weight is the share of each destination over total gross exports.
Table 7: Ranking of sectors according to the currency-based IV index

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<td>GRC</td>
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<td>ISO</td>
<td>Mining and Quarrying</td>
</tr>
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<td>Other Supporting and Auxiliary Transport Activities</td>
<td>SWE</td>
<td>Basic Metals and Fabricated Metal</td>
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<td>BEL</td>
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</tr>
<tr>
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<td>Leather, Linnen and Footwear</td>
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<td>EST</td>
<td>Postal and Telecommunications</td>
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</table>

Notes: The table shows the first 100 sectors with the highest value of the sum of the currency-based FV and RDV indices. Both indices is calculated as a weighted average of destination specific indices, where the weight is the share of each destination over total gross exports.
References


Eichengreen, B. and Gupta, P. (2013). The real exchange rate and export growth: are services different?


