Global Value Chain Participation and Exchange Rate Pass-through*

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December 7, 2017

Abstract

This paper draws a causal link between the rise of global value chains and the decline of exchange rate pass-through to import prices. We first present a structural two-country model in which the sensitivity of an economy's local-currency production costs to exchange rate changes rises as it imports more intermediate goods and thereby participates more in global value chains. In the model, the increased sensitivity of the economy's local-currency export prices to exchange rate changes translates into lower variations in trading-partners' import prices in the latter's currency, i.e. the trading-partner experiences a fall in exchange rate pass-through to domestic currency import prices. We then provide empirical evidence in a panel of advanced and emerging economies that is consistent with the mechanism spelled out in the model. In particular, estimates of exchange rate pass-though to export (import) prices are higher (lower) if the economy (its import trading partners) participates more in global value chains.

Keywords: Global value chain participation, exchange rate pass-through, currency invoicing.
JEL-Classification: F32, F41, F62.

*We would like to thank Cedric Tille, seminar participants at the ECB, and participants at the Computing in Economics and Finance Conference 2017 for useful comments. Supported by funds of the Oesterreichische Nationalbank (Oesterreichische Nationalbank, Anniversary Fund, project number: 15979). The views expressed in the paper are those of the authors and do not necessarily reflect those of the ECB or the Deutsche Bundesbank.

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1 Introduction

A salient feature of the past decades has been the decline in the pass-through of exchange rate changes to the local-currency price of imported goods (Campa et al., 2005; Marazzi et al., 2005; Ihrig et al., 2006; Sekine, 2006; ECB, 2016). In particular, Figure 1 displays the evolution of estimates of the exchange rate pass-through to import prices for the time period from 2000 to 2014 for 20 advanced economies.[1] Understanding the drivers of this decline is important as exchange rate pass-through has implications for the movements of relative prices, the adjustment of global imbalances, business cycle co-movements and the effectiveness of monetary policy.

The literature has put forth several explanations for the decline in exchange rate pass-through to import prices. First, Campa et al. (2005) find that for 23 OECD economies over the time period from 1975 to 2003 a larger share of imports is accounted for by non-energy goods, which exhibit lower exchange rate pass-through to import prices. Second, Gust et al. (2010) set up a structural model with complementarities in price setting in which foreign exporters that compete with domestic firms prefer to let their mark-ups and thereby their foreign-currency price vary rather than adjusting their domestic-currency price in response to exchange rate changes. The model implies that reductions in trade costs that deepen trade integration and increase exporters' productivity will accentuate the complementarities in price setting. Therefore, the fall in trade costs reflected in the growth of cross-border trade and globalisation more generally is a second explanation for the fall in exchange rate pass-through to import prices. Several studies provide empirical evidence supporting the role of increased competition and variations in mark-ups on the *cross-sectional* variation in exchange rate pass-through to import prices (Berman et al., 2012; Amiti et al., 2014; Auer, 2015).

In this paper we consider a third possible explanation for the decline in exchange rate pass-through to import prices: The rise of global value chains. Spurred by the decline in transportation costs, the adoption of trade-liberalising policies as well as advances in information and communication technologies, firms increasingly disperse stages of production across countries (see, for example, Baldwin, 2013; UNCTAD, 2013). By fragmenting production chains internationally, the share of intermediate goods in total trade has risen continuously relative to that of final goods (Antras, 2005). Data suggest that trade in intermediate goods and services nowadays accounts for 56% and 73% of overall trade flows in goods and services (Miroudot et al., 2009). For a given degree of exchange rate pass-through to local-currency import prices, a larger share of imported intermediates in total intermediates used in the production of exports implies a larger exchange rate pass-through to local-currency *export* prices. In turn, the larger sensitivity of local-currency export prices to exchange rate changes implies a smaller sensitivity of foreign-currency import prices.

[1] We describe in more detail how we estimate the exchange rate pass-through to import prices displayed in Figure 1.

For example, assume the euro area imports intermediate goods for the production of its exports from the rest of the world. Moreover, assume that – for the sake of simplicity – changes in the euro area's nominal effective exchange rate transmit fully and instantaneously into euro area local-currency import prices and that foreign and euro area exporters keep their mark-ups constant. Now suppose the euro depreciates in nominal effective terms. For a given level of import price pass-through and foreign exporters' mark-ups, the depreciation of the euro will increase the local-currency costs of imported intermediates for euro area exporters. Moreover, for a given level of mark-ups euro area exporters will increase their local-currency prices commensurately with the rise in their production costs stemming from the depreciation of the euro and the associated rise of the local-currency costs of imported intermediates. Thus, foreign importers will experience a dampened variation of *foreign*-currency import prices of euro area goods in response to variations of the euro's exchange rate. Figure 1 shows that there has indeed been a rather close co-movement between global exchange rate pass-through to import prices and global value chain participation as measured by the VAX ratio which is defined as the ratio of domestic value added in an economy's gross exports (Johnson and Noguera, 2012).

In this paper, we first illustrate the above mechanism in a structural two-country model with trade in intermediate goods, staggered price setting and local/producer-currency pricing by rest-of-the-world exporters. In the model, we vary the degree of global value chain participation by altering the share of imported intermediates in the intermediate input goods bundle and thereby the VAX ratio. The parametrisation of the model implies several statistics that are consistent with the data: First, exchange rate pass-through to import and export prices is positive; second, exchange rate pass-through to export prices is lower than to import prices. Most importantly, the model predicts that exchange rate pass-through to export prices rises as the economy participates more in global value chains. Moreover, the model predicts that due to the increase in exchange rate pass-through to export prices in the domestic economy stemming from greater participation in global value chains, in the foreign economy exchange rate pass-through to import prices falls.

We then investigate the empirical evidence for the role of global value chain participation for the decline in exchange rate pass-through to import prices. In particular, we first obtain estimates of the exchange rate pass-through to export prices for 33 advanced and emerging economies for the time period from 2000 to 2014 and analyse the role of global value chain participation for variation in these estimates. The results suggest that participation in global value chains raises economies' exchange rate pass-through to export prices. In a second step, we obtain estimates of the exchange rate pass-through to import prices analogously to that of export prices and investigate how the former varies with the global value chain participation of economies' *trading-partners*. Consistent with the implications of the structural model, we find that exchange rate pass-through to import prices is smaller for economies' whose trading partners exhibit larger exchange rate pass-through to export prices due to higher participation in global value chains. In the latter analysis, we control for other country characteristics in order to distinguish the role of global value chain participation on exchange rate pass-through to import prices from that of the productivity of an economy's trading partners and the composition of its import bundle discussed above.

The paper contributes to existing literature. Vigfusson et al. (2009) relate variation in exchange rate pass-through to import prices to variation in exchange rate pass-through to export prices of trading partners. They, however, neither study the role of global value chain participation in shaping export price pass-through nor the variation in exchange rate pass-through to import prices over time. Campa and Goldberg (2008) study the effect of the rise in the use of imported intermediates on exchange rate pass-through to domestic tradable goods prices. They find a rise in exchange rate pass-through to export prices but do not relate it to a fall in exchange rate pass-through to import prices. Moreover, the results for the effect of global value chain participation on exchange rate pass-through to export prices in their analysis are derived from a counterfactual in which data on the share of imported intermediates is fed into a structural model to produce model-implied values of exchange rate pass-through to export prices. Auer and Mehrotra (2014) find that domestic producer prices respond more strongly to exchange rate changes in sectors in which the cost share of imported intermediates is higher but their focus is on the role of supply chain integration for inflation co-movements in the Asia-Pacific region. Exchange rate changes are only considered in order to identify changes in the prices of imported intermediates which are not due to common shocks. Finally, Aksoy and Riyanto (2000) study a model with imported intermediates in production and establish that global value chain participation raises exchange rate pass-through to export prices. They do, however, not test the implications of their model empirically, are not concerned with variations of exchange rate pass-through over time, and do not relate changes in exchange rate pass-through to export prices to changes in exchange rate pass-through to import prices.

The remainder of the paper is organised as follows. Section 2 puts forth a structural model of international trade in intermediate and final goods to examine the impact of global value chain participation on exchange rate pass-through to export prices as well as the consequences for trading partner's exchange rate pass-through to import prices. In Section 3 we test the predictions of our theoretical model empirically. Finally, Section 4 concludes.

2 A Simple Structural Two-Country Model with Trade in Intermediate Goods

We aim to shed light on how changes in a country's relative ability to make use of foreign and domestic intermediate inputs in production generate variations in pass-through of changes in the nominal exchange rate to domestic export prices and consequently to foreign import prices. We introduce a standard open-economy dynamic stochastic general equilibrium model which builds on the new open economy macroeconomy (NOEM) literature (*cf. inter alia* Benigno and Thoenissen (2003), Corsetti and Pesenti (2005), Rabanal and Tuesta (2010), Forbes et al. (2015) and references therein) but in which additionally countries engage in trade in intermediate goods that enter the production function as input.[2]

Our models consists of two countries (Home and Foreign) of different size (n and *1-n*). Each country consists of a continuum of firms that utilize labour and intermediate inputs to produce a differentiated tradeable country specific good. The produced goods are either consumed directly at home, reused as intermediate inputs to domestic production, or exported abroad, where they are again, either consumed by foreign households or used as inputs in the production of the foreign good. We assume incomplete financial markets at the international level.

2.1 Household's Consumption

The utility function of the representative agent at home is separable in consumption C_t and labour N_t

$$U_0 = E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} \right] \tag{1}$$

where σ is the relative risk aversion, φ is the inverse elasticity of labour supply with respect to the real wage and β denotes the discount factor.[3]

2.2 International Financial Market and Household's Budget Constraint

Financial markets are assumed to be incomplete, which is introduced in a standard way (*cf. inter alia* Benigno and Thoenissen 2003 and Ferrero et al. 2010). Domestic households can hold domestic and foreign bonds while foreign households can only hold foreign bonds. The net foreign bond holdings of domestic households determine the trade balance of the two countries. Assuming full use of resources, the inter-temporal budget constraint of a representative domestic household is given by

$$\frac{B_{H,t}}{P_t R_t} + \frac{S_t B_{F,t} UIP_t}{P_t R_t^* \Phi(\frac{S_t B_{F,t}}{P_t Y_t})} = \frac{B_{H,t-1}}{P_t} + \frac{S_t B_{F,t-1}}{P_t} + \frac{W_t}{P_t} N_t - C_t + \Pi_t + T_t \tag{2}$$

where $B_{H,t}$ and $B_{F,t}$ denominate holdings of home and foreign bonds, R_t and R_t^* are home

[2]There are other contributions that study variations of the canonical international real business cycle model given that intermediate inputs enter production (*cf. inter alia* Huang and Liu (2007) and Shi and Xu (2010)).

[3]In the case of $\sigma = 1$ the utility function is given by $U_0 = E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln C_t - \frac{N_t^{1+\varphi}}{1+\varphi} \right]$.

and foreign gross nominal interest rates, respectively, the function Φ gives a small financial intermediary cost,[4] UIP_t denotes a shock to the uncovered interest rate parity, S_t is the nominal exchange rate (units of home currency in units of foreign currency), W_t denotes the nominal wage, Π_t are redistributed profits, and T_t are lump-sum transfers, respectively. Foreign agents gain dividends from the financial intermediary and do only have access to foreign bonds, so the budget constraint of a foreign agent differs with that respect.

2.3 Final Goods Consumption Bundling

It is assumed that at the border there is a final goods consumption bundler composing home and foreign produced goods according to following technology

$$C_t \equiv \left[(1-\delta)^{1/\theta}(C_{H,t})^{\frac{\theta-1}{\theta}} + \delta^{1/\theta}(C_{F,t})^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}}, \tag{3}$$

where δ denotes the share of foreign goods in Home final consumption, θ is the consumption elasticity of substitution between goods produced in Home and goods produced in Foreign.

This specification implies the following consumer price index

$$P_t \equiv \left[(1-\delta)(P_{H,t})^{1-\theta} + \delta(P_{F,t})^{1-\theta}\right]^{\frac{1}{1-\theta}}. \tag{4}$$

The implied demand functions are given by

$$C_{H,t} = (1-\delta)\left(\frac{P_{H,t}}{P_t}\right)^{-\theta} C_t, \qquad C_{F,t} = \delta\left(\frac{P_{F,t}}{P_t}\right)^{-\theta} C_t. \tag{5}$$

2.4 Imported Intermediates in the Production Function

The main analysis centers around the question on how a change in the composition of intermediate goods in production between home and foreign produced goods affects the price setting decision of a firm in the case of a change in the exchange rate. We abstract from the use of capital and assume that production employs labour and intermediate goods as factor inputs. Technology of an individual firm f is given by

[4] The introduction of this cost ensures stationarity of net foreign assets (*cf.* Schmitt-Grohé and Uribe 2003). Like in Benigno and Thoenissen (2003), it is assumed that the cost function Φ takes the value 1 when the net foreign asset position approaches its steady-state value which is assumed to be zero. The function is differentiable and decreasing in the neighborhood of zero.

$$Y_t(f) = Z_t \left[\alpha^{\frac{1}{\tau}} N_t(f)^{\frac{\tau-1}{\tau}} + (1-\alpha)^{\frac{1}{\tau}} M_t(f)^{\frac{\tau-1}{\tau}}\right]^{\frac{\tau}{\tau-1}} \tag{6}$$

where Z_t is exogenous Hicks-neutral aggregate productivity, $N_t(f)$ denotes firm specific labour demand, $M_t(f)$ denotes firm specific demand for intermediate inputs that consist of home and foreign intermediates:

$$M_t(f) \equiv \left[(1-\omega)^{1/\phi} M_{H,t}(f)^{\frac{\phi-1}{\phi}} + \omega^{1/\phi} M_{F,t}(f)^{\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{\phi-1}}. \tag{7}$$

The parameter α captures the labour share in production and τ is the elasticity between the use of intermediate goods and labour as inputs. The parameter ω is the share of intermediate goods in production that are imported and ϕ is the elasticity of substitution between domestically produced and imported intermediate inputs.

This specification implies the following intermediate goods price index

$$P_{M,t} \equiv \left[(1-\omega)(P_{H,t})^{1-\phi} + \omega(P_{F,t})^{1-\phi}\right]^{\frac{1}{1-\phi}}. \tag{8}$$

The implied demand functions are given by

$$M_{H,t} = (1-\omega)\left(\frac{P_{H,t}}{P_{M,t}}\right)^{-\phi} M_t, \qquad M_{F,t} = \omega\left(\frac{P_{F,t}}{P_{M,t}}\right)^{-\phi} M_t. \tag{9}$$

2.5 Price setting

We allow for some degree of imperfect exchange rate pass through to import prices that is shaped by other reasons than the composition of intermediate goods in production. First, we assume that foreign currency prices are only affected to a certain extent by movements in the exchange rate. We follow the specification of Corsetti and Pesenti (2005) and assume that for a nominal exchange rate S_t[5] a domestic firm f sets a predetermined price $\tilde{P}_{H,t}(f)$ for the foreign market and the current foreign currency price of the firm's good is given by $P^*_{H,t}(f) = \tilde{P}_{H,t}(f) S_t^{-\zeta^*}$. This specification nests the cases in which prices are set in the currency of the producer $\zeta^* = 1$ (producer currency pricing, PCP) and prices are set in the currency of the partner country $\zeta^* = 0$ (local currency pricing, LCP). Second, prices are set in a staggered fashion (*a la* Calvo (1983)). In each period only a fraction of $(1-\varphi) \in [0,1]$ firms is allowed to readjust prices.

[5]The nominal exchange rate is defined in terms of domestic currency per units of foreign currency, i.e. an increase in the nominal exchange rate is a depreciation in the domestic currency.

Each firm f sets a reset price for home and abroad, $P_{H,t}(f)$ and $\tilde{P}_{H,t}(f)$, respectively. The optimization problem of an individual firm is given by

$$max_{P_{H,t}(f)\tilde{P}_{H,t}(f)} \; E_0 \sum_{j=0}^{\infty} (\varphi\beta)^j \Lambda_{t,t+j} \times$$
$$\times \left(\frac{P_{H,t}(f)}{P_{t+j}} \mathrm{C}_{H,t+j}(f) + \frac{S_{t+j} P^*_{H,t+j|t}(f)}{P_{t+j}} C^*_{H,t+j}(f) - MC_{t+j}\left[C_{H,t+j}(f) + C^*_{H,t+j}(f)\right]\right) \quad (10)$$

subject to the endogenous discount factor $\Lambda_{t,t+j}$ given by the household's optimization problem, the aggregate consumer price level P_t, real marginal cost MC_t measured in terms of the aggregate consumption good and home and foreign demand for goods of firm f given by $C_{H,t}(f)$ and $C^*_{H,t}(f)$.

2.6 Market Clearing

Output is used both as intermediate input in production and to produce a composite final good. The aggregate goods markets at home and foreign clear such that

$$Y_t = C_{H,t} + M_{H,t} + \frac{1-n}{n}\left[C^*_{H,t} + M^*_{H,t}\right] \quad (11)$$

and

$$Y^*_t = C^*_{F,t} + M^*_{F,t} + \frac{n}{1-n}\left[C_{F,t} + M_{F,t}\right]. \quad (12)$$

2.7 Trade Balance and Real Exchange Rate

The trade balance evolves according to

$$\frac{S_t B^F_t}{P_t R^*_t \Phi(\frac{S_t B^F_t}{P_t})} = \frac{S_t B^F_{t-1}}{P_t} + NX_t, \quad (13)$$

$$NX_t = \frac{S_t P^*_{H,t}(1-n)/n\left[C^*_{H,t} + M^*_{H,t}\right] - P_{F,t}\left[C_{F,t} + M_{F,t}\right]}{P_t} \quad (14)$$

where NX_t denotes the value of net exports in terms of the domestic consumption good.

The real exchange rate and the terms of trade are defined as

$$Q_t \equiv \frac{S_t P_t^*}{P_t}, \qquad T_t \equiv \frac{P_{F,t}}{S_t P_{H,t}^*}. \tag{15}$$

2.8 Monetary Policy

Monetary policy follows a Taylor-type rule, i.e. the central bank targets consumer price inflation and the output growth rate

$$R_t = \overline{R}^{(1-\nu_r)} R_{t-1}^{\nu_r} \left(\frac{P_t/P_{t-1}}{\Pi} \right)^{(1-\nu_r)\kappa_\pi} (Y_t/Y_{t-1})^{(1-\nu_r)\kappa_y} \exp(\xi_r) \tag{16}$$

where ν_r characterizes interest rate smoothing, ξ_r is a monetary policy shock and κ_π and κ_y denote the Taylor rule coefficients for inflation and output growth, respectively.

2.9 Model Solution

The solution approach is to log-linearize the model around a deterministic steady state and to solve the linear model using perturbation methods. In steady state, international bond holdings are zero, international trade is balanced and inflation is zero. All price resetting firms set the same price and production is subsidized by fiscal transfers such that the distortion from monopolistic competition is offset.

2.10 Calibration

The model is calibrated to quarterly data, assuming a home and foreign discount factor of $\beta = \beta^* = 0.99$. For both countries, the coefficient of relative risk aversion is set to $\sigma = \sigma^* = 1$. Labour supply elasticity is assumed to be equal to 1 ($\varphi = \varphi^* = 1$). Following Benigno and Thoenissen (2003), the international financial market transaction cost is set to $\chi = 0.001$.

We set $1 - \alpha$ to 0.49 and $1 - \delta$ to 0.84 which matches the expenditure share of intermediate goods in total production and the expenditure share of domestic consumed goods in total consumption from the WIOD input output table data set (see below), respectively. The elasticity of substitution between labour and intermediate inputs τ is set to 0.40. This is in the range of estimates for the sectors producing manufactured goods reported in Koesler and Schymura (2012). Following Backus et al. (1992), the elasticity of substitution between home and foreign final consumption goods θ is set to 1.5. The elasticity of substitution between home and foreign intermediate goods is set to ϕ =0.8. In this way, we assume that home and foreign intermediate inputs are used in a complementary fashion. In the baseline calibration we assume producer currency pricing at Home and abroad.[6] The Calvo parameter in both countries is set such that a firm can reset its price every second period. Monetary policy is assumed to be persistent, responsive to inflation and output growth ($\nu_r = 0.75$, $\kappa_\pi = 1.2$, $\kappa_y = 0.5$).

We follow Johnson and Noguera (2012) and examine the ratio of value added to gross exports (VAX ratio) as a measure for global value chain participation. In the model this ratio can be derived as[7]

$$VAX = \frac{\alpha}{1 - (1-\alpha)(1-\omega) + (1-\alpha)\omega^*} \tag{17}$$

In the baseline calibration we set $\omega = 0.28$ in order to match the mean VAX ratio of 0.79 in the data (see below). We further assume that the Home economy is small ($n = 0.01$). We want to mimic a situation in which the participation in the global value chain is relatively more important for the Home economy because of a high share of imported intermediate goods ω and a relatively large export volume whereas it plays less a role in the foreign country where the share of imported intermediate goods ω^* and the trade volume is relative to output very small. In order to be consistent with balanced trade in steady state and relative prices of one the share of imported intermediate goods is calibrated to $\omega^* = n\omega/(1-n)$ and the share of imported final consumption goods is $\delta^* = n\delta/(1-n)$. The baseline calibration is $\omega^* = 0.002$ and $\delta^* = 0.0016$.[8]

2.11 The role of global value chain participation for exchange-rate pass-through

We want to study the effects of a change in the exchange rate to import and export price inflation for various levels of global value chain participation which is determined by the ratio of value added to gross exports (VAX). For this purpose it is examined to which extent the exchange-rate pass-through changes for different steady state levels of the VAX ratio that varies in the share of imported intermediates ω. Higher trade integration in intermediate goods result in a higher

[6] In a sensitivity analysis we depart from the case of producer currency pricing $\zeta^* = 1$ and assume local currency pricing $\zeta^* = 0$. The qualitative interpretation of the results remains the same.

[7] In the case when the Foreign economy does not use imported intermediates in production $\omega^* = 0$ the VAX relates to the vertical specialization share of total exports (VS) metric introduced by Hummels et al. 2001. In this case the VAX is one minus VS and can be interpreted as the domestic content of gross output needed to produce exports as a fraction of total exports (*cf.* Johnson and Noguera 2012 for a discussion). In this special case the VAX is equal to 1 when the home economy does not participate in the global value chain and uses no imported intermediate goods ($\omega = 0$) and equal the share of labour in production α if the home economy uses only intermediate goods that are imported ($\omega = 1$).

[8] The assumption of a small home economy is useful for illustrative purposes. The key predictions are qualitatively similar in the case of a larger size of the home country.

share in imported intermediate goods and a lower VAX, which indicates higher global value chain participation.[9]

For a given shock that affects the nominal exchange rate, exchange-rate pass-through on export prices (on import prices) of Home is defined as the dynamic response of aggregate Home export price (import price) inflation, relative to changes in the nominal exchange rate (all expressed in percentage deviation from steady state). A similar measure can be obtained for exchange-rate pass-through to import prices of Foreign. In order to make the model predictions comparable to the empirical specification below we look at the exchange-rate pass-through response in the first three periods after the shock.

$$XRPT_{export} = \frac{\sum_{irf=1}^{3}(\pi^*_{H,irf} + \Delta s_{irf})}{\sum_{irf=1}^{3}\Delta s_{irf}} \tag{18}$$

$$XRPT_{import} = \frac{\sum_{irf=1}^{3}\pi_{F,irf}}{\sum_{irf=1}^{3}\Delta s_{irf}} \tag{19}$$

$$XRPT^*_{import} = \frac{\sum_{irf=1}^{3}\pi^*_{H,irf}}{\sum_{irf=1}^{3}-\Delta s_{irf}} \tag{20}$$

In the model, the nominal exchange rate is endogenous and therefore directly affected by supply and demand conditions. In order to abstract from these direct effects, we focus on the shock to the demand for foreign assets in the budget constraint (2) that changes the uncovered interest rate condition (*cf.* equation 21) and affects the exchange rate but has negligible effects on the supply and demand conditions in Foreign.

$$\frac{R_t}{R^*_t} = \frac{1}{UIP_t} E_t \frac{S_{t+1}}{S_t} \Phi(\frac{S_t \overline{B}^F_t}{P_t Y_t}). \tag{21}$$

This UIP shock UIP_t creates a wedge to the differential between the Home and Foreign interest rate $\frac{R_t}{R^*_t}$, causing, *ceteris paribus*, a nominal appreciation of the Home currency.[10]

For assessing the effect of the global value chain participation on exchange-rate pass-through, we depart from the baseline calibration by varying the share in imported intermediate goods

[9]Note that the VAX also changes in the share of value added in production α. In the experiment we leave this parameter unchanged and look at variations in the share of imported intermediates in total intermediates ω. This is motivated by a strong negative correlation between the VAX and the share of imported intermediates in total intermediates in the data.

[10]Itskhoki and Mukhin (2016) discuss the quantitative relevance of this shock for rationalizing the exchange rate disconnect. Forbes et al. (2015) find evidence for the empirical relevance of this disturbance explaining the exchange rate transmission in the UK.

in total intermediates and study the effect on $XRPT_{export}$ and $XRPT^*_{import}$ given that a UIP shock hits the economy. The results are plotted in Figure 2.

As a first result, for the baseline calibration of the Home economy the model predicts that exchange rate pass-through to export prices is lower than exchange rate pass-through to import prices.

Turning to the effects of global value chain participation, we have that with a decreasing VAX (a rising share of imported intermediates in total intermediates) the exchange-rate pass-through to export prices of Home $XRPT_{export}$ is increasing. From the perspective of the Home economy, the import price of foreign goods $P_{F,t}$ depends on the nominal exchange rate S_t. In the case of a depreciation of the Foreign currency, the price for goods produced in Foreign is decreasing at Home. When Home firms use foreign goods as intermediate inputs, marginal costs decline and so does the price of the Home produced good.

Importantly, the model predicts that the level of exchange-rate pass-through to import prices in Foreign is *decreasing* with a higher participation of Home in the global value chain (a lower VAX ratio of Home). From the perspective of agents in Foreign, the depreciation of the Foreign currency leads to a rise in import prices, however, this effect is lower, the more Home is using intermediate inputs from Foreign and therefore stronger lowering export prices in case of a depreciation of the Foreign currency.

3 Empirical Evidence

Our empirical strategy for the investigation of the role of global value chain participation for exchange rate pass-through to export and import prices consists of two steps. First, we obtain time-varying estimates of exchange rate pass-through to export and import prices for a cross-section of economies. Second, we analyse the determinants of the heterogeneity in exchange rate pass-through to export and import prices, paying particular consideration to the role of an economy's own global value chain participation as well as that of the trading partners from which the economy imports.

3.1 Estimating exchange rate pass-through to export and import prices

3.1.1 Empirical framework

We follow the literature and consider a standard log-linear regression model in order to estimate country-specific exchange rate pass-through to export and import prices (Campa et al., 2005; Vigfusson et al., 2009; Bussière et al., 2014). Specifically, for exchange rate pass-through to export prices the regression model is given by

$$\Delta p^{x}_{it} = \alpha^{x}_{i,\tau} + \sum_{j=0}^{3} \beta^{x}_{ij,\tau} \Delta e_{i,t-j} + \sum_{j=0}^{1} \gamma^{x}_{ij,\tau} \Delta p^{ppi}_{i,t-j} + \sum_{j=0}^{1} \delta^{x}_{ij,\tau} \Delta y^{w}_{t-j} + \epsilon^{x}_{it,\tau}, \tag{22}$$

where Δp^{x}_{it} denotes the quarter-on-quarter log-change of the export price unit value of economy i, Δe_{it} is the quarter-on-quarter log-change of economy i's nominal effective exchange rate, Δp^{ppi}_{it} is the quarter-on-quarter log-change of the producer-price index of economy i, and Δy^{w}_{t} is the quarter-on-quarter log-change of world GDP.[11] We estimate Equation (22) in country-specific regressions over rolling windows $\tau = 1, 2, \ldots, \mathcal{T}_i$ within our sample period in order to obtain time-varying estimates of economies' exchange rate pass-through to export prices. Analogously to export prices, for the exchange rate pass-through to import prices the regression model is given by

$$\Delta p^{m}_{it} = \alpha^{m}_{i,\tau} + \sum_{j=0}^{3} \beta^{m}_{ij,\tau} \Delta e_{i,t-j} + \sum_{j=0}^{3} \gamma^{m}_{ij,\tau} \Delta c_{i,t-j} + \sum_{j=0}^{3} \delta^{m}_{ij,\tau} \Delta y_{i,t-j} + \epsilon^{m}_{it,\tau}, \tag{23}$$

where Δp^{m}_{it} is the quarter-on-quarter log-change of the import price unit value of economy i, Δc_{it} is the quarter-on-quarter log-change of the global (GDP-weighted) average of export prices as a proxy for global production costs, and Δy_{it} is the quarter-on-quarter log-change of GDP of economy i.

We estimate Equations (22) and (23) on data for rolling windows within the time period from 1981q1 to 2014q4 and obtain a sample of time-varying estimates of exchange rate pass-through to export and import prices for economies $i = 1, 2, \ldots, N$. In each case, the rolling estimation window spans a period of 20 years. Specifically, the first rolling sample spans the time period from 1981q1 to 2000q4, and the last one 1995q1 to2014q4.[12] We thus have (at most) $\mathcal{T}_i = 64$ estimates of exchange rate pass-through to export and import prices per economy. The estimates of exchange rate pass-through to export and import prices for economy i are given by

$$\widehat{\pi}^{\ell}_{i\tau} \equiv \sum_{j=0}^{3} \beta^{\ell}_{ij,\tau}, \quad \ell \in \{x, m\}. \tag{24}$$

3.1.2 Data and sample

Table 1 reports the sample of advanced and emerging market economies and states for each country the sample period for the estimation of time-varying exchange rate pass-through to export and import prices. We only include economies in our sample for which we also have data

[11] Coefficient estimates beyond the first lag are not statistically significant and therefore not included in our baseline specification.

[12] For each economy we use the longest available time series (see Table 1).

on their participation in global value chains based on the World-Input-Output Database (WIOD; see below).[13] We obtain quarterly data on import and export price indices from the OECD. Data on changes in nominal effective exchange rates are taken from the IMF's International Financial Statistics (IFS). We define the exchange rate in terms of domestic currency per units of foreign currency. Thus, an increase in the nominal effective exchange rate index represents a depreciation. Data on domestic GDP growth as well as on producer-price inflation are also taken from the IMF's IFS. Data on world GDP growth is taken from the OECD.

3.1.3 Estimates of exchange rate pass-through to export and import prices

Figure 3 presents the country-specific estimates of exchange rate pass-through to export and import prices for the economies in our sample.[14] Consistent with the findings in the literature there is pronounced cross-country heterogeneity in the estimates of exchange rate pass-through to export and import prices (see Campa and Goldberg, 2005; Ihrig et al., 2006; Vigfusson et al., 2009; Frankel et al., 2012; Bussière et al., 2014). The cross-country average of exchange rate pass-through to import (export) prices is around 0.5 (0.35), implying that a nominal effective appreciation of the domestic currency by one percent has on average resulted in an increase of import (export) prices by 0.5 (0.35) percent in our sample period. In contrast to the findings of Bussière et al. (2014) estimates of exchange rate pass-through to export prices tend to be lower than estimates of exchange rate pass-through to import prices. Consistent with the findings of Bussière et al. (2014), Figure 4 shows that estimates of exchange rate pass-through to export and import prices are correlated for a given economy.

Figure 5 presents the results for the cross-country average of the time-varying estimates of exchange rate pass-through to export and import prices based on the rolling regressions of Equations (22) and (23). Both exchange rate pass-through to export and import prices have undergone noticeable changes, with the latter falling and the former increasing over time, especially if one neglects the period of the global financial crisis and its immediate aftermath. This evidence is consistent with the hypothesis that at least some of the observed decline in exchange rate pass-through to import prices stems from the rise in exchange rate pass-through to export prices.

[13] We exclude Luxembourg and Mexico for the following reasons. Luxembourg is an outlier in global value chain participation, and we want to preclude that one economy might be driving our results. Specifically, the average VAX ratio of Luxembourg over the sample period is 0.48, which compares to a cross-country mean of .79 and cross-country standard deviation of .09. The second most integrated economy, Ireland, has an average VAX ratio over the sample period of 0.65. We drop Mexico from our sample because the underlying export and import price data exhibit rather substantial volatility, reflecting the uncertainty surrounding the measurement of import and export price data. As a result, estimates of exchange rate pass-through for Mexico are never statistically significantly different from zero over the entire sample period.

[14] For simplicity the estimates presented in Figure 3 are obtained from on a cross-section regression versions of Equations (22) and (23).

3.2 The role of global value chain participation for variation in exchange rate pass-through

3.2.1 Export prices

In order to explore the role of global value chain participation for exchange rate pass-through to export prices we estimate the regression

$$\widehat{\pi}^x_{i\tau} = \alpha^x_i + \delta^x_\tau + \gamma^x gvcp_{i\tau} + \chi^x_1 ypc_{i\tau} + \chi^x_2 energy^x_{i\tau} + \phi^x \widehat{\pi}^m_{i\tau} + \boldsymbol{X}^x_{i\tau}\boldsymbol{\theta}^x + u^x_{i\tau}. \tag{25}$$

where $\widehat{\pi}^x_{i\tau}$ is the estimated exchange rate pass-through to export prices in economy i obtained from Equation (22) for the rolling window τ, $gvcp_{i\tau}$ is a measure of global value chain participation of economy i, $ypc_{i\tau}$ denotes real GDP per hour worked and $energy^x_{i\tau}$ the share of energy goods in economy i's export bundle, $\widehat{\pi}^m_{i\tau}$ is the estimated exchange rate pass-through to import prices, and $\boldsymbol{X}^x_{i\tau}$ is a vector of additional controls. The inclusion of $\widehat{\pi}^m_{i\tau}$ as control allows us to account for variations in pass-through to export prices that are driven by differences in exchange rate pass-through to import prices, such as differences in local vs. foreign currency invoicing of imports. The control variables in $\boldsymbol{X}^x_{i\tau}$ include exchange rate volatility and the share of high-technology exports (see Taylor, 2000; Devereux et al., 2004; Campa and Goldberg, 2005; Campa and Gonzalez Mìnguez, 2006; Bussière et al., 2014). One advantage of the panel regression model in Equation (25) over a cross-sectional analogue is that it allows us to control for time-invariant, unobserved determinants of exchange rate pass-through to export prices, and therefore reduce the likelihood that our estimates are subject to omitted variable bias. Likewise, the time fixed effects in Equation (25) capture common shifts in exchange rate pass-through to export prices, as observed for example during the global financial crisis (see Figure 5). We estimate the panel data model in Equation (25) in annual rather than quarterly frequency, as the right-hand side variables are not available in quarterly frequency.

3.2.2 Import prices

Analogously to exchange rate pass-through to export prices, for import prices we estimate

$$\widehat{\pi}^m_{i\tau} = \alpha^m_i + \delta^m_\tau + \gamma^m gvcp^*_{i\tau} + \chi^m_1 ypc^*_{i\tau} + \chi^m_2 energy^m_{i\tau} + \phi^m \widehat{\pi}^{m*}_{i\tau} + \boldsymbol{X}^m_{i\tau}\boldsymbol{\theta}^m + u^m_{i\tau}. \tag{26}$$

where $gvcp^*_{i\tau}$ and $ypc^*_{i\tau}$ denote the bilateral, trade-share weighted average of the global value chain participation and real GDP per hour worked of the trading partners from which economy i receives its imports, $energy^m_{i\tau}$ the share of energy in economy i's import bundle, and $\boldsymbol{X}^m_{i\tau}$ is a vector of additional controls. We include $ypc^*_{i\tau}$ and $energy^m_{i\tau}$ in order to control for alternative explanations for the decline in exchange rate pass-through to import prices put forth in the literature (see Campa et al., 2005; Gust et al., 2010). The control variables $\boldsymbol{X}^m_{i\tau}$ include inflation volatility, the share of manufacturing and high-technology imports as well as trade openness (see Taylor, 2000; Devereux et al., 2004; Campa and Goldberg, 2005; Campa and Gonzalez Mìnguez, 2006; Bussière et al., 2014).

3.2.3 Data

Various concepts and metrics have been proposed in the literature to measure trade in value added and global value chain participation based on global input-output tables (see, for instance, Hummels et al., 2001; Johnson and Noguera, 2012; Koopman et al., 2014; OECD, 2015). In this paper, we measure economies' global value chain participation by the VAX ratio. The VAX ratio is defined as the ratio of domestic value added in an economy's gross exports (Johnson and Noguera, 2012). In order to construct the VAX ratio for a broad panel of economies, we exploit the World Input-Output-Database (Timmer et al., 2013; Stehrer et al., 2014). The latest WIOD edition provides global input-output tables at annual frequency for 43 countries and 56 sectors for the time period from 2000 to 2014.[15] The bilateral trade weights for the construction of trading partners' global value chain participation are taken from the BIS. The data for real GDP per hour worked is obtained from the OECD. The sample spans the time period from 2000 to 2014.

Figure 6 displays the unconditional correlation between the time averages of the estimates of economies' exchange rate pass-through to export prices and their global value chain participation as measured by the VAX ratio. The unconditional correlations are not statistically significant, suggesting that one might have to control for confounding factors in order to estimate the effect of economies' global value chain participation on the exchange rate pass-through to export prices. Analogously, Figure 7 displays the unconditional correlation between the time averages of the estimates of economies' exchange rate pass-through to import prices and the global value chain participation of the trading-partners from which they receive their imports. In contrast to Figure 6, the unconditional correlation between economies' exchange rate pass-through to import prices and the global value chain participation of economies' trading-partners is positive. This evidence is consistent with the prediction from the structural model discussed in Section 2, even without controlling for other confounding factors.

[15] The first edition of the WIOD provides data from 1995 to 2011. Unfortunately, the two editions of the WIOD are not consistent in terms of variable definitions and country coverage, and can hence not be combined to extend the sample period.

3.2.4 Results

Table 2 reports the results of the estimation of the regression for the determinants of differences in exchange rate pass-through to export prices in Equation (25).[16,17,18] The coefficient estimates of the VAX ratio are statistically significantly different from zero and have the expected negative sign in all cross-sectional samples. The results are thus consistent with the hypothesis that being more integrated in global value chains by using a higher share of imported in total intermediates in the production of exports raises the sensitivity of an economy's local-currency export prices to exchange rate movements.

Also the coefficient estimate for the exchange rate pass-through to import prices is statistically significant with the expected sign. Specifically, the local-currency price of an economy's exports is more sensitive to changes in the changes in the exchange rate if the latter also transmits more strongly into the economy's local-currency import prices. Moreover, the coefficient estimates for the share of energy in total exports and real GDP per hour worked are also statistically significant with the expected sign, at least for advanced economies. The results are thus also consistent with the alternative explanations for the decline in exchange rate pass-through to import prices put forth in the literature: Exchange rate pass-through to export prices is higher if (i) a higher share of exports is accounted for by energy goods whose prices exhibit a higher pass-through (see Campa et al., 2005), and if (ii) the domestic economy's exporters are more productive so that their markup is higher and there are stronger complementarities in price setting with competitors in export markets (see Gust et al., 2010).

Table 3 reports the results of the estimation of the regression for the determinants of cross-country differences in exchange rate pass-through to import prices in Equation (26).[19] The coefficient estimates for the average of the VAX ratio across the trading partners from which an economy receives its imports are all statistically significant and have the expected positive sign. Specifically, the results are consistent with the hypothesis that an economy whose trading partners from which imports are received are more strongly integrated in global value chains exhibit higher exchange rate pass-through to their foreign-currency export prices and thus, in turn, the importing economy exhibits lower exchange rate pass-through to its local-currency import prices.

Analogous to the results for the energy share and real GDP per hours worked in the export price pass-through regressions, the evidence in the import-price pass-through regressions is also consistent with the alternative explanations for the decline in exchange rate pass-through to import prices put forth in the literature. Specifically, economies whose trading partners from

[16]When the estimate of the exchange rate pass-through to export and import prices is not statistically significantly different from zero we replace the estimate by a zero.

[17]In the estimation of Equations (25) and (26) we use Driscoll and Kraay (1998) standard errors which are robust to heteroskedasticity and autocorrelation.

[18]We do not report the estimates of the controls in $\boldsymbol{X}^{x}_{i\tau}$ in Equation (25) in order to save space.

[19]We do not report the estimates of the controls in $\boldsymbol{X}^{m}_{i\tau}$ in Equation (26) in order to save space.

imports are received are more productive, set higher markups and are thus subject to stronger complementarities in price setting with competitors in export markets display a lower exchange rate pass-through to import prices (see Gust et al., 2010). And economies which feature a higher share of imported energy goods in total imports exhibit a larger exchange rate pass-through to import prices, at least for emerging market economies (see Campa et al., 2005). Finally, the results for the import-price pass-through are plausible: Economies' display a lower exchange rate pass-though to their local-currency import prices if their trading partners foreign-currency export prices are more sensitive to exchange rate changes.

3.3 Robustness

In a robustness analysis we replace the VAX ratio in Equations (25) and (26) by backward participation defined as the ratio of an economy's gross intermediate imports to total gross output on the basis of the WIOD data as an alternative measure of GVC participation. This metric can also be directly linked into the theoretical model as it maps to the share of imports in intermediate goods in production. The results are qualitatively unchanged (cf. Tables 4 and 5), which suggests that our findings of a positive relationship between levels of GVC participation and export price pass-through and a negative relationship between levels of GVC and import price pass-through are not confined to a specific metric of GVC participation.

4 Conclusion

This paper draws a causal link between the rise of global value chains and the decline of exchange rate pass-through (ERPT) to import prices. In a structural two-country model with trade in intermediate goods, staggered price setting, and local/producer-currency pricing we study the variation in the share of imports in intermediate goods used in production implying a varying VAX ratio (defined as the ratio of domestic value added in an economy's gross exports, cf. (Johnson and Noguera, 2012)). The model predicts that higher participation in global value chains (expressed by a lower VAX ratio) results in higher ERPT to local currency export prices. As an outcome, this effect translates into lower trading partner's ERPT to local currency import prices.

Using input-output data for a broad sample of 33 advanced and emerging economies over the time span 2000 to 2014, we find that, in line with the theoretical predictions, (1) estimates of ERPT to local currency export prices are increasing in global value chain participation (decreasing in the VAX ratio) and (2) estimates of ERPT to local currency import prices are decreasing in global value chain participation of the *trading partner* (increasing in the trading partner's VAX ratio).

Given the large share of intermediate goods in total trade and the deep international integration of global production chains, our results help in gaining a better understanding in important issues in international macroeconomics, such as the movements of relative prices, the adjustment of global imbalances, business cycle co-movements and the transmission and effectiveness of monetary policy.

Our paper adds to other contributions that aim at rationalizing the observed decline in ERPT to import prices. In our empirical specification we are able to control for alternative mechanisms spelled out in the literature and find consistent results. In future work we aim at enriching our theoretical model in order to explore potential interdependencies between the various channels.

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A Tables

Table 1: Sample periods for estimation of ERPT into Export and Import Prices

	Estimation sample Panel	
Advanced economies		
Australia	1980 Q1	2014Q4
Austria	1980 Q1	2014Q4
Belgium	1980 Q1	2014Q4
Canada	1980 Q1	2014Q4
Denmark	1980 Q1	2014Q4
Finland	1980 Q1	2014Q4
France	1980 Q1	2014Q4
Germany	1980 Q1	2014Q4
Greece	1999Q2	2014Q4
Ireland	1997Q2	2014Q4
Italy	1999 Q1	2014Q4
Japan	1994Q1	2014Q4
Netherlands	1980 Q1	2014Q4
Norway	1980 Q1	2014Q4
Portugal	1995Q1	2014Q4
Spain	1980 Q1	2014Q4
Sweden	1993 Q2	2014Q4
Switzerland	1980 Q1	2014Q4
USA	1980 Q1	2014Q4
UK	1980 Q1	2014Q4
Emerging market economies		
Brazil	1996Q2	2014Q4
Czech Republic	1996Q2	2014Q4
Estonia	1995Q3	2014Q4
Hungary	1995Q3	2014Q4
India	2011Q2	2014Q4
Indonesia	1991Q3	2014Q4
Korea	2000Q1	2014Q4
Latvia	1995Q3	2014Q4
Lithuania	1995Q3	2014Q4
Poland	1995Q1	2014Q4
Slovakia	1997Q2	2014Q4
Slovenia	1995Q2	2014Q4
Turkey	2000Q2	2014Q4

Table 2: Exchange Rate Pass-through to Export Prices—Panel Regression

	(1) Advanced b/p	(2) EMEs b/p	(3) All b/p
Exported energy share	-0.948***	-0.124	-0.754***
	(0.00)	(0.70)	(0.00)
lRGDP per Hour	0.151***	-0.113	0.010
	(0.00)	(0.17)	(0.82)
VAX	-2.521***	-0.839*	-1.757***
	(0.01)	(0.08)	(0.00)
ERPT Imp Price	0.062***	0.161***	0.131***
	(0.01)	(0.00)	(0.00)
Country fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Observations	298	170	468
R-squared	0.23	0.23	0.17
No. of Countries	20	13	33

Robust standard errors

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3: Exchange Rate Pass-through to Import Prices—Panel Regression

	(1) Advanced b/p	(2) EMEs b/p	(3) All b/p
lRGDP per Hour trad part	-0.375*	-3.218***	-3.247***
	(0.08)	(0.00)	(0.00)
Imported energy share	0.124	1.081**	0.044
	(0.46)	(0.03)	(0.89)
VAX trad part	3.761***	17.338**	2.526*
	(0.00)	(0.02)	(0.09)
ERPT Imp trad part	-0.192*	-1.488***	-0.645**
	(0.08)	(0.00)	(0.03)
Country fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Observations	298	170	468
R-squared	0.09	0.63	0.26
No. of Countries	20	13	33

Robust standard errors

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

A.1 Robustness

Table 4: Exchange Rate Pass-through to Export prices—Panel Regression—Backward participation

	(1) Advanced b/p	(2) EMEs b/p	(3) All b/p
Exported energy share	-1.045***	-0.174	-0.782***
	(0.00)	(0.62)	(0.00)
lRGDP per Hour	0.014	-0.123	-0.028
	(0.90)	(0.15)	(0.62)
Backward particip	2.733**	0.984	1.669***
	(0.04)	(0.10)	(0.00)
ERPT Imp Price	0.062**	0.170***	0.148***
	(0.01)	(0.00)	(0.00)
Country fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Observations	298	170	468
R-squared	0.21	0.23	0.17
No. of Countries	20	13	33

Robust standard errors
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

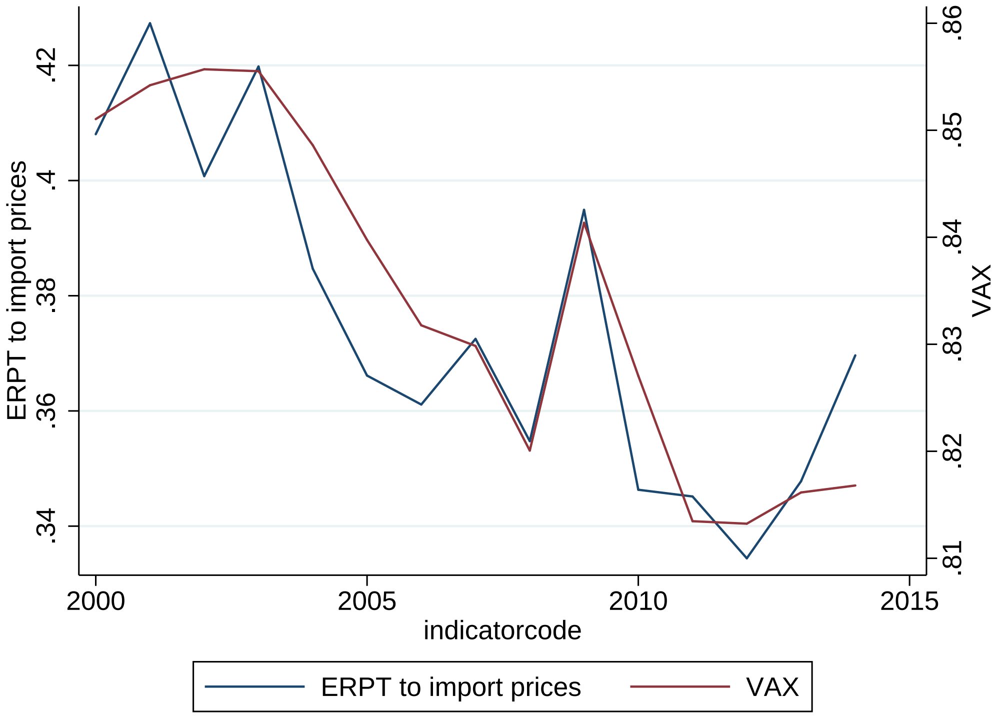
Table 5: Exchange Rate Pass-through to Import prices—Panel Regression—Backward participation

	(1) Advanced b/p	(2) EMEs b/p	(3) All b/p
lRGDP per Hour trad part	-0.421	-3.556***	-3.325***
	(0.12)	(0.00)	(0.00)
Imported energy share	0.148	1.266**	0.098
	(0.43)	(0.01)	(0.75)
Bward trad part	-5.403**	-18.750*	4.587
	(0.02)	(0.10)	(0.35)
ERPT Imp trad part	-0.177	-1.514***	-0.615**
	(0.11)	(0.01)	(0.03)
Country fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Observations	298	170	468
R-squared	0.08	0.62	0.26
No. of Countries	20	13	33

Robust standard errors
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

B Figures

Figure 1: Exchange Rate Pass-through to Import Prices and the VAX



Average ERPT estimates and VAX ratios (advanced economies)

Figure 2: $XRPT_{export}$ and $XRPT^{*}_{import}$ with varying global value chain participation of the Home economy (expressed by the Home VAX ratio; a lower VAX ratio indicates higher global value chain participation)

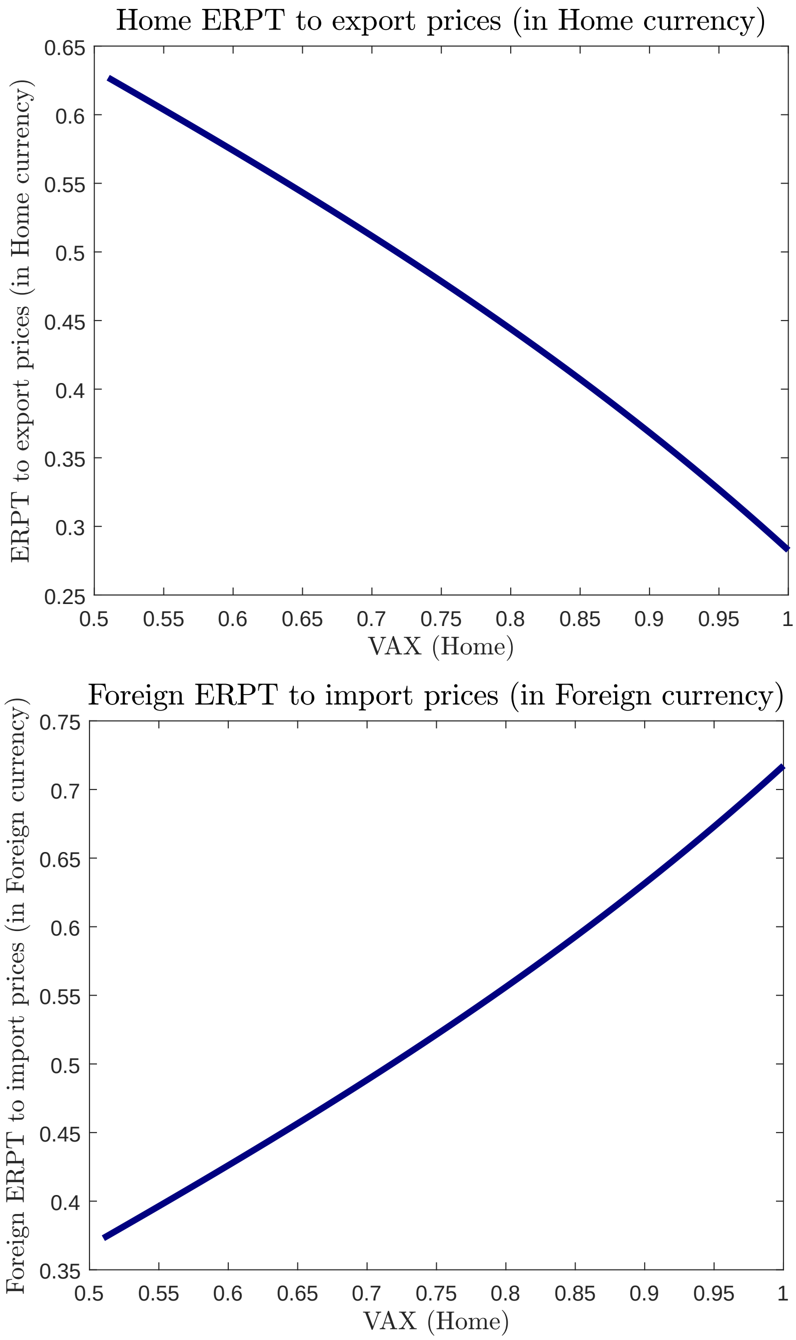
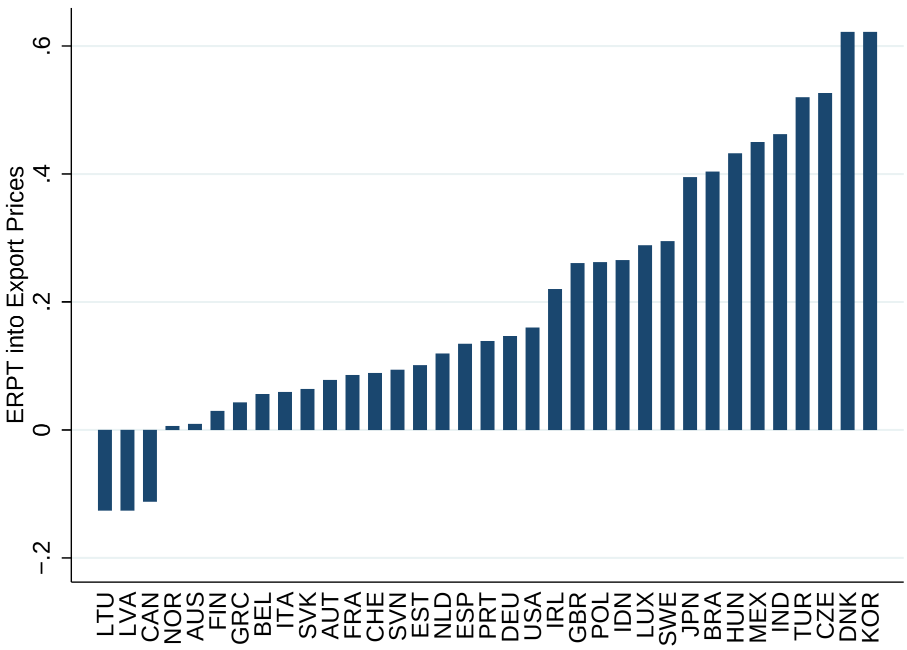


Figure 3: Exchange Rate Pass-through to Export and Import Prices

Export Prices



Import Prices

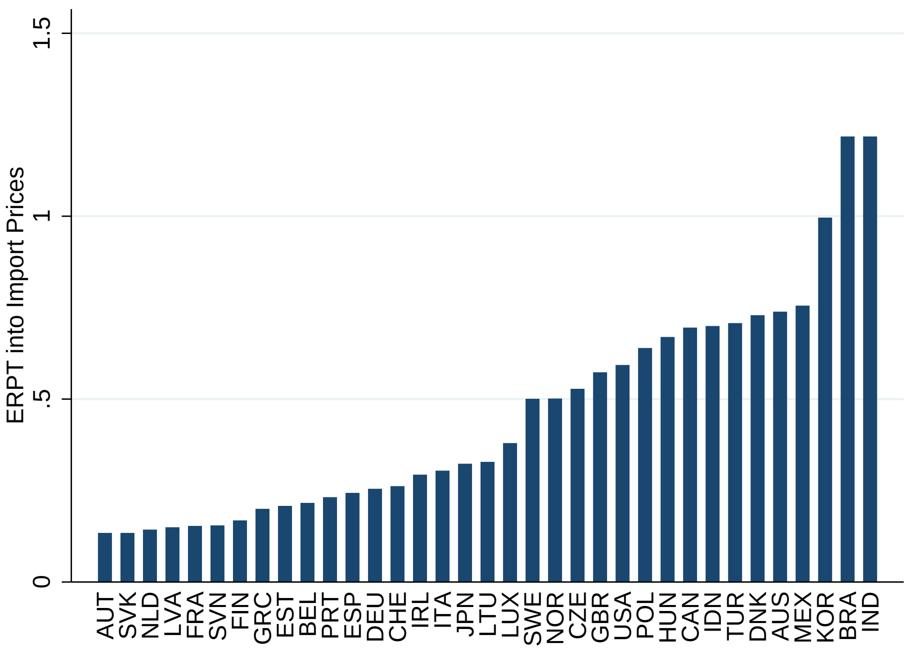


Figure 4: Correlation between Exchange Rate Pass-through to Import and Export Prices

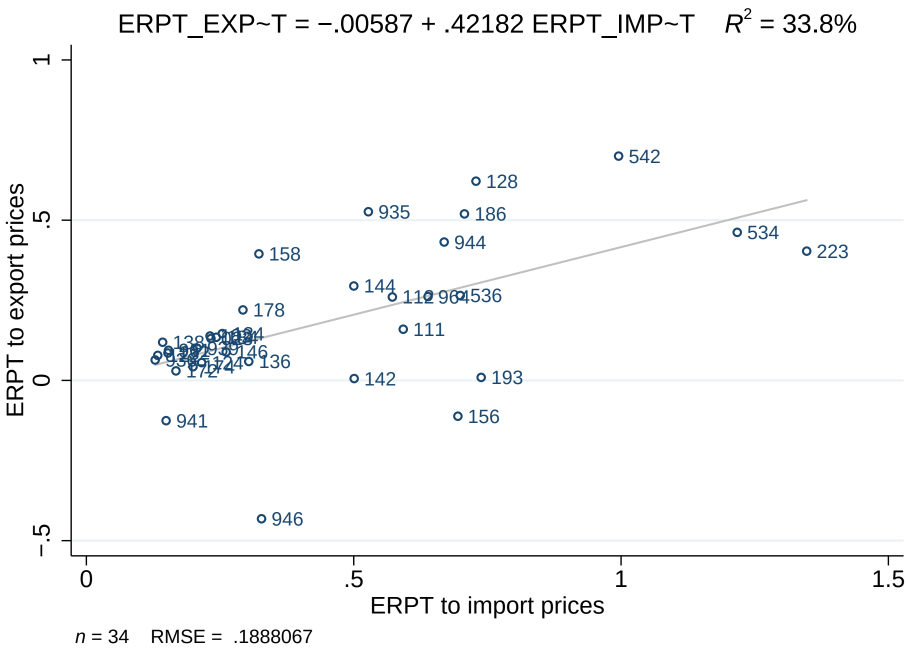


Figure 5: Exchange Rate Pass-through to Import and Export Prices

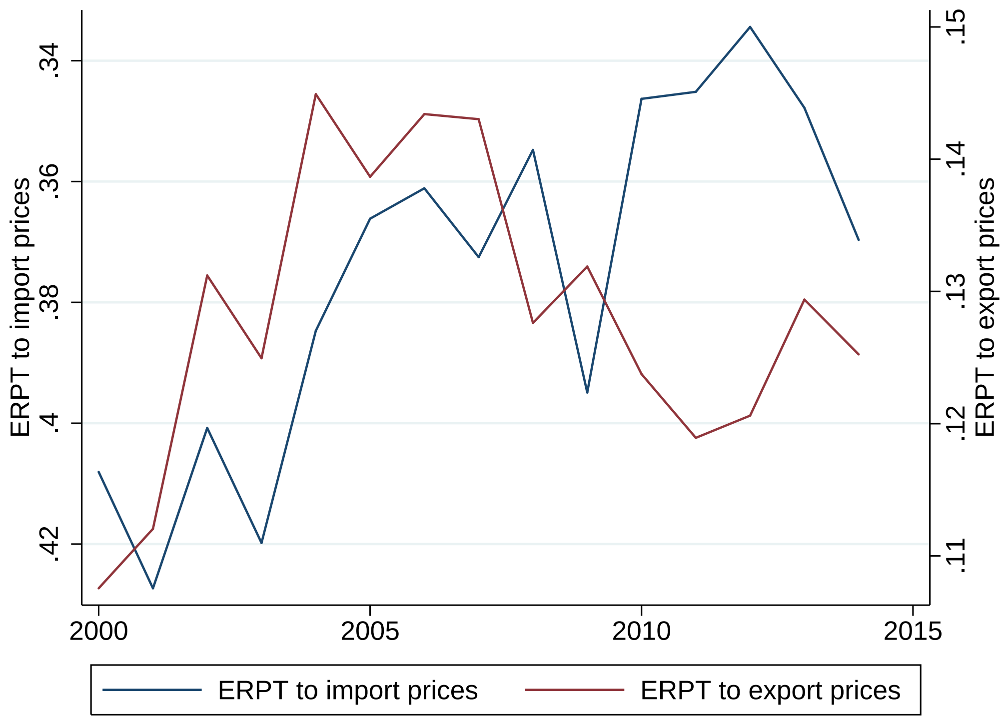
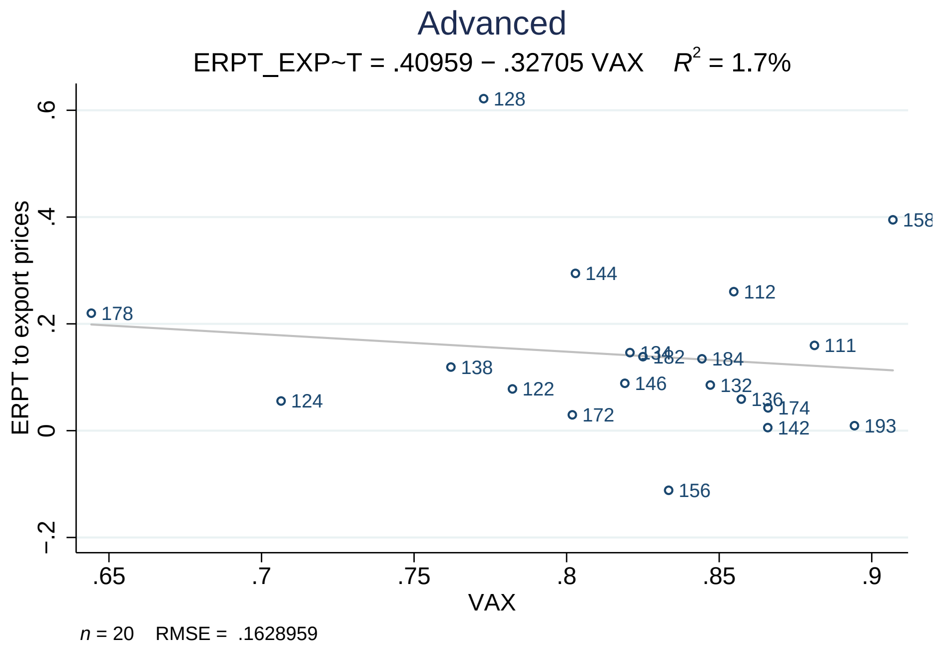


Figure 6: Exchange Rate Pass-through to Export Prices and Global Value Chain Participation



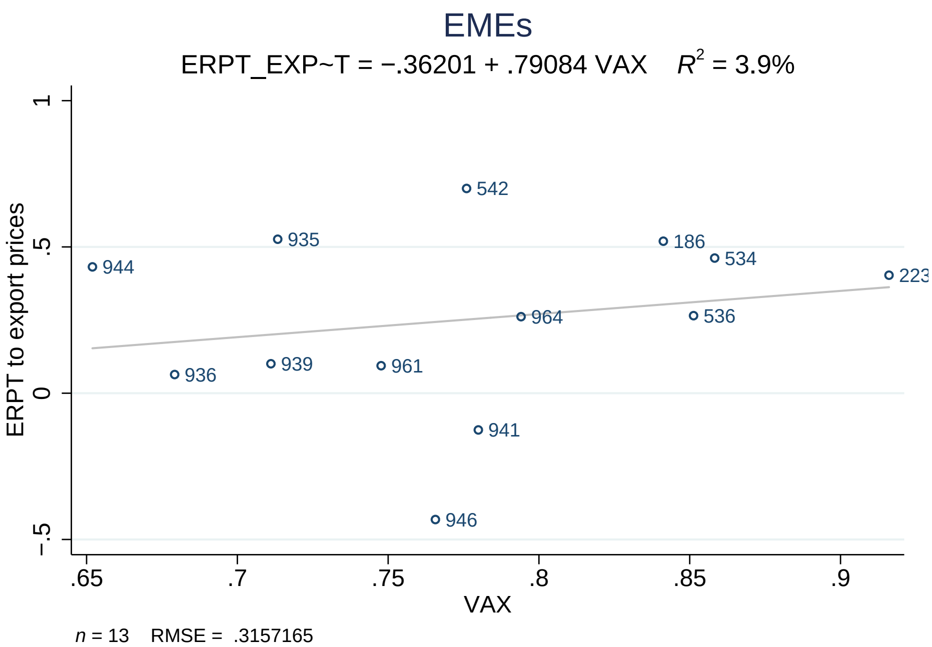


Figure 7: Exchange Rate Pass-through to Import Prices and Global Value Chain Participation