Global Value Chain Participation and Exchange Rate Pass-through*

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Abstract

This paper draws a causal link between the rise of global value chain participation and the decline of exchange rate pass-through to import prices that has been observed over the last decades. We first present a structural two-country model in order to illustrate how participation in global value chains can impact exchange rate pass-through to import prices. In the model, the sensitivity of an economy's local-currency production costs to exchange rate changes rises as it participates more in global value chains by importing a larger share of its intermediate inputs. The increased sensitivity of the economy's local-currency production costs to exchange rate changes translates into a lower sensitivity of its foreign-currency export prices to exchange rate changes. As the economy's foreign-currency export price equals its trading partner's local-currency import price, an increase in the economy's global value chain participation implies a fall in its trading partner's exchange rate pass-through to local-currency import prices. We then provide empirical evidence in a panel of advanced and emerging economies that is consistent with the mechanisms spelled out in the structural model. In particular, the data suggest that exchange rate pass-though to *export* prices is *higher* in economies which participate more in global value chains, and that exchange rate pass-though to *import* prices is *lower* in economies with trading partners which participate more in global value chains.

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

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Non-technical summary

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. Understanding the drivers of this decline is important as exchange rate pass-through (ERPT) is a key determinant of the international propagation of shocks, with implications for the movements of relative prices, the adjustment of external imbalances, business cycle co-movements and the effectiveness of monetary policy. The degree of ERPT is particularly relevant for central banks with an explicit inflation target. For example, a lower ERPT to import prices in part insulates the domestic economy from foreign monetary policy shocks. At the same time, a lower ERPT to import prices weakens the exchange rate channel of domestic monetary policy.

The literature has put forth several explanations for the secular decline in ERPT to import prices. While some studies relate the lower ERPT to import prices to a declining share of energy goods—which tend to have a higher pass-through—in total imports, other provide evidence for the role of increased competition for variations in ERPT to import prices.

In this paper we consider a third possible explanation for the secular decline in ERPT 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. By fragmenting production chains internationally, the share of intermediate goods in total trade has risen continuously relative to that of final goods. Data suggest that trade in intermediate goods and services nowadays accounts for 56% and 73% of overall trade flows in goods and services. For a given degree of ERPT to local-currency import prices and a given mark-up, a larger share of imported intermediates in total intermediates used in the production of exports implies a larger ERPT 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 abroad.

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 ERPT to local-currency import prices in the euro area and given 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 dampened variation of *foreign*-currency import prices of euro area goods in response to variations of the euro's exchange rate.

We first illustrate the mechanism described above in a structural two-country model with trade in intermediate goods. The model predicts that ERPT to export prices rises as the economy's GVCP increases. Moreover, the model predicts that due to the increase in ERPT to local-currency export prices in the Home economy stemming from greater GVCP, in the Foreign economy ERPT to local-currency import prices falls.

We then investigate empirically the role of GVCP for the decline in ERPT to import prices. In particular, we first obtain estimates of the ERPT to export prices for 33 advanced and emerging economies for the time period from 1995 to 2014, and analyse the role of GVCP for variation in these estimates. The results suggest that GVCP raises economies' ERPT to export prices. In a second step, we obtain estimates of the ERPT to import prices analogously to that of export prices, and investigate how the former varies with the GVCP of economies' *trading-partners*. Consistent with the implications of the structural model, we find that ERPT to import prices is smaller for economies' whose trading partners exhibit larger ERPT to export prices due to higher GVCP. In the latter analysis, we control for other country characteristics in order to distinguish the role of GVCP on ERPT to import prices from that of the productivity of an economy's trading partners and the composition of its import bundle discussed above.

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). Understanding the drivers of this decline is important as exchange rate pass-through (ERPT) is a key determinant of the international propagation of shocks, with implications for the movements of relative prices, the adjustment of external imbalances, business cycle co-movement and the effectiveness of monetary policy. Intuitively, the degree of ERPT is particularly relevant for central banks pursuing inflation targeting. A lower ERPT to import prices weakens the exchange rate channel of domestic monetary policy. At the same time, a lower ERPT to import prices in part insulates the domestic economy from foreign monetary policy.

The literature has put forth several explanations for the secular decline in ERPT to import prices, emphasising the role of changes in the composition of trade flows as well as expanding trade and financial integration. First, Campa et al. (2005) find that for 23 OECD economies over the time period from 1975 to 2003 a larger share of imports has been accounted for by non-energy goods which exhibit lower ERPT to import prices. Second, Gust et al. (2010) set up a structural model with strategic complementarities in price setting and in which Foreign exporters who compete with Home firms prefer to let their markups and thereby their Foreign-currency export price vary rather than adjusting their Home-currency export price in response to exchange rate changes. In the model, reductions in trade costs that deepen trade integration and increase exporters' productivity accentuate the strategic complementarities in price setting, and further strengthen the willingness of firms to vary their markups in order to stabilise their export prices in the importer's currency. Third, Enders et al. (2018) set up a structural model in which following financial integration agents use cross-border equity in addition to bond holdings in order to hedge against shocks. The resulting optimal portfolio includes a higher share of bonds denominated in foreign currency, and impacts the correlation structure of costs and sales in a way such that producers move towards more local-currency pricing which features a lower ERPT to export prices in the destination's currency.

In this paper we consider a fourth possible explanation for the secular decline in ERPT 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). Importantly for this paper, imported intermediates are not only used for the production of goods that are then absorbed domestically, but also in the production of exports. For example, Amiti et al. (2014) document that the largest importers at the same time also account for the largest share of an economy's exports. And Tintelnot et al. (2018) document that even if exporters do not use imported intermediates in their production, they are still strongly exposed to imported inputs through their domestic suppliers which use imported intermediates. In the context of ERPT, we argue in this paper that for a given degree of ERPT to local-currency import prices and a given mark-up, a larger share of imported intermediates in total intermediates used in the production of an economy's exports implies a larger ERPT to local-currency *export* prices at the aggregate level. In turn, the larger sensitivity of local-currency export prices to exchange rate changes at the aggregate level implies a smaller sensitivity of foreign-currency import prices at the aggregate level abroad.[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 ERPT to local-currency import prices in the euro area and given 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. For the other side of the trade, the rise in the euro area's local-currency export price is at least partly offset by the depreciation of euro, resulting in a dampened increase of local-currency import prices abroad. Thus, for a greater global value chain participation (GVCP) of the euro area, importers abroad will experience a dampened variation of their local-currency import prices in response to variations of the euro's exchange rate.

In this paper we first illustrate this mechanism in a structural two-country model that is able analyse the dynamic adjustment to shocks at the business cycle frequency and to account for international general equilibrium effects. The latter is important, as in the example above the impact of GVCP on ERPT to import prices was laid out assuming constant ERPT to import prices in the euro area; however, as in the example the euro area also exhibits GVCP, by the same logic as for the rest of the world ERPT to import prices should also decline in the euro area, potentially breaking the chain of thoughts that eventually implied a decline in ERPT to import prices abroad. In the model, GVCP is reflected by trade in intermediate goods which are used in production along with domestic inputs. Economies' steady-state GVCP varies with the steady-state share of imported intermediates in the intermediate input goods bundle. The latter

[1]That variation in ERPT to export prices can cause variation in ERPT to import prices in the opposite direction has also been discussed by Vigfusson et al. (2009). However, neither do Vigfusson et al. (2009) study the role of GVCP for shaping ERPT to export prices nor the variation in ERPT to import prices over time.

steady-state share is not determined endogenously in the model, consistent with the empirical evidence on the degree of an economy's GVCP being determined by factors underlying trade and offshoring costs. In the baseline specification of the model we assume producer-currency pricing, but we also explore alternative versions of the model with local and dominant-currency pricing. Moreover, in the baseline we abstract from strategic complementarities and hence variable markups, but relax this assumption in an alternative version of the model. Plausible parameterisations of the model imply that ERPT to local-currency export prices rises as the economy's GVCP increases. Moreover, the model predicts that due to the increase in ERPT to local-currency export prices in the Home economy stemming from greater GVCP, in the Foreign economy ERPT to local-currency import prices falls.

Against the background of these predictions from the structural model we then explore the relationship between GVCP and ERPT to export and import prices using cross-country data for the time period from 1995 to 2014. In particular, we first estimate ERPT to export prices for 33 advanced and emerging economies. We then assess to what extent differences in economies' GVCP can account for differences in the estimates of their ERPT to local-currency export prices. Consistent with the predictions from the structural model, the results suggest that greater domestic GVCP is associated with higher ERPT to local-currency export prices. Second, we obtain estimates of ERPT to local-currency import prices for the same 33 advanced and emerging economies. We then assess to what extent differences in the GVCP of economies' *trading partners* can account for differences in the estimates of economies' ERPT to local-currency import prices. Again consistent with the predictions from the structural model, we find that ERPT to local-currency import prices is smaller for economies' whose trading partners exhibit greater GVCP. In the latter analysis on the role of GVCP for ERPT to import prices, we control for alternative explanations for the secular decline in ERPT to import prices put forth in the literature, such as changes in the composition of import bundles, the productivity of economies' trading partners and invoicing-currency patterns (Campa et al., 2005; Gust et al., 2010; Enders et al., 2018).

The paper contributes and is related to additional existing literature on the implications of GVCP on ERPT. In an early contribution, Aksoy and Riyanto (2000) study a structural model with imported intermediates in production and establish that GVCP raises ERPT to export prices. However, Aksoy and Riyanto (2000) not test the implications of their model empirically, are not concerned with variations of ERPT over time, and do not relate changes in ERPT to export prices to changes in ERPT to import prices abroad. Campa and Goldberg (2008) use a structural model to show that greater use of imported intermediates raises ERPT to export prices, but do not relate the latter to a fall in ERPT to import prices abroad. Auer (2015) documents that ERPT to US producer prices in case of the government-controlled appreciation of the Renminbi vis-à-vis the US dollar between 2005 and 2008 was higher in sectors that rely more on imported inputs. Similarly, Auer and Mehrotra (2014) find that domestic producer prices in the Asia-Pacific region respond more strongly to exchange rate changes in sectors in which the cost share of imported intermediates is higher. However, neither Auer (2015) nor Auer and Mehrotra (2014) are concerned with the evolution of ERPT over time, and do not relate the increase in ERPT to producer prices in case of GVCP to a decrease in ERPT to import prices abroad. Amiti et al. (2014) document that firms which feature higher imported input intensity exhibit lower ERPT to destination-currency export prices. Additionally, Amiti et al. (2018) show that cross-sectional heterogeneity in imported input intensity and markup elasticity at the firm level imply muted ERPT to destination-currency export prices in the aggregate. However, due to their use of microeconomic models neither Amiti et al. (2014) nor Amiti et al. (2018) take into account international general equilibrium effects; also, they are not concerned with the secular decline in ERPT to import prices discussed in the macroeconomic literature. Bems (2014) shows that "gross output" models — that account for intermediate inputs in production — and "value added" models — without intermediate inputs in production — imply different predictions regarding the relative price response to external re-balancing. Somehow relatedly, Bems and Johnson (2017) discusses that GVCP implies that economies are not only tied together on the demand side through expenditure switching on final goods but also on the supply side. In contrast to our paper, Bems (2014) as well as Bems and Johnson (2017) consider static general equilibrium models and are not specifically concerned with the secular decline of ERPT over time. Finally, Rodnyansky (2018) builds a New Keynesian DSGE model to rationalise his empirical finding that depreciations do not benefit exporters, especially when they use a lot of imported intermediates. Again, in contrast to our paper Rodnyansky (2018) is not concerned specifically with the role of GVCP for ERPT and its decline over time.

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 GVCP on ERPT to export prices as well as the consequences for trading partner's ERPT to import prices. In Section 3 we test the predictions of our theoretical model empirically. Finally, Section 4 concludes.

2 A structural two-country model with trade in intermediate goods

In this section we explore how changes in an economy's relative use of foreign and domestic intermediate inputs in production generate variations in ERPT to local-currency export prices in the Home economy and consequently to local-currency import prices in the Foreign economy in a structural model. The model we consider builds on the New Open Economy Macroeconomics literature (see, inter alia, Benigno and Thoenissen, 2003; Corsetti and Pesenti, 2005; **?**), but we additionally consider that economies engage in trade in intermediate inputs.[2]

Our benchmark model consists of two symmetric economies (Home and Foreign) of different size

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

(n_H and n_F, with $n_H + n_F = 1$). Each economy consists of a continuum of firms that utilise labour and intermediate input to produce a differentiated, tradeable, country-specific good. The produced good is either consumed in the domestic economy, re-used as intermediate input to domestic production, or exported, where it is again either consumed by households or used as input in production. We moreover assume incomplete financial markets at the international level and nominal rigidity in wages and prices.

The pricing paradigm adhered to by exporters may have important implications for the transmission of shocks and thereby ERPT. Therefore, we choose a setup that allows for different assumptions on the pricing of exports. In particular, the benchmark model nests the cases of producer-currency pricing (PCP) and local-currency pricing (LCP). Gopinath (2016) has shown that a large share of global trade is invoiced in particular in US dollar. Moreover, **?** as well as Boz et al. (2017) provide empirical evidence suggesting that export prices are not only invoiced but also sticky in US dollar rather than the currency of the exporter or importer, even in case of trade relationships that do not involve the United States (US). We therefore also consider a variation of the benchmark model in which prices of Home and Foreign exports are set in a dominant currency (dominant-currency paradigm, DCP). In this latter model we introduce the US as a third economy, and specify the US dollar as the dominant currency. This version of our model shares features of the model introduced by **?** as well as Boz et al. (2017).

2.1 Model structure

2.1.1 Household consumption and budget constraint

The utility function of the representative agent in Home is separable in consumption C_t and labour N_t and is given by

$$U_0 = E_0 \sum_{t=0}^{\infty} \beta^t \psi_t \left(\frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\rho}}{1+\rho} \right), \tag{1}$$

where σ is the relative risk aversion, ρ is the inverse elasticity of labour supply with respect to the real wage, $\beta \in (0,1)$ denotes the discount factor and ψ_t is an exogenous impatience shock (demand shock) which follows an AR(1) process in logs. We assume that Home and Foreign final goods are bundled to a consumption good according to

$$C_t \equiv \left[(1-\delta)^{1/\theta} (C_{H,t})^{\frac{\theta-1}{\theta}} + \delta^{1/\theta} (C_{F,t})^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}, \tag{2}$$

where δ denotes the steady-state share of Foreign goods in Home final consumption and θ the consumption elasticity of substitution between goods produced in Home, $C_{H,t}$, and goods produced in Foreign, $C_{F,t}$. The specification of the consumption bundle in Equation (2) implies the consumer price index $P_t = \left[(1-\delta)(P_{H,t})^{1-\theta} + \delta(P_{F,t})^{1-\theta}\right]^{\frac{1}{1-\theta}}$. The implied demand functions are given by $C_{H,t} = (1-\delta)\left(\frac{P_{H,t}}{P_t}\right)^{-\theta} C_t$ and $C_{F,t} = \delta\left(\frac{P_{F,t}}{P_t}\right)^{-\theta} C_t$.

Assuming full use of resources, the inter-temporal budget constraint of a representative Home household is given by

$$\frac{B_{H,t}}{R_t P_t} + \frac{S_t B_{F,t} \Psi_t}{R_t^* P_t \Phi\left(\frac{S_t \overline{B}_{F,t}}{Y_t P_t}\right)} = \frac{B_{H,t-1}}{P_t} + \frac{S_t B_{F,t-1}}{P_t} + \frac{W_t}{P_t} N_t - C_t + \Pi_t + T_t, \tag{3}$$

where $B_{H,t}$ and $B_{F,t}$ denote holdings of Home-issued and Foreign-issued bonds, W_t the nominal wage, S_t the nominal bilateral exchange rate measured as the price of Home currency per unit of Foreign currency, Π_t redistributed profits, and T_t net taxes. We assume financial markets are incomplete such that Home and Foreign agents can hold Foreign-issued bonds. Additionally, in order to avoid having to model portfolio choice, we follow Benigno and Thoenissen (2003) and assume that only Home agents can hold Home-issued bonds. The function $\Phi(\cdot)$ represents a small financial intermediation cost that depends on the aggregate holdings of bonds issued abroad $\overline{B}_F$ scaled by nominal GDP $Y_t P_t$.[3] Ψ_t denotes a shock to the uncovered interest rate parity condition (UIP shock) that drives a wedge between Home and Foreign interest rates (see, for instance **?**). The profits from financial intermediation are reimbursed lump-sum to households. We assume foreign households only have access to Foreign bonds, so their budget constraint differs accordingly.

In a standard way, households provide differentiated labour and face nominal rigidity in their wage income a la Calvo (1983), i.e. only a fraction of $1 - \varphi_w$ of all wages can be adjusted every period.

2.1.2 Production

We abstract from the use of capital and assume that production employs only labour and intermediate goods as inputs. Specifically, production of an individual firm f is given by

$$Y_t(f) = Z_t \left[\alpha_N N_t(f)^{\frac{\tau-1}{\tau}} + \alpha_M M_t(f)^{\frac{\tau-1}{\tau}}\right]^{\frac{\tau}{\tau-1}}, \tag{4}$$

where Z_t is exogenous Hicks-neutral aggregate productivity, $N_t(f)$ firm-specific labour demand, $M_t(f)$ firm-specific demand for intermediate inputs that consist of Home intermediates, $M_{H,t}(f)$,

[3] The introduction of this cost ensures stationarity of the net foreign asset position (see, for instance, Schmitt-Grohé and Uribe, 2003). As in Benigno and Thoenissen (2003), we assume that the cost function $\Phi(\cdot)$ takes the value of unity when the net foreign asset position approaches its steady-state value, which we assume to be zero. We also assume the function $\Phi(\cdot)$ is differentiable and decreasing in the neighborhood of zero.

and Foreign intermediates, $M_{F,t}(f)$, aggregated according to

$$M_t(f) \equiv \left[(1-\omega)^{1/\phi} M_{H,t}(f)^{\frac{\phi-1}{\phi}} + \omega^{1/\phi} M_{F,t}(f)^{\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{\phi-1}}. \tag{5}$$

In Equation (4), the distribution parameters α_N, α_M describe the use of labour and intermediate inputs in production, and τ the elasticity of substitution between intermediate goods and labour. In Equation (5), the parameter ω represents the steady-state share of intermediate goods in production that are imported, and ϕ the elasticity of substitution between domestically produced and imported intermediate inputs. The specification in Equation (5) implies the aggregate intermediate goods price index $P_{M,t} = \left[(1-\omega)(P_{H,t})^{1-\phi} + \omega(P_{F,t})^{1-\phi}\right]^{\frac{1}{1-\phi}}$. The implied aggregate demand functions for domestically produced intermediates and imported intermediates are given by $M_{H,t} = (1-\omega)\left(\frac{P_{H,t}}{P_{M,t}}\right)^{-\phi} M_t$ and $M_{F,t} = \omega\left(\frac{P_{F,t}}{P_{M,t}}\right)^{-\phi} M_t$.

2.1.3 Price setting

Prices are subject to a Calvo lottery. Specifically, in each period only a fraction $(1-\varphi) \in [0,1]$ of firms is allowed to adjust prices. Moreover, each firm f sets a price for the Home and the Foreign market. In particular, given the nominal exchange rate S_t, a firm f in Home sets a price $\widetilde{P}_{H,t}(f)$ for the Foreign market, which implies a Foreign-currency export price

$$P^*_{H,t}(f) = \widetilde{P}_{H,t}(f) \cdot S_t^{-\zeta^*}, \tag{6}$$

for $\zeta^* \in \{0,1\}$. This specification nests the cases in which prices are set in the currency of the producer (PCP), $\zeta^* = 1$, and in the currency of the trading partner (LCP), $\zeta^* = 0$ (see, for instance, Corsetti and Pesenti, 2005). The price for goods consumed in Home is pre-set in local currency $P_{H,t}(f)$. An individual firm sets $P_{H,t}(f)$ and $\tilde{P}_{H,t}$ as to maximise

$$E_0 \sum_{j=0}^{\infty} (\varphi\beta)^j \Lambda_{t,t+j} \times \left\{ \frac{P_{H,t}(f)}{P_{t+j}} \mathrm{Y}_{H,t+j}(f) + \frac{S_{t+j} P^*_{H,t+j|t}(f)}{P_{t+j}} Y^*_{H,t+j}(f) - \right.$$
$$\left. - (1-\eta) MC_{t+j} \left[Y_{H,t+j}(f) + Y^*_{H,t+j}(f)\right] \right\}, \tag{7}$$

subject to the endogenous discount factor $\Lambda_{t,t+j}$ given by the household optimisation problem, the consumer price level P_t, real marginal costs MC_t measured in terms of the aggregate consumption good, a fiscal subsidy to all factors of production η, as well as Home and Foreign demand for goods of firm f given by $Y_{H,t}(f) = C_{H,t}(f) + M_{H,t}(f)$ and $Y^*_{H,t}(f) = C^*_{H,t}(f) + M^*_{H,t}(f)$.

We do not consider strategic complementarities in price setting that give rise to variable markups as in Gust et al. (2010) or **?** for simplicity. However, the predictions from the model are unchanged if we introduce strategic complementarities in price setting by replacing the relevant equations — in particular in the Phillips curve — by those in **?**.

2.1.4 Market clearing

Recall that output is used both as intermediate input in production and to produce a composite final good. Therefore, and accounting for differences in country size, aggregate goods markets clearing requires $Y_t = C_{H,t} + M_{H,t} + \frac{n_F}{n_H}\left[C^*_{H,t} + M^*_{H,t}\right]$, and $Y^*_t = C^*_{F,t} + M^*_{F,t} + \frac{n_H}{n_F}\left[C_{F,t} + M_{F,t}\right]$. For Foreign-issued bond markets to clear it is required that $n_H B_{F,t} + n_F B^*_{F,t} = 0$,and for Home-issued bonds it is required that $B_t = 0$.

2.1.5 Monetary policy

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

$$R_t = R_{t-1}^{\nu_r} \cdot \left[\overline{R}\left(\frac{P_t/P_{t-1}}{\Pi}\right)^{\kappa_\pi}\left(\frac{Y_t}{Y_{t-1}}\right)^{\kappa_y}\right]^{(1-\nu_r)} \cdot \exp\left(\xi_{t,r}\right), \tag{8}$$

where ν_r governs the degree of interest-rate smoothing, $\xi_{t,r}$ is a monetary policy shock, κ_π and κ_y denote Taylor-rule coefficients for inflation and output growth, and Π the steady-state gross inflation rate.

2.2 Model solution

In the steady state, markets clear, international trade is balanced and net inflation is zero. All firms able to re-set their prices choose the same price, and, as is standard, the fiscal subsidy η is set such that the distortion from monopolistic competition is offset. We log-linearise the model around a deterministic steady state.[4]

2.3 Measuring GVCP in the model

In order to reflect economies' GVCP in the model we consider the ratio of domestic value added in an economy's gross exports (VAX; see Johnson and Noguera, 2012). As we show in the Appendix, due to the assumption of symmetric production structure and balanced trade, in the model the steady-state VAX ratio is given by

$$VAX = \frac{\widetilde{\alpha}}{1-(1-\widetilde{\alpha})(1-\omega)+(1-\widetilde{\alpha}^*)\omega^*}, \tag{9}$$

[4]In the quantiative analysis below we mainly rely on analytical solutions from the first-order approximation. The full linearised model can be solved using Dynare.

where $\widetilde{a} \equiv \left(\frac{\overline{W/P}}{\overline{MC*Z}}\right)^{1-\tau} \alpha_N^{\tau}$ denotes the steady-state share of labour costs in firms' total marginal costs, and $(1-\widetilde{\alpha})\omega$ the corresponding share of imported intermediates. We set $1-\widetilde{\alpha} = 1-\widetilde{\alpha}^* = 0.49$, which matches the average expenditure share of intermediate goods in total production across considered countries from the WIOD database (cf. below).

An alternative notion for GVCP is the value added content of output needed to produce exports as a fraction of total exports (cf. inter alia Hummels et al., 2001) which is given in the model by

$$VAC = \frac{\widetilde{\alpha}}{1-(1-\widetilde{\alpha})(1-\omega)}. \tag{10}$$

In our calibration, in the case when the Foreign economy does not use imported intermediates in production ($\omega^* = 0$) the VAX nests this metric (see Johnson and Noguera, 2012, for a discussion). It takes the value of unity when no intermediate goods are imported ($\omega = 0$), and equals $\widetilde{\alpha}$ when no domestically produced intermediate goods of Home are used in production ($\omega = 1$).

In contrast to this latter metric, for $\omega^* > 0$, the VAX ratio is declining in the share of imported intermediate goods used in Foreign production $(1-\widetilde{\alpha}^*)\omega^*$, because, in the notion of Johnson and Noguera (2012), value added exports excludes Home value added that enters as input in Foreign production but is ultimately re-imported and absorbed in Home.

2.4 Measuring ERPT in the model

In the model, export and import prices as well as the nominal exchange rate are endogenous and therefore simultaneously determined by the evolution of supply and demand. In order to isolate the price effects of changes in the the exchange rate, ERPT to local-currency export prices (ERPT to local currency import prices) is defined as the contemporaneous effect of a one percent change in the bilateral nominal exchange rate for local-currency export prices (local-currency import prices), other things equal (cf. inter alia Corsetti et al., 2008; **?**). This definition of ERPT is motivated by the measurement of ERPT in our empirical specification below and definitions of ERPT in a large empirical literature (inter alia Campa et al., 2005; Vigfusson et al., 2009; Bussière et al., 2014; Burstein and Gopinath, 2014).[5]

As we show in the Appendix, in the log-linearised model, assuming PCP as a benchmark, ERPT to local-currency export prices (from the Home perspective) is given by

$$ERPT^x = \Omega^{-1}\left\{\frac{\kappa(1-\tilde{\alpha})\omega}{(1+\beta)+\kappa(1-(1-\tilde{\alpha})(1-\omega))} - 1\right\} + 1, \tag{11}$$

[5] From the model perspective, in an OLS specification measuring ERPT one would have to control for movements in Home and Foreign nominal wages and productivity as well as lag and lead terms of nominal import and export prices and exchange rates to obtain structural ERPT. The empirical measurement of structural ERPT is, however, constrained by data limitations.

and for ERPT to local-currency import prices for the Foreign economy is given by

$$ERPT^{m*} = (-1) * \Omega^{-1} \left\{ \frac{\kappa(1-\tilde{\alpha})\omega}{(1+\beta) + \kappa(1-(1-\tilde{\alpha})(1-\omega))} - 1 \right\} \quad (12)$$

where $\kappa \equiv \frac{(1-\beta\varphi)(1-\varphi)}{\varphi}$, $\kappa^* \equiv \frac{(1-\beta^*\varphi^*)(1-\varphi^*)}{\varphi^*}$,
and $\Omega \equiv \left\{ 1 - \frac{\kappa(1-\tilde{\alpha})\omega}{(1+\beta)+\kappa(1-(1-\tilde{\alpha})(1-\omega))} \frac{\kappa^*(1-\tilde{\alpha}^*)\omega^*}{(1+\beta^*)+\kappa^*(1-(1-\tilde{\alpha}^*)(1-\omega^*))} \right\}$.

In the Appendix, similar expressions are obtained for the cases of LCP and DCP which are discussed in more detail below. Notably, ERPT does only change in the degree of price rigidity, the household discount factor, and in the expenditure shares corresponding to the use of labour inputs as well as domestically-produced and imported intermediates inputs in production. Other model parameters shape the dynamics of the model (responses to technology shock, monetary policy shock, impatience shock, UIP shock) but not the degree of structural ERPT which is itself shock-invariant.

In the model, the nominal exchange rate is not exogenous and the particular source of a change in the exchange rate matters for the relationship between the nominal exchange rate and export (import) prices. On purpose, the definition of structural ERPT in Equation (11) and Equation (12) abstracts from general equilibrium effects that specific shocks would have on nominal exchange rates and export and import prices. Nevertheless, when keeping nominal wages and technology constant, then in the special case of flexible prices, ERPT in general equilibrium (i.e. the dynamic response of local-currency import or export prices relative to the dynamic response of the nominal exchange rate) is equal to the structural ERPT measure (cf. Appendix D).[6] In other words, under the model calibration of fully flexible goods prices ($\varphi \to 0$) and fully rigid wages ($\varphi_w \to 1$) all possible shocks in the model except technology shocks yield dynamics of local-currency export (import) prices relative to nominal exchange rate changes described by Equation (11) (Equation (12)).[7]

2.5 Relationship between GVCP and ERPT

Recall that we want to study the effects of a change in the exchange rate on import and export-price inflation for different degrees of GVCP. For this purpose, we examine to what extent

[6] **?** have explored this general equilibrium ERPT under flexible prices and sticky wages in a small open economy model. The relationship can be generalized to the two-country case.

[7] With a more general calibration, the presence of structural pass-through in general equilibrium can best be explored for the shock Ψ_t which drives a wedge between Home and Foreign interest rates (see, for instance **?**). This shock affects the nominal exchange rate through the uncovered interest rate parity relation and is not stemming from changes in supply or demand conditions in Home or Foreign. In the numerical solution of the model with a reasonable calibration, the general equilibrium ERPT – measured by the cumulative response of local-currency export (import) prices relative to the cumulative response of the nominal exchange rate in the first four periods – implied by this shock is quantitatively similar to the corresponding structural ERPT measures in Equation (11) and Equation (12).

ERPT changes with different steady-state values of the VAX ratio, which in turn varies with the steady-state share of imported intermediates ω in Equation (5). In particular, a higher share of intermediate goods accounted for by imported intermediate goods implies a lower VAX ratio, which reflects stronger GVCP.[8]

For illustrative purposes, we start with discussing the case in which prices are fully flexible. Under this assumption ERPT in Equation (11) and Equation (12) converges to

$$ERPT^x = \Omega^{-1}\left(\frac{(1-\tilde{\alpha})\omega}{(1-(1-\tilde{\alpha})(1-\omega))} - 1\right) + 1 = 1 - \frac{VAC}{1-(1-VAC)(1-VAC^*)}, \tag{13}$$

Analogously for ERPT to local-currency import prices for the Foreign economy is given by

$$ERPT^{m*} = \Omega^{-1}\left(1 - \frac{(1-\tilde{\alpha})\omega}{(1-(1-\tilde{\alpha})(1-\omega))}\right) = \frac{VAC}{1-(1-VAC)(1-VAC^*)} \tag{14}$$

where $\Omega = 1 - \frac{(1-\tilde{\alpha})\omega}{1-(1-\tilde{\alpha})(1-\omega)}\frac{(1-\tilde{\alpha}^*)\omega^*}{1-(1-\tilde{\alpha}^*)(1-\omega^*)} = 1-(1-VAC)(1-VAC^*)$, VAC is the Home value added content of output needed to produce exports as a fraction of total exports as defined in Equation (10) and VAC^* is the corresponding measure for Foreign.

If Home and Foreign exporters do not participate in the other country's chain of production, then $VAC = 1$ and $VAC^* = 1$, implying full ERPT to local currency import prices and zero ERPT to local currency export prices.

In general GVCP affects ERPT. For instance, let's take the perspective of the Home economy as an exporting country and Foreign as an importing country and assume that Home is very small in comparison to Foreign ($n_H \to 0$). Then, from equations Equation (13) and Equation (14), using the definition of the VAX ratio and because VAC^* is close to one in the case Home is very small we obtain

$$ERPT^x = 1 - VAX. \tag{15}$$

Analogously for ERPT to local-currency import prices for the Foreign economy is given by

$$ERPT^{m*} = VAX. \tag{16}$$

The first expression in Equation (15) indicates that *stronger Home GVCP* — reflected by a lower VAX ratio — is associated with a *higher Home ERPT to local-currency export prices.* The intuition underlying this relationship is the following: The Home local-currency import price of Foreign goods, $P_{F,t}$, depends on the nominal exchange rate, S_t. In case of a depreciation of the Foreign currency, the Home local-currency import price of Foreign goods falls.[9] When Home

[8] Note that the VAX ratio also changes with the steady-state share of value added in production $\widetilde{\alpha}$. We leave this parameter unchanged in our analysis and instead only look at variations in the steady-state share of imported intermediates in total intermediates ω. This is motivated by a strong negative correlation between the VAX ratio and the share of imported intermediates in total intermediates in the data.

[9] In this case ERPT to *Home* import prices is close to 100%. Home is relatively small compared to Foreign,

firms use Foreign goods as intermediate inputs, their marginal costs decline, and so does the local-currency price of the goods exported by Home. The drop in Home local-currency export prices is stronger the larger the share of intermediate inputs that are imported, and hence the stronger Home GVCP.

In turn, as indicated by the second expression in Equation (16), *stronger Home GVCP* — reflected by a lower VAX ratio — is associated with *lower Foreign ERPT to local-currency import prices*. The intuition underlying this relationship is the following: The depreciation of the Foreign currency implies an increase of local-currency import prices in Foreign. However, the rise in local-currency import prices in Foreign is weaker the more Home local-currency export prices fall. Importantly, as explained above, Home local-currency export prices fall more strongly the larger the share of intermediate inputs that it imports, and hence the stronger Home GVCP.

The described relationship between GVCP on ERPT remains qualitatively unchanged when assuming a larger country size for Home relative to Foreign. Figure 1 plots the relationship between Home ERPT to local-currency export prices and the Home VAX ratio (equation Equation (13)), as well as the link between Foreign ERPT to local-currency import prices and the Home VAX ratio (equation Equation (14)) for the cases of (1) Home being a small economy relative to Foreign and (2) Home and Foreign having the same country size. The Figures indicate that the effect is quantitatively smaller when the two countries have the same size. In this case, from the perspective of exporters in Home that use imported intermediate goods in their production, the sensitivity of marginal cost with respect to exchange rates is slightly damped. The reason is that ERPT to *Home* import prices is not close to 100% any longer but lower because Foreign production now relies to a relevant extent on Home-produced intermediate goods. Home ERPT to local-currency import prices is therefore declining in *Foreign GVCP*, which lowers the positive effect of Home GVCP for Home ERPT to local-currency export prices.[10]

Notably, in the empirical part below we will estimate response of local-currency import and export prices to changes in the exchange rate within four preceding quarters assuming that all firms adjust prices once within a year. For that reason the flexible price case is a good benchmark to compare the model predictions with the empirical result. Also, under flexible prices the assumption of currency denomination (PCP, LCP or DCP) is irrelevant.

Nevertheless, in the data some nominal rigidity might till be present, thus making it important to study the sticky price case as well. Figure 1 plots the link between GVCP and ERPT (Equation (13) and Equation (14)) under the assumptions that business cylce frequency is one year ($\beta = 0.96$) and firms – operating under PCP – can adjust prices within 14 month ($\varphi = 0.1428$).

which implies that Foreign does not use a significant amount of Home-produced intermediates as inputs and real marginal costs remain unaffected. Also, Foreign is pricing its exports in Foreign currency, which implies that Foreign export prices do not directly change because of a depreciation of the Foreign currency.

[10] The derivatives of Equation (13) and Equation (14) with respect to the amount of imported inputs in Home's production indicate that the described relationship does not depend on a particular country size of Home.

Importantly, the qualitative predictions remain robust under this slight adjustment. The effect of GVCP on ERPT is nevertheless smaller in relation to the benchmark case of flexible prices.

To summarise, the model predicts that stronger GVCP of Home is associated with a higher ERPT to local-currency export prices in Home, which, in turn, implies a lower ERPT to local-currency import prices in Foreign. More generally, the model predicts that ERPT to local-currency import prices are lower in economies whose trading partners exhibit stronger GVCP.

Chung (2016) sets up a model which predicts that exporters that depend more on imported intermediates are less likely to price exports in their home currency and instead adopt LCP. Hence, as the Home economy participates more in GVCP it may also transition from PCP to LCP. It is hence interesting to explore if the relationship between GVCP and ERPT documented in the model under PCP continues to hold under LCP. One way to address this question would be to endogenise invoicing-currency choice. We adopt less demanding approach by exploring the relationship between GVCP and ERPT under LCP rather than PCP. In particular, analogous to the case of PCP presented in Figure 1, and assuming for simplicity that Home is small relative to Foreign, Figure 2 documents that the predictions from the model regarding the relationship between ERPT and GVCP are very similar if we assume LCP instead of PCP by setting $\zeta = \zeta^* = 0$ in Equation (6).[11] [12] Notice that ERPT to export prices is higher under LCP than under PCP and that ERPT to import prices is lower under LCP than under PCP. Hence, not only does the relationship between GVCP and ERPT documented for the case of PCP carry over qualitatively to the case of LCP, but it also is reinforced quantitatively.

2.6 The case of DCP

Recent literature has documented that a large amount of global trade is denominated and sticky in particular in US dollar, even in case of trade relationships that do not involve the US. This phenomenon has been referred to as DCP (Gopinath, 2016; **?**; Boz et al., 2017). In our setting, DCP implies that Home and Foreign exporters do not price their exports in their own currency (i.e. PCP) or in the currency of the trading partner (i.e. LCP), but in the currency issued by a third economy. Against this background, the question arises if the results presented above are robust to assuming DCP instead of PCP.

[11] The equations describing the structural ERPT in case of LCP can be found in the Appendix.

[12] The results are also robust to assuming that one economy has PCP exporters while the other economy has LCP exporters.

2.6.1 Price setting with DCP

We consider an extension of the benchmark model presented above in which we introduce the US as a third economy, and replace the assumption of PCP by DCP.[13] Home, Foreign and the US differ in their size as measured by n_H, n_F and n_{US}, with $n_H + n_F + n_{US} = 1$. The structure of each economy in the three-country model is very similar to the structure of the two economies in the benchmark model.

An important difference relative to the benchmark two-country model is that we assume that Home and Foreign firms price all their exports in US dollar. Specifically, a firm f in Home sets prices for domestically consumed goods $P_{H,t}(f)$ and for exported goods $\widetilde{P}_{H,t}(f)$ in order to maximise the objective function

$$E_0 \sum_{j=0}^{\infty} (\varphi\beta)^j \Lambda_{t,t+j} \times \Bigg\{ \frac{P_{H,t}(f)}{P_{t+j}} \mathrm{Y}_{H,t+j}(f) + \frac{S_{t+j}^{US} \widetilde{P}_{H,t}(f)}{P_{t+j}} \left[Y_{H,t+j}^{*}(f) + Y_{H,t+j}^{US}(f) \right] - \\ - (1-\eta) MC_{t+j} \left[Y_{H,t+j}(f) + Y_{H,t+j}^{*}(f) + Y_{H,t+j}^{US}(f) \right] \Bigg\} \quad (17)$$

subject to the endogenous discount factor $\Lambda_{t,t+j}$, the consumer price level P_t, real marginal costs MC_t measured in terms of the aggregate consumption good, a fiscal subsidy to all factors of production η, Home, Foreign and US demand for goods of firm f given by $Y_{H,t}(f) = C_{H,t}(f) + M_{H,t}(f)$, $Y_{H,t}^{*}(f) = C_{H,t}^{*}(f) + M_{H,t}^{*}(f)$ and $Y_{H,t}^{US}(f) = C_{H,t}^{US}(f) + M_{H,t}^{US}(f)$, respectively, as well as the nominal exchange rate vis-à-vis the US dollar, S_t^{US}.

2.6.2 Quantitative results for the relationship between GVCP and ERPT in the model with DCP

We want to study ERPT to local-currency import prices in Foreign for different values of Home GVCP in a DCP scenario. To ensure comparability with the benchmark model, we assume that Home and Foreign trade volumes with the US are close to zero, so that Home GVCP can still be measured by the VAX ratio in Equation (9).[14] Also, all preference parameters and the ratio between the size of the Home and Foreign economies are calibrated as in the two-country case.

Under the DCP, structural ERPT – measured as the elasticity of the local-currency export price (import prices) with respect to the *bilateral* exchange rate of Home currency to Foreign currency – depends on how the bilateral nominal exchange rate is correlated with the nominal exchange

[13] The setting shares features with the models of **?** as well as Boz et al. (2017). However, again for simplicity, we do not assume strategic complementarities in price setting that give rise to variable mark-ups. Also, we explicitly model the interlinkages between Foreign and the US.

[14] Note that the trade-weighted nominal effective exchange rate of Home and Foreign is then the same as the bilateral exchange rate between Home and Foreign from the perspective of the respective economy.

rates of Home and Foreign currency against the US dollar. In the Appendix, we compute ERPT for three DCP scenarios of interest: (1) the bilateral exchange rate moves 1:1 with the Foreign currency exchange rate against the US dollar, (2) the bilateral exchange rate moves 1:1 with the Home currency exchange rate against the US dollar, (3) we use the two-country model to assume that Foreign is the US economy and all international trade is denominated in one currency.[15]

For simplicity, we discuss the case of a small Home economy ($n_H \rightarrow 0$, $n_F >> 0$).[16] Figure 2 plots the derived relations – as in the benchmark case assuming $\tilde{\alpha} = 0.51$, $\beta = 0.96$, and that firms can reset prices every 14 month ($\varphi = 0.1428$) – for all three cases described above. It documents that also under DCP the model predicts that Home ERPT to local-currency export prices (Foreign ERPT to local-currency import prices) rises (decreases) with stronger Home GVCP.

In the first DCP scenario (1), a depreciation of the Foreign currency against the US dollar – which is also a depreciation of the Foreign currency against the Home currency – implies an increase in Foreign local-currency export prices. However, since Foreign imports only little from the US (by assumption) and Home (as Home is very small relative to Foreign), Foreign real marginal costs barely change. In order to stabilise their mark-up in local-currency terms Foreign firms reduce their US dollar export prices. As the Home-US dollar exchange rate does not change, the reduction in Foreign US dollar export prices implies a fall in Home local-currency import prices. As a result, Home firms' real marginal costs fall, which induces them to decrease their local-currency export prices. Importantly, this effect is stronger the larger the share of imported intermediate goods used in production, i.e. the stronger Home GVCP. In sum, the correlation between the change in Home local-currency export prices and the change in the exchange rate between the Home and the Foreign currency and its dependence on Home GVCP documented for the case of PCP in the benchmark model is preserved under DCP.

Also, the model predicts that ERPT to local-currency import prices in Foreign falls with stronger Home GVCP. In particular, as the Home-US dollar exchange rate does not change, the decrease of Home local-currency export prices partially offsets the rise in Foreign local-currency import prices implied by the depreciation of the Foreign currency vis-à-vis the US dollar. Again, this effect is stronger the larger the share of imported intermediate goods used in production in Home, i.e. the stronger Home GVCP. In sum, the correlation between the change in Foreign local-currency import prices and the change in the exchange rate between the Home and the Foreign currency and its dependence on Home GVCP documented for the case of PCP in the benchmark model in the bottom panel in Figure 1 is preserved under DCP.[17]

[15] Alternatively, one could formulate a scenario in which the US dollar depreciates vis-à-vis all currencies. In such a setting, the bilateral exchange rate between Home and Foreign as well as the nominal effective exchange rate between the Home and the Foreign currency would per construction not move, making the case irrelevant with regard to our empirical specification.

[16] As in the PCP and LCP case, the results are robust when assuming, for example, that Home and Foreign are equally large.

[17] It can be noted that this DCP case has similarities with the case in which Foreign exporters practice LCP,

In the second DCP scenario (2), an appreciation of the Home currency against the US dollar – which is also an appreciation of the Home currency against the Foreign currency – implies that Home local-currency export prices decline on impact. Those Home exporters that can change prices counteract to some extent the exchange rate effect with increasing local-currency export prices. Nevertheless, the appreciation of the Home currency contemporaneously causes lower cost of imported intermediates for Home firms importing Foreign goods that are denominated in US dollar. Thus, with a larger amount of imported intermediates, Home exporters have less incentive to counteract exchange rate changes in their export prices and the local-currency export price decline is more pronounced. This translates into a higher Home ERPT to local-currency export prices with larger Home GVCP. Since the nominal exchange rate of Foreign currency with respect to the US dollar is unchanged, the bilateral ERPT to local-currency Foreign import prices is again decreasing in Home GVCP.

The last DCP scenario (3) in which the US is a relevant trading partner for Home and all international trade is invoiced in US dollar is studied above. It refers to the two-country case in which Home firms set export prices in destination currency while Foreign (US) firms are PCP exporters and leads to the same result as the DCP scenario (2).

3 Empirical Evidence

Against the background of the findings in the structural model, we assess the empirical evidence for the role of GVCP for ERPT to export and import prices in the data in two steps. First, we obtain time-varying estimates of ERPT to export and import prices for a cross-section of economies. Second, we analyse the determinants of the cross-country heterogeneity and time-series variation in ERPT to export and import prices, giving particular consideration to the role of an economy's own GVCP as well as to the GVCP of its trading partners.

3.1 Estimating ERPT to export and import prices

3.1.1 Empirical framework

We follow the literature and consider a linear regression model in order to estimate country-specific ERPT to export and import prices (Campa et al., 2005; Vigfusson et al., 2009; Bussière et al., 2014; Burstein and Gopinath, 2014). Specifically, for ERPT to export prices the regression

which refers to assuming $\zeta = 0$ in the two-country case. If Foreign export prices are not priced in US dollar, but in the trading partner (Home) currency, then, in the case of Home being small relative to Foreign ($n_H \to 0$), Foreign firms would also decrease their prices with a depreciation of Foreign currency, implying an ERPT to *local*-currency import prices in Home of less than 100%. Only under PCP is this ERPT to local-currency import prices in Home close to 100%.

model is given by

$$\Delta p_{it}^{x} = \alpha_{i,\tau}^{x} + \sum_{j=0}^{3} \beta_{ij,\tau}^{x} \Delta e_{i,t-j} + \sum_{j=0}^{1} \gamma_{ij,\tau}^{x} \Delta p_{i,t-j}^{ppi} + \sum_{j=0}^{1} \delta_{ij,\tau}^{x} \Delta y_{t-j}^{w} + \epsilon_{it,\tau}^{x}, \tag{18}$$

where Δp_{it}^{x} 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_{it}^{ppi} is the quarter-on-quarter log-change of the producer-price index of economy i, and Δy_{t}^{w} is the quarter-on-quarter log-change of the (trade-weighted) average of trading partners' GDP.[18] Analogously to export prices, for ERPT to import prices the regression model is given by

$$\Delta p_{it}^{m} = \alpha_{i,\tau}^{m} + \sum_{j=0}^{3} \beta_{ij,\tau}^{m} \Delta e_{i,t-j} + \sum_{j=0}^{3} \gamma_{ij,\tau}^{m} \Delta c_{t-j} + \sum_{j=0}^{3} \delta_{ij,\tau}^{m} \Delta y_{i,t-j} + \epsilon_{it,\tau}^{m}, \tag{19}$$

where Δp_{it}^{m} is the quarter-on-quarter log-change of the import price unit value of economy i, Δc_t is the quarter-on-quarter log-change of the (trade-weighted) average of trading partners' export prices as a proxy for trading partners' production costs, and Δy_{it} is the quarter-on-quarter log-change of GDP of economy i. The estimates of ERPT to export and import prices for economy i are given by

$$\widehat{ERPT}_{i\tau}^{\ell} \equiv \sum_{j=0}^{3} \widehat{\beta}_{ij,\tau}^{\ell}, \quad \ell \in \{x, m\},\ \tau = 1, 2, \ldots, \mathcal{T}_i. \tag{20}$$

We estimate Equations (18) and (19) on rolling windows $\tau = 1, 2, \ldots, \mathcal{T}_i$ for the time period from 1986 to 2014 to obtain a sample of time-varying, country-specific estimates of ERPT to export and import prices. Each rolling window spans a time period of ten years. Specifically, the first window spans the time period from 1986 to 1995, and the last the time period from 2005 to 2014. We thus have (at most) $\mathcal{T}_i = 20$ estimates of ERPT to export and import prices per economy.

3.1.2 Data and sample for the estimation of ERPT

Table 1 reports the set of advanced and emerging market economies as well as the sample periods for which we estimate time-varying ERPT to export and import prices. We only include economies in our sample for which we also have data on GVCP in the World-Input-Output Database (WIOD; see below).[19] We obtain quarterly data on import and export price indices

[18] Higher lag orders are not statistically significant and therefore not included in our baseline specification.

[19] We exclude Luxembourg for the following reason. Luxembourg is an outlier regarding the numerical value of its measure of GVCP, and we want to preclude that the data for 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.

from the OECD. Data on nominal effective exchange rates, domestic GDP growth and producer-price inflation are taken from the IMF's International Financial Statistics. Consistent with the model in Section 2, we define the exchange rate in terms of domestic currency per unit of foreign currency. Thus, an increase in the nominal effective exchange rate index represents a depreciation of the domestic currency. Data on world GDP growth is taken from the OECD.

3.1.3 Estimates of ERPT to export and import prices

Figure 3 presents time-averages of the estimates of ERPT to export and import prices for the economies in our sample.[20] Consistent with the findings in the literature, our estimates of ERPT to export and import prices exhibit notable cross-country heterogeneity (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 ERPT to import (export) prices is around 0.4 (0.25), implying that a nominal effective depreciation of the domestic currency by one percent has on average been followed by an increase of import (export) prices by 0.45 (0.3) percent during our sample period. Consistent with the findings of Bussière et al. (2014), Figure 4 shows that the estimates of ERPT to export and import prices are correlated for a given economy.

3.2 The role of GVCP for variation in ERPT

3.2.1 Export prices

In order to examine the role of GVCP for ERPT to export prices in the data, we first estimate the regression

$$\widehat{ERPT}^{x}_{i\tau} = \alpha^x_i + \delta^x_\tau + \gamma^x vax_{i\tau} + \chi^x_1 ypc_{i\tau} + \chi^x_2 energy^x_{i\tau} + \boldsymbol{X}^x_{i\tau}\boldsymbol{\theta}^x + u^x_{i\tau}. \tag{21}$$

where $\widehat{ERPT}^{x}_{i\tau}$ is the estimated ERPT to export prices in economy i obtained from Equation (18) for rolling window τ, $vax_{i\tau}$ is the VAX ratio of economy i, $ypc_{i\tau}$ and $energy^x_{i\tau}$ control for alternative explanations for time-variation in ERPT put forth in the literature (see Campa et al., 2005; Gust et al., 2010), and $\boldsymbol{X}^x_{i\tau}$ is a vector of additional controls. The latter include openness (measured as imports to GDP ratio) and the share of high-technology products in total trade (see Taylor, 2000; Devereux et al., 2004; Campa and Goldberg, 2005; Campa and Gonzalez Mìnguez, 2006).[21]

An alternative to the panel regression model estimated based on rolling-window ERPT estimates is a cross-section regression in which we obtain a single estimate of ERPT to import and export

[20] For simplicity the estimates presented in Figure 3 are obtained from cross-sectional versions of Equations (18) and (19).

[21] The share of high-technology products in exports is proxy for the degree of product differentiation (see Bussière et al., 2014)

prices for the full sample period for every economy, and in which the right-hand side variables are time-averages over the sample period. For our baseline we prefer a panel regression over a cross-section regression because it allows us to control for time-invariant, unobserved determinants of ERPT to export prices, which mitigates possible omitted variable bias.

We estimate the panel data model in Equation (21) using annual rather than quarterly frequency, as the right-hand side variables are not available in quarterly frequency. To the extent possible, the right-hand side variables in Equation (21) — $vax_{i\tau}$, $\widehat{ERPT}^{m}_{i,\tau}$ and $\boldsymbol{X}^{x}_{i\tau}$ — are constructed as time-averages over the time period spanned by the corresponding rolling window. For the variables that are derived from the WIOD, which provides data at annual frequency for the period from 1995 to 2014, the variables are measured as time averages over the longest possible time period spanned by the corresponding rolling window. Thus, for the first rolling window, which spans the time period from 1986 to 1995, the value of the VAX ratio we consider in the regression corresponds to the value for 1995 in the WIOD; for the second rolling window, which spans the time period from 1987 to 1996, the value of the VAX ratio we consider in the regression corresponds to the average for 1995 and 1996, and so on. For $\tau \geq 10$, i.e. from 2004 onwards, the time-averages of the VAX ratio are measured over precisely the same time windows as all other variables.

3.2.2 Import prices

Analogous to ERPT to export prices, for ERPT to import prices we estimate

$$\widehat{ERPT}^{m}_{i\tau} = \alpha^{m}_{i} + \delta^{m}_{\tau} + \gamma^{m} vax^{*}_{i\tau} + \chi^{m}_{1} ypc^{*}_{i\tau} + \chi^{m}_{2} energy^{m}_{i\tau} + \boldsymbol{X}^{m}_{i\tau}\boldsymbol{\theta}^{m} + u^{m}_{i\tau}. \qquad (22)$$

where $vax^{*}_{i\tau}$ and $ypc^{*}_{i\tau}$ denote the bilateral, the average of other countries' multilateral VAX ratio and real GDP per hour worked of economy i's trading partners, $energy^{m}_{i\tau}$ the share of energy in economy i's import bundle, and $\boldsymbol{X}^{m}_{i\tau}$ is a vector of additional controls. The control variables $\boldsymbol{X}^{m}_{i\tau}$ include inflation volatility, the share of manufacturing and high-technology imports, the ratio of export to imports as well as trade openness of the domestic economy (see Taylor, 2000; Devereux et al., 2004; Campa and Goldberg, 2005; Campa and Gonzalez Mìnguez, 2006; Bussière et al., 2014).

3.2.3 Data and sample for the analysis of the relationship between GVCP and ERPT

Various concepts and measures have been proposed in the literature to measure GVCP 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' GVCP 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 WIOD (Timmer et al., 2013; Stehrer et al., 2014). In two editions, the WIOD provides global input-output tables at annual frequency for a large number of countries and sectors. The 2013 edition covers the time period from 1995 to 2011, and the 2016 edition the time period from 2000 to 2014. In order to maximise the time dimension of our dataset, we combine the two WIOD editions.[22,23] We also derive measures of the share of energy, manufacturing and high-technology goods in economies' imports and exports based on the WIOD. The bilateral trade weights for the construction of variables which correspond to averages of an economy's major trading partners are taken from the BIS. The data for real GDP per hour worked is taken from the OECD. The sample used for the estimation of Equations (21) and (22) eventually spans the time period from 1995 to 2014.

3.2.4 Results

Figure 5 displays the unconditional correlation between the time averages of the estimates of economies' ERPT to export prices and their GVCP as measured by the VAX ratio. For advanced economies (upper panel), the unconditional correlation is not statistically significant, suggesting that one might have to control for confounding factors in order to estimate the effect of economies' GVCP on ERPT to export prices. For emerging market economies (lower panel), the unconditional correlation is statistically significant with the expected sign. Analogously, Figure 6 displays the unconditional correlation between the time averages of the estimates of economies' ERPT to import prices and the average of other countries' multilateral VAX ratio. In contrast to Figure 5, the unconditional correlation between economies' ERPT to import prices and the average of other countries' multilateral VAX ratio has the expected sign and is statistically significant for advanced economies, albeit not for emerging market economies.

Table 2 reports the results of the estimation of the regression for the determinants of differences in ERPT to export prices in Equation (21).[24,25,26] The coefficient estimates of the VAX ratio are statistically significantly different from zero and have the expected negative sign. The results are thus consistent with the prediction from the model in Section 2 that higher GVCP raises the

[22]The two editions of the WIOD are not fully consistent in terms of variable definitions and country coverage. In robustness checks we assess whether the results are sensitive to the combination of the two vintages by using only the latest WIOD edition.

[23]We derive all WIOD-based variables separately for the 2013 and the 2016 vintages. For each variable and country-by-country, we then compare the consistency of the two time series across the vintages for the overlapping time periods. The cross-vintage correlation is very large across countries and variables, with the exception of Malta, which accordingly has been dropped from the sample. Finally, we chain-link the values for the time period from 1995 to 1999 taken from the 2013 vintage with the values from the time period from 2000 to 2014 taken from the 2016 edition.

[24]When the estimate of the ERPT to export and import prices is not statistically significantly different from zero we replace it by zero.

[25]In the estimation of Equations (21) and (22) we use Driscoll and Kraay (1998) standard errors which are robust to heteroskedasticity and autocorrelation as well as cross-section dependence.

[26]We do not report the coefficient estimates of the controls in $\boldsymbol{X}_{i\tau}^{x}$ in Equation (21) in order to save space.

sensitivity of an economy's local-currency export prices to exchange rate movements. This result holds for both advanced and emerging market economies. Moreover, the coefficient estimates for the share of energy in total exports and real GDP per hour worked are statistically significant with the expected sign. The results are thus consistent with the finding that ERPT to export prices is lower if a higher share of exports is accounted for by energy goods whose prices exhibit a lower pass-through (see Campa et al., 2005) and that more productive economies have a higher ERPT to export prices Gust et al. (2010).

Table 3 reports the results of the estimation of the regression for the determinants of cross-country differences in ERPT to import prices in Equation (22).[27] The coefficient estimates for the average of other countries' multilateral VAX ratio are all statistically significant and have the expected positive sign in all cross-sectional samples (at least at the 20% significance level). Specifically, the results are consistent with the prediction from the model in Section 2 that an economy exhibits lower ERPT to its local-currency import prices when its trading partners exhibit greater GVCP as measured by their VAX ratios.

The evidence in Table 3 is also consistent with some of the alternative explanations for the secular decline of ERPT to import-prices put forth in the literature. Specifically, we find that economies display a lower ERPT to import prices when their trading partners are more productive. This is consistent with the analysis of Gust et al. (2010), who argue that more productive firms are subject to stronger complementarities in price setting with competitors in export markets. However, for our sample period we do not find evidence that economies which feature a higher share of energy goods in total imports exhibit a larger ERPT to import prices, as suggested by Campa et al. (2005).

3.3 Robustness

In our baseline specification of the second-stage regressions in Equations (21) and (22) some of the right-hand side variables are not measured over the same time period for which ERPT on the left-hand side is estimated. We investigate whether our results are affected by this incongruence in measurement. First, we restrict our second-stage panel regression sample to the time period from 2004 to 2014. In this case, the time averages of the WIOD-based variables are measured over precisely the same time windows as all other variables. Second, we estimate a cross-section regression instead of a panel regression. Specifically, we first obtain cross-sectional estimates of ERPT to export and import prices over the time period from 1995 to 2014 rather than from 1986 to 2014. In the second stage, we run a cross-section regression of these ERPT estimates on time averages of the right-hand side variables which are calculated over the same window.

The results for the determinants of ERPT to export prices are reported in Table 4 for the

[27] We again do not report the coefficient estimates of the controls in $\boldsymbol{X}_{i\tau}^{m}$ in Equation (22) in order to save space.

sample starting only in 2004 and in Table 5 for the cross-section regressions. In both cases, the coefficient estimates of the VAX ratio have the expected negative sign and are statistically significantly different from zero, at least at the 20 percent confidence level. The corresponding results for ERPT to import prices in Tables 6 and 7 are also very similar to those from the baseline.

Recall that in the baseline we combine the two existing WIOD editions in order to extend the time-series dimension of the dataset. Given that the two editions are not fully consistent in terms of variable definitions as well as country and sectoral coverage, as a robustness check we use only the latest WIOD edition to construct the WIOD-based variables; accordingly, we restrict the sample to the time period from 2000 to 2014. The results reported in Tables 8 and 9 are very similar to those from the baseline.

Finally, we test whether our results are robust to different measures of GVCP. Specifically, we replace the VAX ratio in Equations (21) and (22) by "backward participation", defined as the ratio between an economy's gross intermediate imports to total gross output taken from the WIOD.[28] The results reported in Tables 10 and 11 are again qualitatively unchanged relative to the baseline.

4 Conclusion

This paper draws a causal link between the rise of global value chains and the decline of ERPT to import prices. We first illustrate in a structural two-country model with trade in intermediate goods and staggered price setting that higher GVCP results in higher ERPT to local-currency export prices in the Home economy. In turn, the reduction in the Home economy's local-currency export prices as it increases its GVCP translates into a lower ERPT to local-currency import prices in its trading partners. Second, using input-output data for a broad sample of 33 advanced and emerging economies over the time period from 1995 to 2014, we document that in line with the theoretical predictions (1) estimates of economies' ERPT to local-currency export prices are increasing in economies' GVCP, and (2) estimates of economies' ERPT to local-currency import prices are decreasing in the GVCP of economies' *trading partners*. Against the background of the large share of intermediate goods in total trade and the international integration of global production chains, our findings have implications for the understanding of 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.

[28] This measure can also be mapped into the model in Section 2, where it represents the share of imports in intermediate goods in production.

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A Tables

Table 1: Sample periods for estimation of ERPT to export and import prices

	Estimation sample Panel	
Advanced economies		
Australia	1986 Q1	2014Q4
Austria	1986 Q1	2014Q4
Belgium	1986 Q1	2014Q4
Canada	1986 Q1	2014Q4
Denmark	1986 Q1	2014Q4
Finland	1986 Q1	2014Q4
France	1986 Q1	2014Q4
Germany	1986 Q1	2014Q4
Greece	1999Q2	2014Q4
Ireland	1997Q2	2014Q4
Italy	1999 Q1	2014Q4
Japan	1994Q1	2014Q4
Netherlands	1986 Q1	2014Q4
Norway	1986 Q1	2014Q4
Portugal	1995Q1	2014Q4
Spain	1986 Q1	2014Q4
Sweden	1993 Q2	2014Q4
Switzerland	1986 Q1	2014Q4
USA	1986 Q1	2014Q4
UK	1986 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: ERPT to export prices

	(1) Advanced	(2) EMEs	(3) All
	b/p	b/p	b/p
VAX	-0.974***	-3.159***	-2.104***
	(0.00)	(0.01)	(0.00)
Exported energy share	0.062	-0.091	-0.106*
	(0.32)	(0.92)	(0.05)
lRGDP per Hour	0.185***	-0.279**	0.130***
	(0.00)	(0.03)	(0.00)
Country fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Observations	298	175	473
R-squared	0.88	0.74	0.77
No. of Countries	20	14	34

Robust standard errors
$^{+}$ $p < 0.2$, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3: ERPT to import prices

	(1) Advanced	(2) EMEs	(3) All
	b/p	b/p	b/p
RoW bilateral VAX	0.285**	0.494**	-0.064
	(0.03)	(0.03)	(0.83)
Imported energy share	-0.494*	3.427***	0.028
	(0.06)	(0.00)	(0.89)
lRGDP per Hour trad part	0.408***	2.027**	-0.319**
	(0.00)	(0.02)	(0.02)
Country fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Observations	297	161	458
R-squared	0.85	0.80	0.78
No. of Countries	20	13	33

Robust standard errors
$^{+}$ $p < 0.2$, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

A.1 Cross-sectional results

Table 4: ERPT to Export Prices: Sample Starting in 2004

	(1) Advanced b/p	(2) EMEs b/p	(3) All b/p
VAX	-3.160**	-1.970**	-1.849***
	(0.01)	(0.03)	(0.01)
ERPT Imp Price	0.095**	0.110***	0.104***
	(0.01)	(0.00)	(0.00)
Country fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Observations	256	148	404
R-squared	0.25	0.15	0.12
No. of Countries	20	13	33

Robust standard errors

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

Table 5: ERPT to export prices: Cross-section regression

	(1) Advanced b/p	(2) EMEs b/p	(3) All b/p
VAX	-5.016	-10.487***	-7.397***
	(0.20)	(0.00)	(0.00)
Exported energy share	-0.547	1.403*	0.391
	(0.28)	(0.09)	(0.44)
lRGDP per Hour	-0.109	0.028	-0.265**
	(0.64)	(0.90)	(0.02)
Observations	20	12	32
R-squared	0.25	0.93	0.45
Adj-R-squared	-0.09	0.84	0.31

Robust standard errors

+ $p < 0.2$, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6: ERPT to import prices: Sample starting in 2004

	(1) Advanced b/p	(2) EMEs b/p	(3) All b/p
lRGDP per Hour trad part	-3.062***	-3.322***	-5.154***
	(0.00)	(0.00)	(0.00)
Imported energy share	-2.548***	2.326	-2.914***
	(0.00)	(0.12)	(0.00)
VAX trad part	17.691***	7.341	18.277*
	(0.00)	(0.77)	(0.05)
ERPT Imp trad part	-1.313***	-1.734***	-1.275***
	(0.00)	(0.00)	(0.00)
Country fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Observations	256	148	404
R-squared	0.23	0.34	0.19
No. of Countries	20	13	33

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

Table 7: ERPT to import prices: Cross-section regression

	(1) Advanced b/p	(2) EMEs b/p	(3) All b/p
RoW bilateral VAX	0.997	-0.983	-0.246
	(0.22)	(0.62)	(0.69)
Imported energy share	-3.470***	2.011***	-0.463
	(0.00)	(0.01)	(0.62)
lRGDP per Hour trad part	-1.050^{+}	-0.638	-0.847^{+}
	(0.14)	(0.62)	(0.13)
Observations	20	13	33
R-squared	0.42	0.65	0.28
Adj-R-squared	0.21	0.39	0.14

Robust standard errors
$^{+}$ $p < 0.2$, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 8: ERPT to export prices: Latest WIOD vintage

	(1) Advanced b/p	(2) EMEs b/p	(3) All b/p
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 9: ERPT to import prices: Latest WIOD vintage

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

Table 10: ERPT to export prices: Backward participation

	(1) Advanced b/p	(2) EMEs b/p	(3) All b/p
Backward particip	5.971***	1.577	2.299***
	(0.00)	(0.17)	(0.00)
ERPT Imp Price	0.095***	0.169***	0.159***
	(0.00)	(0.00)	(0.00)
Country fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Observations	333	193	526
R-squared	0.25	0.26	0.17
No. of Countries	20	13	33

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

Table 11: ERPT to import prices: Backward participation

	(1) Advanced b/p	(2) EMEs b/p	(3) All b/p
lRGDP per Hour trad part	-1.646**	-1.390	-3.138***
	(0.02)	(0.12)	(0.00)
Imported energy share	-0.633	-1.590	-1.850***
	(0.48)	(0.40)	(0.00)
Bward trad part	-16.220***	14.757	-7.124
	(0.01)	(0.25)	(0.12)
ERPT Imp trad part	-0.987***	-1.374***	-1.024***
	(0.00)	(0.00)	(0.00)
Country fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Observations	421	240	661
R-squared	0.32	0.43	0.25
No. of Countries	20	13	33

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

B Figures

Figure 1: Structural Home ERPT to local-currency export prices $ERPT^x$ and Foreign ERPT to local-currency import prices $ERPT_*^m$ with varying GVCP of the Home economy (expressed by the Home VAX ratio; a lower VAX ratio indicates higher GVCP). Producer-currency pricing and flexible price benchmark

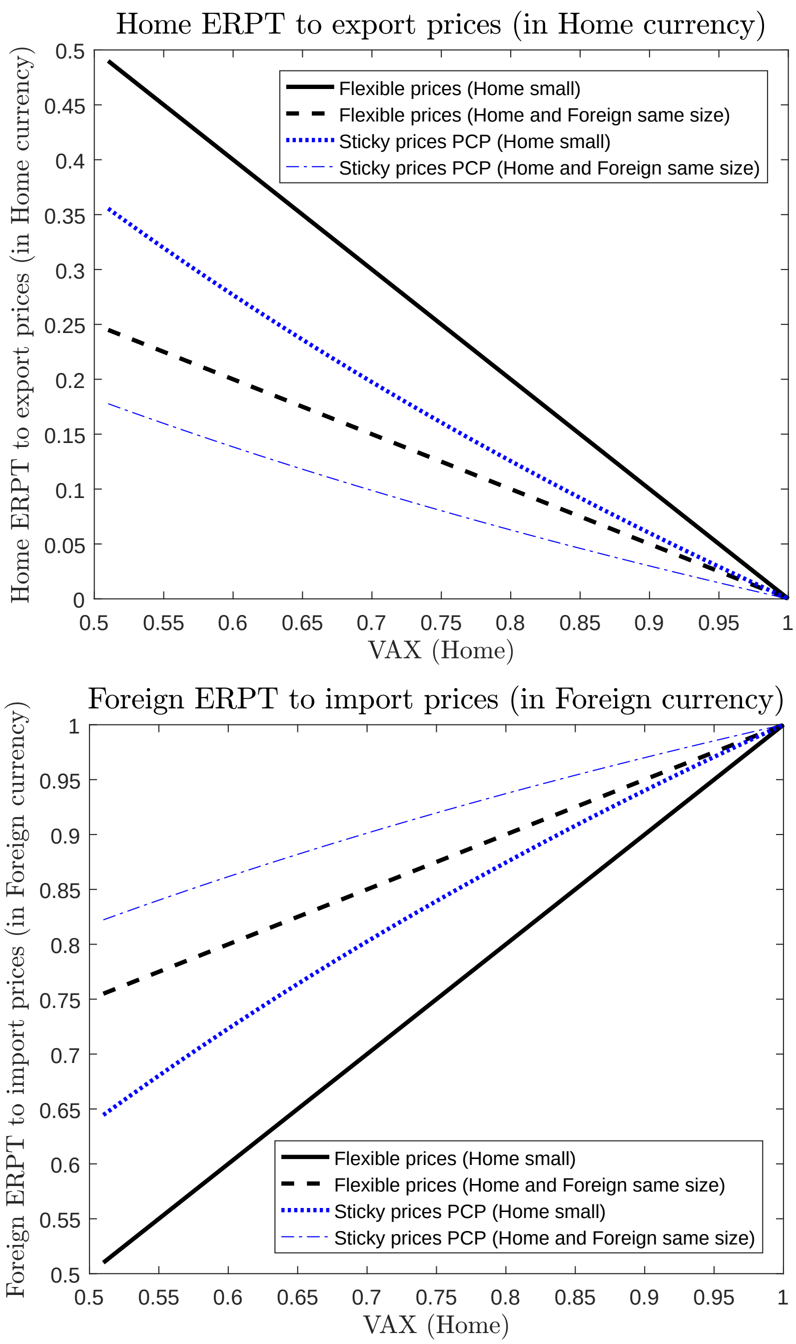


Figure 2: Home ERPT to local-currency export prices $ERPT^x$ and Foreign ERPT to local-currency import prices $ERPT_*^m$ with varying GVCP of the Home economy (expressed by the Home VAX ratio; a lower VAX ratio indicates higher GVCP). Local-currency pricing, Dominant currency paradigm and flexible price benchmark.

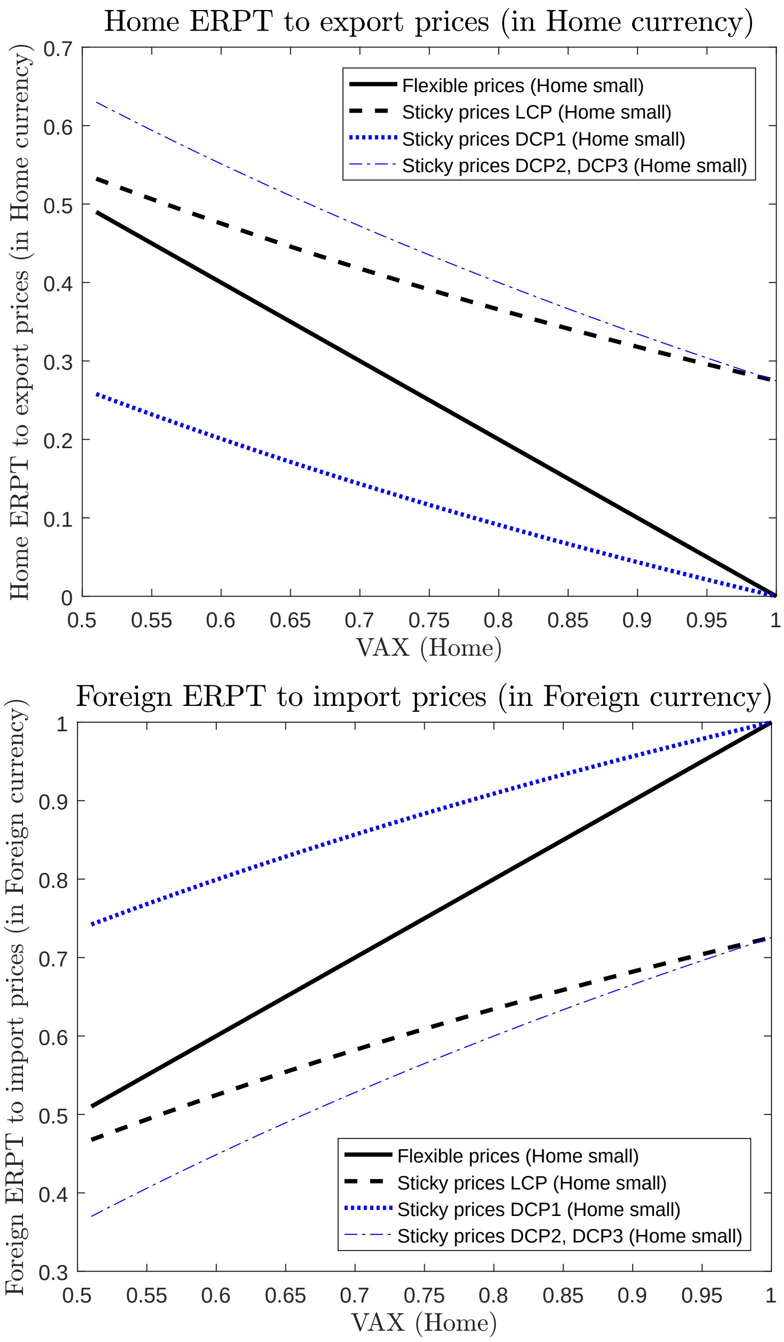
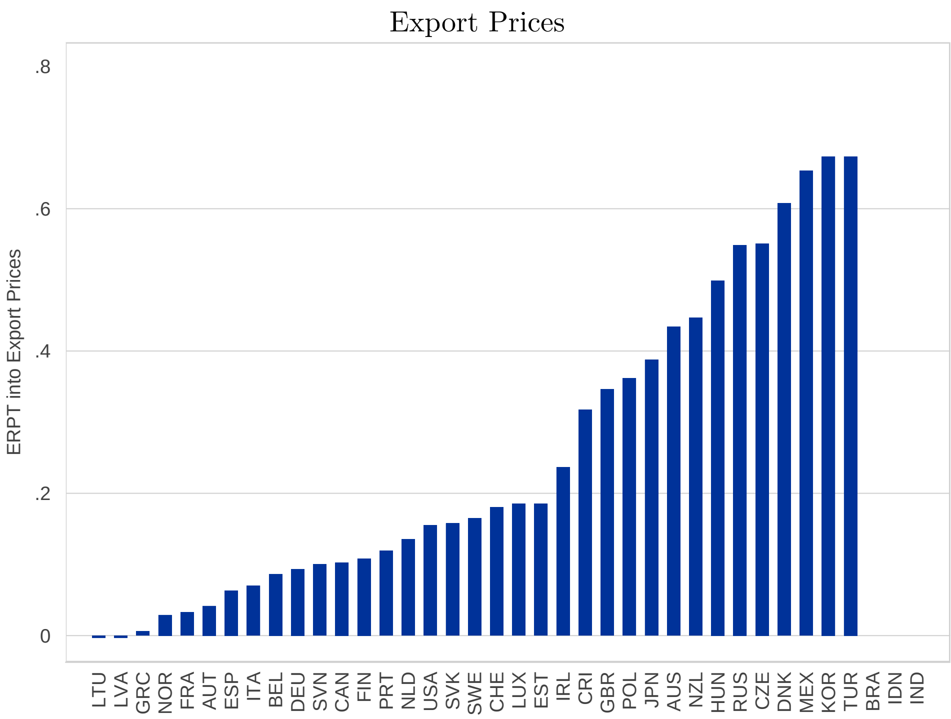


Figure 3: ERPT to export and import prices



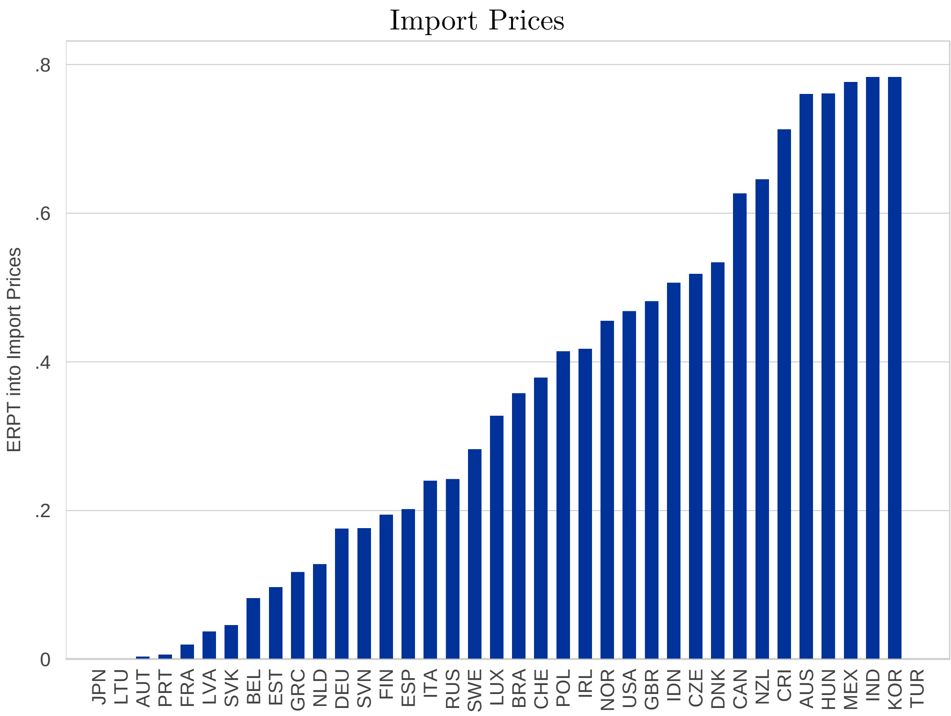


Figure 4: Correlation between ERPT to import and export prices

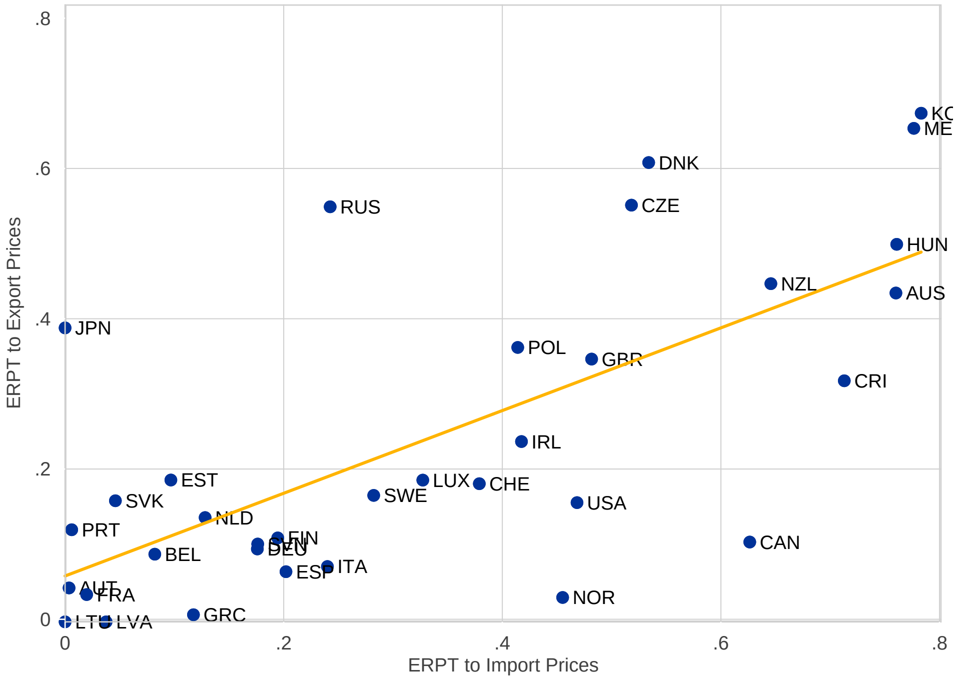


Figure 5: ERPT to export prices and GVCP

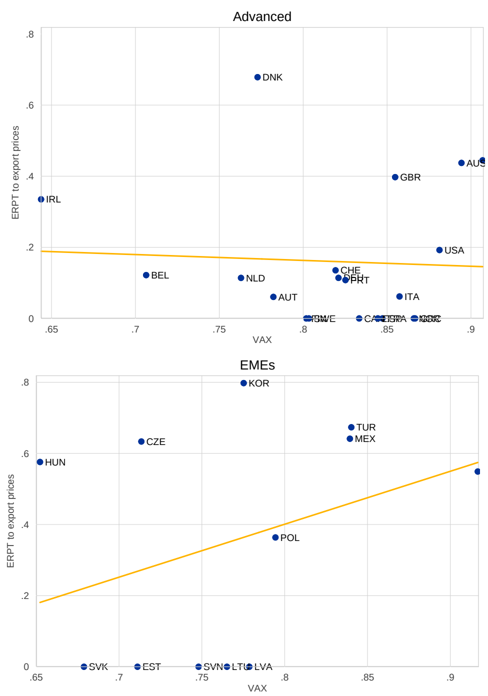
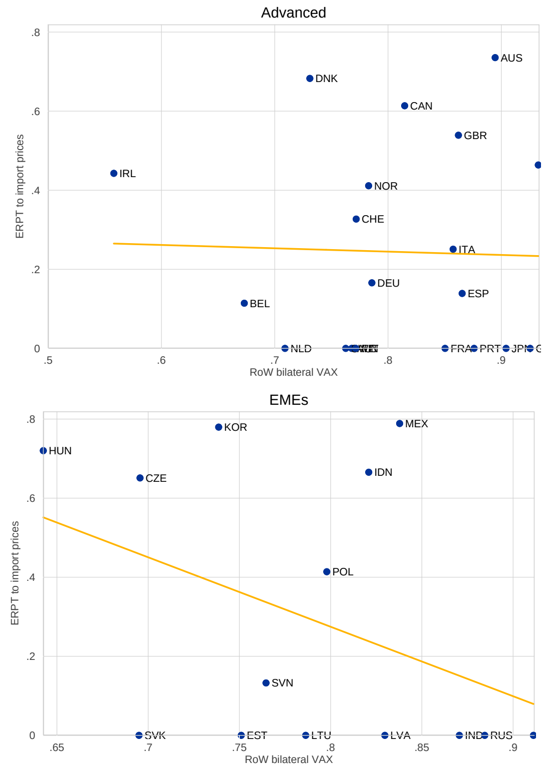


Figure 6: ERPT to import prices and GVCP



C Calibration of the VAX ratio

Johnson and Noguera (2012) compute the VAX for the case of a two-country model

$$VAX = \frac{1 - a_{11} - a_{21}}{1 - a_{11}} \left(\frac{x_{12} - a_{12} y_{21}}{x_{12}} \right) \tag{C.1}$$

$$x_{12} - a_{12} y_{21} = (1 - a_{11}) y_{12} \tag{C.2}$$

where $a_{ij} \forall ij$ denotes the amout of intermediate inputs that are produced in country i and serve as input in production in country j, expressed as a share of total output in country j. x_{12} are gross exports from country i to country j, y_{21} is output of country 2 absorbed in country 1 and y_{12} is output of country 1 absorbed in country 2.

In the calibration of our two-country model, we have $a_{11} = (1 - \tilde{\alpha})(1 - \omega)$, $a_{12} = (1 - \tilde{\alpha}^*)\omega^*, a_{21} = (1 - \tilde{\alpha})\omega$. Also, in steady state, we assume balanced trade $y_{12} = y_{21}$.

By substitution of equation (C.2) into equation (C.1), one obtains

$$VAX = \frac{1 - a_{11} - a_{21}}{1 - a_{11}} \frac{(1 - a_{11}) y_{12}}{(1 - a_{11} + a_{12}) y_{12}} = \frac{1 - a_{11} - a_{21}}{1 - a_{11} + a_{12}}.$$

Plugging in the a_{ij} $\forall ij$, we get

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

D Structural ERPT in the calibrated model

ERPT to local-currency export prices (ERPT to local currency import prices) is defined as the contemporaneous effect of a one percent change in the bilateral nominal exchange rate for local-currency export prices (local-currency import prices), other things equal. In the following, we derive ERPT for the case of sticky prices and for different assumptions regarding the denomination of currencies. In the case of producer currency pricing (PCP) exports are always denominated in exporter's currency. Under local currency pricing (LCP), exports are priced in destination currency. The dominant currency paradigm (DCP) refers to the case that Home and Foreign exports are priced in US dollar as a third-party currency. Variables are expressed in log-linearised form which is expressed by hats and small letters.

D.1 Producer currency pricing

We start with defining $\kappa \equiv \frac{(1-\beta\varphi)(1-\varphi)}{\varphi}$, $\kappa^* \equiv \frac{(1-\beta^*\varphi^*)(1-\varphi^*)}{\varphi^*}$, and
$\Omega \equiv \left\{1 - \frac{\kappa(1-\tilde{\alpha})\omega}{(1+\beta)+\kappa(1-(1-\tilde{\alpha})(1-\omega))} \frac{\kappa^*(1-\tilde{\alpha}^*)\omega^*}{(1+\beta^*)+\kappa^*(1-(1-\tilde{\alpha}^*)(1-\omega^*))}\right\}$.

The NK Phillips curve for Home-produced Home-consumed goods is given by

$$\hat{p}_{H,t}(1+\beta+\kappa) = \beta E_t \hat{p}_{H,t+1} + \hat{p}_{H,t-1} + \kappa n\hat{m}c_t,$$

$$n\hat{m}c_t = \tilde{\alpha} w_t + (1-\tilde{\alpha})(1-\omega)\hat{p}_{H,t} + (1-\tilde{\alpha})\omega(\hat{p}_{F,t}) - z_t$$

with $n\hat{m}c_t$ describing the evolution of nominal marginal cost denominated in local-currency.

Substitution gives

$$n\hat{m}c_t = \tilde{\alpha} w_t + \frac{(1-\tilde{\alpha})(1-\omega)}{(1+\beta+\kappa)}\left[\beta E_t \hat{p}_{H,t+1} + \hat{p}_{H,t-1} + \kappa n\hat{m}c_t\right] + (1-\tilde{\alpha})\omega(\hat{p}_{F,t}) - z_t.$$

Rearranging (and ignoring nominal wage, technology as well as all lag and lead terms) results in

$$n\hat{m}c_t = ... + \frac{(1+\beta+\kappa)(1-\tilde{\alpha})\omega}{(1+\beta)+\kappa(1-(1-\tilde{\alpha})(1-\omega))}(\hat{p}_{F,t}).$$

Equivalently, for Foreign

$$n\hat{m}c_t^* = ... + \frac{(1+\beta^*+\kappa^*)(1-\tilde{\alpha}^*)\omega^*}{(1+\beta^*)+\kappa^*(1-(1-\tilde{\alpha}^*)(1-\omega^*))}(\hat{p}_{H,t}^*).$$

The NK Phillips curves for Home-produced Foreign-consumed goods as well as

Foreign-produced Home-consumed goods are given by

$$(\hat{p}^*_{H,t} + \hat{s}_t)(1 + \beta + \kappa) = \beta E_t(\hat{p}^*_{H,t+1} + \hat{s}_{t+1}) + (\hat{p}^*_{H,t-1} + \hat{s}_{t-1}) + \kappa n\hat{m}c_t,$$

$$(\hat{p}_{F,t} - \hat{s}_t)(1 + \beta^* + \kappa^*) = \beta^* E_t(\hat{p}_{F,t+1} - \hat{s}_{t-1}) + (\hat{p}_{F,t-1} - \hat{s}_{t-1}) + \kappa^* n\hat{m}c^*_t$$

Rearranging (and ignoring nominal wage, technology as well as all lag and lead terms) results in

$$\hat{p}^*_{H,t} = ... + \frac{\kappa}{1+\beta+\kappa}\left[\frac{(1+\beta+\kappa)(1-\tilde{\alpha})\omega}{(1+\beta)+\kappa(1-(1-\tilde{\alpha})(1-\omega))}(\hat{p}_{F,t})\right] - \hat{s}_t.$$

After substitutions we obtain Foreign ERPT to local currency import prices

$$\hat{p}^*_{H,t}\Omega = ... + \hat{s}_t\left\{\frac{\kappa}{1+\beta+\kappa}\frac{(1+\beta+\kappa)(1-\tilde{\alpha})\omega}{(1+\beta)+\kappa(1-(1-\tilde{\alpha})(1-\omega))} - 1\right\},$$

$$ERPT^{m*} = (-1) * \Omega^{-1}\left\{\frac{\kappa(1-\tilde{\alpha})\omega}{(1+\beta)+\kappa(1-(1-\tilde{\alpha})(1-\omega))} - 1\right\}. \tag{D.1}$$

With some more steps, one can also obtain Home ERPT to local currency export prices

$$ERPT^{x} = \Omega^{-1}\left\{\frac{\kappa(1-\tilde{\alpha})\omega}{(1+\beta)+\kappa(1-(1-\tilde{\alpha})(1-\omega))} - 1\right\} + 1. \tag{D.2}$$

D.2 Local currency pricing

The NK Phillips curves for Home-produced Foreign-consumed goods as well as Foreign-produced Home-consumed goods are given by

$$\hat{p}^*_{H,t}(1+\beta+\kappa) = \beta E_t\hat{p}^*_{H,t+1} + \hat{p}^*_{H,t-1} + \kappa n\hat{m}c_t - \kappa\hat{s}_t,$$

$$\hat{p}_{F,t}(1+\beta^*+\kappa^*) = \beta^* E_t\hat{p}_{F,t+1} + \hat{p}_{F,t-1} + \kappa^* n\hat{m}c^*_t + \kappa^*\hat{s}_t.$$

Rewriting the equations (and ignoring nominal wage, technology as well as all lag and lead terms) yields

$$\hat{p}_{F,t} = ... + \frac{\kappa^*}{1+\beta^*+\kappa^*}n\hat{m}c^*_t + \frac{\kappa^*}{1+\beta^*+\kappa^*}\hat{s}_t,$$

$$\hat{p}^*_{H,t} = ... + \frac{\kappa}{1+\beta+\kappa}n\hat{m}c_t - \frac{\kappa}{1+\beta+\kappa}\hat{s}_t.$$

Plugging in the function for nominal marginal cost gives Foreign ERPT to local-curreny import prices, we get

$$\hat{p}^*_{H,t}\Omega = ... + \hat{s}_t \left[\frac{\kappa(1-\tilde{\alpha})\omega}{(1+\beta)+\kappa(1-(1-\tilde{\alpha})(1-\omega))} \frac{\kappa^*}{1+\beta^*+\kappa^*} - \frac{\kappa}{1+\beta+\kappa} \right],$$

$$ERPT^{m*} = (-1) * \Omega^{-1} \left[\frac{\kappa(1-\tilde{\alpha})\omega}{(1+\beta)+\kappa(1-(1-\tilde{\alpha})(1-\omega))} \frac{\kappa^*}{1+\beta^*+\kappa^*} - \frac{\kappa}{1+\beta+\kappa} \right]. \quad \text{(D.3)}$$

Home ERPT to local currency export prices is given by

$$ERPT^{x} = \Omega^{-1} \left[\frac{\kappa(1-\tilde{\alpha})\omega}{(1+\beta)+\kappa(1-(1-\tilde{\alpha})(1-\omega))} \frac{\kappa^*}{1+\beta^*+\kappa^*} - \frac{\kappa}{1+\beta+\kappa} \right] + 1. \quad \text{(D.4)}$$

D.3 Dominant currency paradigm

Ignoring lag and lead terms, the NK Phillips curves for Home-produced Foreign-consumed goods as well as Foreign-produced Home-consumed goods are described by

$$\hat{p}^*_{H,t} = \hat{p}^*_{H,USD,t} + \hat{s}^{*USD}_t = ... + \frac{\kappa}{1+\beta+\kappa} n\hat{m}c_t - \frac{\kappa}{1+\beta+\kappa}(\hat{s}^{USD}_t) + \hat{s}^{*USD}_t,$$

$$\hat{p}_{F,t} = \hat{p}_{F,USD,t} + \hat{s}^{USD}_t = ... + \frac{\kappa^*}{1+\beta^*+\kappa^*} n\hat{m}c^*_t + \frac{\kappa^*}{1+\beta^*+\kappa^*}(-\hat{s}^{*USD}_t) + \hat{s}^{USD}_t.$$

Plugging in the equations for nominal marginal costs from above yields the dynamics for Foreign import prices in local-currency

$$\hat{p}^*_{H,t} \left\{ 1 - \frac{\kappa(1-\tilde{\alpha})\omega}{(1+\beta)+\kappa(1-(1-\tilde{\alpha})(1-\omega))} \frac{\kappa^*(1-\tilde{\alpha}^*)\omega^*}{(1+\beta^*)+\kappa^*(1-(1-\tilde{\alpha}^*)(1-\omega^*))} \right\} =$$
$$= ... + \frac{\kappa(1-\tilde{\alpha})\omega}{(1+\beta)+\kappa(1-(1-\tilde{\alpha})(1-\omega))} \left[\frac{\kappa^*}{1+\beta^*+\kappa^*}(-\hat{s}^{*USD}_t) + \hat{s}^{USD}_t \right] - \frac{\kappa}{1+\beta+\kappa}(\hat{s}^{USD}_t) + \hat{s}^{*USD}_t.$$

DCP 1 (US third country, Foreign currency appreciates versus all currencies)

Assuming $\hat{s}^{USD}_t = 0$ and $\hat{s}^{*USD}_t = -\hat{s}_t$ gives Foreign ERPT to local-currency import prices

$$\hat{p}^*_{H,t}\Omega = ... + \frac{\kappa(1-\tilde{\alpha})\omega}{(1+\beta)+\kappa(1-(1-\tilde{\alpha})(1-\omega))} \left[\frac{\kappa^*}{1+\beta^*+\kappa^*} \hat{s}_t \right] - \hat{s}_t,$$

$$ERPT^{m*} = (-1) * \Omega^{-1} \left[\frac{\kappa(1-\tilde{\alpha})\omega}{(1+\beta)+\kappa(1-(1-\tilde{\alpha})(1-\omega))} \frac{\kappa^*}{1+\beta^*+\kappa^*} - 1 \right]. \quad \text{(D.5)}$$

With some more steps, one can also obtain Home ERPT to local-currency export prices

$$ERPT^x = \Omega^{-1}\left[\frac{\kappa(1-\tilde{\alpha})\omega}{(1+\beta)+\kappa(1-(1-\tilde{\alpha})(1-\omega))}\frac{\kappa^*}{1+\beta^*+\kappa^*} - 1\right] + 1. \tag{D.6}$$

DCP 2 (US third country, Home currency appreciates versus all currencies)

Under the assumption of $\hat{s}_t^{USD} = s_t$ and $\hat{s}_t^{*USD} = 0$, Foreign ERPT to local-currency import prices is

$$ERPT^{m*} = (-1) * \Omega^{-1}\left[\frac{\kappa(1-\tilde{\alpha})\omega}{(1+\beta)+\kappa(1-(1-\tilde{\alpha})(1-\omega))} - \frac{\kappa}{1+\beta+\kappa}\right]. \tag{D.7}$$

Home ERPT to local currency export prices is given by

$$ERPT^x = \Omega^{-1}\left[\frac{\kappa(1-\tilde{\alpha})\omega}{(1+\beta)+\kappa(1-(1-\tilde{\alpha})(1-\omega))} - \frac{\kappa}{1+\beta+\kappa}\right] + 1. \tag{D.8}$$

DCP 3 (two-country case and Foreign issues a dominant currency) Home operates under LCP, Foreign under PCP

Under Home LCP we have

$$\hat{p}^*_{H,t} = ... + \frac{\kappa}{1+\beta+\kappa} n\hat{m}c_t - \frac{\kappa}{1+\beta+\kappa}\hat{s}_t.$$

Foreign PCP implies

$$\hat{p}_{F,t} = ... + \frac{\kappa^*}{1+\beta^*+\kappa^*} n\hat{m}c^*_t + \hat{s}_t.$$

Plugging in nominal marginal cost from above we get

$$ERPT^{m*} = (-1) * \Omega^{-1} \times \left[\frac{\kappa(1-\tilde{\alpha})\omega}{(1+\beta)+\kappa(1-(1-\tilde{\alpha})(1-\omega))} - \frac{\kappa}{1+\beta+\kappa}\right], \tag{D.9}$$

which results in the same relation as in the DCP 2 case.

D.4 The case of flexible goods prices

In the case of flexible prices ($\varphi \to 0$) the NK Phillips curve for Foreign local-currency import prices is

$$p^*_{H,t} = \frac{1}{1-(1-\tilde{\alpha})(1-\omega)}\left(\tilde{\alpha}w_t + (1-\tilde{\alpha})\omega p^*_{F,t} - z_t - \tilde{\alpha}\hat{s}_t\right).$$

Foreign-produced foreign-consumed goods prices in local currency evolve according to

$$p^*_{F,t} = \frac{\tilde{\alpha}^*}{1-(1-\tilde{\alpha}^*)(1-\omega^*)}w^*_t + \frac{1}{1-(1-\tilde{\alpha}^*)(1-\omega^*)}z^*_t + \frac{(1-\tilde{\alpha}^*)\omega^*}{1-(1-\tilde{\alpha}^*)(1-\omega^*)}p^*_{H,t}.$$

Substitution of the two equations results in

$$\hat{p}^*_{H,t} = \frac{\Omega^{-1}}{1-(1-\tilde{\alpha})(1-\omega)}\left(\tilde{\alpha}w_t - z_t + \frac{(1-\tilde{\alpha})\omega\tilde{\alpha}^*}{1-(1-\tilde{\alpha}^*)(1-\omega^*)}w^*_t + \frac{(1-\tilde{\alpha})\omega}{1-(1-\tilde{\alpha}^*)(1-\omega^*)}z^*_t - \tilde{\alpha}\hat{s}_t\right).$$

Keeping nominal wages w_t and the level of technology z_t constant yields following dynamics of Foreign's local-currency import prices relative to it's nominal exchange rate

$$\frac{\hat{p}^*_{H,t}}{-\hat{s}_t} = \Omega^{-1}\frac{\tilde{\alpha}}{1-(1-\tilde{\alpha})(1-\omega)} = ERPT^{m*}. \tag{D.10}$$

For this case, the dynamics of Home local-currency export prices in relation to the nominal exchange rate are

$$\frac{\hat{p}_{H,t}}{\hat{s}_t} = 1 - \Omega^{-1}\frac{\tilde{\alpha}}{1-(1-\tilde{\alpha})(1-\omega)} = ERPT^{x}. \tag{D.11}$$