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ABSTRACT

This paper explores the relationship between economic growth and the real exchange rate, specifically focusing on the convergence in price levels in Eastern European countries. While these countries have had significant convergence in GDP per capita (relative to the EU average) since the 1990s, convergence in real exchange rates for these countries stalled after the EU crisis. Using a standard theoretical framework, we estimate the main drivers of real exchange rates and show that a combination of productivity growth (Balassa-Samuelson effects) and labor market distortions help explain real exchange rate trends. We develop a structural two-country model that provides a rich decomposition of the long run determinants of the real exchange rate. Simulations based on observed sectoral productivities and labor market wedges show that the model can accurately account for the historical path of Eastern European real exchange rates, both before and after the EU crisis.

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1 Introduction

Wealthier countries have higher price levels. This is one of the most robust facts, denoted the 'Penn Effect', that comes out of international comparisons of the prices of goods and services. But despite this broad fact, there are significant departures from price equality, or PPP, across countries with similar levels of GDP per capita. Rogoff (1996) noted that the most robust evidence for the Penn effect was in the comparison of developing countries with more developed countries. As countries move from one category to another, they tend to exhibit significant real appreciation, but within categories there exists significant heterogeneity.

Our paper focuses on the question of convergence in prices in the European Union, and in particular the new members of the EU from Eastern Europe and the former Soviet Union. This is a critical issue for policy makers in the EU. The expectation that a more integrated single market would lead to a greater convergence in income levels across the union should have as its by-product a fall in price differentials between countries. When we focus on the high income countries of western Europe, the evidence for price convergence is quite weak. But perhaps this is not surprising, because GDP per capita differentials among these high income countries have not significantly diminished over the life of the single market. However, one clear fact comes out of a focus on Eastern European countries, particularly those countries that were members of the former Soviet Bloc. In Figure 1 we see significant and continuing convergence in GDP per capita since these countries became members of the EU. Although there is a slight downturn at the time of the EU crisis, convergence continues strongly until the end of the sample. Then we would expect there to be an equivalent convergence in national price levels, or in other words, significant real exchange rate appreciation relative to the EU average. Do we see this? Figure 1 shows the real exchange rate for the same set of countries, relative to the EU 27 over the same time period. The two series are scaled to begin at unity. There we encounter a puzzle. Up until 2009, we see a strong real appreciation, or equivalently, a convergence in prices to the EU average. But after 2008, the real exchange rate is flat, or even slightly falling, despite the continuing convergence in GDP per capita.

This paper is an exploration of the relationship between convergence in real GDP and real exchange rate determination, with a specific focus on Eastern European countries. These countries represent a textbook example of GDP convergence over the last two decades. If, as we expect, GDP growth in these countries was dominated by growth in the traded goods sector, then by the standard Balassa-Samuelson hypothesis we should have seen continual real exchange rate appreciation. But as the above Figure shows, the pattern of the real exchange rate does not obviously fit the textbook account of relative price convergence.

To address this question, we proceed in three steps. First, we develop a fairly general model of real exchange rate determination involving traded and non-traded goods, distribution services in the supply of traded goods, and endogenous determination of the terms of trade. The model allows for sectoral productivity, labor market wedges, and capital inflows as drivers of both GDP and the real exchange rate. The model can account for various features we see in the data, particularly that the presence of distribution services implies a high correlation between real exchange rate movements measured in traded goods as well as non-traded goods. The model also gives clear testable implications concerning the relationship between GDP and the real exchange rate (the 'Penn Effect'), sectoral productivity growth and the real exchange rate (the 'Balassa-Samuelson' effect), and the effect of labor market wedges and capital inflows on the real exchange rate.

We then explore empirically the determinants of real exchange rates for a sample of 12 countries in Eastern European countries, using data and sectoral productivity by country, as well as measures of unit labor costs, and inferences from observed capital inflows. Our regression equations are derived from the theoretical model, using unit labor costs as an indirect reflection of labor market wedges. The empirical estimates support the implications of the model concerning the association between productivity growth and labor market wedges and the real exchange rate. We show that to fit the real exchange rate data, it is essential to allow for these labor market wedges beyond sectoral productivity, in the form of unit labor costs, as well as indicators of capital flows. The empirical estimates satisfy an amended version of the Balassa-Samuelson hypothesis. Conditional on unit labor costs, the real exchange rate is positively related to changes in traded goods productivity and negatively related to non-traded goods productivity. Beyond this, we confirm that most of the precise testable predictions of the model are satisfied by the empirical estimates, both in terms of sign and size of the estimated coefficients.

We then conduct a more rigorous test of the model in the form of a quantitative exercise. We simulate the model using observations on the historical path of sectoral productivity levels. A test of the model in this context is to ask how the model-implied path of real exchange rates and other macro aggregates fits the historical sample path, both in levels and rates of change over time. We conduct this exercise for both aggregate and sectoral real exchange rates, as well as aggregate and sectoral real GDP for our group of Eastern European countries, where data are measured relative to the EU average. This exercise matches the data closely, both in levels and over the sample time period. We show that the observed evolution of sectoral productivity alone goes a long way in reproducing the historical sample. In particular, we find that the increased post EU crisis path of non-traded goods productivity growth plays a key role in explaining the divergent movements of real exchange rates relative to GDP following the crisis. When combined with measures of capital inflows and allowing for time varying labor market wedges, the simulations very accurately reproduce the overall path of GDP and real exchange rates in Eastern European countries.

Related literature There is a vast literature on the determinants of the real exchange rate. Our focus is on longer run patterns in the real exchange rate and particularly long run trends associated with the literature on the Balassa-Samuelson hypothesis, and the 'Penn Effect'. Classic references are Balassa (1964) and Samuelson (1964), who emphasized the importance of productivity growth in the traded goods sector, and Kravis, Heston and Summers (1978), who flagged the link between GDP per capita and price levels.[1] Other important early references are Bhagwati (1984), who focused on the importance of differential sector based factor intensity and Bergstrand (1991), who allowed for an interpretation based on non-homothetic demand forces.

There are many empirical investigations of the Penn effect and the Balassa-Samuelson hypothesis. A well known review is Rogoff (1996), and a more recent review of the determination of the real exchange rate is Itskhoki (2021). In a much cited paper, De Gregorio, Giovannini and Wolf (1994) show the importance of non-traded goods prices in real exchange rate measures. Choudhri and Khan (2005) examine the Balassa-Samuelson relevance for developing countries.[2]

From a more episodic perspective, Irwin and Obstfeld (2024) provide a recent review of the Korean real exchange rate from a theoretical perspective. Berka, Devereux and Engel (2018) argue for an amended Balassa-Samuelson interpretation in the Eurozone. Berka and Devereux (2013) provide a different interpretation of European Real Exchange rates that emphasizes the Penn effect. From a more macro perspective Miyamoto, Nguyen and Oh (2025) examine the dominant macroeconomic drivers of real exchange rates and macro aggregates at business cycle frequencies across G7 countries.[3]

There are a small number of papers that focus particularly on real exchange rate determination in Eastern European Economies. Meshulam and Sanfey (2019) carry out an empirical analysis of real exchange rate drivers in transition economies. They, like us, find support for the Balassa-Samuelson hypothesis. Armendariz et al. (2025) investigate real exchange rate determination and competitiveness in the Baltics. Our paper differs from these in a number of dimensions, primarily coming from a more theoretical perspective.

An important related paper to ours is Piton (2021). In that paper, the author notes that unit labor costs have risen much faster in peripheral European countries than in the core countries. She finds that about a third of the growth of unit labor costs in the peripheral countries can be associated with growth in traded goods productivity. Our paper is complementary in that we focus on the real exchange rate drivers in Eastern European countries, but we note in the theoretical section and in the estimation (as well as the quantitative section) the important role of both of sectoral productivity as well as labor market wedges in driving real exchange rates through the channel of unit labor costs.

The rest of the paper is organized as follows. Section 2 outlines the main model of the paper. Section 3 provides an analytical characterization of the model. Section 4 discusses the data on real exchange rates, productivity, and unit labor costs. Section 5 presents the main regression results for real exchange rate determination. Section 6 shows the ability of the model

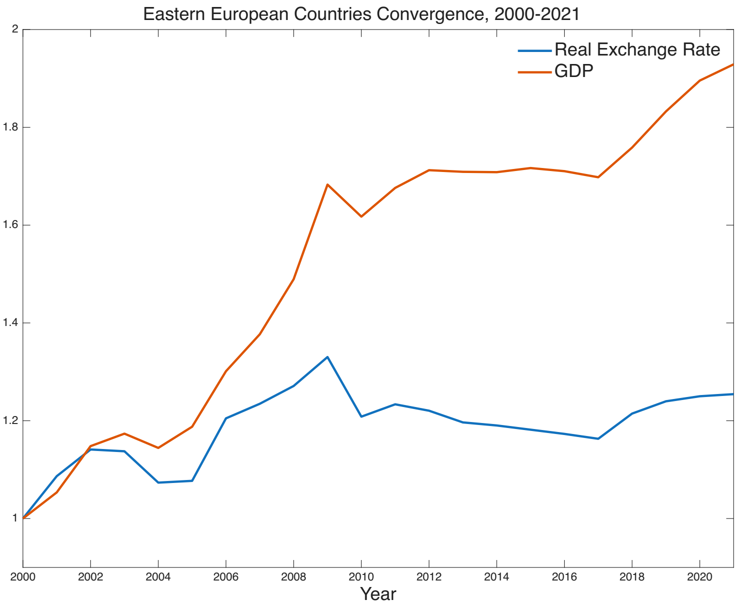
[1]See Feenstra, Inklaar and Timmer (2015) for a later review of the Penn World Tables methodology. See also Obstfeld and Rogoff (1996) for a modern treatment of the Balassa-Samuelson hypothesis.

[2]Other references are Canzoneri, Cumby and Diba (1999), Lee and Tang (2007), Zhang (2017), Hassan (2016), and Bergin, Glick and Taylor (2006).

[3]There is a large literature on high frequency movements in exchange rates, and particularly on the issue of 'exchange rate disconnect'. See for instance Itskhoki and Mukhin (2021). We abstract from these issues in the current paper.

to quantitatively account for the historical path of real exchange rates in the Eastern European data. Some conclusions follow.

Figure 1: Relative GDP and Real Exchange Rates for Eastern European countries



2 A Two country model

Here we outline a basic two country model that we will use to interpret trends in European real exchange rates. Let the countries be Home and Foreign, where we think of Home as being the Eastern European group of countries listed in Section 4 below. In each country there are two sectors, traded (T) and non-traded (NT). Production uses labor with a fixed capital stock in each sector. Since we are focusing on relatively low frequency trends we will assume that prices and wages are fully flexible in both countries.

The full model is set out in detail in Appendix A. Here we briefly describe its main elements.

2.1 Preferences

Utility of Home consumers can be described by the standard CES lifetime utility function:

$$\mathcal{U} = \sum_{t=1}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma} - 1}{1-\sigma} - \Psi_{T,t} \frac{L_{T,t}^{1+\phi}}{1+\phi} - \Psi_{N,t} \frac{L_{N,t}^{1+\phi}}{1+\phi} \right). \tag{1}$$

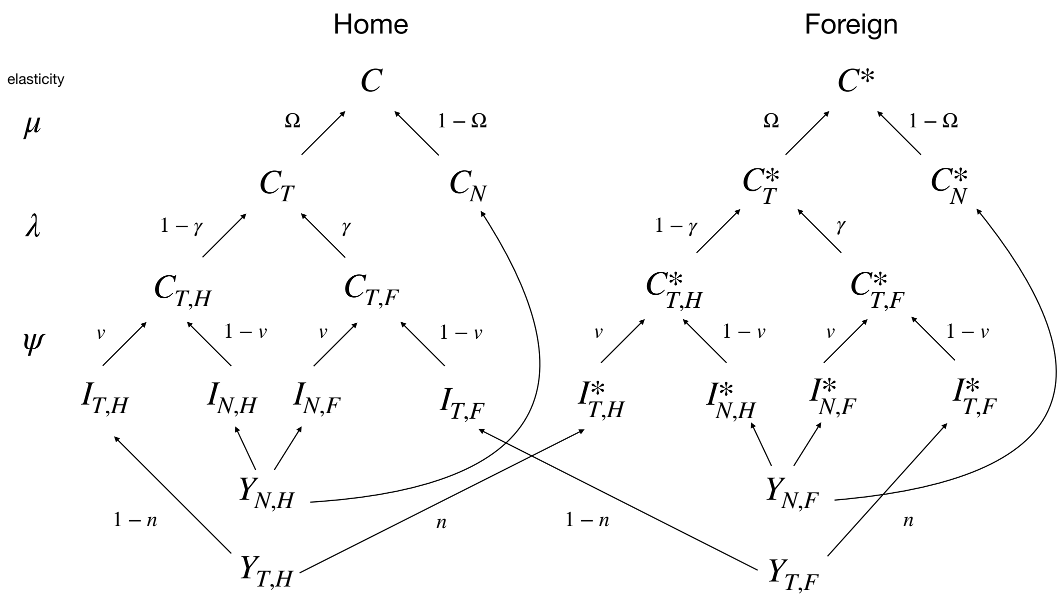
T, N indicates the sectors traded and non-traded, respectively. σ and ϕ denote the relative risk aversion (inverse of the intertemporal elasticity of substitution) and the inverse of Frisch elasticity, respectively. Labor disutility appears separately for each sector, and $\Psi_{j,t}$, $j = T, N$ act as a proxy for the sectoral labor wedges, which will play a role in exchange rate determination.

The preference relationship over traded and non-traded goods is represented by the consumption aggregator:

$$C = \left[\Omega^{\frac{1}{\mu}} C_T^{1-\frac{1}{\mu}} + (1-\Omega)^{\frac{1}{\mu}} C_N^{1-\frac{1}{\mu}} \right]^{\frac{\mu}{\mu-1}}. \tag{2}$$

Ω represents the share of the traded sector, and its associated elasticity of substitution is μ. Within traded goods, households consume home and foreign goods with shares $1-\gamma$ and γ, and the elasticity of substitution between the two goods is given by λ. Here, $\gamma = 1 - x(1-n)$, where n is the population share of the Foreign country, and $0 < x < 1$ allows for some home bias in traded goods preferences. With $x = 1$, there is no home bias. In addition, the final consumption of both home and foreign traded goods requires a distributional input of non-traded goods.[4] The shares of 'raw' traded goods and the non-traded distribution services in the final traded good consumption aggregators are v and $1-v$ respectively, and the elasticity of substitution between the raw traded good and the non-traded distribution input is assumed to be ψ. The production structure of the model is presented in Figure 2:

Figure 2: Production Structure



Note: $C_{j,i}$, $I_{j,i}$, and $Y_{j,i}$ denote, respectively, consumption, the assembly firm's demand, and production, where subscripts $i = \{H, F\}$ and $j = \{T, N\}$ denote the country of origin and the sector, and the superscript * denotes that goods are demanded in the foreign country. For clarity, we deviate from this notation in the case of non-traded inputs ($I_{N,F}$,$I^*_{N,H}$) where the second subscript refers to the type of traded good where the non-traded input is used.

Households in the home country face the following budget constraint:

$$P_t C_t + \frac{B_{t+1}}{1+r_{t+1}} = P_{T,t} C_{T,t} + P_{N,t} C_{N,t} + \frac{B_{t+1}}{1+r_{t+1}} = W_{T,t} L_{T,t} + W_{N,t} L_{N,t} + \Pi_{T,t} + \Pi_{N,t} + B_t, \tag{3}$$

where P, P_T, P_N are price indexes for the CPI, the traded goods price index, and the non-

[4]See for instance (Burstein, Eichenbaum and Rebelo, 2005, 2007).

traded goods price index, respectively. Households receive income from wages W_N and W_T and profits Π from all sector firms, and consume at the given prices. They can purchase one period 'nominal' international bonds B at price $\frac{1}{1+r_{t+1}}$.[5]

Household optimal choices are quite standard, and deliver solutions for the consumption of traded and non-traded goods, and the separate consumption of home and foreign traded goods, as functions of the relative prices $\frac{P_N}{P}$, $\frac{P_T}{P}$, $\frac{\tilde{P}_{T,H}}{P_T}$, $\frac{\tilde{P}_{T,F}}{P_T}$, where $\tilde{P}_{T,H}$ and $\tilde{P}_{T,F}$ are prices of the home and foreign consumed traded goods. Competitive assembly firms purchase raw traded goods at prices $P_{T,H}$ and $P_{T,F}$ as well as non-traded distributional services to sell to households at prices $\tilde{P}_{T,H}$ and $\tilde{P}_{T,F}$.

Equilibrium labor supply conditions are given by

$$\frac{W_T}{P} = \Psi_{T,t} C^{\sigma} L_T^{\phi}, \tag{4}$$

$$\frac{W_N}{P} = \Psi_{N,t} C^{\sigma} L_N^{\phi}. \tag{5}$$

Since our approach to capital flows in the model is described further below in Section A.6, we abstract from the Euler equation implied by an optimal choice of international bonds.

2.2 Firms

Assume decreasing returns production functions in each sector with fixed capital. So, $1-\alpha$ is a measure of the labor share. For the home country we have production in traded and non-traded respectively as

$$Y_{T,H} = A_{T,H} L_{T,H}^{1-\alpha},$$

$$Y_{N,H} = A_{N,H} L_{N,H}^{1-\alpha},$$

where $A_{T,H}$ and $A_{N,H}$ are technologies in the traded and non-traded sectors. Firms in each sector maximize profits given sector-specific wage W_T and W_N. Sectoral wage rates differ due to sector-specific labor disutility in equation (1). In addition, as mentioned above, assembly firms in the home country purchase home and foreign traded goods, along with home non-traded goods, to produce the traded good for consumption of domestic households.

2.3 Nominal policy

Although prices are flexible and money is neutral, it is convenient to assume a monetary rule so that the price index for each country is normalized to unity. Hence we have

$$\left[\Omega P_T^{1-\mu} + (1-\Omega) P_N^{1-\mu}\right]^{\frac{1}{1-\mu}} = 1, \tag{6}$$

[5]Although the model is purely real, we define a nominal numeraire below.

2.4 Goods market clearing

Goods market clearing in the home and foreign traded good market is described as

$$(1-n)\,Y_{T,H} = (1-n)\,I_{T,H} + nI^*_{T,H}, \tag{7}$$

$$nY_{T,F} = (1-n)\,I_{T,F} + nI^*_{T,F}, \tag{8}$$

where I_{TH} and I_{TF} represent home country assembly firm's demand for home and foreign traded goods, and similarly for foreign country assembly firms noted with an asterisk.

Likewise, market clearing in the non-traded good sector is described as

$$Y_{N,H} = C_N + I_{N,H} + I_{N,F}, \tag{9}$$

$$Y_{N,F} = C_N + I_{N,H} + I_{N,F}. \tag{10}$$

2.5 International price setting

The law of one price holds and therefore

$$P^*_{T,H} = SP_{T,H}, \tag{11}$$

$$P_{T,F} = \frac{P^*_{T,F}}{S}. \tag{12}$$

where S refers to the nominal exchange rate, which is defined as the foreign currency price of domestic currency.[6]

The real exchange rate, defined as the relative CPI price of the home to foreign country, is then just equal to the nominal exchange rate, since $P = P^* = 1$ as in equation (6):

$$Q = \frac{SP}{P^*} = S. \tag{13}$$

2.6 Balance of payments

We can rewrite the Home budget constraint in equation (3) as

$$\begin{aligned} PC &= P_{T,H}Y_{T,H} + P_N Y_{N,H} + B_t - \frac{B_{t+1}}{1+r_{t+1}} \\ &= P_{T,H}Y_{T,H} + P_N Y_{N,H} + \theta P_{T,H}Y_{T,H} \\ &= (1+\theta)\,P_{T,H}Y_{T,H} + P_N Y_{N,H}. \end{aligned}$$

We abstract from the Euler equation derived from the optimal choice of bonds. Rather than solving the intertemporal optimization problem, we assume that there is a capital inflow of

[6] This convention is convenient since we define the real exchange rate so that an increase is an appreciation.

amount $\theta P_{T,H} Y_{T,H}$:

$$B_t - \frac{B_{t+1}}{1 + r_{t+1}} = \theta P_{T,H} Y_{T,H}. \tag{14}$$

This capital inflow is measured in terms of the domestic traded goods. We remain agnostic about the underlying causes of this capital flow, which could be driven by factors such as transfers, news shocks, or foreign direct investment, among others. Section 6 below describes how we measure the coefficient θ.

2.7 System of equations

Then, the system of equations consists of equations (29) to (49), in Appendix A, and the analogous equations for the Foreign country together with Appendix A equations (50) to (53).

2.7.1 System of linearized equations

A linear approximation allows us to provide an intuitive understanding of real exchange rate determination in this model.[7] We approximate the system of equations around a symmetric steady state where all relative prices are equal to one. To attain this steady state, we impose the following assumptions: (1) trade is balanced; (2) technologies and labor wedges are identical across sectors; and (3) the demand shares of traded and non-traded goods are equal at the steady state.[8] In addition, we assume that there is no home bias, $x = 1$. These simplifications help in obtaining tractable solutions. Variables with circumflex $\hat{X}$ denote log deviations from the steady state:

$$\hat{X} := \ln(X) - \ln(\bar{X}) \approx \frac{X - \bar{X}}{\bar{X}},$$

where $\bar{X}$ denotes the steady state value. By substituting out several equations, the system of linearized equations consists of 11 equations for 11 endogenous variables $\hat{P}_{T,H}$, $\hat{P}^*_{T,F}$, $\hat{P}_N$, $\hat{P}^*_N$, $\hat{L}_T$, $\hat{L}^*_T$, $\hat{L}_N$, $\hat{L}^*_N$, $\hat{C}$, $\hat{C}^*$, and $\hat{S}$.

Labor market clearing: 4 equations

$$\hat{P}_{T,H} + \hat{A}_{T,H} - \alpha \hat{L}_T = \hat{\Psi}_T + \phi \hat{L}_T + \sigma \hat{C},$$

$$\hat{P}^*_{T,F} + \hat{A}_{T,F} - \alpha \hat{L}^*_T = \hat{\Psi}^*_T + \phi \hat{L}^*_T + \sigma \hat{C}^*,$$

$$\hat{P}_N + \hat{A}_{N,H} - \alpha \hat{L}_N = \hat{\Psi}_N + \phi \hat{L}_N + \sigma \hat{C},$$

$$\hat{P}^*_N + \hat{A}_{N,F} - \alpha \hat{L}^*_N = \hat{\Psi}^*_N + \phi \hat{L}^*_N + \sigma \hat{C}^*,$$

[7] In the quantitative section 6 below, we work with the full non-linear version of the model.

[8] Specifically, we assume $\theta = 0$ for (1), $A_{T,H} = A_{N,H} = A_{T,F} = A_{N,F} = A$, $\Psi_T = \Psi_N = \Psi^*_T = \Psi^*_N = \Psi$ for (2), and $v\Omega = 1 - v\Omega$ for (3).

Goods market clearing: 4 equations

$$\hat{A}_{T,H} + (1-\alpha)\,\hat{L}_T = (1-n)\left(-\Gamma \hat{P}_{T,H} - \Delta \hat{P}_N + \hat{C}\right) + n\left[-\Gamma\left(\hat{P}_{T,H} - \hat{S}\right) - \Delta \hat{P}_N^* + \hat{C}^*\right],$$

$$\hat{A}_{T,F} + (1-\alpha)\,\hat{L}_T^* = n\left(-\Gamma \hat{P}_{T,F}^* - \Delta \hat{P}_N^* + \hat{C}^*\right) + (1-n)\left[-\Gamma\left(\hat{P}_{T,F}^* + \hat{S}\right) - \Delta \hat{P}_N + \hat{C}\right],$$

$$\hat{A}_{N,H} + (1-\alpha)\,\hat{L}_N = \hat{C} - \Xi \hat{P}_N,$$

$$\hat{A}_{N,F} + (1-\alpha)\,\hat{L}_N^* = \hat{C}^* - \Xi \hat{P}_N^*,$$

Prices: 2 equations

$$-\frac{1-\Omega}{\Omega}\hat{P}_N = v\left[(1-n)\,\hat{P}_{T,H} + n\left(\hat{P}_{T,F}^* - \hat{S}\right)\right] + (1-v)\,\hat{P}_N,$$

$$-\frac{1-\Omega}{\Omega}\hat{P}_N^* = v\left[(1-n)\left(\hat{P}_{T,H} + \hat{S}\right) + n\hat{P}_{T,F}^*\right] + (1-v)\,\hat{P}_N,$$

Balance of payments identity: 1 equation

$$-\Gamma\hat{S} - (\Gamma-1)\,\hat{P}_{T,H} + \Delta\hat{P}_N^* + \hat{C}^* = -(\Gamma-1)\left(\hat{P}_{T,F}^* - \hat{S}\right) + \Delta\hat{P}_N + \hat{C} - \hat{\theta}. \tag{15}$$

Note that we define the weighted average of elasticities of substitution as follows:

$$\Gamma := \psi + v(\lambda - \psi) = (1-v)\,\psi + v\lambda > 0,$$

$$\Delta := -(1-v)(\psi - \lambda) + \frac{1-\Omega}{\Omega}(\lambda - \mu) = (1-v)(\mu - \psi) + v(\lambda - \mu),$$

$$\Xi := \frac{1-\Omega}{\Omega}\mu + 2(1-v)\,\psi = v\mu + (1-v)(\psi - \mu) + (1-v)\,\psi > 0.$$

The four equations in "Labor market clearing" show that labor demand (LHS), represented by the marginal product of labor, equals labor supply (RHS), which is the marginal disutility of labor multiplied by the marginal utility of consumption. Wages can differ between traded and non-traded production within the same country due to heterogeneous labor wedges. However, these differences do not lead to significant deviations from the outcome under a unified labor market. This is because relative wages are always negatively correlated with relative labor supply.

The first two equations in "Goods market clearing" describe the conditions for traded goods market equilibrium, where the supply (LHS) equals the demand (RHS). The first term on the RHS represents the demand in the producing country, while the second term represents the demand in the counterpart country. Note that $-\Gamma$ and $-\Delta$ denote the price elasticities of $\hat{P}_{T,H}$ ($\hat{P}_{T,F}^*$) and $\hat{P}_N$ ($\hat{P}_N^*$), respectively. The last two equations describe the equilibrium conditions for non-traded goods, where supply (LHS) again equals demand (RHS). Here, $-\Xi$ denotes the price elasticity of non-traded goods demand with respect to $\hat{P}_N$ ($\hat{P}_N^*$). When simplifying the expressions as shown here, we use the two equations in "Prices" below along with the log-linearized equations for price indices.

The two equations in "Prices" define the theoretical price index for final traded goods, as shown in equation (30) of Appendix A. Since the CPI is normalized to unity, up to a first order approximation the weighted proportional change in the non-traded price (the LHS of each equation in "Prices"), must equal the negative of the proportional change in the consumer retail price of traded goods (the RHS of equation). As described above, producing final traded goods requires v units of raw traded goods and $(1-v)$ units of non-traded services. Additionally, from these two equations, we can derive the equation for the nominal exchange rate, which is the inverse of the real exchange rate, as shown in equation (52) of Appendix A. This equation expresses the nominal exchange rate as a function of the prices of non-traded goods:

$$\hat{S} = \left(\hat{P}_N - \hat{P}_N^*\right) = \hat{Q}. \tag{16}$$

The RHS of the "Balance of payments identity" represents the gross exports of the domestic country, while the LHS represents the gross imports.

Composite elasticities At first glance, the composite elasticities Γ, Δ, Ξ may appear opaque; however, they admit an intuitive interpretation within a nested CES demand system. Let $Y_{T,H}$ denote the demand for the home-produced traded good in the home country; within this framework, $Y_{T,H}$ is derived from the cost-minimization problems at each stage:

$$Y_{T,H} = v \left(\frac{P_{T,H}}{\tilde{P}_{T,H}}\right)^{-\psi} (1-\gamma) \left(\frac{\tilde{P}_{T,H}}{P_T}\right)^{-\lambda} \Omega P_T^{-\mu} C,$$

where

$$\tilde{P}_{T,H} = \left[v P_{T,H}^{1-\psi} + (1-v)\, P_N^{1-\psi}\right]^{\frac{1}{1-\psi}},$$

$$P_T = \left[\frac{1-(1-\Omega)\, P_N^{1-\mu}}{\Omega}\right]^{\frac{1}{1-\mu}}.$$

Recall that production occurs in two stages: first, home raw traded goods are combined with non-traded inputs to produce the home traded intermediate; second, home and foreign traded intermediates are combined to produce the final traded good as shown in Figure 2. The index $\tilde{P}_{T,H}$ is the theoretical price faced by intermediate-goods producers that aggregate traded and non-traded inputs, and the final-goods producer's cost minimization implies that the traded-goods price P_T can be written as a function of the non-traded-goods price P_N via the CPI.

Regarding Γ, an increase in $P_{T,H}$ lowers C_H through a first-stage substitution effect with elasticity $-\psi$ and through an indirect second-stage effect, because higher $P_{T,H}$ raises $\tilde{P}_{T,H}$ and reduces demand for the home traded intermediate with elasticity λ and share v. At the same time, because $\tilde{P}_{T,H}$ serves as the reference price in the first stage, the increase in $\tilde{P}_{T,H}$ partially offsets the first effect with elasticity ψ and share v. Therefore, the elasticity of C_H with respect to $P_{T,H}$ is the composite value $\Gamma = \psi + v(\lambda - \psi) = (1-v)\psi + v\lambda$. Analogously, the effects of P_N on $Y_{T,H}$ and on Y_N are governed by the corresponding composite elasticities Δ and Ξ.

Notice that there exists a straightforward relationship among the three composite elasticities:

$$\Delta = \Gamma - \Xi.$$

This identity also implies that the sign of Δ is, in general, ambiguous. In the special case where the production of traded goods requires no non-traded inputs (i.e., when $v = 1$), the elasticities simplify to $-\lambda$, $-(\lambda - \mu)$ and $-\mu$, respectively.

3 Analytical characterization

Although Section 6 does a full quantitative analysis of the model to explore the fit to European data, in this section we present an analytical characterization that can help give insights about the nature of real exchange rate determination. To do this, we derive some solutions to the log-linearized system of equations as described in Section 2.7.1.

3.1 Solution of target variables

3.1.1 Real exchange rate

The solution for the real exchange rate is given by

$$\begin{aligned}\hat{Q} \quad = \quad & \frac{\Sigma(\Gamma-1)}{\Lambda}\left[(1+\phi)\tilde{A}_T - (1-\alpha)\tilde{\Psi}_T\right] \\ & -\frac{\Phi + (1-\alpha)\sigma(\Gamma-1)}{\Lambda}\left[(1+\phi)\tilde{A}_N - (1-\alpha)\tilde{\Psi}_N\right] \\ & +\frac{\Sigma\Phi}{\Lambda}\hat{\theta}, \end{aligned} \tag{17}$$

where

$$\tilde{A}_j := \hat{A}_{j,H} - \hat{A}_{j,F},$$

$$\tilde{\Psi}_j := \hat{\Psi}_j - \hat{\Psi}_j^*,$$

$$\Phi := (1-\alpha) + (\alpha+\phi)\,\Gamma > 0,$$

$$\Theta := (1-\alpha) + (\alpha+\phi)\,\Xi > 0,$$

$$\Lambda := \Phi\,(\Sigma\Xi + \Theta) + (1-\alpha)\,(\Gamma-1)\,(\Sigma + \sigma\Theta)\,.$$

The real exchange rate is driven by sectoral productivity changes as well as shocks to labor wedges.[9] The condition (17) shows that a critical term is Γ, which we noted above as a lin-

[9] Σ captures the responsiveness of labor to technological changes. A larger value of Σ implies a weaker labor response to variations in technology and labor wedges. Similarly, Φ measures the sensitivity of the terms of trade to technological changes. As Φ increases, the terms of trade become less responsive to shifts in technology and

ear combination of the trade elasticity λ and the elasticity of substitution between raw traded goods and non-traded inputs in the production of traded goods consumption ψ. We note that $\Gamma \geq 1$ is a sufficient but not necessary condition for the denominator Λ to be positive. In all our calibration exercises, this is the case, and we proceed on that assumption. Then a rise in traded goods productivity A_T leads to a real appreciation whenever $\Gamma > 1$. The intuition is as follows. A rise in productivity in traded goods production A_T raises real income, and leads to a rise in demand for non-traded goods and a shift back in labor supply in the non-traded sector. Both of these forces raise the home country relative price of non-traded goods. Whether this leads to a real appreciation depends on the response of the terms of trade. With perfect substitutability between foreign and home traded goods ($\lambda \to \infty$, $\Gamma \to \infty$) the terms of trade is constant and the rise in the relative price of non-traded goods in the home country translates into a real exchange rate appreciation. But when $\Gamma < \infty$, the rise in A_T leads to a terms of trade deterioration. In the case $\Gamma = 1$ the home terms of trade deterioration leads to an equal rise in real income in the foreign economy as its terms of trade improves. Then the relative price of non-traded goods in the foreign country rises in equal measure, so there is no effect on the home real exchange rate.

The Balassa-Samuelson hypothesis predicts that real exchange rate appreciation is generated by higher productivity growth in the traded goods sector relative to the non-traded goods sector. In the textbook version of the theory (e.g. Obstfeld and Rogoff 1996), all traded goods are perfect substitutes, so that in our notation $\Gamma \to \infty$. In this case, the Balassa-Samuelson hypothesis holds. But in our model, home and foreign traded goods are imperfect substitutes in consumption, meaning $\lambda < \infty$, but also traded goods consumption requires non-traded inputs. When $\psi < 1$, raw traded goods and non-traded inputs are imperfect substitutes, so that adjustment to a productivity increase in traded goods requires a greater fall in the price of the traded good, magnifying the terms of trade deterioration, and again reducing the likelihood of real exchange rate appreciation.

This mechanism can be better understood by slightly rewriting the balance of payments identity in equation (15):

$$\left(\hat{C}^* - \hat{C}\right) - \Gamma\hat{S} + (\Gamma - 1)\left(\hat{P}^*_{T,F} - \hat{S} - \hat{P}_{T,H}\right) + \Delta\left(\hat{P}^*_N - \hat{P}_N\right) + \hat{\theta} = 0.$$

Noting that $\hat{S} = -(\hat{P}^*_N - \hat{P}_N)$, and observing condition (17), we can establish that a rise in traded goods productivity has no effect on either the real exchange rate or relative consumption when $\Gamma = 1$. This reveals a link between the Balassa-Samuelson mechanism and consumption risk-sharing through the endogenous movement in the terms of trade, a channel first discussed by Cole and Obstfeld (1991). When $\Gamma > 1$, ($\Gamma < 1$) a rise in A_T leads to both a real exchange rate appreciation (depreciation) and a rise (fall) in home relative to foreign consumption. With $\Gamma = 1$, the productivity increase leaves the real exchange rate unaffected, and the endogenous

labor wedges in the general equilibrium. Finally, Θ reflects the responsiveness of consumption to the price of non-traded goods. An increase in Θ indicates a reduced sensitivity of consumption to changes in the relative price of non-traded goods in the general equilibrium.

deterioration in the terms of trade achieves full risk sharing across countries.[10] In the calibrated model of section 6 below, we choose parameter values so that $\Gamma > 1$ always holds, and therefore a rise in traded goods productivity is associated with a rise in GDP per capita and a real appreciation.

A key insight from this discussion is that the Balassa-Samuelson effect disappears when all aggregators are Cobb-Douglas. In that case $\Gamma = 1$ always holds, and the wealth effects of a traded goods productivity enhancement are fully shared across countries, leaving the real exchange rate unchanged.

To further explore condition (17), we may ask what is the real exchange rate response to a uniform productivity increase, where $\tilde{A}_T = \tilde{A}_N = \tilde{A}$? Using equation (17), we may show that

$$\hat{Q} = -\frac{(1+\phi)^2}{\Lambda}\tilde{A} \tag{18}$$

Equation (18) shows that a uniform increase in relative productivity growth will lead to a real exchange rate depreciation. Intuitively, because a traded goods productivity increase leads to a terms of trade deterioration, tempering the effect on the real exchange rate, as described above, the impact on the real exchange rate must be more than offset by the negative effect of non-traded goods productivity growth. By contrast, in the textbook Balassa-Samuelson case, by contrast, where $\Gamma \to \infty$, we find that $\Lambda \to \infty$, showing that a uniform productivity increase in both sectors leaves the real exchange rate unaffected.

From this discussion, we can establish the following Proposition

Proposition 1. Balassa-Samuelson Hypothesis

(1) A positive productivity shock in the traded goods sector generates real exchange rate appreciation (no change) (depreciation) when $\Gamma > 1$, $(\Gamma = 1)$, $(\Gamma < 1)$.

(2) A uniform increase in productivity growth across sectors leads to a real exchange rate depreciation when $\Gamma < \infty$.

(3) Let $\tilde{A}_T = \tilde{A}_N + \delta \equiv \tilde{A} + \delta$, *where* $\delta > 0$. *Higher productivity growth in traded goods productivity than in non-traded goods productivity is associated with a real exchange rate appreciation if and only if*

$$\Sigma\,(\Gamma - 1)\delta - (1+\phi)\tilde{A} > 0 \tag{19}$$

Parts (1) and (2) of the proposition have been explained in the previous discussion. Part (3) follows from the discussion also. For excess productivity growth in the traded good sector to cause a real appreciation requires not just that $\Gamma > 1$ but also that the differential growth δ satisfy condition (19), so that the impact of the traded goods productivity growth exceeds the negative effect of the uniform growth rate.

Equation (17) shows that sectoral labor wedges impact the real exchange rate in the reverse

[10] Note that our analytical solution abstracts from home bias in preferences over traded goods, so that in response to a traded goods productivity shock, full risk sharing implies equal consumption responses.

direction to that of productivity shocks. By raising firms marginal costs, a rise in the sectoral labor wedge is isomorphic to a fall in sectoral productivity and has offsetting effects on the terms of trade and relative price of non-traded goods as discussed above. Finally, (17) shows that capital inflows will lead to an appreciation of the real exchange rate by increasing the domestic country's relative consumption.

As discussed in the introduction, a robust empirical finding is that countries with a higher level of real per capita GDP have higher relative price levels. This is generally called the 'Penn Effect'. The Balassa-Samuelson effect is consistent with the Penn effect to the extent that differences in GDP per capita are mainly driven by different productivity in traded goods sectors.[11] But the Penn effect is theoretically possible even if the Balassa-Samuelson effect fails. We can show this in the following Proposition

Proposition 2. The Penn Effect

Controlling for productivity shocks and the labor wedge in the non-traded sector, there is a positive correlation between relative GDP per capita and the real exchange rate.

To show this, note that we may describe the relationship between GDP per capita from the solutions in Section A, the real exchange rate relates to relative consumption as

$$\tilde{Q} = \frac{\Sigma\left(\hat{C} - \hat{C}^*\right) - \left[(1+\phi)\,\tilde{A}_N - (1-\alpha)\,\tilde{\Psi}_N\right]}{\Theta}.$$

Controlling for movements in the non-traded sector productivity and labor wedges in each country, relative GDP and the real exchange rate will move in the same direction, since these will reflect the influence of productivity shocks or labor wedges in the traded goods sector, or capital inflows.[12] Note that $\frac{\Sigma}{\Theta}$ is independent of Γ. So even if the Balassa-Samuelson effect fails, the Penn effect may still be observed, while in the knife-edge case where $\Gamma = 1$, neither relative consumption nor the real exchange rate responds to productivity shocks. We note also that in this model, an observation of a positive correlation between relative GDP per capita and the real exchange rate suggests an absence of full risk-sharing in response to traded goods productivity shocks.

Propositions 1 and 2 establish that from a theoretical point of view, the association between GDP growth and the real exchange rate is nuanced. Even when GDP is driven primarily by productivity growth in the traded goods sector, it may not be combined with real exchange rate appreciation. Furthermore, as we show below, this same lack of coincidence between output

[11] More generally, Bhagwati (1984) provides a different explanation of the Penn effect arising from balanced growth (e.g. equal growth rates in traded and non-traded goods productivity) but differential factor intensities across sectors. In particular, if the non-traded goods sector is more labor intensive and capital is mobile across countries, then the relative price level of the faster growing country should be rising given labor as a fixed or limited factor. In our model, we don't have capital accumulation so this channel would not be expected to work in the same way. In addition, the illustration in this section assumes equal factor intensities across sectors. But in addition, with uniform growth rates in traded and non-traded goods productivity in our model, the real exchange rate would experience continual depreciation due to declining terms of trade, as can be shown from equation (17).

[12] Note that in the model without intertemporal trade, relative GDP is proportional to relative consumption. This is not exactly true in the case of capital inflows, but we may assume that net capital inflows are small relative to GDP.

growth and real exchange rate appreciation also holds at the sectoral level. This insight will help us to better understand the Eastern European data in Sections 5 and 6 below.

3.1.2 Real exchange rate of non-traded goods

The real exchange rate of non-traded goods is defined as

$$Q_N := \frac{SP_N}{P_N^*}.$$

Substituting equation (17) into the log-exact formulation yields the solution for the real exchange rate of non-traded goods:

$$\hat{Q}_N = \hat{S} + \left(\hat{P}_N - \hat{P}_N^*\right) = 2\hat{Q}. \tag{20}$$

The non-traded goods real exchange rate is proportional to the aggregate real exchange and exhibits more volatile dynamics.

3.1.3 Real exchange rate of traded goods

The real exchange rate of traded goods is defined as

$$Q_T := \frac{SP_T}{P_T^*}.$$

Substituting equation (17) into the log-exact formulation yields the solution for the real exchange rate of non-traded goods:

$$\hat{Q}_T = \hat{S} + \left(\hat{P}_T - \hat{P}_T^*\right) = \hat{S} - \frac{1-\Omega}{\Omega}\left(\hat{P}_N - \hat{P}_N^*\right) = 2\left(1-v\right)\hat{Q}. \tag{21}$$

The real exchange rate of traded goods is proportional to the aggregate real exchange and it shows less volatile dynamics than the real exchange rate of non-traded goods. In the case where the traded goods consumer bundle does not use non-traded inputs, $\hat{Q}_T$ is constant.

3.1.4 Relative output of non-traded goods

We define the relative output of non-traded goods as follows:

$$y_N = \frac{A_{N,H} L_N^{1-\alpha}}{A_{N,F}\left(L_N^*\right)^{1-\alpha}}.$$

By using equations in Appendix A.9, we have

$$
\begin{aligned}
\hat{y}_N \;=\; & -\frac{(1-\alpha)(\Gamma-1)(\sigma\Xi-1)}{\Lambda}\left[(1+\phi)\,\tilde{A}_T-(1-\alpha)\,\tilde{\Psi}_T\right] \\
& +\frac{(1-\alpha)(\Gamma-1)(\sigma\Xi+1)+2\Phi\Xi}{\Lambda}\left[(1+\phi)\,\tilde{A}_N-(1-\alpha)\,\tilde{\Psi}_N\right] \\
& -\frac{(1-\alpha)\,\Phi\,(\sigma\Xi-1)}{\Lambda}\hat{\theta}.
\end{aligned}
$$

Assuming that $\Gamma > 1$, the effect of a traded goods productivity shock on the non-traded sector depends on the value of $\sigma\Xi = \sigma\left[(1-v)\,\psi + v\mu + (1-v)\,(\psi-\mu)\right]$. When $\sigma\Xi < 1$, ($\sigma\Xi > 1$), traded and non-traded goods are considered to be Edgeworth complements (substitutes), and non-traded goods productivity rises (falls) after a positive shock to A_T.

3.1.5 Relative output of traded goods

We define the relative output of traded goods as follows:

$$
y_T = \frac{A_{T,H} L_T^{1-\alpha}}{A_{T,F}\left(L_T^*\right)^{1-\alpha}}.
$$

By using equations in Appendix A.9, we have

$$
\begin{aligned}
\hat{y}_T \;=\; & \frac{\Gamma\left[(1-\alpha)+\Sigma\Xi\right]}{\Lambda}\left[(1+\phi)\,\tilde{A}_T-(1-\alpha)\,\tilde{\Psi}_T\right] \\
& -\frac{\Gamma\,(1-\alpha)(\sigma\Xi-1)}{\Lambda}\left[(1+\phi)\,\tilde{A}_N-(1-\alpha)\,\tilde{\Psi}_N\right] \\
& -\frac{\Gamma\,(1-\alpha)(\Sigma+\sigma\Theta)}{\Lambda}\hat{\theta}.
\end{aligned}
$$

As explained in the previous section, similar mechanisms are at play in the case of the relative output in traded goods.

3.1.6 Relative unit labor cost in non-traded sector

The relative unit labor cost in the non-traded sector is defined as

$$
u_N = \frac{\dfrac{W_N}{A_{N,H} L_N^{1-\alpha}/L_N}}{S\dfrac{W_N^*}{A_{N,F}\left(L_N^*\right)^{1-\alpha}/L_N^*}}.
$$

Using equations in Appendix A.9, we have

$$
\hat{u}_N = \hat{Q}_N = 2\hat{Q}. \tag{22}
$$

The unit labor cost in the non-traded sector moves in the same direction as the real exchange rate of non-traded goods. Thus, as shown in equation (17), an increase in the labor wedge and the decrease in the productivity in the non-traded (traded) goods sector in the home country increases (reduces) the unit labor cost in the non-traded sector. Technological improvements in the traded goods sector and a reduction in the labor wedge increase the demand for non-traded goods and raise wages in the non-traded goods sector, which is indeed the Balassa-Samuelson effect.

3.1.7 Relative unit labor cost of traded goods

The relative unit labor cost in the traded sector is defined as

$$u_T = \frac{\frac{W_T}{A_{T,H} L_T^{1-\alpha} / L_T}}{S \frac{W_T^*}{A_{T,F} \left(L_T^*\right)^{1-\alpha} / L_T^*}}.$$

Using equations in Appendix A.9, we have

$$\hat{u}_T = \left(\hat{P}_{T,H} - \hat{P}_{T,F}^*\right) - \hat{S},$$

or

$$\begin{aligned} \hat{u}_T \quad = \quad & -\frac{\Sigma\Xi + \Theta}{\Lambda} \left[(1+\phi)\,\tilde{A}_T - (1-\alpha)\,\tilde{\Psi}_T\right] \\ & + \frac{(1-\alpha)\,(\sigma\Xi - 1)}{\Lambda} \left[(1+\phi)\,\tilde{A}_N - (1-\alpha)\,\tilde{\Psi}_N\right] \\ & + \frac{(1-\alpha)\,(\Sigma + \sigma\Theta)}{\Lambda} \hat{\theta}. \end{aligned} \tag{23}$$

The unit labor cost in the traded sector moves almost in the same direction as the relative output in traded goods. Both labor wedges increase the unit labor cost in the traded sector.

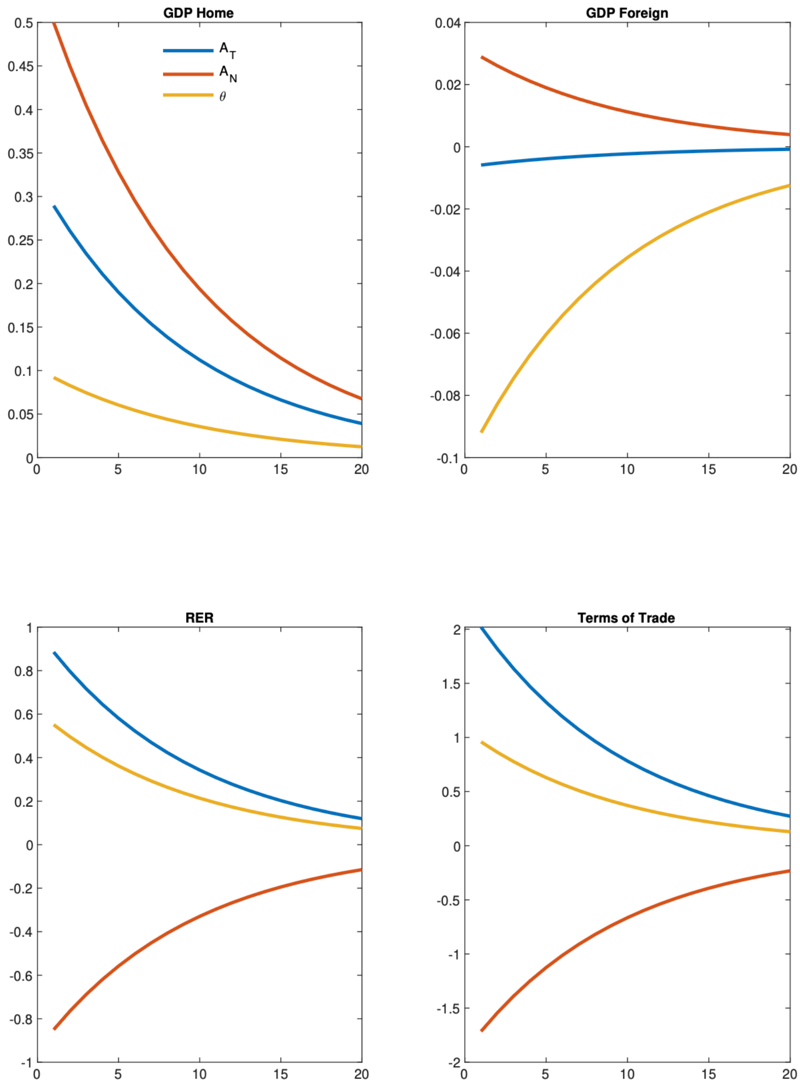
Note that in the regressions below, we only use the aggregate unit labor cost which is the weighted average of equations (22) and (23). Thus, the unit labor cost in the regression represents the aggregate labor wedge.

3.1.8 Impulse responses

Figure 3 reports the theoretical impulse responses to shocks to three key exogenous variables in the model, for the parameter values that are used in the calibrated model below, except using the particular assumptions of the linear approximations. A rise in traded goods productivity leads to a rise in Home GDP and a real exchange rate appreciation. For this calibration, there is a small negative spillover to the foreign country.[13] A shock to non-traded goods productivity has a positive effect on GDP also but leads to a real exchange rate depreciation, and a positive spillover. A capital inflow θ leads to a simultaneous rise in GDP and a real exchange rate appreciation also.

[13] A rise in Ψ_T, the home labor wedge has an impact qualitatively the reverse of a traded goods productivity shock.

Figure 3: Shocks to Productivity and Capital Inflows



3.2 Estimation strategy

We now discuss the econometric strategy based on the solutions obtained in our real exchange rate model. A key feature of the model is that real exchange rates are likely to be driven both by productivity forces and other labor market wedges. While the former are in principle observed in the data, the latter represent market distortions or markups which are difficult to measure. In this section we show how unit labor cost, which is observed in the data, may be used as an empirical proxy to capture the effect of labor market wedges on the real exchange rate.

Suppose that the data-generating process for the real exchange rate is given by the solution in equation (17):

$$\hat{Q} = \bar{A}\tilde{A}_T - \bar{B}\tilde{A}_N - \bar{C}\tilde{\Psi}_T + \bar{D}\tilde{\Psi}_N + \bar{E}\hat{\theta}, \tag{24}$$

where

$$\bar{A} := \frac{\Sigma\,(\Gamma - 1)\,(1 + \phi)}{\Lambda} > 0,$$

$$\bar{B} := \frac{[\Phi + (1-\alpha)\,\sigma\,(\Gamma-1)]\,(1+\phi)}{\Lambda} > 0,$$

$$\bar{C} := \frac{\Sigma\,(\Gamma-1)\,(1-\alpha)}{\Lambda} > 0,$$

$$\bar{D} := \frac{[\Phi + (1-\alpha)\,\sigma\,(\Gamma-1)]\,(1-\alpha)}{\Lambda} > 0,$$

$$\bar{E} := \frac{\Sigma\Phi}{\Lambda} > 0.$$

If we have data counterparts for all exogenous variables, namely, $\tilde{A}_T$, $\tilde{A}_N$, $\tilde{\Psi}_T$, $\tilde{\Psi}_N$ and $\hat{\theta}$, we can recover the coefficients $\bar{A}$, $\bar{B}$, $\bar{C}$, $\bar{D}$ and $\bar{E}$ via OLS.

3.2.1 Omitted variables

However, data counterparts for labor wedges $\tilde{\Psi}_T$ and $\tilde{\Psi}_N$ are not available. If we estimate the real exchange rate equation omitting these variables:

$$\hat{Q} = \hat{a}\tilde{A}_T + \hat{b}\tilde{A}_N + \hat{e}\hat{\theta} + \varepsilon,$$

where ε denotes the residuals, we can still recover the true coefficients $\bar{A}$, $\bar{B}$, and since variables are assumed i.i.d. However, the variances of the estimates are

$$\mathrm{Var}(\hat{a}) = \mathrm{Var}(\hat{b}) = \mathrm{Var}(\hat{e}) = \frac{\bar{C}^2 + \bar{D}^2}{n},$$

where n is the sample size. For simplicity, assume all exogenous variables are i.i.d with unit variance. Due to these omitted variables, parameters that should originally be significant may be estimated as insignificant.

3.2.2 ULC as a proxy for labor wedge

To address the problem stemming from omitted variables, we use the relative aggregate unit labor cost $\hat{u}$ as a proxy. Up to the first order approximation, this is given by the weighted average of the relative unit labor cost in the traded sector $\hat{u}_T$ and that in the non-traded sector $\hat{u}_N$:

$$\hat{u} = \frac{1}{2}\hat{u}_T + \frac{1}{2}\hat{u}_N.$$

By inserting equations (22) and (23), this can be rewritten as

$$\hat{u} = \bar{F}\tilde{A}_T - \bar{G}\tilde{A}_N - \bar{H}\tilde{\Psi}_T + \bar{I}\tilde{\Psi}_N + \bar{J}\hat{\theta}, \tag{25}$$

where

$$\bar{F} := \left[-\frac{\Sigma\Xi + \Theta}{2\Lambda} + \frac{\Sigma\,(\Gamma-1)}{\Lambda}\right](1+\phi),$$

$$-\bar{G} := \left[\frac{(1-\alpha)\,(\sigma\Xi-1)}{2\Lambda} - \frac{(1-\alpha)\,(1-\sigma) + \Sigma\Gamma}{\Lambda}\right](1+\phi),$$

$$-\bar{H} := \left[\frac{\Sigma\Xi + \Theta}{2\Lambda} - \frac{\Sigma(\Gamma - 1)}{\Lambda}\right](1-\alpha),$$

$$\bar{I} := \left[-\frac{(1-\alpha)(\sigma\Xi - 1)}{2\Lambda} + \frac{(1-\alpha)(1-\sigma) + \Sigma\Gamma}{\Lambda}\right](1-\alpha),$$

$$\bar{J} := \left[\frac{(1-\alpha)(\Sigma + \sigma\Theta)}{2\Lambda} + \frac{\Sigma\Phi}{\Lambda}\right] > 0.$$

As demonstrated in equations (22) and (23), unit labor costs in the traded and non-traded sectors exhibit opposing responses to technological shocks and labor wedges, consistent with the mechanisms outlined earlier. Given that the aggregate unit labor cost is computed as the simple average of the respective costs in the traded and non-traded sectors, the resulting coefficients in equation (25) are, in general, ambiguous in sign—except for the coefficient on the capital flow proxy, θ, which is positive.

Since the trade elasticity λ in Γ is typically much larger than the elasticities ψ and μ in Ξ, a realistic calibration implies $\bar{F}, \bar{G}, \bar{H}, \bar{I} > 0$. Thus, the relative aggregate unit labor cost has the potential to serve as an effective proxy, given that the signs of the labor wedge terms are consistent across both the real exchange rate equation (24) and the relative aggregate unit labor cost in equation (25).

Now, we estimate the real exchange rate on $\hat{u}$ in addition to$\tilde{A}_T$, $\tilde{A}_N$ and $\hat{\theta}$:

$$\hat{Q} = \tilde{a}\tilde{A}_T + \tilde{b}\tilde{A}_N + \tilde{c}\hat{u} + \tilde{e}\hat{\theta} + \varepsilon.$$

Estimated parameters are given by

$$\begin{aligned}
\tilde{a} &= \bar{A} - \tilde{c}\bar{F}, \\
\tilde{b} &= -\bar{B} + \tilde{c}\bar{G}, \\
\tilde{c} &= \frac{\bar{C}\bar{H} + \bar{D}\bar{I}}{\bar{H}^2 + \bar{I}^2} > 0, \\
\tilde{d} &= \bar{E} - \tilde{c}\bar{J}.
\end{aligned}$$

3.2.3 Testable implications

The solutions of real exchange rates, namely, equations (17), (20) and (21), offer testable implications as follows.

1. The signs of estimated coefficients are consistent with theoretical prediction. The sign is positive on the traded technology and negative on the non-traded technology.

$$\hat{a}, \tilde{a} > 0,$$

$$\hat{b}, \tilde{b} < 0.$$

2. Estimated coefficients on non-traded technology are larger in absolute value than those

on traded technology.

$$|\hat{a}| < |\hat{b}|, |\tilde{a}| < |\tilde{b}|.$$

3. Estimated coefficients exhibit consistent signs across all equations when the dependent variables are the real exchange rate, the real exchange rate for traded goods, and the real exchange rate for non-traded goods.

4. The absolute value of the estimated coefficients on relative technologies is largest when the dependent variable is the real exchange rate for non-traded goods. The coefficients are of similar magnitude when the dependent variables are the overall real exchange rate and the real exchange rate for traded goods.

Analysis in Section 3.2.2 also offers another testable implication.

5. Estimated coefficients are smaller in absolute value when ULC is used as an additional explanatory variable.

$$|\hat{a}| > |\tilde{a}|, |\hat{b}| > |\tilde{b}|.$$

It is important to note that the testable implications rely on several underlying assumptions. Even if the model presented in Section 3 accurately reflects the true data-generating process, the analytical solutions may still diverge from the true solutions. In deriving the closed-form expressions, we made a simplifying assumption — we focus on a first-order approximation around a symmetric steady state. Furthermore, in the estimation strategy discussed in Section 3.2, we assume that all explanatory variables, except for unit labor cost, are mutually independent and have unit variance. In practice, however, explanatory variables may exhibit correlation and their variances are heterogenous. Therefore, the testable implications derived above are not necessarily expected to hold exactly in the regressions presented in the following section.

4 Data

Our data consists of real exchange rates covering all goods, both traded and non-traded, as well as a number of labor market fundamentals. Our sample of countries are Bulgaria, Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovenia, and Slovakia. In most cases we also consider the same variables for the European Union 27 countries group (EU27). Our sample is annual and covers the period 1999-2020.

4.1 Real exchange rates

We construct real exchange rates for the sample of Eastern European countries from disaggregated price data. The data are provided by Eurostat as part of the Eurostat-OECD PPP Programme. They are arranged in the form of price level indices (PLIs). A PLI gives the price of a good at a given time for a given country, relative to a reference country price. Hence, it is a good-specific PPP, although if the country chosen is in the Eurozone this measure does not involve different currencies. The reporting frequency is annual for 1999-2020 and the PLIs are available for 223 "basic headings" of consumer goods and services. These include food (including food away from home), clothing, housing costs, durable goods, transportation costs, as well as medical and educational services. They cover 100 percent of the consumption basket. The full list of PLIs for the basic headings of consumer goods and services is contained in the online Appendix Table 21. For each item, the reference price is obtained as a ratio of the domestic price of each good to the EU27 analog and re-expressed in terms of the corresponding EU15 price level for a better comparability for the Eastern European economies case.[14] Hence, the prices are comparable in levels, so that both cross-section and time-series real exchange rate variation can be examined. Our sample contains the 12 Eastern European economies mentioned above. We construct aggregate and sectoral real exchange rates from the underlying price series, using expenditure weights. The expenditure weights are constructed using euro expenditures on every basic heading in every country and every year. Thus, the expenditure weights are time-varying, year by year.[15] Let q_{it} be the real exchange rate for country i at time t and let q_{iTt} (q_{iNt}) represent the average real exchange rate for the subset of traded (non-traded) goods. Real exchange rates are measured so that an increase represents an appreciation for the home country.[16]

Relative to other studies that have compared price levels internationally, these data have a number of advantages. They cover the entire consumer basket. For a detailed explanation meant to convey the care taken to make prices comparable see Berka, Devereux and Engel (2018). Here we mention only that exhaustive efforts are made at the item priced level to ensure comparability across countries, including to consider that some products are priced at various types of outlets (for example, department stores, supermarkets, specialty outlets) by increasing the sampling of products when their prices across similar outlets show higher variation.

We separate goods into traded and non-traded categories using a criteria by item reported in Table 21 in the (online) Appendix and along the lines followed by Berka et al. (2018) and Crucini, Telmer and Zachariadis (2005) where all goods with a positive trade share are categorized as "traded", and those with a zero trade as "non-traded."

The composition of the consumption baskets differs across goods, countries, and time. To account for this, we construct expenditure weights for each good, country, and year, using the expenditure data provided in the same Eurostat-OECD Programme. Specifically, for good i, country j, and year t, we construct a weight $\gamma_{i,j,t} = \frac{\text{exp}_{i,j,t}}{\sum_{i=1}^{223} \text{exp}_{i,j,t}}$ where exp is the local expenditure.

[14]The EU15 group includes Austria, Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Spain, Sweden, Portugal, Finland, and the United Kingdom, and the EU27 Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden.

[15]We also experimented with the use of time invariant weights, using average weights over the sample, and the results were essentially identical to those reported below.

[16]Therefore, q_{it} represents the average price level for country i, relative to the European average.

We then construct expenditure-weighted PLIs for all countries using $\gamma_{i,j,t}$.

Denoting $p_{i,j,t}$ as the log of a PLI, in year t, for a good i in country j relative to EU15, we calculate the log of the real exchange rate of country j, $q_{j,t}$, as the expenditure-weighted arithmetic average:

$$q_{j,t} = \sum_{i=1}^{223} \gamma_{i,j,t} p_{i,j,t}$$

Based on these aggregate measures we report some descriptive statistics for a set of variables in Table 1. The table first reports the average log real exchange rate over the sample for each country, denoted $\bar{q}$, as well as the equivalent measures for the traded goods real exchange rate $\bar{q}_T$, the non-traded goods real exchange rate, $\bar{q}_N$, and also the relative price of non-traded goods $\bar{q}_n = \bar{q}_N - \bar{q}_T$. Note that the level data are expressed as proportions of the EU27 average. Thus if an entry is negative in logs it implies that the country's price is below the average.

Table 1: Country Summary Statistics

Country	$\bar{q}$	$\bar{q}_T$	$\bar{q}_N$	$\bar{q}_n$	$s(q)$	$s(q_T)$	$s(q_N)$	$s(q_n)$
BG	-0.65	-0.45	-1.12	-0.67	0.09	0.09	0.15	0.07
CY*	-0.12	-0.01	-0.26	-0.25	0.03	0.03	0.04	0.05
CZ	-0.45	-0.31	-0.69	-0.38	0.11	0.10	0.16	0.08
EE*	-0.35	-0.23	-0.57	-0.34	0.10	0.09	0.12	0.05
HU	-0.47	-0.32	-0.73	-0.42	0.07	0.07	0.09	0.04
LT*	-0.43	-0.31	-0.84	-0.54	0.08	0.09	0.10	0.09
LV*	-0.38	-0.25	-0.66	-0.41	0.09	0.10	0.12	0.08
MT*	-0.21	-0.07	-0.39	-0.32	0.03	0.04	0.06	0.07
PL	-0.51	-0.38	-0.79	-0.42	0.06	0.06	0.09	0.07
RO	-0.63	-0.45	-1.06	-0.61	0.10	0.11	0.11	0.07
SI*	-0.24	-0.16	-0.40	-0.25	0.04	0.04	0.06	0.04
SK*	-0.43	-0.30	-0.69	-0.39	0.18	0.15	0.27	0.14
	$\bar{a}_T$	$\bar{a}_N$	$\bar{a}_{TN}$	$\overline{rulc}$	$s(a_T)$	$s(a_N)$	$s(a_{TN})$	$s(rulc)$
BG	-2.13	-0.51	-1.62	-2.19	0.11	0.21	0.11	0.22
CY*	-0.57	0.19	-0.76	-0.50	0.06	0.04	0.05	0.11
CZ	-0.50	-0.54	0.05	-0.96	0.19	0.04	0.18	0.25
EE*	-0.94	-0.06	-0.88	-1.20	0.18	0.23	0.08	0.32
HU	-0.47	-0.38	-0.08	-1.24	0.11	0.05	0.11	0.15
LT*	-1.21	-0.85	-0.36	-1.44	0.20	0.20	0.07	0.24
LV*	-0.93	-0.30	-0.63	-1.69	0.24	0.21	0.05	0.23
MT*	-0.81	-0.40	-0.41	-0.39	0.05	0.10	0.13	0.21
PL	-0.62	-0.35	-0.27	-1.38	0.13	0.16	0.08	0.11
RO	-1.31	-0.51	-0.81	-2.70	0.25	0.21	0.10	0.19
SI*	-0.45	-0.26	-0.19	-0.45	0.10	0.05	0.08	0.07
SK*	-0.39	-0.17	-0.22	-1.12	0.28	0.12	0.18	0.39

Notes: All real exchange rate variables (q, q_T, q_N, q_n) are home country values relative to EU15 average. q is the expenditure-weighted log real exchange rate (an increase is an appreciation). q_T (q_N) is the real exchange rate for traded (non-traded) goods only, both relative to EU15 average. $q_n \equiv q_N - q_T$. $s(\cdot)$ denotes standard deviation. a_T (a_N) is the logarithm of traded (non-traded) labor productivity of the home country relative to EU27. Traded is an aggregate of one-digit sector's labor productivities aggregated using sectoral gross outputs as weights. $a_{TN} \equiv a_T - a_N$. $rulc$ is the logarithm of relative unit labor costs the home country relative to the EU27 average. The balanced sample period is 1999-2020.
* Countries joining the Eurozone at some point in our sample.

The characteristics of the sectoral real exchange rates, and the average relative price of non-traded goods closely mirror the aggregate real exchange rates. In general, we see that if for a given country i, we have $\bar{q}_i > 0, (< 0)$, we also have $\bar{q}_{Ti} > 0, (< 0), \bar{q}_{Ni} > 0, (< 0)$, and in more than half of the cases $\bar{q}_{Ni} - \bar{q}_{Ti} > 0, (< 0)$. That is, if a country has a low (high) average price level relative to the European average, its non-traded goods price tends to be proportionately lower (higher) than its traded goods price, relative to the average.

The right panel of Table 1 reports standard deviations of annual real exchange rates. They range from three to eleven percent for most countries. As we would anticipate from equations (20) and (21), the standard deviation of non-traded real exchange rates exceeds that of the traded real exchange rates. We can also see some of these features in Table 2, where we report summary statistics by variable. We can see that the volatility and average level of the real exchange rate of non-traded goods exceeds that of traded goods. Similarly, the real exchange rates tend to display a non-trivial autoregressive component, consistent with the trend towards appreciation across the countries in our sample.[17]

Table 2: Variable Summary Statistics

	q	q_T	q_N	q_n	a_T	a_N	a_{TN}	$rulc$
$mean(std_i(\cdot))$	0.08	0.08	0.11	0.07	0.16	0.14	0.10	0.21
$std(mean_i(\cdot))$	0.16	0.14	0.26	0.13	0.50	0.26	0.46	0.69
$AR(1)$	0.81	0.81	0.81	0.80	0.86	0.82	0.63	0.94

Notes: All real exchange rate variables (q, q_T, q_N, qn) are expressed as home country relative to EU15. q is the expenditure-weighted log real exchange rate (an increase is an appreciation). q_T (q_N) is the real exchange rate for traded (non-traded) goods only, both relative to EU15 average (an increase is an appreciation). $q_n \equiv q_N - q_T.a_T$ (a_N) is the logarithm of traded (non-traded) labor productivity in the home country relative to EU27. Traded is an aggregate of one-digit sector's TFP levels aggregated using sectoral gross outputs as weights. *rulc* is the logarithm of relative unit labor costs of each home country relative to EU27. The balanced sample period is 1999-2020. The top row reports average time series standard deviation $(\text{std}_i(\cdot)$, where i indexes countries) and the second row standard deviation of average real exchange rates $(\text{mean}_i(\cdot)$, where i indexes countries). The bottom row reports the autocorrelation coefficient from a fixed-effects panel AR(1) regression.

Figure 4 displays some properties of the aggregate real exchange rates in our Eastern European sample. We can see that there is a substantial convergence towards the mean in the whole sample for all levels of aggregation (all goods, traded, non-traded); furthermore we see that the relative price of non-traded goods, shown in panel D, shows a noticeable stability in most countries, which reflects either a substantial comovement between the traded and non-traded components of the real exchange rate (RER), or even a convergence of these variables. At the same time, figures 5 and 6 show cross-sectional and time-series evidence of the positive comovement between the real exchange rate and relative output.

[17]Note that these are standard deviations of logs, rather than log differences.

Figure 4: Real Exchange Rates

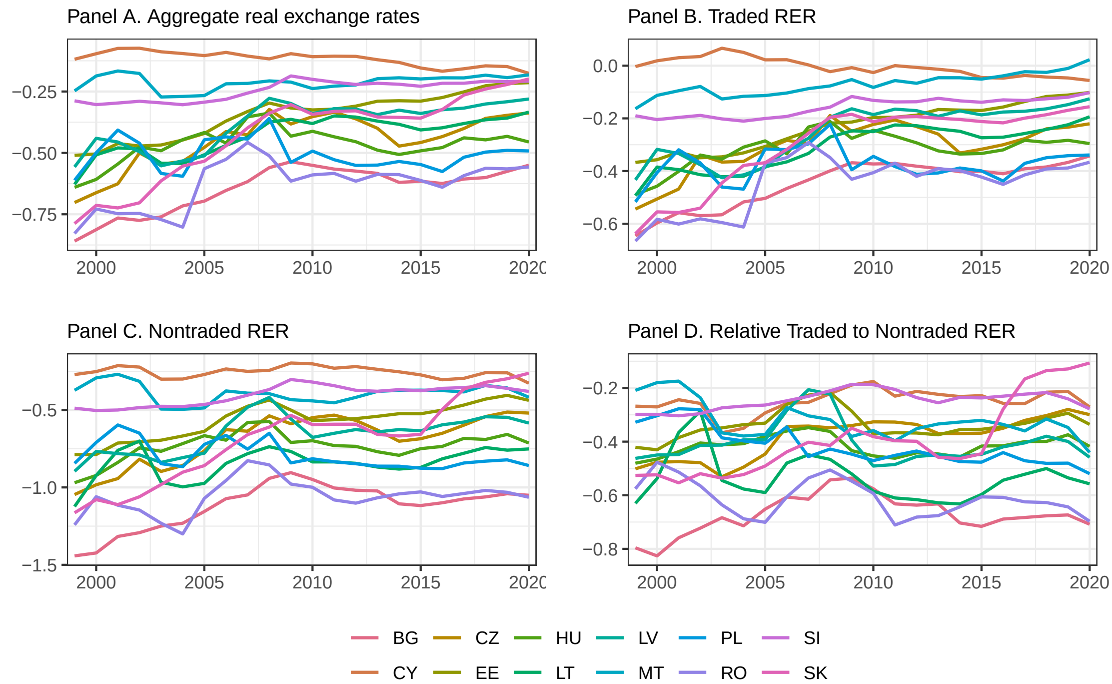


Figure 5: Real Exchange Rate and Relative GDP

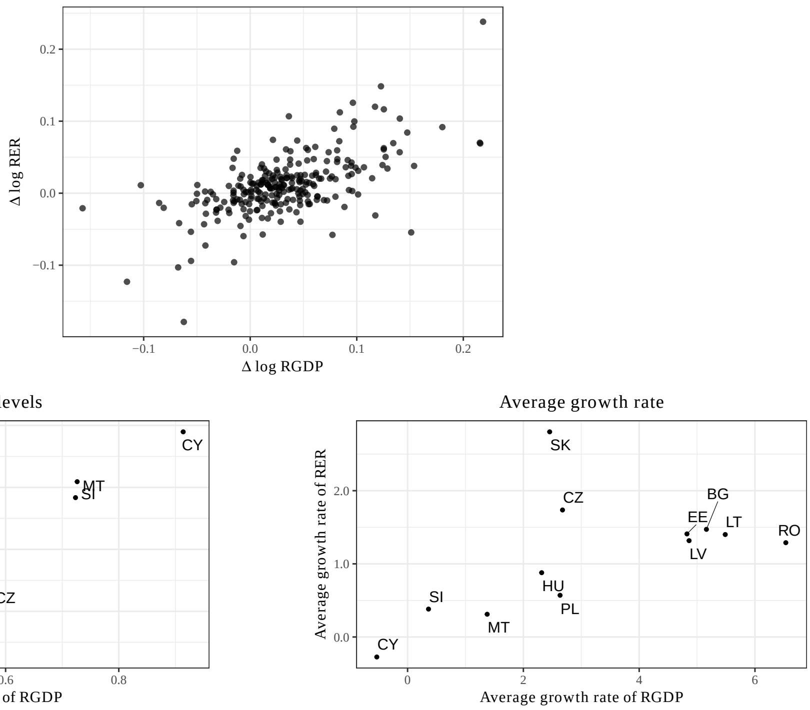
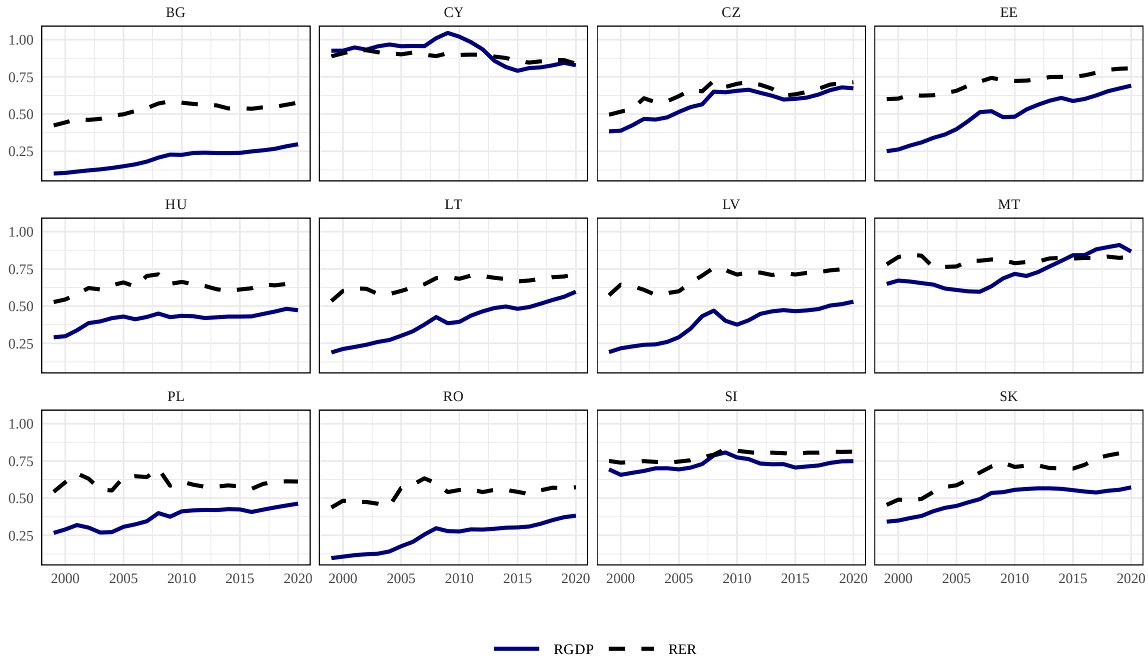


Figure 6: Real Exchange Rate (in levels) and Relative GDP by country



4.2 Productivity and unit labor costs data

We wish to associate the real exchange rate data with supply-side indicators that are suggested by the theoretical discussion above. For the latter we consider labor productivity data for the whole economy and at the sectoral level.[18] Similarly, we consider labor market conditions to account for the possibility that the real exchange rates are influenced by factors besides productivity. These are accounted for by including the unit labor costs.

We obtain indexes of real labor productivity per hour from Eurostat at the sectoral level for the single-letter NACE Rev. 2 classification. We proceed to adjust these indexes by the sectoral output level relative to the EU25 analog. To do this adjustment, we multiply each labor productivity sectoral index by the corresponding sectoral output per-hour worked from the 1997 Productivity Level Database reported by the Groningen Growth and Development Centre (GGDC) and along the lines of Berka et al. (2018) where, importantly, we adjust the levels to be expressed in terms of the EU25 sectoral output rather than the US levels as in the official data release. Once we have sectoral level adjusted indexes, we aggregate these into traded and non-traded broader-sector categories, using a weighted average of the traded and non-traded sectors with weights approximated by the sectoral contribution to the total economy value added obtained from the 2023 Productivity Level Database reported by the GGDC (see Inklaar, Marapin and Gräler, 2023, for details). For this calculation, we adapt the sectoral mapping into traded and non-traded sectors from Berka et al. (2018) into the single letter NACE Rev. 2

[18] One might want to consider TFP data directly instead of factor-specific productivity data as in Berka et al. (2018). However, in contrast to the Western Europe case, this data is not available for our sample of Eastern European countries. Thus, we use the labor productivity indexes sectoral data from Eurostat.

sectoral classification that are considered in the Eurostat, and GGDC datasets. Table 3 shows the sectors considered and their tradability categorization we use.

At the same time, we compute a measure of relative labor productivity in the traded sector with respect to the non-traded one, and express this ratio, in relative terms with respect to the analog quantity for the EU27 group. This variable can be obtained based on the relative real labor productivity of each type of aggregate (traded, non-traded) with respect to EU27 as follows:

$$RLprod = \frac{\frac{realLabProd_{T,it}}{realLabProd_{T,EUt}}}{\frac{realLabProd_{N,it}}{realLabProd_{N,EUt}}} = \frac{\frac{realLabProd_{T,it}}{realLabProd_{N,it}}}{\frac{realLabProd_{T,EUt}}{realLabProd_{N,EUt}}}.$$

In addition, we consider a measure of real relative unit labor costs, which we compute based on Nominal Unit Labor Cost data in euros from Eurostat at the sectoral level, divided by the Producer Price Index data (PPI) of each economy, which we obtain from the IMF-IFS database (and complement for the EU27 group using the industry PPI from 2018 to 2020 from Eurostat). After obtaining such real labor unit costs per hour, we divide it in each case by the same measure for the EU27 group, which gives us the real relative unit labor costs per sector.

Tables 1 (lower panel) and 2 report descriptive statistics for traded and non-traded labor productivity in the same form as reported for the real exchange rate data. In general, we see that the traded labor productivity tends to be more volatile than the non-traded one. We also illustrate the properties of these variables across time in Figure 7. We can see in Panel C that there is substantial variation in the unit labor costs over time, which justifies the inclusion of these costs as a separate determinant for the real exchange rate.

Figure 7: labor productivity by sectors and unit labor costs

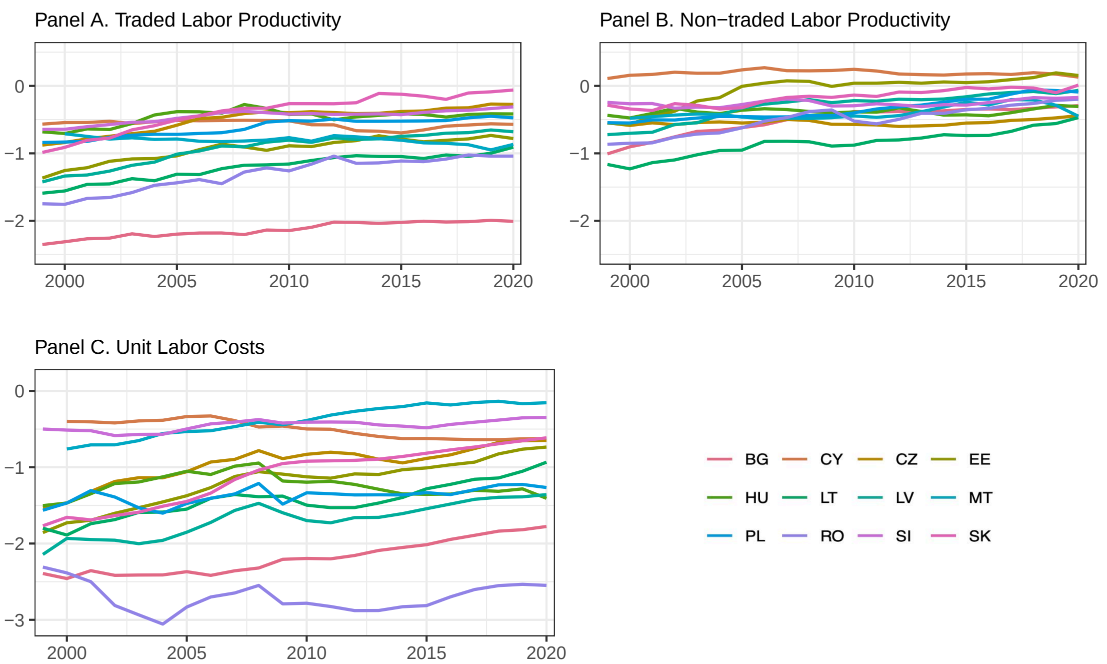


Table 3: Sectoral Classification and Tradability

NACE Rev. 2 Sector Letter	Sector Name	Tradability
A	Agriculture, forestry and fishing	T
B	Mining and quarrying	T
C	Manufacturing	T
D	Electricity, gas, steam and air conditioning supply	N
E	Water supply; sewerage, waste management and remediation activities	N
F	Construction	N
G	Wholesale and retail trade	T
H	Transportation and storage	N
I	Accommodation and food service activities	N
J	Information and communication	N
K	Financial and insurance activities	N
M	Professional, scientific and technical activities	N
N	Administrative and support service activities	N
R	Arts, entertainment and recreation	N
S	Other service activities	N
B-E	Industry (except construction)	T
G-I	Wholesale and retail trade, transport, accommodation and food services	N
M-N	Professional, scientific. services	N
R-U	Arts, entertainment, recreation, and other services	N

Notes: T and N refer to the traded and non-traded sectoral classification.

We can also summarize the relative productivities and unit labor costs by sectors. To this end, we consider population-weighted averages across the countries in our sample and illustrate the associated Eastern European region indicators over time in Figures 8 and 9. We can see that the comovement between sectoral productivities and the substantial unit labor costs variation over time we highlighted before is also visible at the regional level for both traded (T) and non-traded sectors (N).

Figure 8: Average Relative Real labor Productivity for Eastern Europe (12 countries).

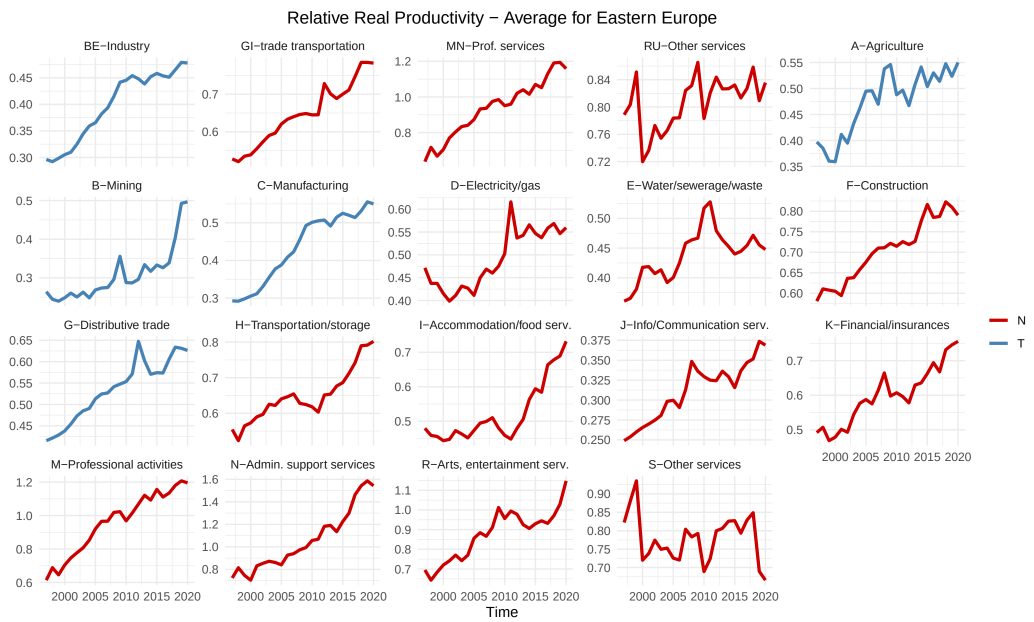
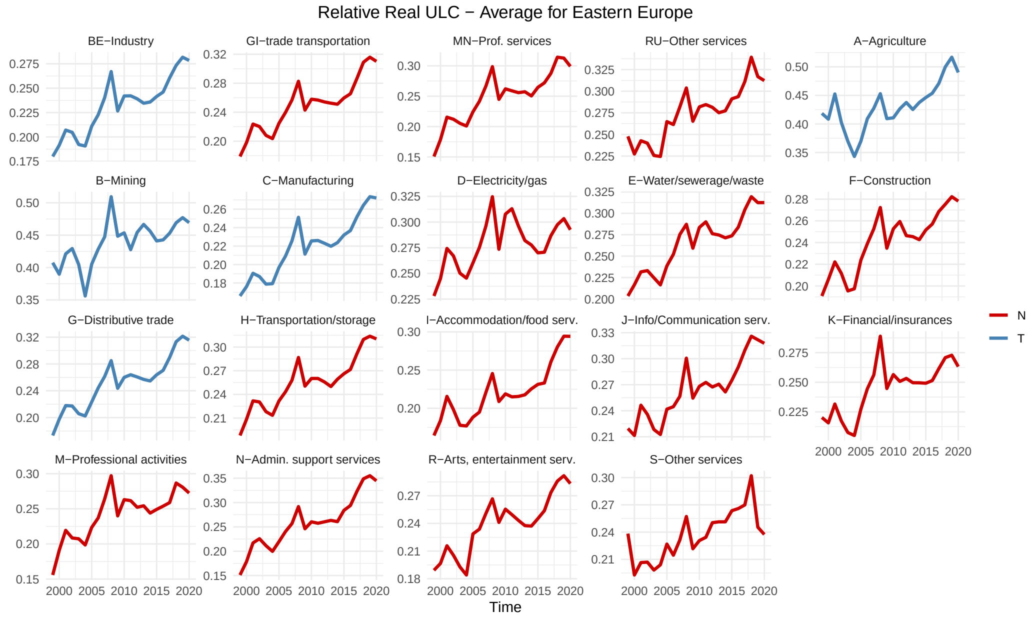


Figure 9: Average Relative Real Unit labor Cost for Eastern Europe (12 countries).



5 Real exchange rate regressions

Equation (17) in section 2 describes the drivers of the real exchange rate. We use this to motivate a regression strategy using the Eurostat real exchange rate measures. Based on our data described above, here we summarize a set of estimations to explore the relationship between real exchange rates at different levels of aggregation and the relative sectoral productivities and the labor cost dynamics.

Estimations with productivity for traded and non-traded sectors

We present an empirical setup in which the real exchange rate (RER) is dependent on the relative labor productivity of the traded and non-traded sectors, as well as the real labor unit cost (relative to the EU). We consider versions of the regression where the relative (traded to non-traded) labor productivity enters as a single variable ($RLprod$), then one in which we consider the real labor productivity of traded and non-traded sectors as separate variables (relative to EU27), and a final estimation where we consider the separate productivities, and the relative unit labor costs ($RULC$).

Our data consists of a panel with annual frequency and country-level observations (computed from sectoral data). We report panel estimations with fixed and random effects. All standard errors are computed using a panel corrected standard errors clustering method following Beck and Katz (1995). We also report the result of the Hausman test (HT) for the random effects regression (rejection of the null implies no difference between the Fixed effects and Random effects estimations, interpreted as a weak preference for the Fixed effects model).

We report estimations for the real exchange rate for all goods, a second group of estimates for the real exchange rate of traded goods, and a final for non-traded goods. Recall that the RER is defined in a way that an increase indicates a real appreciation.

The regression specifications are described as follows:

$$\log RER^j_{it} = \alpha_0 + \beta_1 \log \overbrace{\left(\frac{\frac{realLabProd_{T,it}}{realLabProd_{N,it}}}{\frac{realLabProd_{T,EUt}}{realLabProd_{N,EUt}}} \right)}^{RLprod} + \beta_2 \log \overbrace{\left(\frac{RealULC_{it}}{RealULC_{EUt}} \right)}^{RULC} + \epsilon_{ti},$$

$$\log RER^j_{it} = \alpha_0 + \beta_1 \log Lprod_{T,it} + \beta_2 \log Lprod_{N,it} + \beta_3 \log RULC_{it} + \epsilon_{ti}, \quad \text{for } j = \{All, T, N\},$$

where in the first type of regression $RLprod$ denotes the real labor productivity of the traded sector relative to the non-traded one expressed itself in relative terms with respect to the same quantity for the EU. Similarly, $RULC$ is the real unit labor cost of each country relative to the same measure in the EU. As for the second type of panel, $Lprod_T$ and $Lprod_N$ denote respectively the real labor productivity of the traded and non-traded sectors with respect to the analogous quantity for the EU.

As implied by equations (17), (20) and (21) in Section 3 above, we note that the presumptive sign on both β_1 and β_2 in the first regression is positive. A rise in traded relative to non-traded goods productivity as well as a rise in the labor wedge and/or the terms of trade —both of which enter into the relative unit labor cost, should be associated with a real exchange rate appreciation. Likewise, for the same reasons, in the second regression, we expect that β_1 and β_3 to be positive, while β_2 to be negative. We note that the estimated coefficients should be the largest for RER of non-traded goods and they are similar for the RER and RER of traded goods.

In evaluating the empirical results, it is important to consider the following two points. (1) The primitives in the model are the labor wedges for the traded and non-traded sectors. Ideally, estimation should be conducted using exogenous variables, with these labor wedges included as explanatory variables. However, since these variables are unavailable, we use unit labor cost as a proxy that combines the labor wedges. (2) Unit labor cost is not a primitive; rather, it is expressed as a function of technology and the labor wedge. But controlling for sectoral productivity coefficient estimates on unit labor cost should reflect variation in labor wedges.[19]

Table 4 shows the results for regressions for the real exchange of all goods (as dependent variable). Similarly, in the Tables 5 and 6 we report the results for the real exchange of traded and non-traded goods. The coefficients on traded and non-traded productivity have the right sign, and the former is significant. At the same time, it is important to include the relative unit cost variable which is also significant in all cases.

[19] As a caution however, we note that using unit labor cost in the estimation may introduce multicollinearity, which could lead to estimated parameters whose signs may not fully align with the theoretically consistent ones as assumed above.

Table 4: Model for the RER (all goods)

	Fixed effects				Random effects			
	(1a)	(1b)	(1c)	(1d)	(2a)	(2b)	(2c)	(2d)
$RLprod$	**0.281****	**0.198****	—	—	**0.207*****	0.093	—	—
	(0.13)	(0.08)			(0.08)	(0.04)		
$Lprod_T$	—	—	**0.397*****	**0.296*****	—	—	**0.325*****	**0.202*****
			(0.07)	(0.06)			(0.06)	(0.05)
$Lprod_N$	—	—	0.005	-0.063	—	—	0.062	0.023
			(0.08)	(0.07)			(0.07)	(0.07)
$RULC$	—	**0.298*****	—	**0.188*****	—	**0.266*****	—	**0.175*****
		(0.04)		(0.04)				(0.04)
$R^2(adj.)$	0.23	0.63	0.61	0.71	0.26	0.62	0.6	0.69
N	263	262	263	262	263	262	263	262
HT					not reject	reject	reject	reject

Notes: Dependant variable: log real exchange rate (expenditure-weighted) expressed as the country i price level relative to EU15 (an increase is an appreciation). $RLprod_i$ is the log of the traded labor productivity relative to non-traded sector for country i ($realLabProd_{T,i,t}/realLabProd_{N,i,t}$) made itself relative with respect to EU15. $Lprod_T$ is the log of an aggregation of one-letter sectoral labor productivity of traded sectors using sectoral outputs as weights. $Lprod_N$ is an analog measure for non-traded sectors. $RULC_{it}$ is the log an aggregation of sectoral level (single letter NACE rev. 2) nominal compensation of employees per hour worked for a country i as a ratio to the Producer Price Index and expressed relative to EU27. The nominal ULC involved in the calculations is sourced in euros for all countries. The data sample period is 1999-2020. Fixed effects is a panel regression with countries as cross-sections. Random effects is a random effects panel with countries as cross-sections. All standard errors are computed using a panel corrected standard errors method (Beck and Katz, 1995) under the assumption of period correlation (cross-sectional clustering). Standard errors are in parentheses. The estimate of the constant is not reported. Rejection of the null in the Hausman test (HT) implies a statistical difference between the FE and RE, viewed as a preference for FE.

Table 5: Model for the RER of Traded goods

	Fixed effects				Random effects			
	(1a)	(1b)	(1c)	(1d)	(2a)	(2b)	(2c)	(2d)
$RLprod$	**0.245***	**0.168****	—	—	**0.171****	0.063	—	—
	(0.13)	(0.08)			(0.07)	(0.04)		
$Lprod_T$	—	—	**0.36*****	**0.28*****	—	—	**0.295*****	**0.19*****
			(0.06)	(0.05)			(0.05)	(0.05)
$Lprod_N$	—	—	0.041	-0.012	—	—	0.092	0.064
			(0.06)	(0.06)			(0.06)	(0.06)
$RULC$	—	**0.276*****	—	**0.149*****	—	**0.241*****	—	**0.139*****
		(0.04)		(0.04)				(0.03)
$R^2(adj.)$	0.23	0.61	0.65	0.71	0.26	0.59	0.63	0.69
N	263	262	263	262	263	262	263	262
HT					not reject	reject	reject	reject

Notes: Dependant variable: log real exchange rate for traded goods (expenditure-weighted) expressed as the country i price level relative to EU15 (an increase is an appreciation). $RLprod_i$ is the log of the traded labor productivity relative to non-traded sector for country i ($realLabProd_{T,i,t}/realLabProd_{N,i,t}$) made itself relative with respect to EU15. $Lprod_T$ is the log of an aggregation of one-letter sectoral labor productivity of traded sectors using sectoral outputs as weights. $Lprod_N$ is an analog measure for non-traded sectors. $RULC_{it}$ is the log of an aggregation of sectoral level (single letter NACE rev. 2) nominal compensation of employees per hour worked for a country i as a ratio to the Producer Price Index and expressed relative to EU27. The nominal ULC involved in the calculations are sourced in euros for all countries. The data sample period is 1999-2020. Fixed effects is a panel regression with countries as cross-sections. Random effects is a random effects panel with countries as cross-sections. All standard errors are computed using a panel corrected standard errors method (Beck and Katz, 1995) under the assumption of period correlation (cross-sectional clustering). Standard errors are in parentheses. The estimate of the constant is not reported. Rejection of the null in the Hausman test (HT) implies a statistical difference between the FE and RE, viewed as a preference for FE.

Table 6: Model for the RER of Non-traded goods

	Fixed effects				Random effects			
	(1a)	(1b)	(1c)	(1d)	(2a)	(2b)	(2c)	(2d)
$RLprod$	**0.359****	**0.248****	—	—	**0.308*****	0.14	—	—
	(0.17)	(0.12)			(0.12)	(0.06)		
$Lprod_T$	—	—	**0.49*****	**0.321*****	—	—	**0.41*****	**0.19****
			(0.13)	(0.12)			(0.1)	(0.09)
$Lprod_N$	—	—	-0.033	-0.147	—	—	0.048	0.001
			(0.15)	(0.13)			(0.12)	(0.11)
$RULC$	—	**0.4*****	—	**0.317*****	—	**0.375*****	—	**0.292*****
		(0.07)		(0.08)				(0.06)
$R^2(adj.)$	0.19	0.54	0.43	0.56	0.23	0.57	0.46	0.61
N	263	262	263	262	263	262	263	262
HT					not reject	reject	reject	reject

Notes: Dependent variable: log real exchange rate for non-traded goods (expenditure-weighted) expressed as the country i price level relative to EU15 (an increase is an appreciation). $RLprod_i$ is the log of the traded labor productivity relative to non-traded sector for country i ($realLabProd_{T,i,t}/realLabProd_{N,i,t}$) made itself relative with respect to EU15. $Lprod_T$ is the log of an aggregation of one-letter sectoral labor productivity of traded sectors using sectoral outputs as weights. $Lprod_N$ is an analog measure for non-traded sectors. $RULC_{it}$ is the log of an aggregation of sectoral level (single letter NACE rev. 2) nominal compensation of employees per hour worked for a country i as a ratio to the Producer Price Index and expressed relative to EU27. The nominal ULC involved in the calculations are sourced in euros for all countries. The data sample period is 1999-2020. Fixed effects is a panel regression with countries as cross-sections. Random effects is a random effects panel with countries as cross-sections. All standard errors are computed using a panel corrected standard errors method (Beck and Katz, 1995) under the assumption of period correlation (cross-sectional clustering). Standard errors are in parentheses. The estimate of the constant is not reported. Rejection of the null in the Hausman test (HT) implies a statistical difference between the FE and RE, viewed as a preference for FE.

Additional explanatory variables

We consider specifications with additional controls, namely fiscal indicators (relative government expenditure and deficit), and financial indicators (relative long-run interest rates). The full set of regressions is shown in Appendix C. Here we report a summarized output of the models where the financial conditions are introduced in the model and an interaction with a Global Financial Crisis (GFC) dummy is included. This leads to an improvement in the significance of the sectoral productivity indicators. As shown in equations (17), (20), and (21), capital inflows increase the real exchange rate. Here, this interaction term of relative long-run interest rates and GFC dummy is expected to have a negative coefficient, as it represents capital outflows for Eastern European countries.

The results are shown in Table 7 for the real exchange rate of all goods, and in Tables 8 and 9 for the real exchange rate of traded and non-traded goods.

In this case, after including additional economic variables as controls the results indicate not only the right signs for the relative sectoral productivities and labor unit costs, but also their significance. In addition, the financial conditions, measured either via the long-run interest rate spread vis-a-vis the Euro area (EU27) or the interaction of the spread with GFC dummy becomes significant in the panels for the real exchange rate of traded and non-traded goods.

Table 7: Model for the RER (all goods)

	Fixed effects				Random effects			
	(1a)	(1b)	(1c)	(1d)	(2a)	(2b)	(2c)	(2d)
$RLprod$	**0.189*****	**0.192*****	—	—	0.068	**0.08***	—	—
	(0.05)	(0.05)			(0.05)	(0.05)		
$Lprod_T$	—	—	**0.186*****	**0.19*****	—	—	**0.095***	**0.107***
			(0.07)	(0.06)			(0.06)	(0.06)
$Lprod_N$	—	—	**-0.193*****	**-0.195*****	—	—	-0.05	-0.067
			(0.07)	(0.07)			(0.07)	(0.07)
$RULC$	**0.283*****	**0.284*****	**0.286*****	**0.286*****	**0.246*****	**0.25*****	**0.232*****	**0.238*****
	(0.04)	(0.03)	(0.05)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)
LR	0.0016	0.0039	0.0016	0.0039	0.0019	0.0039	0.0019	0.0040
	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)
$LR \times GFC$	—	-0.0048	—	-0.0048	—	-0.0042	—	-0.0043
		(0.003)		(0.003)		(0.003)		(0.003)
$R^2(adj.)$	0.63	0.64	0.63	0.64	0.9	0.9	0.9	0.89
N	214	214	214	214	214	214	214	214
HT					reject	reject	reject	reject

Notes: Dependent variable: log real exchange rate (expenditure-weighted) expressed as the country i price level relative to EU15 (an increase is an appreciation). $RLprod_i$ is the log of the traded labor productivity relative to non-traded sector for country i ($realLabProd_{T,i,t}/realLabProd_{N,i,t}$) made itself relative with respect to EU15. $Lprod_T$ is the log of an aggregation of one-letter sectoral labor productivity of traded sectors using sectoral outputs as weights. $Lprod_N$ is an analog measure for non-traded sectors. $RULC_{it}$ is the log of an aggregation of sectoral level (single letter NACE rev. 2) nominal compensation of employees per hour worked for a country i as a ratio to the Producer Price Index and expressed relative to EU27. The nominal ULC involved in the calculations are sourced in euros for all countries. LR is the spread between the real long-run (10-year) bonds rate of each country relative to EU (EU19). The rates are made real by subtracting CPI inflation. GFC is a dummy variable taking the value of 1 for the years 2007-2009. The data sample period is 1999-2020. Fixed effects is a panel regression with countries as cross-sections. Random effects is a random effects panel with countries as cross-sections. All standard errors are computed using a panel corrected standard errors method (Beck and Katz, 1995) under the assumption of period correlation (cross-sectional clustering). Standard errors are in parentheses. The estimate of the constant is not reported. Rejection of the null in the Hausman test (HT) implies a statistical difference between the FE and RE, viewed as a preference for FE.

Table 8: Model for the RER of Traded goods

	Fixed effects				Random effects			
	(1a)	(1b)	(1c)	(1d)	(2a)	(2b)	(2c)	(2d)
$RLprod$	**0.136*****	**0.137*****	—	—	0.042	0.052	—	—
	(0.05)	(0.05)			(0.04)	(0.04)		
$Lprod_T$	—	—	**0.158*****	**0.159*****	—	—	**0.084***	**0.095***
			(0.06)	(0.06)			(0.05)	(0.05)
$Lprod_N$	—	—	-0.1	-0.101	—	—	0.004	-0.009
			(0.07)	(0.07)			(0.06)	(0.06)
$RULC$	**0.267*****	**0.268*****	**0.242*****	**0.242*****	**0.233*****	**0.237*****	**0.202*****	**0.207*****
	(0.03)	(0.03)	(0.05)	(0.05)	(0.03)	(0.03)	(0.04)	(0.04)
LR	**0.0030***	0.0040	**0.0030***	0.0041	**0.0033***	0.0040	**0.0032***	0.0041
	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)
$LR \times GFC$	—	-0.0020	—	-0.0021	—	-0.0015	—	-0.0017
		(0.003)		(0.003)		(0.003)		(0.003)
$R^2(adj.)$	0.64	0.64	0.64	0.64	0.91	0.9	0.91	0.9
N	214	214	214	214	214	214	214	214
HT					reject	reject	reject	reject

Notes: Dependant variable: log real exchange rate for traded goods (expenditure-weighted) expressed as the country i price level relative to EU15 (an increase is an appreciation). $RLprod_i$ is the log of the traded labor productivity relative to non-traded sector for country i ($realLabProd_{T,i,t}/realLabProd_{N,i,t}$) made itself relative with respect to EU15. $Lprod_T$ is the log of an aggregation of one-letter sectoral labor productivity of traded sectors using sectoral outputs as weights. $Lprod_N$ is an analog measure for non-traded sectors. $RULC_{it}$ is the log of an aggregation of sectoral level (single letter NACE rev. 2) nominal compensation of employees per hour worked for a country i as a ratio to the Producer Price Index and expressed relative to EU27. The nominal ULC involved in the calculations are sourced in euros for all countries. LR is the spread between the real long-run (10-year) bonds rate of each country relative to EU (EU19). The rates are made real by subtracting CPI inflation. GFC is a dummy variable taking the value of 1 for the years 2007-2009. The data sample period is 1999-2020. Fixed effects is a panel regression with countries as cross-sections. Random effects is a random effects panel with countries as cross-sections. All standard errors are computed using a panel corrected standard errors method (Beck and Katz, 1995) under the assumption of period correlation (cross-sectional clustering). Standard errors are in parentheses. The estimate of the constant is not reported. Rejection of the null in the Hausman test (HT) implies a statistical difference between the FE and RE, viewed as a preference for FE.

Table 9: Model for the RER of Non-traded goods

	Fixed effects				Random effects			
	(1a)	(1b)	(1c)	(1d)	(2a)	(2b)	(2c)	(2d)
$RLprod$	**0.269****	**0.277*****	—	—	0.124	**0.138***	—	—
	(0.11)	(0.1)			(0.08)	(0.08)		
$Lprod_T$	—	—	0.197	**0.207***	—	—	0.096	0.107
			(0.12)	(0.12)			(0.09)	(0.09)
$Lprod_N$	—	—	**-0.387*****	**-0.393*****	—	—	-0.135	-0.152
			(0.14)	(0.14)			(0.11)	(0.11)
$RULC$	**0.356*****	**0.359*****	**0.441*****	**0.442*****	**0.332*****	**0.335*****	**0.344*****	**0.349*****
	(0.07)	(0.07)	(0.1)	(0.09)	(0.06)	(0.06)	(0.07)	(0.07)
LR	-0.0010	0.0048	-0.0010	0.0046	-0.0004	0.0051	-0.0003	0.0051
	(0.003)	(0.005)	(0.003)	(0.005)	(0.003)	(0.005)	(0.003)	(0.005)
$LR \times GFC$	—	**-0.0117****	—	**-0.0114****	—	**-0.0112****	—	**-0.0111****
		(0.005)		(0.005)		(0.005)		(0.005)
$R^2(adj.)$	0.47	0.48	0.48	0.49	0.78	0.78	0.79	0.79
N	214	214	214	214	214	214	214	214
HT					reject	reject	reject	reject

Notes: Dependent variable: log real exchange rate for non-traded goods (expenditure-weighted) expressed as the country i price level relative to EU15 (an increase is an appreciation). $RLprod_i$ is the log of the traded labor productivity relative to non-traded sector for country i ($realLabProd_{T,i,t}/realLabProd_{N,i,t}$) made itself relative with respect to EU15. $Lprod_T$ is the log of an aggregation of one-letter sectoral labor productivity of traded sectors using sectoral outputs as weights. $Lprod_N$ is an analog measure for non-traded sectors. $RULC_{it}$ is the log of an aggregation of sectoral level (single letter NACE rev. 2) nominal compensation of employees per hour worked for a country i as a ratio to the Producer Price Index and expressed relative to EU27. The nominal ULC involved in the calculations are sourced in euros for all countries. LR is the spread between the real long-run (10-year) bonds rate of each country relative to EU (EU19). The rates are made real by subtracting CPI inflation. GFC is a dummy variable taking the value of 1 for the years 2007-2009. The data sample period is 1999-2020. Fixed effects is a panel regression with countries as cross-sections. Random effects is a random effects panel with countries as cross-sections. All standard errors are computed using a panel corrected standard errors method (Beck and Katz, 1995) under the assumption of period correlation (cross-sectional clustering). Standard errors are in parentheses. The estimate of the constant is not reported. Rejection of the null in the Hausman test (HT) implies a statistical difference between the FE and RE, viewed as a preference for FE.

Consistency with the testable implications from the structural model We can see that the panel regressions in these tables broadly satisfy the testable conditions implied by the structural model of Section 3.2.3. Table 10 provides an explanation. The simplest specification in Tables 4 to 6 yields correct signs that are consistent across different versions of real exchange rates (all goods, traded goods, non-traded goods). As predicted, the absolute value of the coefficients falls as unit labor costs are added as a regressor. On the other hand, this simple setup does not deliver a larger estimated coefficient (in absolute value) on non-traded sector productivity, or generate higher magnitude of coefficients for all variables when the dependent variable is the real exchange rate of non-traded goods. But these issues are resolved in the more complete specifications with additional controls. In particular, by including the financial controls as in our baseline estimation in Tables 7 to 9 we find estimates that are virtually all consistent with all the predictions of the model. Similarly, the alternative specifications reported in the Appendix C, with additional demand side variables (Tables 12 to 14), with capital inflows as a substitute for the long-run rates (Tables 15 to 17), and with the relative GDP per capita as a control (Tables 18 to 20) are largely consistent with the model predictions.

Table 10: Model testable conditions in the panel estimations

		Panel specifications				
		Simplest (Tables 4–6)	Baseline (Tables 7–9)	Fiscal variables (Tables 12–14)	Capital inflows (Tables 15–17)	Relative GDP (Tables 18–20)
1	β signs: Positive for T sector productivity, negative for N sector ($\beta_T > 0$, $\beta_N < 0$)	✓	✓	✓	✓	✓
2	$\lvert\beta_N\rvert > \lvert\beta_T\rvert$	×	$✓^{-}$	$✓^{-}$	×	✓
3	Consistent coefficient signs for $y = \{RER, RER_T, RER_N\}$	✓	✓	✓	✓	✓
4	Larger scale coefs. if $y = RER_N$; similar scale otherwise	×	✓	✓	✓	✓
5	Coefs. smaller in absolute value if ULC is added to panel*	✓	–	–	–	–

Notes: A superscript "−" indicates the condition holds in most but not all cases (e.g., $✓^{-}$). The results of the last three columns are shown in Appendix C.

* Fact 5 holds in all significant cases (coefficients). Likewise, this fact also holds broadly for the setups with more controls. However, this is only visible in the simplest specification tables as for other reported tables we always include the ULC and focus on marginally adding other controls.

6 Quantitative evaluation of the model

We now return to the theoretical model to ask whether it can account for the historical evolution of the real exchange rate, GDP, and other macro aggregates in the Eastern European data. The model is extremely sparse —there are just two countries and two sectors in each country. There are no trade or financial frictions, and except for measures of the labor wedge, as described in Section 2 above, there are no other distortions. Preferences are homothetic, so differential income elasticities play no role in the baseline model. Thus, the exercise here should be seen as an exploration of the ability of a minimally parameterized general equilibrium model to account for the joint behaviour of relative real exchange rates and GDP in the region.

Our simulation strategy is to take the observed labor productivities by sector as in the data, for both regions, and use these as an input in the model. We then compare the model solution with the data for the full sample years. The measure of success of the model is represented by the degree to which the simulated model can fit the data, both in levels and changes over the sample years.

Table 11 reports the minimal calibration used for the model. All parameters and elasticities are identical across countries except for the labor wedge in traded goods as described below. The share of produced traded goods in the retail traded goods consumption aggregate (for both home and foreign goods) is set at $v = 0.5$, following Burstein et al. (2003). Ω is set so that the share of the traded goods share becomes 0.5 as is consistent with the data. The population share of Western Europe is set at $n = 0.78$, to match the data or relative population size. The elasticity terms λ, ψ, and μ are taken from Berka et al. (2018).

To come close to matching the data, it is important to take a stand on the size of the sectoral labor wedges. Our regression estimates indicate that sectoral labor productivity alone is insufficient to account for the movement in real exchange rates in the Eastern European data. The importance of the relative unit labor cost in the regressions suggests the need to allow for differential labor wedges across regions with the calibration. In reality, it is likely that there have been substantial labor market distortions in Eastern Europe, unrelated to measures of labor productivity.[20] In order to allow for these distortions, we calibrate the labor wedge in the traded good sector in the home country so as to match the model solution for the relative unit labor cost in the initial period. In the baseline solution, this parameter is then kept constant for all years in the sample. Given this matching of the initial simulated relative ULC series with the data, we can then see how close the simulated series of real exchange rates and GDPs match those of the data.

Table 11: Model Calibration

	Parameter
$n = 0.78$	Size of Western European countries
$\Omega = 0.75$	Share of traded goods on final consumption aggregate
$\gamma = 1 - x(1 - n)$	Share of foreign traded goods on traded consumption aggregate
$v = 0.5$	Share of wholesale traded good in C_T
$x = 1$	Home bias parameter (1: No home bias in traded goods)
$\lambda = 8$	Elasticity of substitution between H and F retail traded goods
$\mu = 0.25$	Elasticity of substitution between traded good and retail service
$\psi = 0.7$	Elasticity of substitution between traded and non-traded good
$\sigma = 2$	Inverse elasticity of inter-temporal substitution
$\phi = 1$	Inverse Frisch elasticity of labor supply
$\alpha = \frac{1}{3}$	Labor share (1 minus)
$\theta = \{0, 0.059\}$	Capital flows (0: no capital flows; 0.059: positive capital inflows)

Model simulation We now simulate the model using the measured sectoral labor productivity series as proxies for $A_{T,H}$ and $A_{N,H}$ in the model. The model is solved period by period. In the baseline version of the model we assume $\theta = 0$, so there are no transfers from the foreign to the home country.

Figure 10 illustrates the 'Penn Effect' in the data and the model. The left hand panel shows the scatter plot of GDP and the real exchange rate across all countries and time periods for the simulated model and the data. It is apparent that there is a strong Penn effect in both series, although the model does not have the same curvature as we see in the data. The right hand panel shows the same relationship, but at the aggregate level over time periods. At this level of aggregation, there is a greater concordance between model and data.

[20]This view is also supported by the measures in Piton (2021).

Figure 10: Penn Effect in the model simulations and in the data

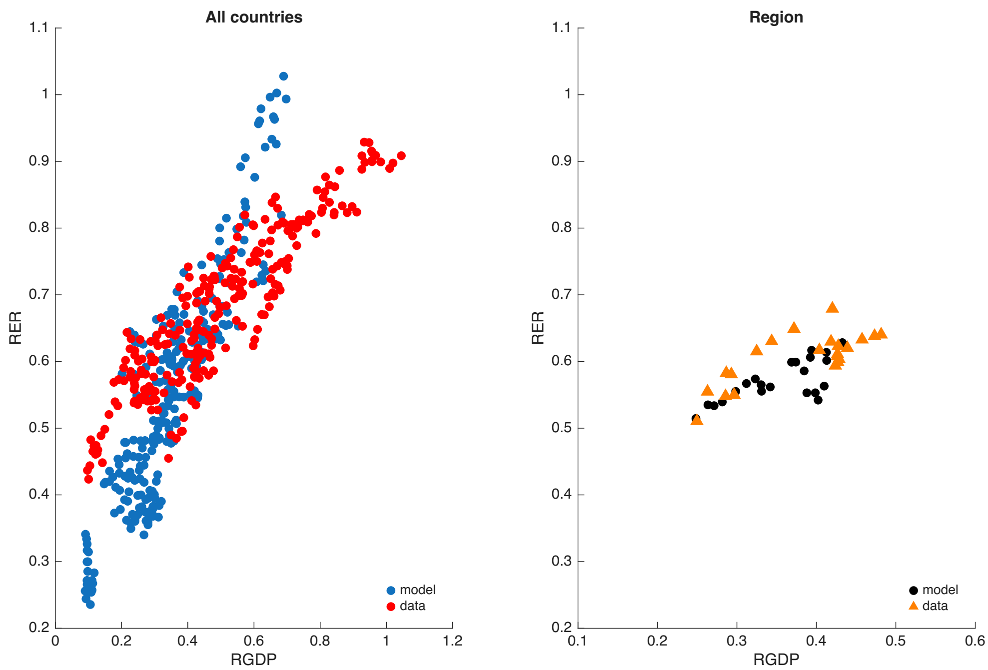
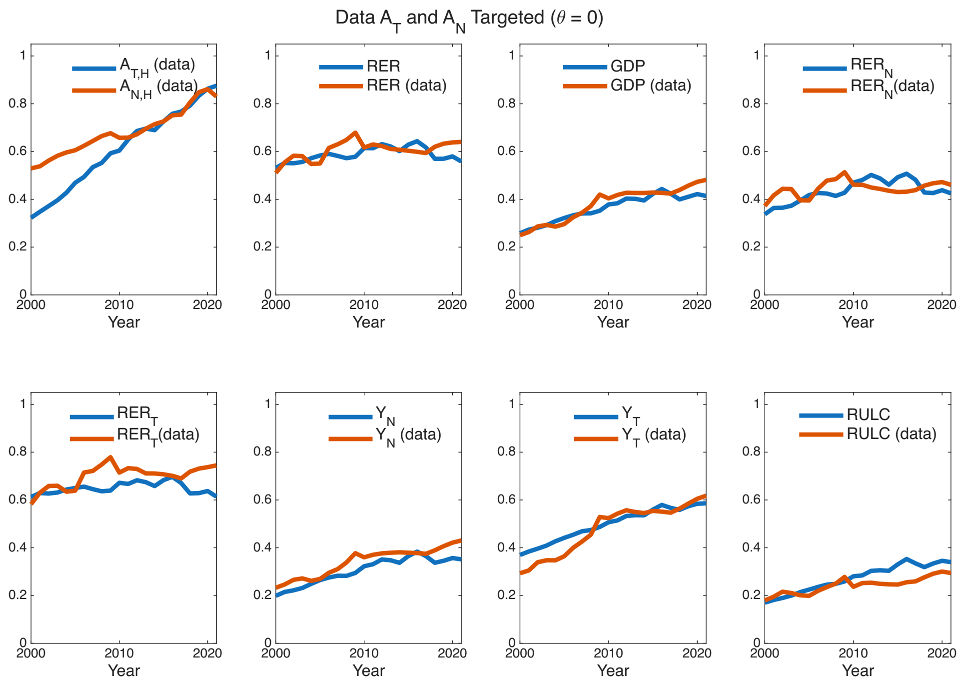


Figure 11 illustrates the data and model historical sample path comparison for the baseline case of the model using the population weighted average across countries both in the data and the model. We conduct this comparison for aggregate and sectoral real exchange rates, aggregate and sectoral GDP, and for the measure of relative unit labor cost, which were an important explanatory variable in the regression estimates. We note that all variables are measured relative to the EU27 means.

Figure 11: Model with observed productivities in traded and non-traded sectors

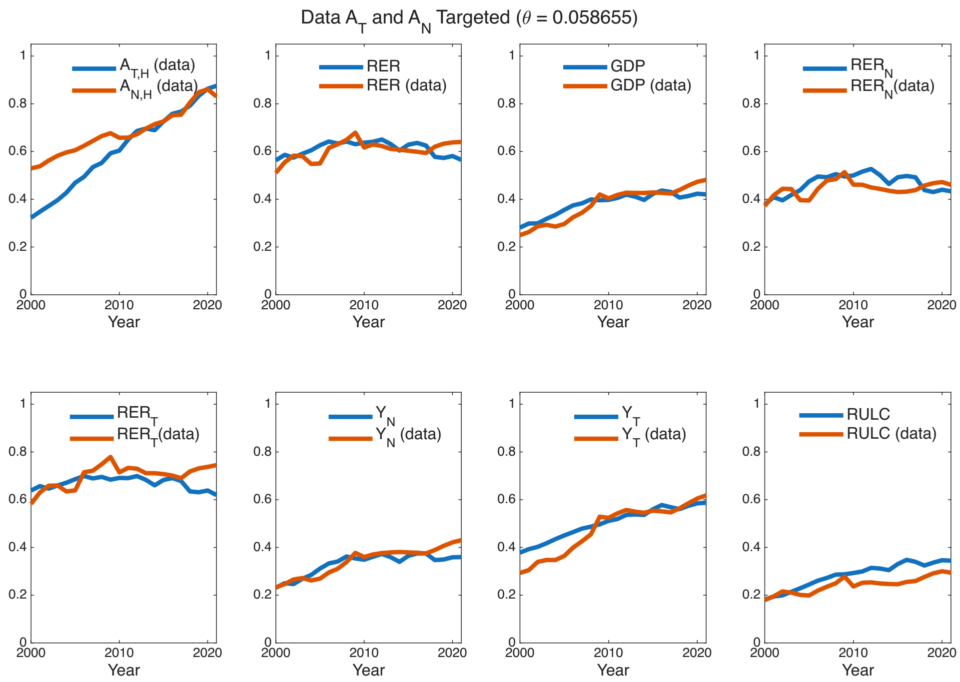


The top left panel displays the data for labor productivity in the traded and non-traded sectors for the average across the Eastern European countries. Note that the scale in all panels in the figure is the same, in each case indicating that the variable is measured relative to the EU27. For instance, the GDP panel shows that GDP per capita for Eastern Europe began at approximately 25 percent of the EU27 average. The simulated model matches closely the levels of aggregate and sectoral GDP as well as the overall real exchange rate and the sectoral real exchange rates, both in terms of levels and time variation over the sample period. In the second and third from left top panel, we see that the model is surprisingly successful in matching the rapid rise in the real exchange rate and GDP at the beginning of the sample, and the subsequent leveling off in the real exchange rate (with some fluctuations) despite the continuing convergence in GDP. The key feature behind this seems to be the rapid recovery in non-traded goods productivity after the GFC and EU crisis, relative to the relatively smooth growth in traded good productivity. As described in Section 3 above, the rise in the growth rate of non-traded productivity imparts a negative force on the real exchange rate. In the data during the first half of the sample, traded goods productivity growth strongly outpaced non-traded goods productivity growth, while after 2008 both growth rates were similar, accounting for the flattening out of the real exchange rate in the model.

We note that despite the slowdown in the real exchange rate in the model, the simulations still account for the continuing growth in both traded and non-traded output. The calibration in Table 11 is consistent with the results of Section 3, where the condition $\sigma\Xi < 1$ implies that traded and non-traded goods are effectively Edgeworth complements. While productivity growth in traded and non-traded sectors have opposite effects on the real exchange rate, they move the sectoral output levels in the same direction. Thus, though the real exchange rate stagnated after 2008, output in each sector continued to grow.

Figure 12 adds to the baseline model by including capital flows into the model. Capital flows are introduced as a transfer in the balance of payments condition of the model, and their presence in the model is governed by the parameter θ. We pin down this parameter with a minimum distance estimation that minimizes the difference between both sides of the equation (14), where the left-hand side corresponds to the observed capital flows for the region, and the right-hand side is endogenously driven by the parameters that include θ.

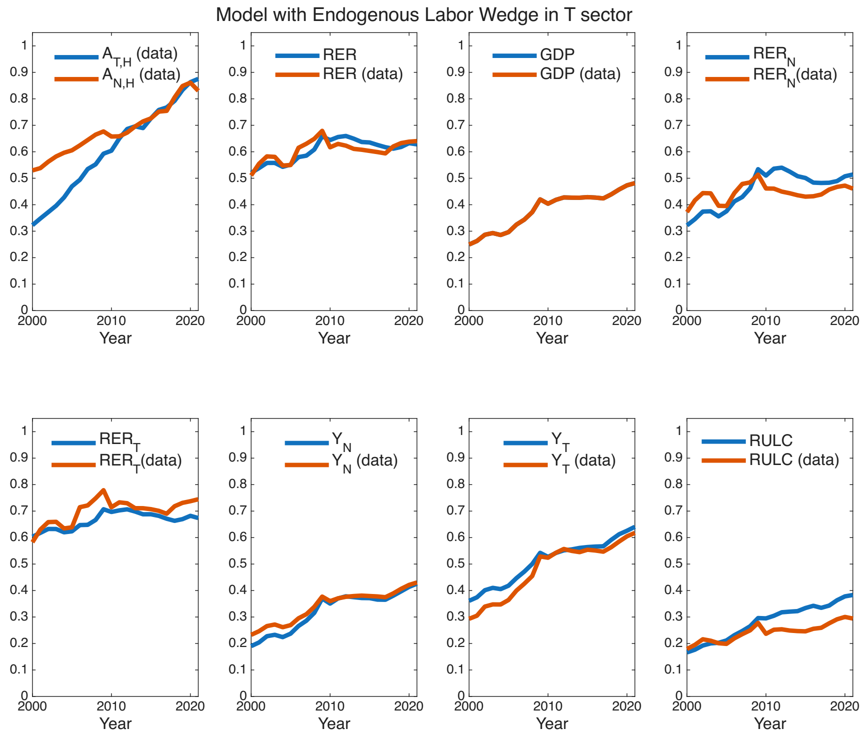
Figure 12: Model with observed productivities in traded and non-traded sectors and capital inflows



Even though the correspondence between data and model is quite similar to Figure 11, capital flows significantly improve the fit of the real exchange rate. In particular, the drop in capital inflows after the GFC help to better explain the slowdown in real exchange rate convergence after the crisis, relative to the model with productivity drivers alone. On the other hand, capital inflows do not appreciably affect the fit of the model-based real GDP with the data.

While Figure 11 assumes a constant labor wedge, which is set to match the initial observed unit labor cost, we explore an alternative hypothesis by allowing for a time-varying labor wedge. The labor wedge may be interpreted as the presence of labor market distortions, markups, or other frictions that affect the overall supply of labor. In reality, this wedge is unlikely to be constant over time. We take our direction from Berka and Devereux (2013), who show that among both Western European and Eastern European countries, the path of GDP alone explains a substantial share of the trend in relative real exchange rates. Accordingly, we set the path of the traded goods labor wedge so as to match the value of relative GDP over the sample. Figure 13 illustrates the sample simulation results for the real exchange rate, the sectoral GDP and sectoral real exchange rates, and the relative unit labor costs. We see that adjusted in this way, the simulations obtain a significantly closer match to the sample data. While aggregate GDP is matched by construction, sectoral GDPs follow the data closely. In addition, the real exchange rate inferred from this simulation is almost identical to the historical sample path and very closely matches the slowdown in real exchange rate convergence around the GFC. Figure 15 (left-hand panel) plots the inferred path of the traded good labor wedge underlying this simulation. We see that the wedge starts at a considerably elevated level, before dropping sharply in the early 2000's, and then fluctuating around a relative stable value thereafter. The fact that an addition of the inferred labor wedge improves the simulation fit of the model real exchange rate dovetails well with the regression estimates in Section 5 above, which suggest that the dynamics of the labor wedge (as part of the drivers of the RULC) play a significant role in real exchange rate trends in Eastern Europe.

Figure 13: Model with observed productivities in traded and non-traded sectors and an endogenous traded sector wedge



We may ask to what degree the labor wedge alone can explain the real exchange rate movement over the sample? To this end, Figure 14 sets the relative sectoral productivity constant at their mean levels, and again sets the traded goods labor wedge so as to match the movement in relative GDP. Here we see that the model still matches the average real exchange rate quite well, but misses out on the dynamics. The implied real exchange rate is too low in the early part of the sample, since the sample mean productivity in the traded goods sector is lower than that in the non-traded goods sector, and then the real exchange rate is too high in the later part of the sample, since the continuing convergence of relative GDP drives a greater than warranted real appreciation, without taking account of the fact that traded goods and non-traded goods productivity display equal growth rates after the GFC.

Figure 14: Model with constant productivities in traded and non-traded sectors and an endogenous traded sector wedge

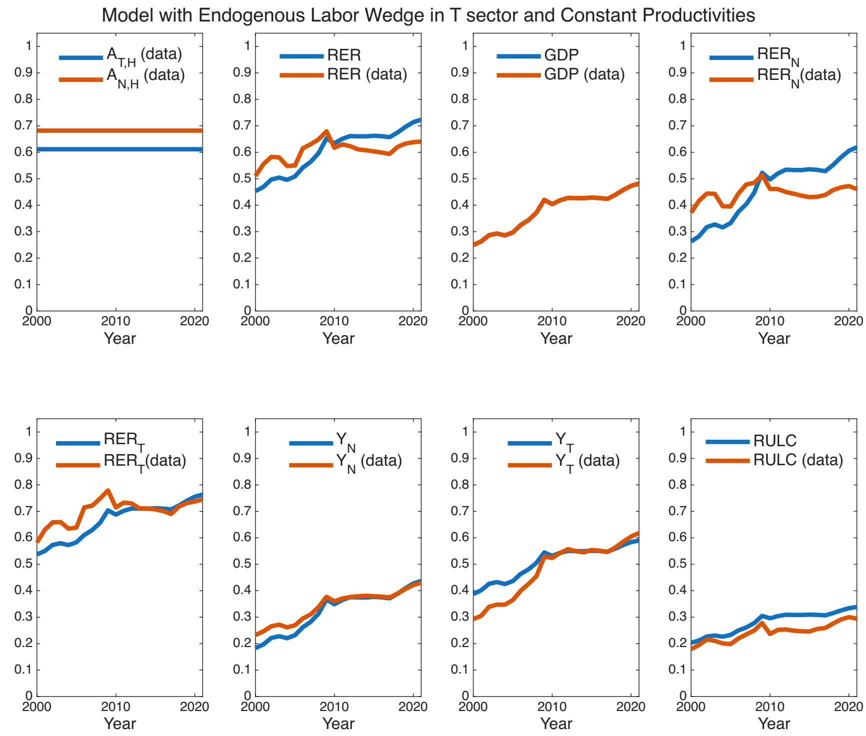
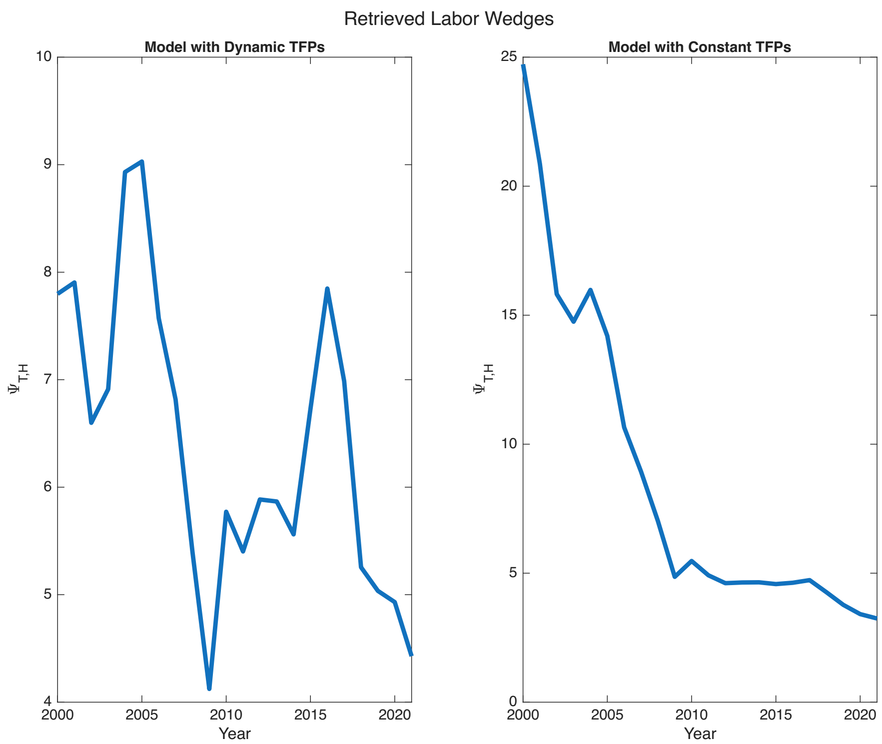


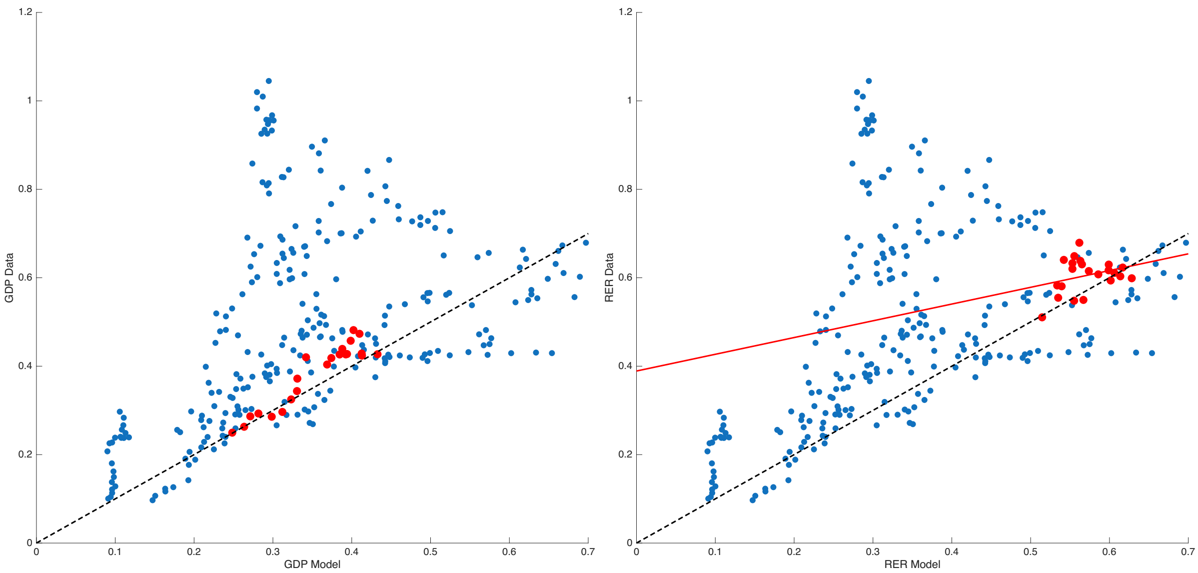
Figure 15: Retrieved labor wedges in traded sectors associated to models that target GDP



Figures 16 presents an alternative perspective. The figure illustrates the relationship between the model simulations for GDP and the real exchange rate and the equivalent values in the data when sectoral productivities represent the only driving inputs. Each data point in the scatter plots represents the country-year representation for each country over the whole sample period. The red-filled circles represent the equivalent for the weighted average over all countries. Note that all variation in the model is coming from time and country variation in productivity levels in traded and non-traded goods sectors, so it is not to be expected that there should be a perfect fit along the 45-degree line. Although there is substantial volatility, there is a clear positive association between the model and data. That said, the fit is more obvious for GDP than the real exchange rate.

On the other hand, figures 17 and 18 show the results on a country-by-country basis for the real exchange rate and GDP, where in each case the country model is driven only by country-specific sectoral productivity. The results vary considerably by country. The main outliers are Cyprus and Malta, where both GDP and the real exchange rate are significantly higher than inferred from levels of sectoral productivity. Aside from these two, Figure 17 shows that the model-based GDP captures the data well for Czech Republic, Hungary, Poland, Slokavia, and Romania, and does a reasonable job for the other countries. For most countries except Hungary, the inferred level of GDP is lower than measured in the data. Figure 18 shows the analogous comparison for the real exchange rate. The fit is very good for Latvia, Poland and Slovakia. Again, except for Czech Republic and Hungary, the model inferred real exchange rate falls short of that of the data.

Figure 16: GDP and RER in the data and simulated models (for individual countries)



Note: In this figure, the dashed line is a 45-degree line. The red line in the right panel is a regression line calculated with the red dots of the same plot. The red dots denote data for the region and the blue ones for individual countries.

Figure 17: GDP time series the data and simulated models (for individual countries)

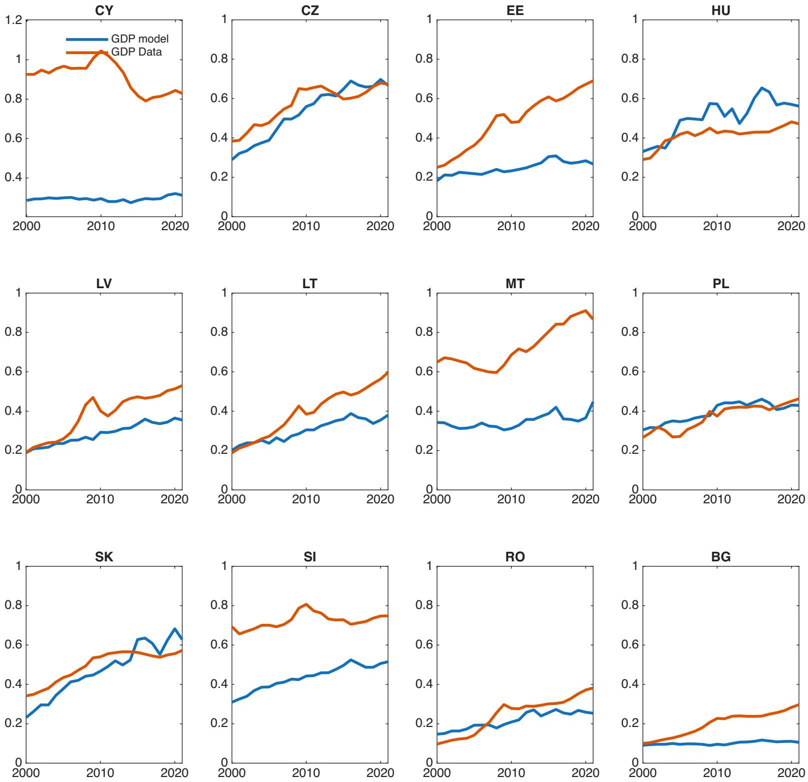


Figure 18: RER time series the data and simulated models (for individual countries)

Note: The yellow line in some selected subplots denotes the nominal effective exchange rate.

Figure 18 also reports the nominal effective exchange rate for four of the countries in our sample (yellow lines), namely the countries that had independent currencies for the whole sample period. These are the Czech Republic, Poland, Romania, and Bulgaria. In each case, the nominal exchange rate series are normalized to equal the real exchange rate at the beginning of the sample. Not surprisingly, we see that in these cases, the nominal effective exchange rate closely tracks the real exchange rate constructed using the Eurostat data.

7 Conclusions

A large literature in international macroeconomics has focused on the understanding of high-frequency movements in real and nominal exchange rates. A common conclusion from these studies is that it is hard to establish the relevance of fundamental-based models of exchange rates, particularly among floating exchange rate countries. In the longer run, we expect to see real exchange rate appreciation in fast-growing countries, consistent with the 'Penn Effect'. But evidence supporting the Penn effect is mixed. This paper focuses on longer-run determinants of real exchange rates, and on real exchange rate movements between countries of Eastern Europe relative to the EU as a whole. Some of these countries are pegged to the Euro, while most others maintain stable exchange rates vis-à-vis the Euro. We find support for the Penn effect, and the more specific Balassa-Samuelson version of this relationship. Our exchange rate regressions quite successfully support the predictions of the model of real exchange rate determination with sectoral productivity and labor wedges as the main drivers. But as documented in the introduction, there is an apparent puzzle regarding the lack of convergence in the real exchange rate after the EU crisis. To explore this further, we then simulate the model using observed sectoral productivity and inferences on capital flows and the labor wedge. Our results show that the model can quite closely account for the historical path of aggregate and sectoral real exchange rates as well as GDP. The main conclusion suggests that GDP convergence can take place without the expectation of real exchange rate appreciation.

References

Armendariz, Santiago, Carlos da Resende, Angana Fan, Gianluigi Ferrucci, Bingjie Hu, Sriram Naik, and Ceyhun Ugur, "Competitiveness and Productivity in the Baltics: Common Shocks, Different Implications," IMF Working Paper 2025/018, International Monetary Fund 2025.

Balassa, Bela, "The Purchasing-Power Parity Doctrine: A Reappraisal," *Journal of Political Economy*, 1964, *72* (6).

Beck, Nathaniel and Jonathan Katz, "What To Do (and Not to Do) with Time-Series Cross-Section Data," *American Political Science Review*, 1995, *89* (3), 634–647.

Bergin, Paul R., Reuven Glick, and Alan M. Taylor, "Productivity, tradability, and the long-run price puzzle," *Journal of Monetary Economics*, 2006, *53* (8), 2041–2066.

Bergstrand, Jeffrey H, "Structural Determinants of Real Exchange Rates and National Price Levels: Some Empirical Evidence," *American Economic Review*, March 1991, *81* (1), 325–334.

Berka, Martin and Michael B. Devereux, "Trends in European real exchange rates [Trade costs]," *Economic Policy*, 2013, *28* (74), 193–242.

— , — , and Charles Engel, "Real Exchange Rates and Sectoral Productivity in the Eurozone," *American Economic Review*, June 2018, *108* (6), 1543–1581.

Bhagwati, Jagdish N., "Why are Services Cheaper in the Poor Countries?," *The Economic Journal*, 06 1984, *94* (374), 279–286.

Burstein, Ariel, Martin Eichenbaum, and Sergio Rebelo, "Large Devaluations and the Real Exchange Rate," *Journal of Political Economy*, August 2005, *113* (4), 742–784.

— , — , and — , "Modeling exchange rate passthrough after large devaluations," *Journal of Monetary Economics*, March 2007, *54* (2), 346–368.

Burstein, Ariel T., Joao C. Neves, and Sergio Rebelo, "Distribution costs and real exchange rate dynamics during exchange-rate-based stabilizations," *Journal of Monetary Economics*, September 2003, *50* (6), 1189–1214.

Canzoneri, Matthew B., Robert E. Cumby, and Behzad Diba, "Relative labor productivity and the real exchange rate in the long run: evidence for a panel of OECD countries," *Journal of International Economics*, April 1999, *47* (2), 245–266.

Choudhri, Ehsan U. and Mohsin S. Khan, "Real Exchange Rates in Developing Countries: Are Balassa-Samuelson Effects Present?," *IMF Staff Papers*, 2005, *52* (3), 387–409.

Cole, Harold L. and Maurice Obstfeld, "Commodity trade and international risk sharing: How much do financial markets matter?," *Journal of Monetary Economics*, 1991, *28* (1), 3–24.

Crucini, Mario J., Chris I. Telmer, and Marios Zachariadis, "Understanding European Real Exchange Rates," *American Economic Review*, June 2005, *95* (3), 724–738.

Feenstra, Robert C., Robert Inklaar, and Marcel P. Timmer, "The Next Generation of the Penn World Table," *The American Economic Review*, 2015, *105* (10), 3150–3182.

Gregorio, Jose De, Alberto Giovannini, and Holger C. Wolf, "International evidence on tradables and nontradables inflation," *European Economic Review*, June 1994, *38* (6), 1225–1244.

Hassan, Fadi, "The price of development: The Pennâ€"Balassaâ€"Samuelson effect revisited," *Journal of International Economics*, None 2016, *102* (C), 291–309.

Inklaar, Robert, Ryan Marapin, and Kaira Gräler, "Tradability and sectoral productivity differences across countries," WorkingPaper 195, GGDC oct 2023.

Irwin, Douglas A. and Maurice Obstfeld, "Understanding Koreaâ€™s Long-Run Real Exchange Rate Behavior," NBER Working Papers 32769, National Bureau of Economic Research, Inc Aug 2024.

Itskhoki, Oleg, "The Story of the Real Exchange Rate," *Annual Review of Economics*, August 2021, *13* (1), 423–455.

— and Dmitry Mukhin, "Exchange Rate Disconnect in General Equilibrium," *Journal of Political Economy*, 2021, *129* (8), 2183–2232.

Kravis, Irving B, Alan W Heston, and Robert Summers, "Real GDP per Capita for More Than One Hundred Countries," *Economic Journal*, June 1978, *88* (350), 215–242.

Lee, Jaewoo and Man-Keung Tang, "Does Productivity Growth Appreciate the Real Exchange Rate?," *Review of International Economics*, February 2007, *15* (1), 164–187.

Meshulam, Dan and Peter Sanfey, "The Determinants of Real Exchange Rates in Transition Economies," EBRD Working Paper 228, European Bank for Reconstruction and Development July 2019.

Miyamoto, Wataru, Thuy Lan Nguyen, and Hyunseung Oh, "In Search of Dominant Drivers of the Real Exchange Rate," *The Review of Economics and Statistics*, 07 2025, *107* (4), 1059–1073.

Obstfeld, Maurice and Kenneth S. Rogoff, *Foundations of International Macroeconomics*, 1 ed., Vol. 1 of *MIT Press Books*, The MIT Press, December 1996.

Piton, Sophie, "Economic integration and unit labour costs," *European Economic Review*, 2021, *136*, 103746.

Rogoff, Kenneth, "The Purchasing Power Parity Puzzle," *Journal of Economic Literature*, June 1996, *34* (2), 647–668.

Samuelson, Paul A., "Theoretical Notes on Trade Problems," *The Review of Economics and Statistics*, 1964, *46* (2), 145–154.

Zhang, Qi, "The Balassaâ€"Samuelson relationship: Services, manufacturing and product quality," *Journal of International Economics*, None 2017, *106* (C), 55–82.

Appendix

Table of Contents

A Full list of equations in the model

A.1 Preferences

Utility of Home consumers can be described by the standard CES lifetime utility function:

$$\mathcal{U} = \sum_{t=1}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma} - 1}{1-\sigma} - \Psi_{T,t} \frac{L_{T,t}^{1+\phi}}{1+\phi} - \Psi_{N,t} \frac{L_{N,t}^{1+\phi}}{1+\phi} \right). \tag{26}$$

$T,\ N$ indicates the sectors traded and non-traded, respectively. σ and ϕ denote the relative risk aversion (inverse of the intertemporal elasticity of substitution) and the inverse of Frisch elasticity, respectively. We assume separately labor supply in each sector, and $\Psi_{j,t},\ j = T, N$ represents the sectoral labor wedge which will play a role in exchange rate determination.

The preference relationship over traded and non-traded goods is represented by the consumption aggregator:

$$C = \left[\Omega^{\frac{1}{\mu}} C_T^{1-\frac{1}{\mu}} + (1-\Omega)^{\frac{1}{\mu}} C_N^{1-\frac{1}{\mu}} \right]^{\frac{\mu}{\mu-1}}. \tag{27}$$

Ω represents the share of the traded sector. Within traded goods, households consume a home and foreign good with shares $(1-\gamma)$ and γ so that

$$C_T = \left[(1-\gamma)^{\frac{1}{\lambda}} C_{T,H}^{1-\frac{1}{\lambda}} + \gamma^{\frac{1}{\lambda}} C_{T,F}^{1-\frac{1}{\lambda}} \right]^{\frac{\lambda}{\lambda-1}}.$$

Note that μ represents the elasticity of substitution across sectors, while λ represents the elasticity of substitution across Home and Foreign goods.

Finally, for both home and foreign traded goods, there is a requirement to use distribution services of non-traded goods in order to produce final consumption goods. Hence we have

$$C_{T,H} = \left[v^{\frac{1}{\psi}} I_{T,H}^{1-\frac{1}{\psi}} + (1-v)^{\frac{1}{\psi}} I_{N,H}^{1-\frac{1}{\psi}} \right]^{\frac{\psi}{\psi-1}},$$

$$C_{T,F} = \left[v^{\frac{1}{\psi}} I_{T,F}^{1-\frac{1}{\psi}} + (1-v)^{\frac{1}{\psi}} I_{N,F}^{1-\frac{1}{\psi}} \right]^{\frac{\psi}{\psi-1}}.$$

where $I_{T,H}$ and $I_{N,H}$ refer to the use of traded goods and non-traded goods of the home country in the final consumption of the home traded good $C_{T,H}$. Analogous descriptions apply to the consumption of the foreign traded good $C_{T,F}$. The elasticity of substitution between the 'raw' traded good and non-traded inputs is ψ.

Households in the home country face the following budget constraint:

$$P_t C_t + \frac{B_{t+1}}{1+r_{t+1}} = P_{T,t} C_{T,t} + P_{N,t} C_{N,t} + \frac{B_{t+1}}{1+r_{t+1}} = W_{T,t} L_{T,t} + W_{N,t} L_{N,t} + \Pi_{T,t} + \Pi_{N,t} + B_t, \tag{28}$$

where price indexes are given by

$$P = \left(\Omega P_T^{1-\mu} + (1-\Omega) P_N^{1-\mu}\right)^{\frac{1}{1-\mu}}, \tag{29}$$

$$P_T = \left[\gamma \tilde{P}_{T,H}^{1-\lambda} + (1-\gamma)\, \tilde{P}_{T,F}^{1-\lambda}\right]^{\frac{1}{1-\lambda}}, \tag{30}$$

and

$$\tilde{P}_{T,H} = \left[v P_{T,H}^{1-\psi} + (1-v)\, P_N^{1-\psi}\right]^{\frac{1}{1-\psi}}, \tag{31}$$

$$\tilde{P}_{T,F} = \left[v P_{T,F}^{1-\psi} + (1-v)\, P_N^{1-\psi}\right]^{\frac{1}{1-\psi}}. \tag{32}$$

Households receive income from wages W_N and W_T and profits Π from all sector firms, and consume at the given prices. They can purchase one period 'nominal' international bonds B at price $\frac{1}{1+r_{t+1}}$.[21] γ and v denote share parameters.

Household optimal choices are quite standard, and deliver the solution for the consumption of traded and non-traded goods as

$$C_T = \Omega \left(\frac{P_T}{P}\right)^{-\mu} C, \tag{33}$$

$$C_N = (1-\Omega) \left(\frac{P_N}{P}\right)^{-\mu} C. \tag{34}$$

Given the definition of traded goods, the demand for consumption of home and foreign traded goods is

$$C_{T,H} = (1-\gamma) \left(\frac{\tilde{P}_{T,H}}{P_T}\right)^{-\lambda} C_T, \tag{35}$$

$$C_{T,F} = \gamma \left(\frac{\tilde{P}_{T,F}}{P_T}\right)^{-\lambda} C_T. \tag{36}$$

Likewise, we have the demand for raw traded goods and non-traded distribution services given by:

$$I_{T,H} = vH \left(\frac{P_{T,H}}{\tilde{P}_{T,H}}\right)^{-\psi} C_{T,H}, \tag{37}$$

$$I_{N,H} = (1-v) \left(\frac{P_N}{\tilde{P}_{T,H}}\right)^{-\psi} C_{T,H}, \tag{38}$$

$$I_{T,F} = v \left(\frac{P_{T,F}}{\tilde{P}_{T,F}}\right)^{-\psi} C_{T,F}, \tag{39}$$

[21] Although the model is purely real, we define a nominal numeraire below.

$$I_{N,F} = (1-v)\left(\frac{P_N}{\tilde{P}_{T,F}}\right)^{-\psi} C_{T,F}. \tag{40}$$

Equilibrium labor supply conditions are given by

$$\frac{W_T}{P} = \Psi_{T,t} C^{\sigma} L_T^{\phi}, \tag{41}$$

$$\frac{W_N}{P} = \Psi_{N,t} C^{\sigma} L_N^{\phi}. \tag{42}$$

Since our approach to capital flows in the model is described further below in Section A.6, we abstract from the Euler equation implied by an optimal choice of international bonds.

A.2 Firms

Assume decreasing returns production functions in each sector with fixed capital. So, $1-\alpha$ is a measure of the labor share. For the home country we have production in traded and non-traded respectively as

$$Y_{T,H} = A_{T,H} L_{T,H}^{1-\alpha},$$

$$Y_{N,H} = A_{N,H} L_{N,H}^{1-\alpha}.$$

Firms in each sector maximize profits given sector-specific wage W_T and W_N. Sectoral wage rates differ due to sector-specific labor disutility in equation (1). First order conditions for the firm are described as:

$$P_{T,H} A_{T,H} (1-\alpha) L_{T,H}^{-\alpha} = W_T, \tag{43}$$

$$P_N (1-\alpha) A_{T,N} L_{N,H}^{-\alpha} = W_N. \tag{44}$$

In addition, assembly firms in the home country purchase home and foreign traded goods, along with home non-traded goods, to produce the traded good for consumption of domestic households.

A.3 Nominal policy

Although prices are flexible and money neutral, it is convenient to assume a monetary rule so that the price index for each country is normalized to unity. Hence we have

$$\left[\Omega P_T^{1-\mu} + (1-\Omega) P_N^{1-\mu}\right]^{\frac{1}{1-\mu}} = 1, \tag{45}$$

A.4 Goods market clearing

Goods market clearing in the home and foreign traded good market is described as

$$Y_{T,H} = I_{T,H} + I_{T,H}^{*}, \tag{46}$$

$$Y_{T,F} = I_{T,F} + I^*_{T,F}, \tag{47}$$

Note that we label foreign variables with an asterisk where appropriate.

Likewise, market clearing in the non-traded good sector is described as

$$Y_{N,H} = C_N + I_{N,H} + I_{N,F}, \tag{48}$$

$$Y_{N,F} = C_N + I_{N,H} + I_{N,F}. \tag{49}$$

A.5 International price setting

The law of one price holds and therefore

$$P^*_{T,H} = SP_{T,H}, \tag{50}$$

$$P_{T,F} = \frac{P^*_{T,F}}{S}. \tag{51}$$

S refers to the nominal exchange rate.

The real exchange rate, defined as the relative CPI price of the home to foreign country, is then just equal to the inverse of the nominal exchange rate:

$$Q = \frac{SP}{P^*} = S. \tag{52}$$

This holds because $P = P^* = 1$ as in equation (6).

A.6 Balance of payments

We can rewrite the Home budget constraint in equation (3) as

$$\begin{aligned} PC &= P_{T,H}Y_{T,H} + P_N Y_{N,H} + B_t - \frac{B_{t+1}}{1 + r_{t+1}} \\ &= P_{T,H}Y_{T,H} + P_N Y_{N,H} + \theta P_{T,H}Y_{T,H} \\ &= (1 + \theta)\, P_{T,H}Y_{T,H} + P_N Y_{N,H}. \end{aligned}$$

We abstract from the Euler equation derived from the optimal choice of bonds. Rather than solving the intertemporal optimization problem, we assume that there is a capital inflow of amount $\theta P_{T,H}Y_{T,H}$:

$$B_t - \frac{B_{t+1}}{1 + r_{t+1}} = \theta P_{T,H}Y_{T,H}. \tag{53}$$

This capital inflow is measured in terms of the domestic traded goods. We remain agnostic about the underlying causes of this capital flow, which could be driven by factors such as transfers, news shocks, foreign direct investment *etc*.

A.7 The system of equations

The system of equations consists of 11 equations for $P_{T,H}$, $P^*_{T,F}$, P_N, P^*_N, L_T, L^*_T, L_N, L^*_N, C, C^*, and S.

labor market clearing

$$(1-\alpha)\,P_{T,H}A_{T,H}L_T^{-\alpha}=\Psi_T C^{\sigma}L_T^{\phi},$$

$$(1-\alpha)\,P^*_{T,F}A_{T,F}\left(L^*_T\right)^{-\alpha}=\Psi^*_T\left(C^*\right)^{\sigma}\left(L^*_T\right)^{\phi},$$

$$(1-\alpha)\,P_N A_{N,H}L_N^{-\alpha}=\Psi_N C^{\sigma}L_N^{\phi},$$

$$(1-\alpha)\,P^*_N A_{N,F}\left(L^*_N\right)^{-\alpha}=\Psi^*_N\left(C^*\right)^{\sigma}\left(L^*_N\right)^{\phi}.$$

Goods market clearing

$$\begin{aligned}A_{T,H}L_T^{1-\alpha} &= (1-\gamma)\,v\left(\frac{P_{T,H}}{\tilde{P}_{T,H}}\right)^{-\psi}\left(\frac{\tilde{P}_{T,H}}{P_T}\right)^{-\lambda}\Omega P_T^{-\mu}C\\ &\quad +n\frac{1-\gamma}{1-n}v\left(\frac{P_{T,H}}{S\tilde{P}^*_{T,H}}\right)^{-\psi}\left(\frac{\tilde{P}^*_{T,H}}{P^*_T}\right)^{-\lambda}\Omega\left(P^*_T\right)^{-\mu}C^*,\end{aligned}$$

$$\begin{aligned}A_{T,F}\left(L^*_T\right)^{1-\alpha} &= (1-n)\,\frac{\gamma}{n}v\left(\frac{SP^*_{T,F}}{\tilde{P}_{T,F}}\right)^{-\psi}\left(\frac{\tilde{P}_{T,F}}{P_T}\right)^{-\lambda}\Omega P_T^{-\mu}C\\ &\quad +\gamma v\left(\frac{P^*_{T,F}}{\tilde{P}^*_{T,F}}\right)^{-\psi}\left(\frac{\tilde{P}^*_{T,F}}{P^*_T}\right)^{-\lambda}\Omega\left(P^*_T\right)^{-\mu}C^*,\end{aligned}$$

$$\begin{aligned}A_{N,H}L_N^{1-\alpha} &= (1-\Omega)\,P_N^{-\mu}C+(1-v)\left(\frac{P_N}{\tilde{P}_{T,H}}\right)^{-\psi}(1-n)\left(\frac{\tilde{P}_{T,H}}{P_T}\right)^{-\lambda}\Omega P_T^{-\mu}C\\ &\quad +(1-v)\left(\frac{P_N}{\tilde{P}_{T,F}}\right)^{-\psi}n\left(\frac{\tilde{P}_{T,F}}{P_T}\right)^{-\lambda}\Omega P_T^{-\mu}C,\end{aligned}$$

$$\begin{aligned}A_{N,F}\left(L^*_N\right)^{1-\alpha} &= (1-\Omega)\left(P^*_N\right)^{-\mu}C^*+(1-v)\left(\frac{P^*_N}{\tilde{P}^*_{T,H}}\right)^{-\psi}(1-n)\left(\frac{\tilde{P}^*_{T,H}}{P^*_T}\right)^{-\lambda}\Omega\left(P^*_T\right)^{-\mu}C^*\\ &\quad +(1-v)\left(\frac{P^*_N}{\tilde{P}^*_{T,F}}\right)^{-\psi}n\left(\frac{\tilde{P}^*_{T,F}}{P^*_T}\right)^{-\lambda}\Omega\left(P^*_T\right)^{-\mu}C^*.\end{aligned}$$

Balance of payments

$$\frac{1-\gamma}{1-n} P_{T,H} \left(\frac{S P_{T,H}}{\tilde{P}^*_{T,H}} \right)^{-\psi} \left(\frac{\tilde{P}^*_{T,H}}{P^*_T} \right)^{-\lambda} \left(P^*_T \right)^{-\mu} C^* \left(1+\theta\right) = \frac{\gamma}{n} \frac{P^*_{T,F}}{S} \left(\frac{P^*_{T,F}}{S \tilde{P}_{T,F}} \right)^{-\psi} \left(\frac{\tilde{P}_{T,F}}{P_T} \right)^{-\lambda} P_T^{-\mu} C.$$

Prices

$$1 = \left[\Omega P_T^{1-\mu} + (1-\Omega) P_N^{1-\mu} \right]^{\frac{1}{1-\mu}},$$

$$1 = \left[\Omega \left(P^*_T \right)^{1-\mu} + (1-\Omega) \left(P^*_N \right)^{1-\mu} \right]^{\frac{1}{1-\mu}},$$

$$P_T = \left[(1-\gamma) \tilde{P}_{T,H}^{1-\lambda} + \gamma \tilde{P}_{T,F}^{1-\lambda} \right]^{\frac{1}{1-\lambda}},$$

$$P^*_T = \left[\gamma \left(\tilde{P}^*_{T,F} \right)^{1-\lambda} + (1-\gamma) \left(\tilde{P}^*_{T,H} \right)^{1-\lambda} \right]^{\frac{1}{1-\lambda}},$$

$$\tilde{P}_{T,H} = \left[v P_{T,H}^{1-\psi} + (1-v) P_N^{1-\psi} \right]^{\frac{1}{1-\psi}},$$

$$\tilde{P}^*_{T,F} = \left[v \left(P^*_{T,F} \right)^{1-\psi} + (1-v) \left(P^*_N \right)^{1-\psi} \right]^{\frac{1}{1-\psi}},$$

$$\tilde{P}_{T,F} = \left[v \left(S P^*_{T,F} \right)^{1-\psi} + (1-v) P_N^{1-\psi} \right]^{\frac{1}{1-\psi}},$$

$$\tilde{P}^*_{T,H} = \left[v \left(\frac{P_{T,H}}{S} \right)^{1-\psi} + (1-v) \left(P^*_N \right)^{1-\psi} \right]^{\frac{1}{1-\psi}}.$$

A.8 Log-linearization

We approximate the equations in Section A.7 around the symmetric steady state to derive the system of the linearized equations presented in Section 2.7.1. In the steady state, all relative prices are unity:

$$\begin{aligned} 1 &= P = P^* = S \\ &= P_N = P_{T,H} = P_T = \tilde{P}_{T,H} = \tilde{P}_{T,F} \\ &= P^*_N = P^*_{T,F} = P^*_T = \tilde{P}^*_{T,F} = \tilde{P}^*_{T,F}. \end{aligned}$$

This is achieved when $A = A_{T,H} = A_{T,F} = A_{N,H} = A_{N,F}$, $\Psi = \Psi_T = \Psi_N = \Psi^*_T = \Psi^*_N$, $\theta = 0$, and $v\Omega = 1 - \Omega$.

Then, conditions below must be satisfied in the steady state:

$$C^\sigma L^{\alpha+\phi} = \frac{(1-\alpha) A}{\Psi},$$

$$\frac{v\Omega C}{AL^{1-\alpha}} = \frac{(1-v\Omega)\,C}{AL^{1-\alpha}} = 1.$$

A.9 Solution

From the labor market clearing condition and the resource constraint for non-traded goods discussed in Section 2.7.1, consumption in both economies is given by

$$\hat{C} = \frac{1+\phi}{\Sigma}\hat{A}_{N,H} - \frac{1-\alpha}{\Sigma}\hat{\Psi}_N + \frac{\Theta}{\Sigma}\hat{P}_N,$$

and

$$\hat{C}^* = \frac{1+\phi}{\Sigma}\hat{A}_{N,F} - \frac{1-\alpha}{\Sigma}\hat{\Psi}^*_N + \frac{\Theta}{\Sigma}\hat{P}^*_N.$$

Taking the difference between the home and foreign consumption equations yields

$$\hat{C}^* - \hat{C} = -\frac{1}{\Sigma}\left[(1+\phi)\left(\hat{A}_{N,H} - \hat{A}_{N,F}\right) - (1-\alpha)\left(\hat{\Psi}_N - \hat{\Psi}^*_N\right)\right] + \frac{\Theta}{\Sigma}\left(\hat{P}^*_N - \hat{P}_N\right). \tag{54}$$

From the labor market equilibrium conditions for traded goods, presented in Section 2.7.1, the relative price of traded goods in each country satisfies

$$\hat{P}_{T,H} = \frac{(1+\phi)\,\sigma}{\Sigma}\hat{A}_{N,H} - \hat{A}_{T,H} - \frac{(1-\alpha)\,\sigma}{\Sigma}\hat{\Psi}_N + \hat{\Psi}_T + \frac{\sigma\Theta}{\Sigma}\hat{P}_N + (\alpha+\phi)\,\hat{L}_T,$$
$$\hat{P}^*_{T,F} = \frac{(1+\phi)\,\sigma}{\Sigma}\hat{A}_{N,F} - \hat{A}_{T,F} - \frac{(1-\alpha)\,\sigma}{\Sigma}\hat{\Psi}^*_N + \hat{\Psi}^*_T + \frac{\sigma\Theta}{\Sigma}\hat{P}^*_N + (\alpha+\phi)\,\hat{L}^*_T.$$

Subtracting the foreign traded goods price equation from the home equation yields the relative traded price differential:

$$\begin{aligned}\hat{P}_{T,H} - \hat{P}^*_{T,F} \;=\;& \hat{A}_{T,F} - \hat{A}_{T,H} + \hat{\Psi}_T - \hat{\Psi}^*_T \\ &+\frac{\sigma}{\Sigma}\left[(1+\phi)\left(\hat{A}_{N,H} - \hat{A}_{N,F}\right) - (1-\alpha)\left(\hat{\Psi}_N - \hat{\Psi}^*_N\right)\right] \\ &-\frac{\sigma\Theta}{\Sigma}\left(\hat{P}^*_N - \hat{P}_N\right) \\ &+ (\alpha+\phi)\left(\hat{L}_T - \hat{L}^*_T\right).\end{aligned} \tag{55}$$

Next, consider the difference between the resource constraints for traded goods from Section 2.7.1, which gives

$$\left(\hat{L}_T - \hat{L}^*_T\right) = -\frac{1}{1-\alpha}\left(\hat{A}_{T,H} - \hat{A}_{T,F}\right) - \frac{\Gamma}{1-\alpha}\hat{S} - \frac{\Gamma}{1-\alpha}\left(\hat{P}_{T,H} - \hat{P}^*_{T,F}\right), \tag{56}$$

Substituting this expression into equation (55) yields

$$\begin{aligned}\left(\hat{P}_{T,H}-\hat{P}^*_{T,F}\right) \quad = \quad & \frac{\sigma\left(1-\alpha\right)}{\Phi\Sigma}\left[\left(1+\phi\right)\left(\hat{A}_{N,H}-\hat{A}_{N,F}\right)-\left(1-\alpha\right)\left(\hat{\Psi}_N-\hat{\Psi}^*_N\right)\right] \\ & -\frac{1}{\Phi}\left[\left(1+\phi\right)\left(\hat{A}_{T,H}-\hat{A}_{T,F}\right)-\left(1-\alpha\right)\left(\hat{\Psi}_T-\hat{\Psi}^*_T\right)\right] \\ & +\frac{\left(\alpha+\phi\right)\Gamma\Sigma-\left(1-\alpha\right)\sigma\Theta}{\Phi\Sigma}\left(\hat{P}^*_N-\hat{P}_N\right),\end{aligned}$$

Substituting this equation, along with equations (16) and (54), into the balance of payments identity provided in Section 2.7.1, we obtain an expression for the relative price of non-traded:

$$\begin{aligned}\left(\hat{P}^*_N-\hat{P}_N\right) \quad = & \\ -\frac{\left(\Gamma-1\right)\Sigma}{\Lambda}\left[\left(1+\phi\right)\left(\hat{A}_{T,H}-\hat{A}_{T,F}\right)-\left(1-\alpha\right)\left(\hat{\Psi}_T-\hat{\Psi}^*_T\right)\right] & \\ +\frac{\left(1-\alpha\right)\left(1-\sigma\right)+\Sigma\Gamma}{\Lambda}\left[\left(1+\phi\right)\left(\hat{A}_{N,H}-\hat{A}_{N,F}\right)-\left(1-\alpha\right)\left(\hat{\Psi}_N-\hat{\Psi}^*_N\right)\right] & \\ -\frac{\Sigma\Phi}{\Lambda}\hat{\theta}, &\end{aligned}$$

Finally, inserting this equation into equation (16) yields the solution of the real exchange rate in equation (17).

B Additional data figures

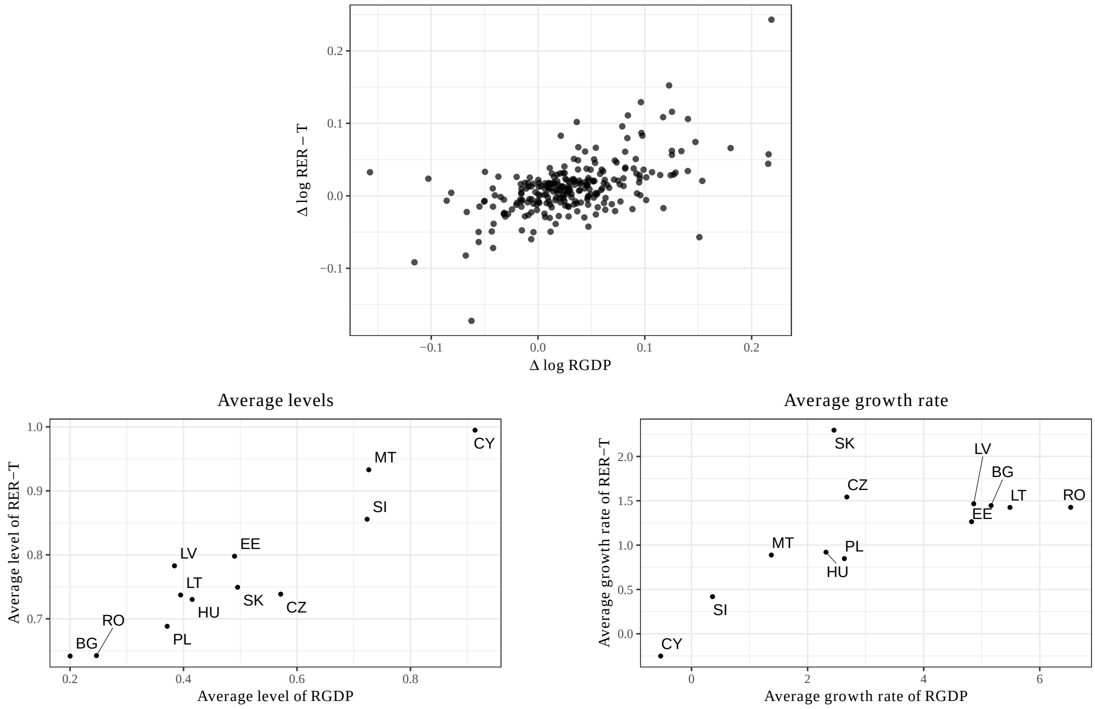


Figure 19: Real Exchange Rate of Traded Goods and Relative GDP

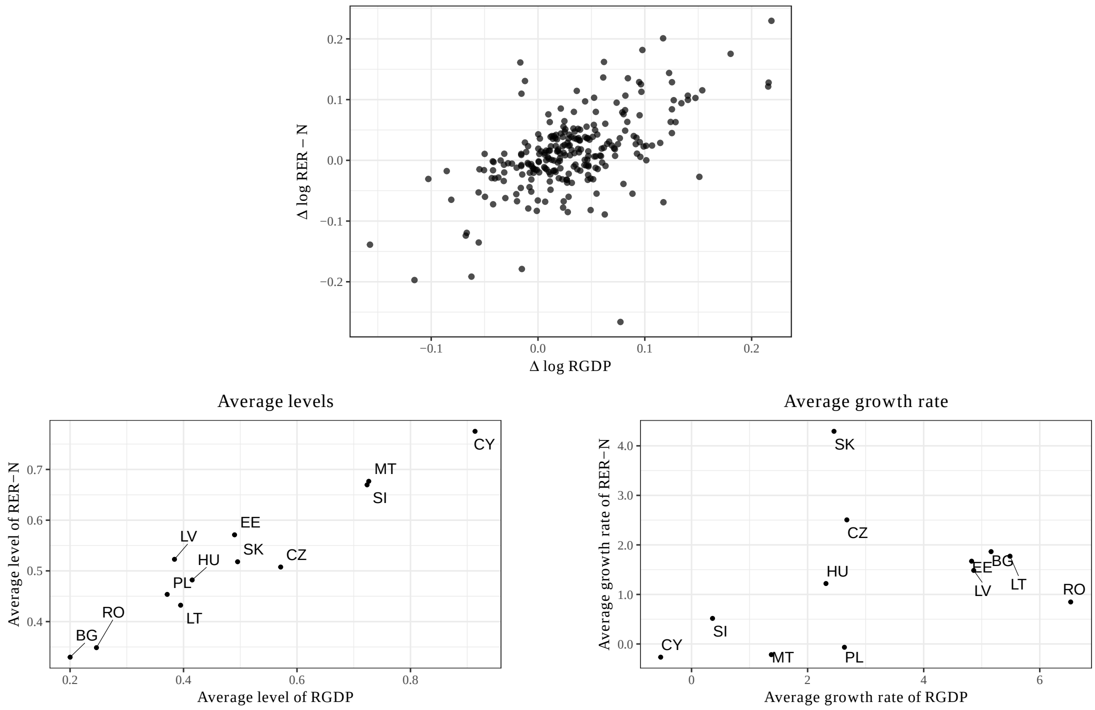


Figure 20: Real Exchange Rate of Non-traded Goods and Relative GDP

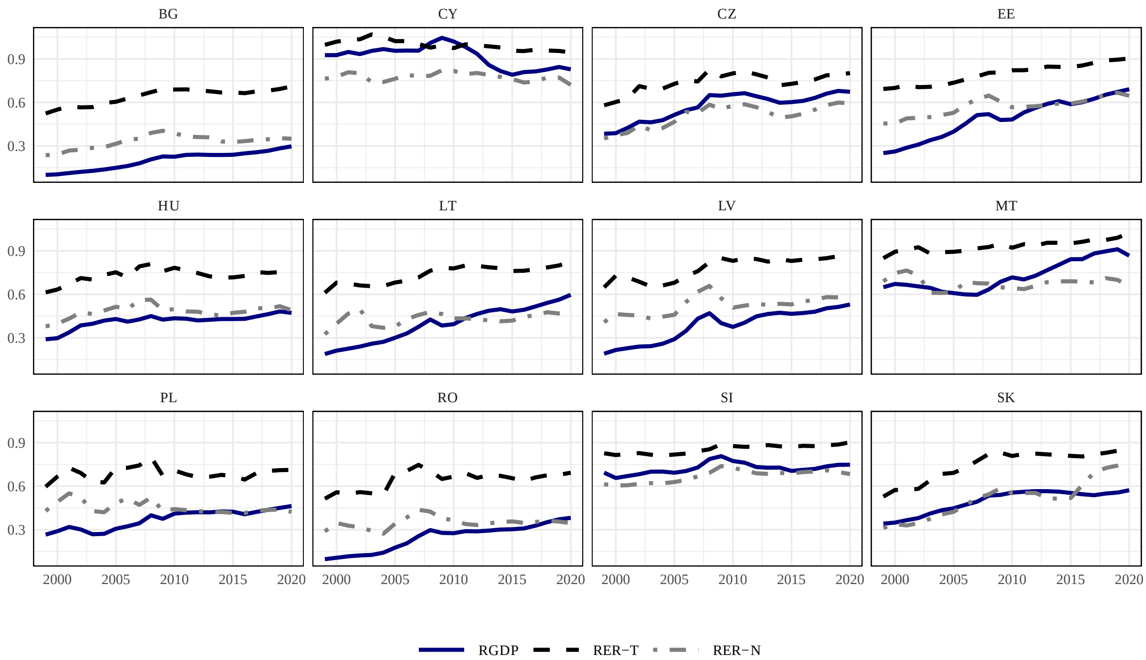


Figure 21: Real Exchange Rates of Traded and Non-traded goods and Relative GDP by country

C Additional panel regression results

To verify the robustness of the RER regressions we consider estimations with additional or alternative variables. Other additional specifications can be found in the online appendix.

Panel with additional demand-side control variables

Table 12: Model for the RER (all goods)

	Fixed effects					Random effects				
	(1a)	(1b)	(1c)	(1d)	(1e)	(2a)	(2b)	(2c)	(2d)	(2e)
$Lprod_T$	**0.296*****	**0.298*****	**0.263*****	**0.186*****	**0.185*****	**0.202*****	**0.195*****	**0.174*****	**0.095***	**0.167*****
	(0.06)	(0.06)	(0.06)	(0.07)	(0.06)	(0.05)	(0.05)	(0.06)	(0.06)	(0.06)
$Lprod_N$	-0.063	-0.062	-0.09	**-0.193*****	**-0.193*****	0.023	0.025	0.001	-0.05	**-0.165****
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
$RULC$	**0.188*****	**0.188*****	**0.22*****	**0.286*****	**0.291*****	**0.175*****	**0.175*****	**0.197*****	**0.232*****	**0.28*****
	(0.04)	(0.04)	(0.04)	(0.05)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)
G	—	0.031	—	—	0.057	—	-0.049	—	—	0.043
		(0.08)			(0.1)		(0.09)			(0.1)
SG	—	—	**0.004****	—	0.003	—	—	0.003	—	0.004
			(0.002)		(0.002)			(0.002)		(0.002)
LR	—	—	—	0.002	0.001	—	—	—	0.0019	0.0011
				(0.002)	(0.002)				(0.002)	(0.002)
$R^2(adj.)$	0.71	0.71	0.68	0.63	0.64	0.69	0.69	0.66	0.9	0.77
N	262	262	252	214	214	262	262	252	214	214
HT						reject	reject	reject	reject	not reject

Notes: Dependant variable: log real exchange rate (expenditure-weighted) expressed as the country i price level relative to EU15 (an increase is an appreciation). $RLprod_i$ is the log of the traded labor productivity relative to non-traded sector for country i ($realLabProd_{T,i,t}/realLabProd_{N,i,t}$) made itself relative with respect to EU15. $Lprod_T$ is the log of an aggregation of one-letter sectoral labor productivity of traded sectors using sectoral outputs as weights. $Lprod_N$ is an analog measure for non-traded sectors. $RULC_{it}$ is the log of an aggregation of sectoral level (single letter NACE rev. 2) nominal compensation of employees per hour worked for a country i as a ratio to the Producer Price Index and expressed relative to EU27. The nominal ULC involved in the calculations are sourced in euros for all countries. G is the log of the general government's final consumption expenditure as a fraction of GDP expressed relative to the same quantity for the EU27. SG is the government surplus or deficit as a percentage of GDP in each country, relative to the EU27 analog. LR is the spread between the real long-run (10-year) bonds rate of each country relative to EU (EU19). The rates are made real by subtracting CPI inflation. The data sample period is 1999-2020. Fixed effects is a panel regression with countries as cross-sections. Random effects is a random effects panel with countries as cross-sections. All standard errors are computed using a panel corrected standard errors method (Beck and Katz, 1995) under the assumption of period correlation (cross-sectional clustering). Standard errors are in parentheses. The estimate of the constant is not reported. Rejection of the null in the Hausman test (HT) implies a statistical difference between the FE and RE, viewed as a preference for FE.

Table 13: Model for the RER for Traded goods

	Fixed effects					Random effects				
	(1a)	(1b)	(1c)	(1d)	(1e)	(2a)	(2b)	(2c)	(2d)	(2e)
$Lprod_T$	**0.28*****	**0.282*****	**0.241*****	**0.158*****	**0.157*****	**0.19*****	**0.185*****	**0.159*****	**0.084***	**0.14****
	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
$Lprod_N$	-0.012	-0.011	-0.026	-0.1	-0.099	0.064	0.065	0.051	0.004	-0.074
	(0.06)	(0.06)	(0.06)	(0.07)	(0.07)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
$RULC$	**0.149*****	**0.149*****	**0.175*****	**0.242*****	**0.243*****	**0.139*****	**0.14*****	**0.157*****	**0.202*****	**0.233*****
	(0.04)	(0.04)	(0.03)	(0.05)	(0.05)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)
G	—	0.031	—	—	0.071	—	-0.043	—	—	0.057
		(0.08)			(0.09)		(0.08)			(0.09)
SG	—	—	0.002	—	0	—	—	0.001	—	0
			(0.002)		(0.002)			(0.002)		(0.002)
LR	—	—	—	**0.003***	0.003	—	—	—	**0.0032***	0.0028
				(0.002)	(0.002)				(0.002)	(0.002)
$R^2(adj.)$	0.71	0.71	0.69	0.64	0.64	0.69	0.69	0.66	0.91	0.8
N	262	262	252	214	214	262	262	252	214	214
HT						reject	reject	reject	reject	not reject

Notes: Dependant variable: log real exchange rate (expenditure-weighted) expressed as the country i price level relative to EU15 (an increase is an appreciation). $RLprod_i$ is the log of the traded labor productivity relative to non-traded sector for country i ($realLabProd_{T,i,t}/realLabProd_{N,i,t}$) made itself relative with respect to EU15. $Lprod_T$ is the log of an aggregation of one-letter sectoral labor productivity of traded sectors using sectoral outputs as weights. $Lprod_N$ is an analog measure for non-traded sectors. $RULC_{it}$ is the log of an aggregation of sectoral level (single letter NACE rev. 2) nominal compensation of employees per hour worked for a country i as a ratio to the Producer Price Index and expressed relative to EU27. The nominal ULC involved in the calculations are sourced in euros for all countries. G is the log of the general government's final consumption expenditure as a fraction of GDP expressed relative to the same quantity for the EU27. SG is the government surplus or deficit as a percentage of GDP in each country, relative to the EU27 analog. LR is the spread between the real long-run (10-year) bonds rate of each country relative to EU (EU19). The rates are made real by subtracting CPI inflation. The data sample period is 1999-2020. Fixed effects is a panel regression with countries as cross-sections. Random effects is a random effects panel with countries as cross-sections. All standard errors are computed using a panel corrected standard errors method (Beck and Katz, 1995) under the assumption of period correlation (cross-sectional clustering). Standard errors are in parentheses. The estimate of the constant is not reported. Rejection of the null in the Hausman test (HT) implies a statistical difference between the FE and RE, viewed as a preference for FE.

Table 14: Model for the RER for Non-traded goods

	Fixed effects					Random effects				
	(1a)	(1b)	(1c)	(1d)	(1e)	(2a)	(2b)	(2c)	(2d)	(2e)
$Lprod_T$	**0.321*****	**0.318*****	**0.275****	0.197	0.195	**0.19****	**0.191****	0.15	0.096	0.162
	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)	(0.09)	(0.09)	(0.09)	(0.09)	(0.11)
$Lprod_N$	-0.147	-0.149	-0.195	**-0.387*****	**-0.388*****	0.001	-0.01	-0.031	-0.135	**-0.316****
	(0.13)	(0.13)	(0.14)	(0.14)	(0.14)	(0.11)	(0.11)	(0.11)	(0.11)	(0.13)
$RULC$	**0.317*****	**0.319*****	**0.361*****	**0.441*****	**0.45*****	**0.292*****	**0.296*****	**0.316*****	**0.344*****	**0.421*****
	(0.08)	(0.08)	(0.09)	(0.1)	(0.09)	(0.06)	(0.06)	(0.07)	(0.07)	(0.09)
G	—	-0.058	—	—	0.013	—	-0.143	—	—	-0.012
		(0.15)			(0.18)		(0.15)			(0.18)
SG	—	—	0.005	—	0.007	—	—	0.004	—	0.007
			(0.004)		(0.005)			(0.004)		(0.005)
LR	—	—	—	-0.001	-0.002	—	—	—	-0.0003	-0.0013
				(0.003)	(0.003)				(0.003)	(0.003)
$R^2(adj.)$	0.56	0.56	0.52	0.48	0.49	0.61	0.61	0.56	0.79	0.66
N	262	262	252	214	214	262	262	252	214	214
HT						reject	reject	reject	reject	not reject

Notes: Dependant variable: log real exchange rate (expenditure-weighted) expressed as the country i price level relative to EU15 (an increase is an appreciation). $RLprod_i$ is the log of the traded labor productivity relative to non-traded sector for country i ($realLabProd_{T,i,t}/realLabProd_{N,i,t}$) made itself relative with respect to EU15. $Lprod_T$ is the log of an aggregation of one-letter sectoral labor productivity of traded sectors using sectoral outputs as weights. $Lprod_N$ is an analog measure for non-traded sectors. $RULC_{it}$ is the log of an aggregation of sectoral level (single letter NACE rev. 2) nominal compensation of employees per hour worked for a country i as a ratio to the Producer Price Index and expressed relative to EU27. The nominal ULC involved in the calculations are sourced in euros for all countries. G is the log of the general government's final consumption expenditure as a fraction of GDP expressed relative to the same quantity for the EU27. SG is the government surplus or deficit as a percentage of GDP in each country, relative to the EU27 analog. LR is the spread between the real long-run (10-year) bonds rate of each country relative to EU (EU19). The rates are made real by subtracting CPI inflation. The data sample period is 1999-2020. Fixed effects is a panel regression with countries as cross-sections. Random effects is a random effects panel with countries as cross-sections. All standard errors are computed using a panel corrected standard errors method (Beck and Katz, 1995) under the assumption of period correlation (cross-sectional clustering). Standard errors are in parentheses. The estimate of the constant is not reported. Rejection of the null in the Hausman test (HT) implies a statistical difference between the FE and RE, viewed as a preference for FE.

Augmented panel specification with capital flows We now consider an alternative specification with the net capital inflows to GDP as the financial variable instead of the long-run interest rate spread as in Table 7.

Table 15: Model for the RER (all goods)

	Fixed effects				Random effects			
	(1a)	(1b)	(1c)	(1d)	(2a)	(2b)	(2c)	(2d)
$RLprod$	**0.198****	**0.212*****	—	—	0.101	**0.113***	—	—
	(0.08)	(0.08)			(0.07)	(0.07)		
$Lprod_T$	—	—	**0.297*****	**0.302*****	—	—	**0.212*****	**0.22*****
			(0.06)	(0.06)			(0.06)	(0.06)
$Lprod_N$	—	—	-0.059	-0.078	—	—	0.018	-0.004
			(0.07)	(0.07)			(0.07)	(0.07)
$RULC$	**0.3*****	**0.28*****	**0.191*****	**0.181*****	**0.269*****	**0.251*****	**0.177*****	**0.169*****
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
$Kinflows$	0.0243	**-0.1547****	0.0670	-0.0831	0.0136	**-0.1692****	0.0590	-0.0936
	(0.077)	(0.073)	(0.088)	(0.078)	(0.075)	(0.079)	(0.086)	(0.079)
$Kinflows \times GFC$	—	**0.4148*****	—	**0.3418*****	—	**0.4302*****	—	**0.3520*****
		(0.080)		(0.068)		(0.086)		(0.070)
$R^2(adj.)$	0.63	0.66	0.71	0.73	0.62	0.65	0.69	0.71
N	262	262	262	262	262	262	262	262
HT					reject	reject	reject	reject

Notes: Dependant variable: log real exchange rate (expenditure-weighted) expressed as the country i price level relative to EU15 (an increase is an appreciation). $RLprod_i$ is the log of the traded labor productivity relative to non-traded sector for country i ($realLabProd_{T,i,t}/realLabProd_{N,i,t}$) made itself relative with respect to EU15. $Lprod_T$ is the log of an aggregation of one-letter sectoral labor productivity of traded sectors using sectoral outputs as weights. $Lprod_N$ is an analog measure for non-traded sectors. $RULC_{it}$ is the logarithm of an aggregation of sectoral level (single letter NACE rev. 2) nominal compensation of employees per hour worked for a country i as a ratio to the Producer Price Index and expressed relative to EU27. The nominal ULC involved in the calculations are sourced in euros for all countries. $Kinflows$ is the ratio of net capital inflows to GDP. GFC is a dummy variable for the financial crisis years. The data sample period is 1999-2020. Fixed effects is a panel regression with countries as cross-sections. Random effects is a random effects panel with countries as cross-sections. All standard errors are computed using a panel corrected standard errors method (Beck and Katz, 1995) under the assumption of period correlation (cross-sectional clustering). Standard errors are in parentheses. The estimate of the constant is not reported. Rejection of the null in the Hausman test (HT) implies a statistical difference between the FE and RE, viewed as a preference for FE.

Table 16: Model for the RER (Traded goods)

	Fixed effects				Random effects			
	(1a)	(1b)	(1c)	(1d)	(2a)	(2b)	(2c)	(2d)
$RLprod$	**0.17****	**0.183****	—	—	0.074	0.092	—	—
	(0.08)	(0.08)			(0.07)	(0.07)		
$Lprod_T$	—	—	**0.279*****	**0.285*****	—	—	**0.197*****	**0.211*****
			(0.05)	(0.05)			(0.05)	(0.05)
$Lprod_N$	—	—	-0.016	-0.035	—	—	0.054	0.028
			(0.06)	(0.06)			(0.06)	(0.06)
$RULC$	**0.268*****	**0.247*****	**0.147*****	**0.137*****	**0.237*****	**0.221*****	**0.137*****	**0.129*****
	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.03)	(0.03)
$Kinflows$	-0.1159	**-0.2956*****	-0.0686	**-0.2156*****	**-0.1271***	**-0.3100*****	-0.0770	**-0.2262*****
	(0.078)	(0.066)	(0.091)	(0.073)	(0.076)	(0.071)	(0.089)	(0.072)
$Kinflows \times GFC$	—	**0.4164*****	—	**0.3348*****	—	**0.4316*****	—	**0.3452*****
		(0.085)		(0.074)		(0.089)		(0.074)
$R^2(adj.)$	0.61	0.64	0.72	0.74	0.6	0.63	0.7	0.72
N	262	262	262	262	262	262	262	262
HT					reject	reject	reject	reject

Notes: Dependant variable: log real exchange rate (expenditure-weighted) expressed as the country i price level relative to EU15 (an increase is an appreciation). $RLprod_i$ is the log of the traded labor productivity relative to non-traded sector for country i ($realLabProd_{T,i,t}/realLabProd_{N,i,t}$) made itself relative with respect to EU15. $Lprod_T$ is the log of an aggregation of one-letter sectoral labor productivity of traded sectors using sectoral outputs as weights. $Lprod_N$ is an analog measure for non-traded sectors. $RULC_{it}$ is the log of an aggregation of sectoral level (single letter NACE rev. 2) nominal compensation of employees per hour worked for a country i as a ratio to the Producer Price Index and expressed relative to EU27. The nominal ULC involved in the calculations are sourced in euros for all countries. $Kinflows$ is the ratio of net capital inflows to GDP. GFC is a dummy variable for the financial crisis years. The data sample period is 1999-2020. Fixed effects is a panel regression with countries as cross-sections. Random effects is a random effects panel with countries as cross-sections. All standard errors are computed using a panel corrected standard errors method (Beck and Katz, 1995) under the assumption of period correlation (cross-sectional clustering). Standard errors are in parentheses. The estimate of the constant is not reported. Rejection of the null in the Hausman test (HT) implies a statistical difference between the FE and RE, viewed as a preference for FE.

Table 17: Model for the RER (Non-traded goods)

	Fixed effects				Random effects			
	(1a)	(1b)	(1c)	(1d)	(2a)	(2b)	(2c)	(2d)
$RLprod$	**0.244****	**0.263****	—	—	0.146	**0.158***	—	—
	(0.12)	(0.11)			(0.1)	(0.09)		
$Lprod_T$	—	—	**0.325*****	**0.333*****	—	—	**0.202****	**0.21****
			(0.12)	(0.12)			(0.09)	(0.09)
$Lprod_N$	—	—	-0.131	-0.16	—	—	0.006	-0.021
			(0.13)	(0.12)			(0.11)	(0.1)
$RULC$	**0.418*****	**0.39*****	**0.329*****	**0.314*****	**0.392*****	**0.368*****	**0.301*****	**0.291*****
	(0.06)	(0.06)	(0.08)	(0.08)	(0.06)	(0.05)	(0.06)	(0.06)
$Kinflows$	**0.2646****	0.0200	**0.2995****	0.0754	**0.2577****	0.0141	**0.2970****	0.0799
	(0.113)	(0.127)	(0.119)	(0.126)	(0.111)	(0.131)	(0.116)	(0.128)
$Kinflows \times GFC$	—	**0.5668*****	—	**0.5103*****	—	**0.5727*****	—	**0.5040*****
		(0.142)		(0.131)		(0.145)		(0.132)
$R^2(adj.)$	0.56	0.59	0.59	0.61	0.59	0.61	0.62	0.64
N	262	262	262	262	262	262	262	262
HT					reject	reject	reject	reject

Notes: Dependant variable: log real exchange rate (expenditure-weighted) expressed as the country i price level relative to EU15 (an increase is an appreciation). $RLprod_i$ is the log of the traded labor productivity relative to non-traded sector for country i ($realLabProd_{T,i,t}/realLabProd_{N,i,t}$) made itself relative with respect to EU15. $Lprod_T$ is the log of an aggregation of one-letter sectoral labor productivity of traded sectors using sectoral outputs as weights. $Lprod_N$ is an analog measure for non-traded sectors. $RULC_{it}$ is the log of an aggregation of sectoral level (single letter NACE rev. 2) nominal compensation of employees per hour worked for a country i as a ratio to the Producer Price Index and expressed relative to EU27. The nominal ULC involved in the calculations are sourced in euros for all countries. $Kinflows$ is the ratio of net capital inflows to GDP. GFC is a dummy variable for the financial crisis years. The data sample period is 1999-2020. Fixed effects is a panel regression with countries as cross-sections. Random effects is a random effects panel with countries as cross-sections. All standard errors are computed using a panel corrected standard errors method (Beck and Katz, 1995) under the assumption of period correlation (cross-sectional clustering). Standard errors are in parentheses. The estimate of the constant is not reported. Rejection of the null in the Hausman test (HT) implies a statistical difference between the FE and RE, viewed as a preference for FE.

Estimations with financial variables and relative GDP per capita

Table 18: Model for the RER (all goods)

	Fixed effects				Random effects				Pool			
	(1a)	(1b)	(1c)	(1d)	(2a)	(2b)	(2c)	(2d)	(3a)	(3b)	(3c)	(3d)
$RLprod$	**0.189*****	**0.193*****	—	—	0.036	0.046	—	—	**-0.062****	**-0.061****	—	—
	(0.06)	(0.05)			(0.04)	(0.04)			(0.03)	(0.03)		
$Lprod_T$	—	—	**0.145***	**0.15****	—	—	0.038	0.05	—	—	**-0.065****	**-0.063***
			(0.07)	(0.07)			(0.06)	(0.06)			(0.03)	(0.03)
$Lprod_N$	—	—	**-0.266*****	**-0.266*****	—	—	-0.067	-0.083	—	—	0.056	0.054
			(0.08)	(0.08)			(0.07)	(0.07)			(0.05)	(0.05)
$RULC$	**0.255*****	**0.256*****	**0.271*****	**0.272*****	**0.182*****	**0.187*****	**0.191*****	**0.199*****	**0.064***	**0.065***	**0.063***	**0.064***
	(0.05)	(0.05)	(0.06)	(0.06)	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)
LR	0.0016	0.0039	0.0016	0.0039	0.0021	0.0040	0.0021	0.0040	0.0033	0.0053	0.0034	0.0053
	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.003)	(0.005)	(0.003)	(0.005)
$LR \times GFC$	—	-0.0047	—	-0.0045	—	-0.0040	—	-0.0040	—	-0.0042	—	-0.0043
		(0.003)		(0.003)		(0.003)		(0.003)		(0.005)		(0.005)
$RGDP$	0.039	0.039	0.092	0.089	0.081	0.077	0.089	0.086	**0.229*****	**0.227*****	**0.234*****	**0.233*****
	(0.05)	(0.05)	(0.07)	(0.07)	(0.06)	(0.06)	(0.07)	(0.07)	(0.06)	(0.06)	(0.07)	(0.07)
$R^2(adj.)$	0.64	0.64	0.64	0.64	0.91	0.91	0.91	0.91	0.82	0.82	0.82	0.63
N	214	214	214	214	214	214	214	214	214	214	214	214
HT					reject	reject	reject	reject				

Notes: Dependant variable: log real exchange rate (expenditure-weighted) expressed as the country i price level relative to EU15 (an increase is an appreciation). $RLprod_i$ is the log of the traded labor productivity relative to non-traded sector for country i ($realLabProd_{T,i,t}/realLabProd_{N,i,t}$) made itself relative with respect to EU15. $Lprod_T$ is the log of an aggregation of one-letter sectoral labor productivity of traded sectors using sectoral outputs as weights. $Lprod_N$ is an analog measure for non-traded sectors. $RULC_{it}$ is the log of an aggregation of sectoral level (single letter NACE rev. 2) nominal compensation of employees per hour worked for a country i as a ratio to the Producer Price Index and expressed relative to EU27. The nominal ULC involved in the calculations are sourced in euros for all countries. LR is the spread between the real long-run (10-year) bonds rate of each country relative to EU (EU19). The rates are made real by subtracting CPI inflation. GFC is a dummy variable taking the value of 1 for the years 2007-2009. $RGDP$ is the logarithm of the real GDP per-capita relative to EU27. The data sample period is 1999-2020. Fixed effects is a panel regression with countries as cross-sections. Random effects is a random effects panel with countries as cross-sections. Pool is a panel regression without country effects. All standard errors are computed using a panel corrected standard errors method (Beck and Katz, 1995) under the assumption of period correlation (cross-sectional clustering). Standard errors are in parentheses. The estimate of the constant is not reported. Rejection of the null in the Hausman test (HT) implies a statistical difference between the FE and RE, viewed as a preference for FE.

Table 19: Model for the RER of Traded goods

	Fixed effects				Random effects				Pool			
	(1a)	(1b)	(1c)	(1d)	(2a)	(2b)	(2c)	(2d)	(3a)	(3b)	(3c)	(3d)
$RLprod$	**0.138*****	**0.139*****	—	—	0.015	0.027	—	—	**-0.085*****	**-0.085*****	—	—
	(0.05)	(0.05)			(0.03)	(0.04)			(0.02)	(0.03)		
$Lprod_T$	—	—	0.076	0.078	—	—	0	0.012	—	—	**-0.091*****	**-0.091*****
			(0.06)	(0.06)			(0.05)	(0.05)			(0.03)	(0.03)
$Lprod_N$	—	—	**-0.242*****	**-0.242*****	—	—	-0.076	**-0.098***	—	—	0.068	0.068
			(0.07)	(0.07)			(0.06)	(0.06)			(0.05)	(0.05)
$RULC$	**0.19*****	**0.191*****	**0.213*****	**0.213*****	**0.133*****	**0.14*****	**0.145*****	**0.155*****	0.039	0.039	0.036	0.036
	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)
LR	**0.0031***	0.0041	**0.0032***	0.0040	**0.0035***	0.0041	**0.0035***	0.0040	**0.0040***	0.0042	**0.0042***	0.0044
	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.004)	(0.002)	(0.004)
$LR \times GFC$	—	-0.0019	—	-0.0017	—	-0.0013	—	-0.0012	—	-0.0005	—	-0.0006
		(0.003)		(0.003)		(0.003)		(0.003)		(0.004)		(0.004)
$RGDP$	**0.107****	**0.107****	**0.179*****	**0.178*****	**0.135****	**0.131****	**0.167*****	**0.167*****	**0.24*****	**0.24*****	**0.255*****	**0.254*****
	(0.05)	(0.05)	(0.06)	(0.06)	(0.05)	(0.05)	(0.06)	(0.06)	(0.05)	(0.05)	(0.06)	(0.06)
$R^2(adj.)$	0.67	0.67	0.69	0.69	0.93	0.93	0.93	0.92	0.83	0.83	0.83	0.63
N	214	214	214	214	214	214	214	214	214	214	214	214
HT					reject	reject	reject	reject				

Notes: Dependant variable: log real exchange rate for traded goods (expenditure-weighted) expressed as the country i price level relative to EU15 (an increase is an appreciation). $RLprod_i$ is the log of the traded labor productivity relative to non-traded sector for country i ($realLabProd_{T,i,t}/realLabProd_{N,i,t}$) made itself relative with respect to EU15. $Lprod_T$ is the log of an aggregation of one-letter sectoral labor productivity of traded sectors using sectoral outputs as weights. $Lprod_N$ is an analog measure for non-traded sectors. $RULC_{it}$ is the log of an aggregation of sectoral level (single letter NACE rev. 2) nominal compensation of employees per hour worked for a country i as a ratio to the Producer Price Index and expressed relative to EU27. The nominal ULC involved in the calculations are sourced in euros for all countries. LR is the spread between the real long-run (10-year) bonds rate of each country relative to EU (EU19). The rates are made real by subtracting CPI inflation. GFC is a dummy variable taking the value of 1 for the years 2007-2009. $RGDP$ is the logarithm of the real GDP per-capita relative to EU27. The data sample period is 1999-2020. Fixed effects is a panel regression with countries as cross-sections. Random effects is a random effects panel with countries as cross-sections. Pool is a panel regression without country effects. All standard errors are computed using a panel corrected standard errors method (Beck and Katz, 1995) under the assumption of period correlation (cross-sectional clustering). Standard errors are in parentheses. The estimate of the constant is not reported. Rejection of the null in the Hausman test (HT) implies a statistical difference between the FE and RE, viewed as a preference for FE.

Table 20: Model for the RER of Non-traded goods

	Fixed effects				Random effects				Pool			
	(1a)	(1b)	(1c)	(1d)	(2a)	(2b)	(2c)	(2d)	(3a)	(3b)	(3c)	(3d)
$RLprod$	**0.267*****	**0.275*****	—	—	0.084	0.09	—	—	-0.046	-0.041	—	—
	(0.1)	(0.1)			(0.07)	(0.07)			(0.05)	(0.05)		
$Lprod_T$	—	—	0.209	**0.222***	—	—	0.093	0.099	—	—	-0.005	-0.001
			(0.14)	(0.13)			(0.09)	(0.09)			(0.05)	(0.05)
$Lprod_N$	—	—	**-0.365****	**-0.366****	—	—	-0.049	-0.05	—	—	**0.164****	**0.158***
			(0.15)	(0.15)			(0.11)	(0.11)			(0.08)	(0.08)
$RULC$	**0.424*****	**0.428*****	**0.445*****	**0.448*****	**0.344*****	**0.346*****	**0.339*****	**0.34*****	**0.163*****	**0.164*****	**0.185*****	**0.186*****
	(0.09)	(0.09)	(0.1)	(0.09)	(0.08)	(0.07)	(0.08)	(0.07)	(0.06)	(0.06)	(0.06)	(0.06)
LR	-0.0011	0.0047	-0.0010	0.0047	-0.0002	0.0053	-0.0002	0.0053	0.0024	0.0083	0.0017	0.0073
	(0.003)	(0.005)	(0.003)	(0.005)	(0.003)	(0.005)	(0.003)	(0.005)	(0.005)	(0.008)	(0.004)	(0.007)
$LR \times GFC$	—	**-0.0118****	—	**-0.0115****	—	**-0.0112****	—	**-0.0112****	—	**-0.0131***	—	-0.0124
		(0.005)		(0.005)		(0.005)		(0.005)		(0.008)		(0.008)
$RGDP$	-0.095	-0.096	-0.028	-0.033	-0.028	-0.03	-0.045	-0.048	**0.279*****	**0.273*****	**0.182***	**0.178***
	(0.09)	(0.08)	(0.12)	(0.11)	(0.1)	(0.09)	(0.11)	(0.11)	(0.1)	(0.1)	(0.1)	(0.1)
$R^2(adj.)$	0.48	0.49	0.48	0.49	0.8	0.8	0.8	0.8	0.81	0.81	0.82	0.63
N	214	214	214	214	214	214	214	214	214	214	214	214
HT					not reject	not reject	not reject	reject				

Notes: Dependent variable: log real exchange rate for non-traded goods (expenditure-weighted) expressed as the country i price level relative to EU15 (an increase is an appreciation). $RLprod_i$ is the log of the traded labor productivity relative to non-traded sector for country i ($realLabProd_{T,i,t}/realLabProd_{N,i,t}$) made itself relative with respect to EU15. $Lprod_T$ is the log of an aggregation of one-letter sectoral labor productivity of traded sectors using sectoral outputs as weights. $Lprod_N$ is an analog measure for non-traded sectors. $RULC_{it}$ is the log of an aggregation of sectoral level (single letter NACE rev. 2) nominal compensation of employees per hour worked for a country i as a ratio to the Producer Price Index and expressed relative to EU27. The nominal ULC involved in the calculations are sourced in euros for all countries. LR is the spread between the real long-run (10-year) bonds rate of each country relative to EU (EU19). The rates are made real by subtracting CPI inflation. GFC is a dummy variable taking the value of 1 for the years 2007-2009. $RGDP$ is the logarithm of the real GDP per-capita relative to EU27. The data sample period is 1999-2020. Fixed effects is a panel regression with countries as cross-sections. Random effects is a random effects panel with countries as cross-sections. Pool is a panel regression without country effects. All standard errors are computed using a panel corrected standard errors method (Beck and Katz, 1995) under the assumption of period correlation (cross-sectional clustering). Standard errors are in parentheses. The estimate of the constant is not reported. Rejection of the null in the Hausman test (HT) implies a statistical difference between the FE and RE, viewed as a preference for FE.

D Other

Table 21: Disaggregated goods categories included in the RER calculations

T	Rice	N	Repair and hire of footwear	T	Passenger transport by air
T	Flours and other cereals	N	Actual rentals for housing	N	Passenger transport by sea and inland waterway
T	Bread	N	Imputed rentals for housing	T	Combined passenger transport
T	Other bakery products	T	Materials for the maintenance and repair of the dwelling	N	Other purchased transport services
T	Pizza and quiche	N	Services for the maintenance and repair of the dwelling	N	Postal services
T	Pasta products and couscous	N	Water supply	T	Telephone and telefax equipment
T	Breakfast cereals	N	Refuse collection	N	Wired telephone services
T	Other cereal products	N	Sewage collection	N	Wireless telephone services
T	Beef and veal	N	Other services relating to the dwelling n.e.c.	N	Internet access provision services
T	Pork	T	Electricity	N	Bundled telecommunication services
T	Lamb and goat	T	Natural gas and town gas	N	Other information transmission services
T	Poultry	T	Liquefied hydrocarbons (butane, propane, etc.)	T	Equipment for the reception, recording and reproduction of sound
T	Other meats	T	Liquid fuels	T	Equipment for the reception, recording and reproduction of sound and vision
T	Edible offal	T	Solid fuels	T	Portable sound and vision devices
T	Dried, salted or smoked meat	T	Heat energy	T	Other equipment for the reception, recording and reproduction of sound and picture
T	Other meat preparations	T	Household furniture	T	Photographic and cinematographic equipment and optical instruments
T	Fresh or chilled fish	T	Garden furniture	T	Personal computers
T	Frozen fish	T	Lighting equipment	T	Accessories for information processing equipment
T	Fresh or chilled seafood	T	Other furniture and furnishings	T	Software
T	Frozen seafood	T	Carpets and other floor coverings	T	Calculators and other information processing equipment
T	Dried, smoked or salted fish and seafood	N	Repair of furniture, furnishings and floor coverings	T	Pre-recorded recording media
T	Other preserved or processed fish and seafood-based preparations	T	Furnishing fabrics and curtains	T	Unrecorded recording media
T	Milk, whole, fresh	T	Bed linen	T	Other recording media
T	Milk, low fat, fresh	T	Table linen and bathroom linen	N	Repair of audio-visual, photographic and information processing equipment
T	Milk, preserved	N	Repair of household textiles	T	Major durables for outdoor recreation
T	Yoghurt	T	Other household textiles	T	Musical instruments and major durables for indoor recreation
T	Cheese and curd	T	Refrigerators, freezers and fridge-freezers	N	Maintenance and repair of other major durables for recreation and culture
T	Other milk products	T	Clothes washing machines, clothes drying machines and dish washing machines	T	Games and hobbies
T	Eggs	T	Cookers	T	Toys and celebration articles
T	Butter	T	Heaters, air conditioners	T	Equipment for sport, camping and open-air recreation
T	Margarine and other vegetable fats	T	Cleaning equipment	T	Garden products
T	Olive oil	T	Other major household appliances	T	Plants and flowers
T	Other edible oils	T	Small electric household appliances	T	Pets and related products
T	Other edible animal fats	N	Repair of household appliances	N	Veterinary and other services for pets
T	Fresh or chilled fruit	T	Glassware, crystal-ware, ceramic ware and chinaware	N	Recreational and sporting services
T	Frozen fruit	T	Cutlery, flatware and silverware	N	Cinemas, theatres, concerts
T	Dried fruit and nuts	T	Non-electric kitchen utensils and articles	N	Museums, libraries, zoological gardens
T	Preserved fruit and fruit-based products	N	Repair of glassware, tableware and household utensils	N	Television and radio licence fees, subscriptions
T	Fresh or chilled vegetables other than potatoes and other tubers	T	Major tools and equipment	N	Hire of equipment and accessories for culture
T	Frozen vegetables other than potatoes and other tubers	T	Small tools and miscellaneous accessories	N	Photographic services
T	Dried vegetables, other preserved or processed vegetables	T	Cleaning and maintenance products	N	Other cultural services
T	Potatoes	T	Other non-durable small household articles	T	Games of chance
T	Crisps	N	Domestic services by paid staff	T	Books
T	Other tubers and products of tuber vegetables	N	Cleaning services	T	Newspapers
T	Sugar	N	Hire of furniture and furnishings	T	Magazines and periodicals
T	Jams, marmalades and honey	N	Other domestic services and household services	T	Miscellaneous printed matter
T	Chocolate	T	Pharmaceutical products	T	Stationery and drawing materials
T	Confectionery products	T	Other medical products	T	Package holidays
T	Edible ices and ice cream	T	Therapeutic appliances and equipment	N	Education - HH
T	Artificial sugar substitutes	N	Medical services	N	Restaurants, cafes and dancing establishments
T	Sauces, condiments	N	Dental services	N	Fast food and take away food services
T	Salt, spices and culinary herbs	N	Paramedical services	N	Canteens
T	Baby food	N	General hospitals	N	Hotels, motels, inns and similar accommodation services
T	Ready-made meals	N	Mental health and substance abuse hospitals	N	Holiday centres, camping sites, youth hostels and similar accommodation services
T	Other food products n.e.c.	N	Speciality hospitals	T	Accommodation services of other establishments
T	Coffee	N	Nursing and residential care facilities	N	Hairdressing for men and children
T	Tea	T	New motor cars	N	Hairdressing for women
T	Cocoa and powdered chocolate	T	Second-hand motor cars	N	Personal grooming treatments
T	Mineral or spring waters	T	Motor cycles	T	Electric appliances for personal care
T	Soft drinks	T	Bicycles	T	Non-electrical appliances
T	Fruit and vegetable juices	T	Animal drawn vehicles	T	Articles for personal hygiene and wellness, esoteric products and beauty products
T	Spirits	T	Tyres	N	Prostitution
T	Wine	T	Spare parts for personal transport equipment	T	Jewellery
T	Beer	T	Accessories for personal transport equipment	T	Clocks and watches
T	Tobacco	T	Diesel	N	Repair of jewellery, clocks and watches
T	Narcotics	T	Petrol	T	Other personal effects
T	Clothing materials	T	Other fuels for personal transport equipment	N	Social protection
T	Garments for men	T	Lubricants	N	Life insurance
T	Garments for women	N	Maintenance and repair of personal transport equipment	N	Insurance connected with the dwelling
T	Garments for infants (0 to 2 years) and children (3 to 13 years)	N	Other services in respect of personal transport equipment	N	Insurance connected with health
T	Other articles of clothing and clothing accessories	N	Passenger transport by train	N	Insurance connected with transport
N	Cleaning, repair and hire of clothing	N	Passenger transport by underground and tram	N	Other insurance
T	Footwear for men	N	Passenger transport by bus and coach	N	FISIM
T	Footwear for women	N	Passenger transport by taxi and hired car with driver	N	Other financial services n.e.c.
T	Footwear for infants and children				

D.1 Data sources

Real Unit labor Costs: This measure is calculated based on nominal unit labor costs data at the industry level and PPI indexes:

Nominal Unit labor Costs

Source: Eurostat - labor Productivity and unit labor costs at industry level (national accounts data —ESA 2010)
Name of database: nama_10_lp_a21
Indicator: D1_SAL_HW, Compensation of employees per hour worked. Euros.
Link: https://ec.europa.eu/eurostat/databrowser/product/page/NAMA_10_LP_A21

Producer Price Index
Source: IMF-International Finance Statistics
Name of database: IMF-IFS,
Indicator: PPPI_IX. Prices, Producer Price Index, All Commodities. Index
Link: https://data.imf.org/?sk=4c514d48-b6ba-49ed-8ab9-52b0c1a0179b

The final three years for EU27 are missing in the IMF-IFS database and thus are extrapolated using the PPI growth for All Industry (except construction as in Table 3) from Eurostat:
Source: Eurostat
Name of database: sts_inpp_a,
Indicator: PCH_SM. Percent change with respect to last year.
Link: https://doi.org/10.2908/STS_INPP_A

Real labor productivity
Source: Eurostat - labor Productivity and unit labor costs at industry level (national accounts data)
Name of database: nama_10_lp_a21
Indicator: RLPR_HW, Real labor productivity per hour worked. Index.
Link: https://ec.europa.eu/eurostat/databrowser/product/page/NAMA_10_LP_A21

Sectoral Value Added
Source: Groningen Growth and Development Centre
Name of database: PLD 2023. Productivity Level Database.
Indicator: VA, Nominal Value Added, millions, local currency.
Link: https://www.rug.nl/ggdc/productivity/pld/releases/pld-2023

Sectoral labor Output per Hour
Source: Groningen Growth and Development Centre
Name of database: PLD 1997. Productivity Level Database.
Indicator: LP_SO, Sectoral Output per hour worked
Link: https://www.rug.nl/ggdc/productivity/pld/releases/pld-1997

Long-run Interest Rates Spread
Source: European Central Bank (ECB)
Name of database: Interest Rates Statistics (IRS).
Indicator: Long-term interest rate for convergence purposes - Debt security issued (10 years)

Link: https://data.ecb.europa.eu/data/datasets/IRS

Government defict/surplus
Source: Eurostat
Name of database: gov_10dd_edpt1, Government deficit/surplus, debt and associated data
Indicator: TE, Total General Government Expenditure
Units: PC_GDP, percentage of GDP Link: https://doi.org/10.2908/GOV_10DD_EDPT1

Fiscal Expenditure
Source: Eurostat
Name of database: gov_10a_exp, General Government Expenditure by Function
Indicator: B9, Net Lending/Net borrowing of the General Government (sector: S13)
Unit: PC_GDP, percentage of GDP Link: https://doi.org/10.2908/GOV_10A_EXP

Net capital inflows as percentage to GDP: To compute this variable we calculate the net capital inflows first as the sum of gross inflows minus the sum of gross outflows. The subtypes of flows summed in each case are listed below.

Individual flows
Source: IMF-International Finance Statistics
Name of database: `IMF-IFS`,
Inflows indicators: BFDLXF_BP6_USD: Direct investment (net incurrence of liabilities), BFPLXF_BP6_USD: Portfolio investment (net incurrence of liabilities), BFOLXF_BP6_USD: Other investment (banking), BFFL_BP6_USD: Financial Derivatives (liabilities — inflows)
Outflows indicators: BFDA_BP6_USD: Direct investment (net acquisition of assets), BFPA_BP6_USD: Portfolio investment (net acquisition of assets), BFOA_BP6_USD: Other investment (banking), FFA_BP6_USD: Financial Derivatives (Assets — outflows)
Link: https://data.imf.org/?sk=4c514d48-b6ba-49ed-8ab9-52b0c1a0179b

The total net flows are then divided by the nominal GDP in dollars:
GDP in USD
Source: World Bank
Name of database: World Development Indicators - `WDI`
Indicator: NY.GDP.MKTP.CD, GDP (current US$).
Link: databank.worldbank.org/source/world-development-indicators/Series/NY.GDP.MKTP.CD

Per capita data: Output per capita is sourced directly, other per capita variables are calculated using population data.
GDP per capita
Source: World Bank
Name of database: World Development Indicators - `WDI`

Indicator: NY.GDP.PCAP.CD, GDP per capita (current US$).

Link: databank.worldbank.org/source/world-development-indicators/Series/NY.GDP.PCAP.CD

Population

Source: IMF - International Finance Statistics

Name of database: `IMF-IFS`

Indicator: LP_PE_NUM, Population, number of persons.

Link: https://data.imf.org/?sk=4c514d48-b6ba-49ed-8ab9-52b0c1a0179b