Real Exchange Rates and Sectoral Productivity in and out of the Eurozone

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Abstract

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This paper studies the determination of real exchange rates within and across European countries, focusing on the different properties of real exchange rates for Eurozone countries as compared to the floating exchange rate countries outside the Eurozone. We investigate the link between real exchange rates and sectoral total factor productivity measures. For the Eurozone, real exchange rate patterns, both within and across countries, closely accord with an amended Balassa-Samuelson interpretation. We use a sticky price dynamic general equilibrium model to generate a cross-section and time series of real exchange rates that can be compared to the data. Under fixed exchange rates, the model simulations closely accord with the empirical estimates for the Eurozone. On other other hand, for floating rate countries, the empirical estimates do not support a Balassa-Samuelson interpretation, and there is a considerable gap between the model and the data.

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1 Introduction

Understanding real exchange rate determination remains one of the most important and yet most difficult questions in international economics. The central pillar for modelling real exchange rates remains the celebrated Balassa-Samuelson model, in which persistent movements in real exchange rates, both over time and across countries, are driven by cross-country differentials in sectoral total factor productivities. Yet it is well acknowledged that the Balassa-Samuelson model does not do well in explaining real exchange rates (e.g. Chong, Jorda and Taylor, 2010). In most empirical studies, there especially in time series data, the evidence for the effect of productivity growth on real exchange rates is quite weak.

This paper revisits the investigation of real exchange rate determination using a new data set on European price levels at a disaggregated level. Our sample of European countries allows us to construct a panel of real exchange rates at the sectoral and aggregate level in a large number of European countries over the period 1995-2009. Since the price data is in levels we can construct a real exchange rate distribution across countries at any point in time, and track the movement of this distribution over time.

Our particular focus is to contrast the properties of real exchange rates in the Eurozone, where bilateral nominal exchange rates are fixed, to countries outside the Eurozone that allow their exchange rates to float. We combine our panel of real exchange rates with measures of sectoral total factor productivities for each country, as well as a separate measure of unit labor costs. We then conduct panel regressions of real exchange rates to explore the link between the real exchange rates and productivity.

Our empirical results indicate that for the Eurozone countries, there is strong evidence of an amended Balassa-Samuelson effect. Real exchange rates are positively related to total factor productivity in traded goods (i.e. a real appreciation), and negatively related to total factor productivity in non-traded goods. But this link appears only when we separately control for unit labor cost differentials across countries. We find that, holding productivity constant, higher unit labor costs lead to real exchange rate appreciation.

For the floating rate European countries, the evidence is much more mixed. There is little evidence that total factor productivity affects real exchange rates in ways consistent with the Balassa-Samuelson theory, although unit labor costs are still significantly positive drivers of real exchange rates. In fact, for the floating rate countries, we find that the relationship between real exchange rates and sectoral productivities tends to be the reverse of that predicted by the Balassa-Samuelson model. But our sample of floating rate countries is small, when matched appropriately with sectoral total factor productivity measures.

We construct a small dynamic general equilibrium model of real exchange rates, with sticky prices and monetary policy which allows for either floating or fixed exchange rates. We can use the model to generate a panel of real exchange rate levels and movements over time which matches the European panel both for the Eurozone and the floating rate countries. Using the same cross-section and time series dimensions as the data, the model is simulated using shocks to sectoral productivities, monetary policy, and labor supply shocks that proxy for independent 'unit labor cost' shocks.

For the fixed exchange rate version of the model, we find a remarkably close relationship between the empirical estimates and the model simulation estimates. Real exchange rates in the model are driven by an amended Balassa-Samuelson pattern of shocks to sectoral productivity and unit labor costs, and the simulation estimates are close to those in the Eurozone data.

On the other hand, for the floating rate countries, there is a significant gap between the model simulation results and the empirical estimates. The model simulation estimates a predict significant traditional relationship between some measures of productivity and real exchange rates, but as mentioned above, the empirical estimates tend to predict the relationship going in the other direction. To this extent, we interpret our evidence for the floating rate countries as yet another example of the problem of 'exchange rate disconnect'.

2 Real Exchange Rates in a Theoretical Model

2.1 A Basic New Keynesian model

Our data is a balanced panel of European country real exchange rates. In the model simulations, we construct a panel of equivalent dimensions. But the theoretical explication of the model can be developed using the standard two-country DSGE approach. Let these countries be called 'home' and 'foreign'. Let the utility of a representative infinitely lived home country household evaluated from date 0 be defined as:

$$U_t = E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma}}{1-\sigma} - \chi_t \frac{N_t^{1+\psi}}{1+\psi} \right), \quad \beta < 1. \tag{2.1}$$

where C_t is the composite home consumption bundle, and N_t is home labor supply. We allow that the disutility in labor supply χ_t may be time-varying and country-specific. This plays a role in generating real exchange rate variability across countries and over time, as described below. The composite consumption good is defined as:

$$C_t = \left(\gamma^{\frac{1}{\theta}} C_{Tt}^{1-\frac{1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_{Nt}^{1-\frac{1}{\theta}} \right)^{\frac{\theta}{\theta-1}},$$

where C_{Tt} and C_{Nt} represent respectively, the composite consumption of traded and non-traded goods. The elasticity of substitution between traded and non-traded goods is θ. Traded consumption in turn is decomposed into consumption of home retail goods, and foreign retail goods, as follows:

$$C_{Tt} = \left(\omega^{\frac{1}{\lambda}} C_{Ht}^{1-\frac{1}{\lambda}} + (1-\omega)^{\frac{1}{\lambda}} C_{Ft}^{1-\frac{1}{\lambda}} \right)^{\frac{1}{1-\frac{1}{\lambda}}},$$

where λ is the elasticity of substitution between the home and foreign traded good.

Retail consumption of traded goods requires the use of non-traded goods in order to facilitate consumption, however. This can be rationalized by the argument that there are costs of distribution of traded goods, and these costs must be incurred by local (i.e. non-traded inputs). Hence, we assume that the production of consumption-related retail goods in sectors H and F are assembled according to:

$$C_{Ht} = \left(\kappa^{\frac{1}{\phi}} I_{Ht}^{1-\frac{1}{\phi}} + (1-\kappa)^{\frac{1}{\phi}} V_{Ht}^{1-\frac{1}{\phi}} \right)^{\frac{1}{1-\frac{1}{\phi}}}$$

$$C_{Ft} = \left(\kappa^{\frac{1}{\phi}} I_{Ft}^{(1-\frac{1}{\phi})} + (1-\kappa)^{\frac{1}{\phi}} V_{Ft}^{1-\frac{1}{\phi}}\right)^{\frac{1}{1-\frac{1}{\phi}}}$$

where I_{Ht} represents inputs of the home export good into the retail consumption of that good, and V_{Ht} represents input of the home non-traded good into the retail consumption of the export good. The the elasticity of substitution between non-traded inputs and the export good itself is ϕ. The notation for the retail consumption of imports (foreign goods) is similarly defined.

The consumption aggregates imply the following price index definitions:

$$P_t = \left(\gamma P_{Tt}^{1-\theta} + (1-\gamma) P_{Nt}^{1-\theta}\right)^{\frac{1}{1-\theta}},$$

$$P_{Tt} = \left(\omega \tilde{P}_{Ht}^{1-\lambda} + (1-\omega) \tilde{P}_{Ft}^{1-\lambda}\right)^{\frac{1}{1-\lambda}},$$

where P_{Tt} and P_{Nt} represent traded and non-traded price levels, and P_{Ht} and P_{Ft} are retail prices of consumption of home and foreign traded goods. Finally, these retail prices in turn depend on prices at the dock as well as the non-traded goods price. Hence:

$$\tilde{P}_{Ht} = \left(\kappa P_{Ht}^{(1-\phi)} + (1-\kappa) P_{Nt}^{1-\phi}\right)^{\frac{1}{1-\phi}}$$

$$\tilde{P}_{F} = \left(\kappa P_{Ft}^{(1-\phi)} + (1-\kappa) P_{Nt}^{1-\phi}\right)^{\frac{1}{1-\phi}}$$

We define the real exchange rate as the price of foreign relative to home consumption, where S_t is the nominal exchange rate:

$$RER_t = \frac{S_t P_t^*}{P_t}.$$

We assume that international financial markets are complete. As is well known, this implies a risk sharing condition given by: :

$$\frac{C_t^{-\sigma}}{P_t} = \frac{C_t^{*-\sigma}}{S_t P_t^*} \tag{2.2}$$

Households choose consumption of individual goods and labor supply in each sector in the usual way. The implicit labor supply for home households is given by:

$$W_t = \chi_t P_t C^{\sigma} N_t^{\psi}$$

where W_t is the nominal wage. Demand for goods is characterized as follows. The demand for traded and non-traded goods is described as:

$$C_{Tt} = \gamma \left(\frac{P_{Tt}}{P_t} \right)^{-\theta} C_t, \qquad C_{Nt} = (1-\gamma) \left(\frac{P_{Nt}}{P_t} \right)^{-\theta} C_t$$

Demand for home and foreign composite traded Goods is denoted as:

$$C_{Ht} = \omega \left(\frac{\tilde{P}_{Ht}}{P_{Tt}} \right)^{-\lambda} C_{Tt}, \qquad C_{Ft} = (1-\omega) \left(\frac{\tilde{P}_{Ft}}{P_{Tt}} \right)^{-\lambda} C_{Tt}$$

We can express the individual consumption demand for home and foreign traded goods (net of the distribution services) as

$$I_{Ht} = \kappa\gamma\omega \left(\frac{P_{Ht}}{\tilde{P}_{Ht}} \right)^{-\phi} \left(\frac{\tilde{P}_{Ht}}{P_{Tt}} \right)^{-\lambda} C_{Tt}, \qquad I_{Ft} = \kappa\gamma(1-\omega) \left(\frac{P_{Ft}}{\tilde{P}_{Ft}} \right)^{-\phi} \left(\frac{\tilde{P}_{Ft}}{P_{Tt}} \right)^{-\lambda} C_{Tt},$$

Firms in each sector produce using labor and a fixed capital stock[1] . A typical firm in the non-traded (traded) sector has production function $Y_{Nt}(i) = A_{Nt}N_{Nt}(i)^{\alpha}$, $Y_{Ht}(i) = A_{Ht}N_{Ht}(i)^{\alpha}$. Thus, there are two technology shocks - shocks to the non-traded sector A_{Nt}, and to the traded sectorA_{Ht}. In addition to the labor supply shock χ_t, these shocks are the key fundamental driving forces of efficient equilibrium real exchange rates in the model.

With perfectly flexible prices, assuming that each firm is a monopolistic competitor with constant elasticity of substitution between varieties within each sub-sector, a firm in the home country would set its price equal to marginal cost, adjusted by a constant markup. Thus, for the typical non-traded goods firm and a home traded goods producing firm, we have, in a flexible price environment:

$$P_{Nt}^{flex} = \Omega \frac{W_t}{\alpha A_{Nt} L_{Nt}^{\alpha-1}}, \qquad p_{Ht}^{flex} = \Omega \frac{W_t}{\alpha A_{Ht} L_{Ht}^{\alpha-1}}$$

where Ω is a constant markup, depending on the elasticity of substitution between varieties.

We assume that firms cannot reset prices freely, but rather must follow a Calvo price adjustment specification, using domestic household nominal marginal utilities as

[1] The implications for real exchange rates would not differ materially were we to allow for endogenous capital accumulation.

stochastic discount factors. As described in the Appendix, we allow for the possibility of a mix of producer currency pricing (PCP) firms and local currency pricing (LCP) firms where the share of LCP (PCP) pricing firms in each country is v $(1-v)$. Producer currency pricing firms set prices in the currency of the seller. Local currency pricing firms set prices in the currency of the buyer. In each case, when prices are re-set, firms set their price so that in its own currency, the firm's re-set price is equal to a discounted present value of current and anticipated fully flexible prices. For the non-traded goods firm, this implies

$$\tilde{P}_{Nt} = \frac{E_t \sum_{\tau=t}^{\infty} \Gamma_{N,\tau} P_{N\tau}^{flex}}{E_t \sum_{\tau=t}^{\infty} \Gamma_{N,\tau}}$$

For the PCP and LCP traded goods firms, respectively, the newly set prices are

$$\tilde{P}_{Ht}^{pcp} = \frac{E_t \sum_{\tau=t}^{\infty} \Gamma_{H\tau}^{pcp} P_{H\tau}^{flex}}{E_t \sum_{\tau=t}^{\infty} \Gamma_{H\tau}^{pcp}}$$

$$\tilde{P}_{Ht}^{*lcp} = \frac{E_t \sum_{\tau=t}^{\infty} \Gamma_{H\tau}^{lcp} P_{H\tau}^{flex}}{E_t \sum_{\tau=t}^{\infty} S_\tau \Gamma_{H\tau}^{lcp}}$$

where the terms Γ_{Nt}, Γ_{Ht}^{pcp} and Γ_{Ht}^{lcp} represent stochastic discount rates specific to the pricing regime of the firm.

Monetary policy is set as follows. The home country monetary authority follows a Taylor rule, adjusted for nominal exchange rate changes, except that it targets the consumer price inflation so that the nominal interest rate in the home economy is

$$r_t = \rho + \sigma_p \pi_t + \sigma_q (q_t - u_t) + \sigma_s (s_t - s_{t-1}) \tag{2.3}$$

where $\pi_t = p_t - p_{t-1}$. is the domestic inflation rate of the CPI (and $p_t = log(P_t)$), q_t is the log real exchange rate, s_t the log nominal exchange rate, and σ_i, $i = p, q, s$ are policy determined parameters. The coefficient σ_p determines the weight on CPI inflation in interest rate determination, σ_q, following Steinsson (2008), indicates a weight on real exchange rate targeting, and σ_s indicates the weight on nominal exchange rate targeting. Finally, u_t represents a stochastic monetary policy shock.

In the analysis, we will fix the policy parameters σ_p and σ_q and vary the weight on nominal exchange rates between zero, indicating floating exchange rates, and a vary high positive number, indicating a fixed exchange rate.

We assume that the foreign monetary authority follows a simple Taylor rule adjusting interest rates to CPI inflation and foreign real exchange rate changes. Thus, the foreign monetary rule is given by

$$r_t^* = \rho + \sigma_p \pi_t^* + \sigma_q \left(q_t^* - u_t^* \right)$$

. It would make no material difference to the results if we assumed that the foreign monetary authority also targeted nominal exchange rate changes.

Finally, goods market clearing conditions are given as:

$$\begin{aligned} Y_{Ht} &= I_{Ht} + I_{Ht}^* \qquad (2.4) \\ Y_{Ft}^* &= I_{Ft} + I_{Ft}^*, \\ Y_{Nt} &= C_{Nt} + V_{Ht} + V_{Ft}, \\ Y_{Nt}^* &= C_{Nt}^* + V_{Ht}^* + V_{Ft}^*. \end{aligned}$$

Traded goods production must equal demand derived from home and foreign consumer's consumption of retail traded goods. Non-traded goods production is equal to that accounted for by consumers, and that used in the distribution services of traded goods, in each country.

In addition, we must have labor market clearing in each country, so that:

$$N_t = N_{Nt} + N_{Ht} \qquad (2.5)$$

$$N_t^* = N_{Nt}^* + N_{Ht}^* \qquad (2.6)$$

The definition of equilibrium is standard and we omit it to save space.

2.2 The Real Exchange Rate Decomposition

The real exchange rate in this model is influenced by structural differences across countries and shocks that cause relative prices to move over time. Following Engel (1999), we can write a log linear approximation of the real exchange rate in terms of differences in the relative price of non-traded to traded goods across countries, and differences across countries in the price index of traded goods. Thus:

$$q_t = (1-\gamma)q_{n,t} + q_{T,t} \tag{2.7}$$

where $q_n \equiv (p_N^* - p_T^* - (p_N - p_T))$, and $q_T \equiv_T^* + s - p_T$. Note that the first expression on the right hand side does not contain the nominal exchange rate; it is the difference across countries in the relative local currency price of non-traded to traded goods. A rise in the foreign relative price, relative to the home relative price, causes a home real exchange rate depreciation. The second expression on the right hand side is the traded goods real exchange rate, at the retail level. But in our model, due to distribution costs in retail, this should also be affected by the relative price of non-traded goods. To see this, we may further decompose the second expression as follows:

$$q_{T,t} = \frac{1-\kappa}{\kappa}(p_{N,t}^* - p_{T,t}^* - (p_{N,t} - p_{T,t})) + (2\omega - 1)\tau_t + p_{H,t}^* + s_t - p_{H,t} \tag{2.8}$$

where $\tau_t = p_{Ft}^* - p_{Ht}^* = p_{Ft} - p_{Ht}$ is the terms of trade of the home country, [2], and $p_{H,t}^* + s_t - p_{H,t}$ represents the deviation from the law of one price in home traded goods. This expression tells us that the traded goods real exchange rate is driven by a) differences in relative non-traded goods prices across countries - again a rise in this relative-relative price will cause a real exchange rate depreciation, b) the terms of trade, when there is home bias in preferences (i.e. $\omega > \frac{1}{2}$), and c) deviations from the law of one price - a higher foreign price of equivalent goods relative to the home price is associated with a real exchange rate depreciation.

Putting together these two previous expressions, we see that the exchange rate directly enters the real exchange rate decomposition explicitly only to the extent that there are deviations from the law of one price. In the model described above, deviations from the law of one price will occur only when the exchange rate is uncertain. Thus, in comparing real exchange rate determination within and outside the Eurozone, we should expect to see a closer connection between the traded goods real exchange rate and the relative-relative non-traded goods price in the former than in the latter. Of course expression (2.7) and (2.8) do not say that the only difference

[2] This definition uses the fact that up to a first order approximation, the terms of trade facing foreign and home purchasers is the same. An identical equivalence up to a first order holds for the deviation from the law of one price for home and foreign goods. See Engel, 2011.

between real exchange rate behaviour across fixed and flexible exchange rate regimes is due to deviations in the law of one price. To the extent that the exchange rate regime affects real variables through monetary non-neutrality, then the other components of the real exchange rate will be different across fixed and flexible exchange rates. But we can highlight the comparison between the two regimes by comparing the behaviour of the real exchange rate under fixed and flexible regimes with the implied real exchange rate in the model where prices were perfectly flexible and there were no monetary non-neutralities at all.

While this decomposition stresses the time series movement in the real exchange rate, we want to emphasize that a similar decomposition can be done in terms of the *level* of the real exchange rate between any two countries. A country may have a high real exchange rate (or a high relative price) due to productivity differentials which drive the relative-relative price of non-traded goods, a high terms of trade, or a market structure that leads to higher relative prices of identical traded goods. In our data, we see considerably persistent differentials in relative prices among Eurozone members as well as in the floating exchange rate group.

2.3 Relative Productivity and Real Exchange Rates

The decomposition above tells us what the channels of real exchange determination will be, but it is silent on the underlying determinants of real exchange rates. The theory outlined in the previous section allows for shocks to productivity and to monetary policy rules. In a fully flexible price equilibrium, the real exchange rate will be affected only by shocks to productivity. Under plausible restrictions on elasticities, a rise in the productivity in a country's traded goods sector will generate a real exchange rate appreciation. This will come about through an increase in the relative price of non-traded goods, as in the Balassa-Samuelson model. As we see below, the positive co-movement between real exchange rates and productivity in the traded goods sector continues to hold both under fixed and floating exchange rates, when prices are sticky.

3 Data: Real Exchange Rates and Productivity

3.1 Real Exchange Rates in European Data

We describe the features of European real exchange rates. The data are constructed by Eurostat, based on the Eurostat PPP project. The frequency is annual, over 1995-2009 and the data are comprised of prices of 146 consumer goods, expressed as a ratio of the European average price of each good[3]. Hence the prices are in levels, so that both cross section and time series real exchange rate variation can be examined[4]. Over the sample period, we have 11 countries that entered the Eurozone in 1999 [5], one that entered in 2001 (Greece), and six countries that remained outside the Eurozone for the whole sample [6]. We construct aggregate and sectoral real exchange rates from the underlying price series, using expenditure weights. Let q_{it} be the average overall (log) price level (or real exchange rate, equivalently) for country i at time t, and let q_{iTt} (q_{iNt}) represent the average expenditure weighted price level of the subset of traded (non-traded) goods.

Some descriptive statistics are reported in Table 1. The Table first reports the average log real exchange rate over the sample for each country in the sample, denoted $\bar{q}$, as well as the equivalent numbers for the traded goods real exchange rate $\bar{q}_T$, the non-traded goods real exchange rate, $\bar{q}_N$, and also the relative prince of non-traded goods $\bar{p}_n = \bar{q}_N - \bar{q}_T$. We separate the Eurozone countries from the floating exchange rate countries.

We see from the Table that Belgium, Germany and France have average real exchange rates of close to zero, implying they are at the European average. Ireland and Finland have much higher positive real exchange rates, while Greece, Spain, Portugal and Italy, have much lower average real exchange rates. The characteristics of the sectoral real exchange rates, and the average relative price of non-traded goods

[3]The average is taken over the central 15 European countries given by; Austria, Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Spain, Sweden, Portugal, Finland, and the United Kingdom.

[4]See Berka and Devereux (2013) for a more complete description of the data.

[5]These are Belgium Germany Spain, France, Ireland, Italy, Luxembourg, Netherlands, Austria, Portugal, and Finland.

[6]These are Denmark, Sweden, UK, Iceland, Norway, and Switzerland.

closely mirror that aggregate real exchange rate characteristics. In general, we see that if for country i, we have $\bar{q}_i > 0$, (< 0), we also have $\bar{p}_{ni} > 0$, (< 0) ; that is, if a country has a high (low) average price level relative to the European average, its non-traded goods price tends to be proportionately higher (lower) than its traded goods price, relative to the average.

The floating exchange rate countries tend to have significantly higher average real exchange rates than those of the Eurozone. In addition, for these countries, there is no clear tendency for average non-traded goods real exchange rates to be higher than those of traded goods - for half of the floating exchange rate countries we see $\bar{p}_n < 0$.

The second panel of Table 1 reports standard deviations of annual real exchange rates for Eurozone and floating exchange rate countries. As to be expected, Eurozone countries have lower standard deviations - approximately 3 percent for most countries except Ireland. For floating exchange rate countries, standard deviations are much higher, except for Denmark. Note also that for both groups of countries, the standard deviation of non-traded real exchange rates exceeds that of the traded real exchange rate.

Table 2 reports averages across all countries and for the Eurozone and the floating exchange rate countries separately. The first panel gives the average volatility of aggregate and sectoral real exchange rates. The second panel reports the cross country dispersion in aggregate and sectoral real exchange rates. As implied by Table 1, the aggregate volatility is significantly greater for the floaters than for the Eurozone. In terms of dispersion, the cross country standard deviation of aggregate real exchange rates is over 30 percent, and for almost 50 percent for the non-traded real exchange rates.

In constructing the model below, we explicitly take account of both the time series and cross-section characteristics of real exchange rates, as characterized by the data.

3.2 Productivity and Unit Labor Cost data

We compute measures of total factor productivity that matches our real exchange rate sample. For this, we require TFP levels, both in the aggregate and by sector, for the same sample period as in the data. We do this by combining two sources for TFP. We construct a concordance between the sectors included in the Groningen Growth and Development Center's (GGDC thereafter) 1997 TFP level database, and the sectors included in the KLEMS time-series database. These two databases are meant to be used in conjunction, as outlined in Inklaar and Timmer (2008). Then, the cross-sectional TFP database and the time-series TFP database are linked using the constructed concordance to obtain annual sectoral panel TFP level data. We then use measures of the tradability of each sector and sectoral weights to construct level and time series of TFP for traded and non-traded sectors in each country. Following this, we express these measures relative to the European average, as is done for the measure of real exchange rates. As a result, we end up with a panel of traded and non-traded TFP levels which provide a match for our real exchange rate data[7]. The details of the construction are in the Appendix.

Table 1 and 2 report descriptive statistics for traded and non-traded goods productivity in the same form at the real exchange rate data. In general, we see that traded goods productivity is more volatile than non-traded goods productivity.

Our theoretical model also allows for a separate driver of the real exchange rate attribuTable to labor supply effects, as measured by the variable χ above. We do not have separate evidence on this variable, but if there are country specific labor supply related shocks, such as driven by unionization or regulatory changes, that are independent of productivity, we should see this reflected in real wage movements that are not driven by movements in TFP. We capture this possibility by including unit labor costs as a separate variable in the regressions reported below. Unit labor costs (ULC) are computed from the OECD Stat database, and expressed relative to European averages in a similar way to the sectoral productivity and real exchange rate data. The Appendix gives more details of the ULC construction.

[7]The matching is not quite perfect, because only 12 of the EU15 countries have TFP data: Belgium, Germany, Spain, France, Ireland, Italy, the Netherlands, Austria, Finland, Sweden, Denmark and the United Kingdom.

3.3 Real Exchange Rates, Relative Prices and Productivity

Tables 4 and 5 report the results of panel regressions on real exchange rates and various definitions of relative prices, as well as real exchange rates and productivity. A basic prediction of the Balassa-Samuelson model, captured also by the decomposition in (2.8), is that there should be positive relationship between the aggregate real exchange rate and the ratio of non-traded to traded goods prices. Table 4 indicates that this relationship is quite robust in the data, for both the Eurozone countries and for the floating exchange rate countries. Moreover, this holds both for the pooled regressions, as well as the regressions with fixed or random effects. In fact for the Eurozone countries, the time series and cross section relationships between q and p_n are very close to one another.

Table 5 reports the regression results for the real exchange rate and aggregate productivity, sectoral productivity, and the measure of unit labor costs. Focusing first on the results for the Eurozone, we see that in the pooled regressions, there is a strong positive relationship between aggregate productivity and real exchange rates. Allowing for the separate effects of traded and non-traded productivity gives clear intuitive results; the real exchange rate is positively related to traded goods productivity and negatively related to non-traded goods productivity. With the separate inclusion of the ULC variable, both of these effects are highly significant. In addition, ULC has a very significantly positive effect on Eurozone real exchange rates. Looking at the time series correlations alone (i.e. focusing on the fixed effects or random effects results), the significance of the aggregate productivity term is lost, but the significant relationship between the real exchange rate and sectoral productivity levels remains, once the ULC variable is incorporated. Thus, in the time series as well as the pooled regressions, the real exchange rate for the Eurozone is significantly positively (negatively) related to traded goods (non-traded goods) productivity, and significantly positively related to ULC.

For the floating exchange rate countries illustrated in Table 5, the results are harder to interpret. First, there is a significant *negative* relationship between real exchange rates and aggregated TFP, both in the time series and cross section regressions.

Aggregate TFP growth tends to be associated with real exchange rate depreciation. When TFP is decomposed into its separate traded and non-traded goods components, and the ULC variable is added, the results are also difficult to interpret. As in the case of the Eurozone, the ULC coefficient is positive and significant. The time series sectoral productivity growth coefficients are also significant, but of the wrong sign, relative to the presumptive, Balassa-Samuelson case. The traded goods productivity growth coefficient is negative, and the non-traded coefficient is positive. It is important to note however that these results come from a small sample of floating rate countries. There are only three countries for which we have matched productivity and real exchange rate data.

4 Model Determined Real Exchange Rates under Alternative Exchange Rate Regimes

We now return to the model. The aim is to describe the determination of the real exchange rate under fixed and floating exchange rate regimes, comparing the properties of the simulated real exchange rates to those we observe for the European sample of countries within and outside the Eurozone.

4.1 Model Calibration

To construct a valid comparison, we need to appropriately calibrate and simulate the model. Table 6 lists the calibration values. Here we discuss the choice of parameters.

We set both γ, the share of consumption spent on traded goods, and κ, the share of consumption of each traded good composite that is the actual traded product (as opposed to the distribution service), equal to 0.5. The smaller these parameters, the stronger the Balassa-Samuelson effect. These parameter values roughly correspond to what others in the literature have used. The elasticity of substitution between home and foreign retail goods, λ, is set at 8, which is Corsetti et al. choice [8]. For smaller λ , real exchange rate volatility increases. But larger values tend to make the

[8] Corsetti et. al. (2010) show that this translates into a lower elasticity of substitution between traded wholesale goods, due to the presence of distribution services.

Balassa-Samuelson effect stronger.

We set ω, the weight on home goods in the composite consumption for traded goods, equal to 0.5, implying no home bias for traded goods. The presence of non-traded goods in consumption and distribution services already imparts a considerable degree of home bias in the overall composition of consumption. We set α, the elasticity of labour in the production function, equal to one [9] . The parameter, σ, the coefficient of relative risk aversion, is set to equal to 2. We set ψ, the Frisch elasticity of labor supply, equal to 1. The elasticity of substitution between the physical good and the distribution service, ϕ is set to 0.25 [10].

The elasticity of substitution between traded and non-traded goods, is θ, is set to 0.7. In addition, β, the discount factor, set equal to 0.99 for quarterly data.

The model has four different kinds of shocks; productivity shocks in each of the two sectors, A_{it}, $i = H, N$, shocks to the disutility of labor χ_t, and shocks to the monetary rule under flexible exchange rates, u_t. The foreign country has a similar pattern of productivity and labor disutility shocks. We set the serial correlation of all productivity shocks equal to 0.9. This roughly matches the serial correlation in productivity shocks in the data. We have no clear evidence on serial correlation in the χ_t process, so for concreteness, we assume this has the same persistence as the productivity shocks.

The standard deviations of productivity shocks is set to 0.014, which again roughly matches the data. This implies a quarterly variance of 0.002. Then if productivity were literally a random walk the variance of annual data would be 0.008, which implies a standard deviation of around 0.09, roughly in line with the data. Again, in the absence of better information, the standard deviations of shocks to disutility of labor supply are also set to 0.014.

[9] A linear labor technology is a standard assumption in the open macro literature, and as regards the cross section representation of the model, linearity in labor is a long-run equilibrium property of a model with endogenous capital accumulation and an interest rate determined by a constant subjective rate of time preferences.

[10] Corsetti et al. (2010) set this equal to zero. The argument for a low elasticity of substitution is that wholesale goods have to be purchased in fixed supply to obtain a given amount of retail goods, so there is almost no ability to substitute between the distribution services and the wholesale goods themselves in retail production.

As explained below, our simulation model produces cross section as well as time series observations on real exchange rates. We wish to match the cross sectional standard deviation of productivity in the data. To do this, we allow the long run mean of traded goods productivity to differ among countries, and have a cross section standard deviation of 0.12, as in the data. However, as we see below this assumption on the cross-sectional standard deviation of productivity does not generate enough cross-sectional variance of real exchange rates. So we also let the disutility of work take on the same standard deviation, perfectly correlated with traded goods productivity. Increases in both traded goods productivity and in the disutility of labor supply work toward pushing up the price level . Traded productivity pushes up the price level through the Balassa-Samuelson effect, and χ does so by pushing up the steady-state real wage. For the stochastic part of the shocks to disutility of work and productivity, we assume zero correlation [11].

The speed of adjustment of prices in traded and non-traded sectors is set equal to 0.10 per quarter. We did not find that allowing the two speeds to be different mattered very much in the simulations. This parametrization helps to match the persistence of real exchange rates in the data. While this persistence is slightly greater than the persistence assumption that is based on the Bils-Klenow (2005) estimates, it is more in line with more recent work that has found more price stickiness at the micro level than Bils and Klenow found.

We calibrate the monetary policy rule as follows. The the fixed exchange rate model we set σ_s to a high number, so that the other parameters are irrelevant. Since the exchange rate is fixed, it is also the case that the currency of pricing is irrelevant also.

Under floating exchange rates, we set $\sigma_s = 0$, $\sigma_p = 2$, and $\sigma_q = 0.5$. This follows the parametrization of Steinsson (2008).

We set the serial correlation of the monetary shock u_t to 0.99. The standard

[11] Roughly speaking, we justify assuming high correlation in the cross-section but low correlation in the time series on the following grounds: In the long-run, high productivity countries are rich, and therefore prefer more leisure, because leisure is a luxury good. But in the short run, unions or government policy may act to push up wages and reduce hours, so that in the time series productivity and disutility of work are not correlated.

deviation of u_t is set to roughly match the standard deviation of the real exchange rate in the floating rate countries. This standard deviation must be different depending on the pricing assumption. For PCP, it is set equal to 0.12, for LCP it is set equal to 0.07, and for the model where some firms are pricing LCP and some PCP it is set equal to 0.08. In the LCP-PCP model, we set the fraction of LCP firms equal to 0.5.

4.2 Simulation Results

We construct a panel sample of real exchange rates to match the size of the panels in the data. That is, we compute a panel of 10 countries over 15 periods. Countries differ based on their steady state real exchange rates. We assume differences in productivity in traded goods and non-traded goods is such that the range of real exchange rates within the panel matches the standard deviation across countries within the observed panel. We construct separate fixed and floating exchange rate panels.

We first describe the characteristics of the real exchange rate under completely flexible prices, where the exchange rate regime itself is irrelevant, using the same parameterization and the same shock processes. Of course in this case, the monetary policy shocks have no effect on any components of the real exchange rate.

As in the discussion of data, we focus on the properties of the overall real exchange rate, and the components of the real exchange rate driven by the internal relative prices, and the relationship between real exchange rates, relative productivity, and relative unit labor costs.

Table 7 illustrates the properties of real exchange rates under fully flexible prices, in the cross section and time series. As in the data, everything is reported at annual frequency. The time series standard deviation is 4 percent, while that in the cross section is 10 percent, similar to that in the data. The persistence of the real exchange rate is very close to that in the data. The second panel of Table 7 shows that under flexible prices, real exchange rates are highly correlated with the cross-country relative price of non-traded goods, both in cross section and time series.

How do real exchange rates behave in a model with sticky prices, and how does this depend on the exchange rate regime? Table 7 also illustrates the properties of the model simulations in the case of fixed exchange rates. In this case, as noted above, monetary shocks are irrelevant for the real exchange rate, and hence, as in the case with fully flexible prices, relative prices are driven only by productivity and movements in the unit labor cost term χ. A noTable feature of Table 7 is that under fixed exchange rates, the real exchange rate behaves in a manner very close to the model with fully flexible prices. The standard deviation in time series and cross section is very close to that of the flexible price model, and close to the data, as is the persistence of the real exchange rate. Likewise, the relationship between the real exchange rate and relative price of non-traded goods is almost the same as in the flexible price model.

In the empirical section above, we saw that Eurozone exchange rates are significantly related to sectoral productivities, both in time series and cross-section, and separately, positively associated with measures of unit labor cost. Using the model simulations, we can run the identical regressions as those of the data. Table 8 illustrates the results, for both the flexible price model simulations as well as the fixed exchange rate case. The empirical estimates from Table 3 are repeated, for comparison purposes. In the flexible price model, sectoral productivity shocks drive real exchange rates very much as in the standard Balassa-Samuelson mechanism. Both in cross-section and time-series, an improvement in traded goods productivity generates an appreciation, while an improvement in non-traded goods productivity leads to real exchange rate depreciation. The magnitude of responses in the real exchange rate is approximately equal for both shocks - a one percent increase in traded goods productivity leads to a 0.2 percent real exchange rate appreciation in time series, and about a 0.6 percent appreciation in cross-section. In both cases, a rise in the unit-labor cost parameter leads to a real appreciation. These sign of these estimates match those of the empirical estimates, and the point estimate on traded goods productivity matches the empirics exactly, although the magnitudes differ somewhat for some of the other coefficients.

How are these results changed in the case of sticky prices? Table 8 also reports the sticky price model estimates, under fixed exchange rates. Unlike the results of Table 7, where in the time series moments, there was little difference between the flexible price and sticky price model, we see that the presence of sticky prices does affect the response of the real exchange rate to productivity shocks. The response to traded goods productivity shocks is dampened somewhat, and the response to non-traded goods shocks is enhanced. But still, the sign of the response is the same as under flexible prices, and in fact is closer to the empirical estimates (and the same sign). In addition, the presence of sticky prices reduces considerably the response of the real exchange rate to unit labor cost shocks, and moves the estimate much closer to that in the time-series data.

Not surprisingly, in the cross section, there is much less difference between the flexible price model and the sticky-price (fixed exchange rate) model. Moreover, the cross section relationships in both cases are of the same sign as the empirical estimates, and the magnitude of the comparisons are reasonably close.

Overall, these estimates are quite remarkable for the fact that they indicate that the relationship between real exchange rates and sectoral productivity can be accounted quite well by a standard two-sector New Keynesian model, in a manner which closely resembles the empirical relationship estimated from Eurozone data.

Table 9 extends the model simulations to the case of sticky prices again, but now with floating exchange rates, where the model is calibrated and simulated in the manner described above. The big difference between this and the fixed exchange rate case is that the Taylor rule given above governs monetary policy, and shocks to the monetary rule have a large impact on real exchange rates. We report the results for three separate pricing rules - PCP, LCP, and a mix of PCP and LCP.

Under all cases, real exchange rate volatility in the time series is much higher - essentially doubled, relative to the fixed exchange rate case. Cross section volatility is not affected at all, however. In addition, as was the case for Table 7, there is a strong positive relationship between real exchange rates and the cross-country relative price of non-traded goods. This is not surprising, since this link is part of the structural model. It is noTable that the estimated coefficient of the real exchange rate regressed on the relative price of non-traded goods is much lower in the LCP case. This is because, with LCP, exchange rate pass-through to consumer goods prices is limited, so there is a significantly smaller impact of productivity shocks on domestic currency relative prices.

In the empirical estimates, we found that the relationship between sectoral productivity and real exchange rates for the floating rate countries was much less consistent with the basic Balassa-Samuelson model than the results for the Eurozone. In particular, in the time-series, results, the signs of traded goods and non-traded goods productivity was the reverse of that predicated by the Balassa-Samuelson model. Can our floating exchange rate simulations account for these findings? We find that this is not the case. Table 10 illustrates that in the simulations for the floating exchange rate countries, there is no significant relationship between traded goods productivity and real exchange rates. The sign of the coefficient on non-traded goods productivity is the reverse of that in the empirical estimates (and in fact, consistent with the Balassa-Samuelson interpretation). Moreover, the estimate on the unit labor cost variable in the simulated data is now *negative*, in contrast to the data. Intuitively, the reason for this is that, in the floating rate simulations, the monetary rule shock is playing a big role. In response to a monetary shock, there is a rise in domestic production, which pushes up the real wage and increases unit labor cost, while at the same time the monetary shock generates a real exchange rate depreciation.

Overall, Table 10 illustrates only a weak correspondence between theory and empirical estimates for the floating exchange rate model. In contrast to the fixed exchange rate model, where there was a close intuitive relationship between productivity, unit labor costs, and the real exchange rate, and a notably close relationship between the estimates and the empirics, the conclusion for the floating exchange rate countries indicates that, first, there is only a weak and somewhat perverse empirical relationship between productivity and real exchange rates, and second, there is significant gap between the empirical estimates and the model simulations. It should be again noted however, that our floating exchange rate sample is very small - we have data on sectoral productivity and unit labor costs for only three countries. It remains to be seen whether our results will change appreciably when the sample is extended to more countries.

5 Conclusions

We have seen that the real exchange rates in the Eurozone closely reflect differences in the relative prices of nontraded to traded goods across countries, and in turn differences in the relative productivity levels in the traded versus non-traded sectors. The actual pattern of prices and real exchange rates mirrors the pattern produced in the simulations from our model. Moreover, we see in the model simulations that the distribution of real exchange rates in the currency union matches the pattern produced under flexible prices.

Intuitively, there are three main reasons why the real exchange rates in the currency union are so nearly in line with the real exchange rates under flexible prices. First, the initial accession rates in the Eurozone were set in effect to minimize deviations in traded goods prices across countries. So in 1999, the real exchange rates within the Eurozone were effectively initialized at levels that reflect the differences in their nontraded goods prices and differences in distribution costs.

Second, relative productivity shocks over time within the Eurozone simply are not that big. That is, the equilibrium or flexible-price real exchange rate within the Eurozone does not change very much over time. If the initial real exchange rates are near the equilibrium level then even with no further adjustment of the actual real exchange rates, they will not differ too much from the equilibrium rates simply because the equilibrium rates do not stray very far from the initial levels. In a sense, this observation merely restates the point made by Rogoff (1995) in the context of the puzzling behavior of real exchange rates under floating nominal rates. He said that real exchange rate volatility we observe among floating rate countries is impossible to explain if only real productivity shocks drove real exchange rates - that monetary and financial factors must play a role: "existing models based on real shocks cannot account for short-term exchange rate volatility" (p. 648). Equilibrium real exchange rates are not very volatile, and since the currency union eliminates relative monetary shocks, the real exchange rate under a currency union is also not very volatile.

Third, nominal prices do adjust over time, so even in a currency union there is real exchange rate adjustment. It is worth emphasizing that the choice of exchange rate regime only matters for real exchange rate adjustment because nominal prices are sticky. The speed of adjustment of real exchange rates is limited only by the speed of adjustment of nominal prices. While the point is obvious, it still is often overlooked. For example, it is frequently argued that the Eurozone is a poor candidate for a currency union because labor is not very mobile within the Eurozone. But the degree of labor mobility can only matter for the choice of exchange-rate regime if mobility can substitute for nominal wage and price adjustment. That is, labor immobility may well mean that adjustment to real shocks in the Eurozone is slower than in the U.S. where labor is more mobile. However, this refers to an equilibrium adjustment – the problem would exist in the Eurozone even if prices and wages were flexible. Put another way, labor mobility can substitute for nominal exchange rate adjustment only if labor moves at higher frequencies than prices and wages adjust.

In the end, we have not presented a full-blown welfare analysis of currency unions versus floating exchange rates. Our point is that real exchange rate adjustment in a currency union might be superior to that under floating rates. There is no evidence that real exchange rates under floating rates adjust in a desirable way. A currency union might deliver superior performance because it reduces the deviations from price equality for traded goods that occurs under a floating regime. However, there are many other dimensions to consider. A currency union does not allow for independent monetary policy among countries within the union. On the other hand, currency unions might enhance the credibility of monetary policy for some countries, they might allow countries to overcome "original sin" and borrow internationally in their own currency, and currency unions might spur closer fiscal cooperation. The Friedman argument, however, that floating rates allow efficient real exchange rate adjustment, is spurious.

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6 Tables

Table 1. Country summary statistics

country	$\overline{q}$	$\overline{q_T}$	$\overline{q_N}$	$\overline{pn}$	s(q)	s(q_T)	s(q_N)	s(pn)	$\overline{a_T}$	$\overline{a_N}$	$\overline{a_T - a_N}$	s(a_T)	s(a_N)	s($a_T - a_N$)
BE	0.00	-0.01	0.01	0.02	0.03	0.02	0.03	0.02	0.05	0.03	0.03	0.04	0.04	0.02
GER	0.01	-0.02	0.04	0.06	0.04	0.02	0.07	0.07	0.02	0.08	-0.06	0.01	0.01	0.02
GRE	-0.20	-0.16	-0.25	-0.09	0.03	0.03	0.05	0.03						
SPA	-0.17	-0.16	-0.17	-0.01	0.02	0.02	0.03	0.03	-0.12	0.02	-0.14	0.10	0.05	0.05
FRA	0.03	-0.02	0.08	0.10	0.03	0.03	0.03	0.02	0.01	0.07	-0.06	0.02	0.02	0.02
IRE	0.11	0.09	0.12	0.04	0.08	0.05	0.10	0.05	0.25	0.03	0.22	0.05	0.02	0.05
ITA	-0.05	-0.02	-0.09	-0.07	0.04	0.04	0.04	0.02	-0.03	-0.10	0.08	0.10	0.04	0.07
LUX	0.01	-0.08	0.13	0.21	0.04	0.03	0.06	0.06						
NET	-0.02	-0.03	0.00	0.03	0.02	0.02	0.03	0.03	0.13	0.23	-0.09	0.02	0.03	0.05
AUS	-0.02	0.00	-0.03	-0.04	0.03	0.03	0.04	0.01	-0.05	0.01	-0.06	0.06	0.02	0.04
POR	-0.20	-0.11	-0.33	-0.21	0.01	0.02	0.02	0.03						
FIN	0.16	0.12	0.19	0.07	0.03	0.03	0.03	0.01	0.20	0.16	0.05	0.08	0.04	0.05
SWE	0.13	0.10	0.16	0.06	0.07	0.05	0.10	0.06	0.09	0.05	0.04	0.11	0.02	0.09
DEN	0.24	0.24	0.24	-0.00	0.03	0.02	0.04	0.04	-0.08	0.18	-0.25	0.08	0.02	0.07
UK	0.00	0.01	-0.00	-0.01	0.09	0.09	0.10	0.03	-0.00	0.03	-0.04	0.04	0.02	0.05
ICE	0.21	0.23	0.19	-0.04	0.12	0.12	0.14	0.07						
NOR	0.26	0.30	0.21	-0.09	0.04	0.04	0.05	0.02						
SWI	0.27	0.12	0.36	0.25	0.06	0.05	0.07	0.03						
CYP	-0.14	-0.05	-0.24	-0.19	0.01	0.02	0.02	0.03						
CZE	-0.57	-0.36	-0.87	-0.51	0.13	0.12	0.15	0.05	-0.17	-0.24	0.07	0.05	0.05	0.06
EST	-0.45	-0.33	-0.64	-0.31	0.10	0.07	0.15	0.09						
HUN	-0.54	-0.37	-0.81	-0.44	0.11	0.10	0.13	0.04	-0.15	-0.26	0.11	0.07	0.06	0.02
LAT	-0.54	-0.37	-0.81	-0.44	0.11	0.09	0.16	0.08						
LIT	-0.56	-0.41	-0.95	-0.53	0.09	0.08	0.14	0.06						
MAL	-0.28	-0.13	-0.45	-0.32	0.03	0.03	0.05	0.05						
POL	-0.56	-0.41	-0.78	-0.37	0.08	0.09	0.09	0.06						
SVK	-0.65	-0.42	-1.01	-0.58	0.18	0.17	0.23	0.06						
SVN	-0.30	-0.19	-0.45	-0.26	0.03	0.03	0.05	0.03	-0.16	-0.28	0.12	0.05	0.03	0.07
BUL	-0.86	-0.58	-1.23	-0.64	0.12	0.12	0.11	0.03						
ROM	-0.74	-0.57	-1.06	-0.49	0.16	0.17	0.18	0.05						
TUR	-0.57	-0.38	-0.89	-0.52	0.11	0.10	0.21	0.13						

All real exchange rate variables are expressed relative to EU15 average (=0 each year). q is the expenditure-weighted log real exchange rate (increase is an appreciation). q_T (q_N) is the same real exchange rate but for traded (nontraded) goods only, both relative to EU15 average. $pn \equiv q_N - q_T$. $s(.)$ denotes standard deviation. RER sample is 1995 - 2009 (annual), except for the countries of Southern and Eastern Europe (from Cyprus onwards), where the sample begins in 1999. a_T (a_N) is a logarithm of traded (nontraded) TFP relative to EU12. Traded constitutes an aggregate of 1-digit sector's TFP levels aggregated using sectoral gross outputs as weights. TFP sample is 1995 - 2007 for all countries with data.

Table 2. Standard deviations

	mean(std$_i$(.))				std(mean$_i$(.))			
variable	All	EZ	Float	East	All	EZ	Float	East
q	0.067	0.033	0.070	0.098	0.328	0.113	0.103	0.193
q_T	0.061	0.028	0.060	0.091	0.238	0.087	0.109	0.154
q_N	0.088	0.044	0.084	0.129	0.471	0.158	0.120	0.275
pn	0.045	0.032	0.043	0.059	0.253	0.107	0.119	0.133
a_T	0.059	0.055	0.075	0.055	0.129	0.121	0.083	0.014
a_N	0.031	0.031	0.019	0.045	0.155	0.093	0.078	0.017
$a_T - a_N$	0.049	0.040	0.070	0.052	0.119	0.111	0.151	0.027

All real exchange rate variables are expressed relative to EU15 average (=0 each year). q is the expenditure-weighted log real exchange rate (increase is an appreciation). q_T (q_N) is the same real exchange rate but for traded (nontraded) goods only, both relative to EU15 average. $pn \equiv q_N - q_T$. RER sample is 1995 - 2009 (annual), except for the countries of Southern and Eastern Europe, where the sample begins in 1999. a_T (a_N) is a logarithm of traded (nontraded) TFP relative to EU12. Traded constitutes an aggregate of 1-digit sector's TFP levels aggregated using sectoral gross outputs as weights. TFP sample is 1995 - 2007 for all countries with data (see previous Table).
The left panel reports average time series standard deviation (std$_i$(.), where i indexes countries). The right panel reports the standard deviation of average real exchange rates (mean$_i$(.), where $_i$ indexes countries).

Table 3. Correlations of a_T and a_N within country groups

	overall	time series	cross section
EZ	0.53	0.78	0.49
Float	-0.38	0.49	-0.76
East	0.35	0.41	-0.49

Table 4. Price regressions

q

	Eurozone				**Floating currency countries**			
	1	2	3	4	5	6	7	8
	Pool	FE	RE	XS	Pool	FE	RE	XS
pn	**0.70*****	**0.60*****	**0.61*****	**0.71****	**0.26****	**0.79*****	**0.72*****	0.17
	(0.058)	(0.076)	(0.07)	(0.247)	(0.103)	(0.15)	(0.14)	(0.14)
$\overline{R}^2$	0.44	0.93	0.36	0.40	0.05	0.68	0.20	-0.20
N	180	180	180	12	90	90	90	6
HT	–	–	not reject	–	–	–	not reject	–

pn

	Eurozone				**Floating currency countries**			
	9	10	11	12	13	14	15	16
	Pool	FE	RE	XS	Pool	FE	RE	XS
$\mathbf{q_T}$	**0.39*****	0.17	**0.19***	0.42	**-0.29*****	**0.14****	**0.13***	-0.49
	(0.086)	(0.11)	(0.103)	(0.26)	(0.10)	(0.07)	(0.07)	(0.45)
$\overline{R}^2$	0.10	0.89	0.02	0.03	0.08	0.85	0.02	0.004
N	180	180	180	12	90	90	90	6
HT	–	–	not reject	–	–	–	not reject	–

q

	Eurozone				**Floating currency countries**			
	17	18	19	20	21	22	23	24
	Pool	FE	RE	XS	Pool	FE	RE	XS
$\mathbf{q_T}$	**1.19*****	**1.08*****	**1.09*****	**1.20*****	**0.84*****	**1.07*****	**1.07*****	**0.745****
	(0.038)	(0.053)	(0.048)	(0.11)	(0.057)	(0.03)	(0.03)	(0.258)
$\overline{R}^2$	0.84	0.98	0.77	0.83	0.71	0.97	0.91	0.53
N	180	180	180	12	90	90	90	6
HT	–	–	not reject	–	–	–	not reject	–

q is the logarithm of expenditure-weighted real exchange rate of country i relative to EU15 average (an increase is an appreciation). q_T is the logarithm of the expenditure-weighted real exchange rate of tradables in country i relative to EU15 average. pn is the log of the relative price of nontraded to traded goods (all expenditure-weighted) in country i, relative to EU15 average ($pn \equiv q_N - q_T$). *Pool* is a pooled regression with all countries and years sharing the same estimate of a constant and a slope. FE is a fixed-effects panel regression with countries as cross sections. RE is a random effects regression with countries as cross sections. XS is a cross-sectional regression which uses time-average values of variables in each country. All standard errors are computed using a panel adjustment robust to serial correlation (except for XS, where Newey-West adjustment is used). Standard errors in parentheses. The estimate of the constant is not reported. A * denotes a 10%, ** 5% and *** 1% significance. Eurozone countries are: Austria, Belgium, Germany, Greece, France, Finland, Italy, Ireland, Luxembourg, the Netherlands, Portugal, and Spain. Floating currency countries are: Sweden, Denmark, Iceland, Norway, Switzerland and the UK. Rejection of the null at 5% in Hausman test (HT) implies no difference between FE and RE, viewed as a preference for FE.

Table 5. RER - TFP regression

	Pool			Fixed effects			Random effects			Cross-section		
	Eurozone											
	1a	1b	1c	2a	2b	2c	3a	3b	3c	4a	4b	4c
TFP	**0.43*****	–	–	-0.10	–	–	-0.04	–	–	**0.51****	–	–
	(0.067)			(0.11)			(0.094)			(0.21)		
TFP_T	–	**0.50*****	**0.76*****	–	0.003	**0.18****	–	0.05	**0.26*****	–	**0.67*****	**0.93*****
		(0.059)	(0.062)		(0.11)	(0.090)		(0.09)	(0.079)		(0.145)	(0.19)
TFP_N	–	-0.09	**-0.29*****	–	**-0.36***	**-0.36****	–	**-0.29***	**-0.36*****	–	-0.05	-0.27
		(0.08)	(0.078)		(0.22)	(0.18)		(0.164)	(0.13)		(0.184)	(0.22)
ULC	–	–	**0.42*****	–	–	**0.46*****	–	–	**0.46*****	–	–	**0.43***
			(0.079)			(0.072)			(0.077)			(0.20)
$\overline{R}^2$	0.25	0.41	0.57	0.84	0.85	0.90	-0.007	0.02	0.32	0.28	0.62	0.76
N	117	117	117	117	117	117	117	117	117	9	9	9
HT	–	–	–	–	–	–	reject	reject	reject			
	Floating currency countries$^{\triangle}$											
	5a	5b	5c	6a	6b	6c	7a	7b	7c	8a	8b	8c
TFP	**-0.48*****	–	–	**-0.56*****	–	–	**-0.56*****	–	**-0.46*****	-0.46	–	–
	(0.086)			(0.11)			(0.106)		(0.085)	(0.425)		
TFP_T	–	**-0.21***	-0.078	–	**-0.60*****	**-0.21***	–	**-0.21***	–	–	–	–
		(0.11)	(0.10)		(0.11)	(0.11)		(0.109)				
TFP_N	–	**0.98*****	**1.14*****	–	**1.15****	-0.004	–	**0.98*****	–	–	–	–
		(0.246)	(0.16)		(0.53)	(0.39)		(0.246)				
ULC	–	–	**0.63*****	–	–	**0.504*****	–	–	**0.48*****	–	–	–
			(0.13)			(0.104)			(0.158)			
$\overline{R}^2$	0.41	0.50	0.73	0.84	0.84	0.93	0.47	0.50	0.54	-0.19		
N	39	39	39	39	39	39	39	39	39	3		
HT	–	–	–	–			not reject	reject	not reject			–
	Floating currency countries 2†											
	9a	9b	9c	10a	10b	10c	11a	11b	11c	12a	12b	12c
TFP	**-1.58*****	–	–	**-0.49*****	–	–	**-0.53*****	–	–	**-1.93****	–	–
	(0.196)			(0.144)			(0.13)			(0.513)		
TFP_T	–	0.16	0.03	–	**-0.55*****	**-0.19****	–	**-0.53*****	**-0.28*****	–	**0.76***	-0.32
		(0.17)	(0.115)		(0.115)	(0.083)		(0.105)	(0.087)		(0.244)	(0.33)
TFP_N	–	**1.66*****	**1.37*****	–	**1.92*****	**0.449*****	–	**1.89*****	**1.43*****	–	**1.46****	**1.02****
		(0.107)	(0.071)		(0.4)	(0.239)		(0.27)	(0.122)		(0.255)	(0.162)
ULC	–	–	**0.92*****	–	–	**0.569*****	–	–	**0.53*****	–	–	**1.53****
			(0.09)			(0.052)			(0.06)			(0.263)
$\overline{R}^2$	0.50	0.85	0.95	0.97	0.97	0.99	0.18	0.47	0.84	0.42	0.83	0.986
N	66	66	66	66	66	66	66	66	66	6	6	6
HT	–	–	–	–			not reject	not reject	reject			

Dependant variable: log real exchange rate (expenditure-weighted) of country i vis-a-vis the EU15 average. An increase is an *appreciation*. TFP_i is the log of TFP levels of traded relative to non-traded sector in country i, relative to $\log(TFP_{T,EU12,t}/TFP_{N,EU12,t})$. $TFP_{T,i,t}$ is constructed by aggregating 1-digit sectoral TFP of traded sectors (agriculture is excluded due to issues caused by Common Agricultural Policy) using sectoral output as weights. *Pool* is a pooled regression with all countries and periods sharing the same estimate of a constant and a slope coefficient. Fixed effects is a panel regression with countries as cross-sections. Random effects is a random effects panel estimation with countries as cross sections. Cross-section is a regression which uses the time-average value for each country and runs a cross sectional regression. All standard errors (except for $Cross-section$) are computed using a Panel corrected standard errors method (Beck and Katz, 1995) under the assumption of period correlation (cross-sectional clustering). The standard errors in $Cross-section$ are Newey-West standard errors. Standard errors in parentheses. The estimate of the constant is not reported. A * denotes a 10%, ** 5% and *** 1% significance. The following Eurozone members are included: Austria, Belgium, Germany, Finland, France, Ireland, Italy, the Netherlands and Spain. $\triangle$: UK, Denmark and Sweden. $\dagger$: UK, Denmark, Sweden, Czech Republic, Hungary, Slovenia. Rejection of the null at 5% in Hausman test (HT) implies no difference between FE and RE, viewed as a preference for FE.

Table 5b. RER - Labour Productivity (measure 1) regression

	Pool			Fixed effects			Random effects			Cross-section		
	Eurozone											
	1a	1b	1c	2a	2b	2c	3a	3b	3c	4a	4b	4c
LP	**0.11****	–	–	0.08	–	–	0.08	–	–	0.07	–	–
	(0.044)			(0.07)			(0.06)			(0.08)		
LP_T	–	**0.27*****	**0.16*****	–	0.077	**0.10****	–	0.08	**0.11*****	–	**0.16****	**0.17****
		(0.042)	(0.047)		(0.07)	(0.050)		(0.064)	(0.047)		(0.057)	(0.06)
LP_N	–	0.01	0.03	–	-0.06	**-0.29*****	–	-0.047	**-0.27*****	–	0.004	-0.007
		(0.05)	(0.058)		(0.098)	(0.07)		(0.084)	(0.66)		(0.034)	(0.042)
ULC	–	–	-0.047	–	–	**0.57*****	–	–	**0.55*****	–	–	-0.16
			(0.093)			(0.06)			(0.06)			(0.14)
$\overline{R}^2$	0.05	0.22	0.22	0.84	0.84	0.92	0.01	0.01	0.44	-0.03	0.55	0.51
N	117	117	117	117	117	117	117	117	117	12	12	12
HT	–	–	–	–	–	–		reject	reject			
	Floating currency countries$^{\triangle}$											
	5a	5b	5c	6a	6b	6c	7a	7b	7c	8a	8b	8c
LP	0.048	–	–	-0.12	–	–	-0.06	–	–	0.06	–	**-0.91****
	(0.04)			(0.14)			(0.11)			(0.07)		(0.068)
LP_T	–	0.014	-0.005	–	-0.12	0.024	–	-0.01	-0.005	–	0.005	–
		(0.02)	(0.03)		(0.14)	(0.11)		(0.07)	(0.03)		(0.06)	
LP_N	–	**0.38*****	**0.41*****	–	**0.31****	-0.18	–	**0.25****	**0.41*****	–	**0.49***	–
		(0.06)	(0.05)		(0.14)	(0.14)		(0.108)	(0.049)		(0.127)	
ULC	–	–	-0.07	–	–	**0.66*****	–	–	-0.067	–	–	**-2.99****
			(0.08)			(0.15)			(0.078)			(0.18)
$\overline{R}^2$	0.01	0.56	0.74	0.75	0.79	0.90	-0.01	0.19	0.74	-0.28	0.49	0.94
N	65	65	52	65	65	52	65	65	52	5	5	4
HT	–	–	–	–								–

Dependant variable: log real exchange rate (expenditure-weighted) of country i vis-a-vis the EU15 average. An increase is an *appreciation*. LP_i is the log of Labour Productivity per hour worked of traded relative to non-traded sector in country i, relative to EU 15. $\widetilde{LP_{T,i,t}}$ is constructed by aggregating 1-digit sectoral LP of traded sectors (agriculture is excluded due to issues caused by Common Agricultural Policy) using sectoral output as weights: $\widetilde{LP_{Tit}} = \sum_{j=1}^{3} \omega_{ijt} LP_{ijt}$ where $LP_{ijt} = \frac{Y_{ijt}/H_{ijt}}{P_{ijt}}$ where P_{ijt} are sectoral price deflators. (Except for Norway and Switzerland, where Gross Value Added is used (see measure 2)). Consequently, $LP_{it} = \frac{\widetilde{LP_{Tit}}/\widetilde{LP_{Nit}}}{LP_{T,EU15,t}/LP_{N,EU15,t}}$. Measures LP_T and LP_N are constructed in the same manner, for only Traded and Non-traded sectors, respectively. ULC_{it} comes from OECD.Stat database and is defined as a ratio of nominal Total Labour Costs for the whole economy relative to the real output (2005 base year). We convert ULC_{it} to euro for all countries. The measure used in the regressions is relative to EU 17 (provided by OECD). *Pool* is a pooled regression with all countries and periods sharing the same estimate of a constant and a slope coefficient. Fixed effects is a panel regression with countries as cross-sections. Random effects is a random effects panel estimation with countries as cross sections. Cross-section is a regression which uses the time-average value for each country and runs a cross sectional regression. All standard errors (except for $Cross-section$) are computed using a Panel corrected standard errors method (Beck and Katz, 1995) under the assumption of period correlation (cross-sectional clustering). The standard errors in $Cross-section$ are Newey-West standard errors. Standard errors in parentheses. The estimate of the constant is not reported. A * denotes a 10%, ** 5% and *** 1% significance. The following Eurozone members are included: Austria, Belgium, Germany, Greece, Finland, France, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain. △: UK, Denmark, Sweden, Norway and Switzerland. Rejection of the null at 5% in Hausman test (HT) implies no difference between FE and RE, viewed as a preference for FE.

Table 5c. RER - Labour Productivity (measure 2) regression

	Pool			Fixed effects			Random effects			Cross-section		
						Eurozone						
	1a	1b	1c	2a	2b	2c	3a	3b	3c	4a	4b	4c
LP	**0.18****	–	–	0.077	–	–	**0.09****	–	–	**0.25*****	–	–
	(0.044)			(0.05)			(0.044)			(0.07)		
LP_T	–	**0.14*****	**0.15*****	–	**0.08****	-0.029	–	0.055	-0.02	–	**0.17*****	**0.17*****
		(0.024)	(0.03)		(0.04)	(0.050)		(0.034)	(0.03)		(0.04)	(0.048)
LP_N	–	**0.072***	0.06	–	**-0.35****	-0.10	–	**-0.19***	-0.09	–	0.04	0.042
		(0.042)	(0.054)		(0.13)	(0.11)		(0.097)	(0.086)		(0.06)	(0.06)
ULC	–	–	0.03	–	–	**0.47*****	–	–	**0.45*****	–	–	-0.021
			(0.09)			(0.06)			(0.06)			(0.084)
$\overline{R}^2$	0.22	0.36	0.35	0.84	0.85	0.91	0.03	0.02	0.41	0.35	0.74	0.71
N	135	135	135	135	135	135	135	135	135	12	12	12
HT	–	–	–	–	–	–						
						Floating currency countries△						
	5a	5b	5c	6a	6b	6c	7a	7b	7c	8a	8b	8c
LP	-0.004	–	–	**-0.28****	–	–	**-0.22***	–	–	0.009	–	-0.73
	(0.05)			(0.14)			(0.11)			(0.10)		(0.21)
LP_T	–	**0.08*****	**0.21*****	–	**-0.26****	0.02	–	-0.05	**0.21*****	–	0.1	–
		(0.03)	(0.05)		(0.12)	(0.09)		(0.05)	(0.05)		(0.048)	
LP_N	–	**-0.28*****	**-0.36*****	–	0.24	**-0.48*****	–	**-0.17****	**-0.36*****	–	**-0.32*****	–
		(0.03)	(0.05)		(0.26)	(0.21)		(0.08)	(0.053)		(0.02)	
ULC	–	–	**0.30*****	–	–	**0.62*****	–	–	**0.30****	–	–	-1.96
			(0.11)			(0.10)			(0.11)			(0.32)
$\overline{R}^2$	-0.01	0.56	0.63	0.74	0.74	0.90	0.05	0.14	0.63	-0.33	0.74	0.51
N	74	71	57	74	71	57	74	71	57	5	5	4
HT	–	–	–	–								

Dependant variable: log real exchange rate (expenditure-weighted) of country i vis-a-vis the EU15 average. An increase is an *appreciation*. LP_i is the log of Labour Productivity per hour worked of traded relative to non-traded sector in country i, relative to EU 15. $\widetilde{LP_{T,i,t}}$ is constructed by aggregating 1-digit sectoral LP of traded sectors (agriculture is excluded due to issues caused by Common Agricultural Policy) using sectoral output as weights: $\widetilde{LP_{Tit}} = \frac{\sum_{j=1}^{3} GVA_{ijt}}{\sum_{j=1}^{3} H_{ijt}}$. GVA and corresponding H measures are from Eurostat, using a 1-digit sectoral disaggregation. Consequently, $LP_{it} = \frac{\widetilde{LP_{Tit}}/\widetilde{LP_{Nit}}}{LP_{T,EU15,t}/LP_{N,EU15,t}}$. Measures LP_T and LP_N are constructed in the same manner, for only Traded and Non-traded sectors, respectively. ULC_{it} comes from OECD.Stat database and is defined as a ratio of nominal Total Labour Costs for the whole economy relative to the real output (2005 base year). We convert ULC_{it} to euro for all countries. The measure used in the regressions is relative to EU 17 (provided by OECD). *Pool* is a pooled regression with all countries and periods sharing the same estimate of a constant and a slope coefficient. Fixed effects is a panel regression with countries as cross-sections. Random effects is a random effects panel estimation with countries as cross sections. Cross-section is a regression which uses the time-average value for each country and runs a cross sectional regression. All standard errors (except for $Cross - section$) are computed using a Panel corrected standard errors method (Beck and Katz, 1995) under the assumption of period correlation (cross-sectional clustering). The standard errors in $Cross - section$ are Newey-West standard errors. Standard errors in parentheses. The estimate of the constant is not reported. A * denotes a 10%, ** 5% and *** 1% significance. The following Eurozone members are included: Austria, Belgium, Germany, Greece, Finland, France, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain. △: UK, Denmark, Sweden, Norway and Switzerland. Rejection of the null at 5% in Hausman test (HT) implies no difference between FE and RE, viewed as a preference for FE.

Table 5d. ULC - TFP regression

	Pool		**Fixed effects**		**Random effects**		**Cross-section**	
				Eurozone				
	1a	1b	2a	2b	3a	3b	4a	4b
TFP	**-0.58*****	–	**-0.50*****	–	**-0.52*****	–	**-0.59*****	–
	(0.07)		(0.13)		(0.12)		(0.23)	
TFP_T	–	**-0.61*****	–	**-0.39*****	–	**-0.44*****	–	-0.61
		(0.07)		(0.14)		(0.12)		(0.32)
TFP_N	–	**0.49*****	–	-0.005	–	0.11	–	**0.51****
		(4.6)		(0.27)		(0.21)		(0.17)
$\overline{R}^2$	0.34	0.34	0.81	0.82	0.17	0.21	0.31	0.20
N	117	117	117	117	117	117	9	9
HT	–	–	–	–	not reject	not reject		
				Floating currency countries$^{\triangle}$				
	5a	5b	6a	6b	7a	7b	8a	8b
TFP	-0.05	–	**-0.67*****	–	**-0.16***	–	0.15	–
	(-0.07)		(0.2)		(-0.09)		(0.06)	
TFP_T	–	**-0.21***	–	**-0.78*****	–	**-0.21****	–	–
		(-2.05)		(0.18)		(0.12)		
TFP_N	–	-0.25	–	**2.3*****	–	**-0.25****	–	–
		(0.30)		(0.87)		(0.30)		
$\overline{R}^2$	-0.02	0.02	0.36	0.45	0.02	0.02	0.45	
N	39	39	39	39	39	39	3	
HT	–	–	–		reject	reject		
				Floating currency countries 2†				
	9a	9b	10a	10b	11a	11b	12a	12b
TFP	**-0.37*****	–	0.30	–	0.11	–	-0.50	–
	(0.12)		(0.31)		(0.23)		(0.05)	
TFP_T	–	**0.50*****	–	0.32	–	0.34	–	**0.70****
		(0.19)		(0.32)		(0.26)		(0.22)
TFP_N	–	**0.37*****	–	-0.05	–	0.36	–	0.29
		(0.11)		(0.65)		(0.22)		(0.15)
$\overline{R}^2$	0.07	0.36	0.49	0.49	-0.01	0.08	0.05	0.55
N	78	78	78	78	78	78	6	6
HT	–	–	–		not reject	not reject		

Dependant variable: ULC_{it} (source: OECD.Stat database) is defined as a ratio of nominal Total Labour Costs for the whole economy relative to the real output (2005 base year). We convert ULC_{it} to euro for all countries. The measure used in the regressions is relative to EU 17 (provided by OECD). TFP_{it} is the log of TFP levels of traded relative to non-traded sector in country i, relative to $\log(TFP_{T,EU12,t}/TFP_{N,EU12,t})$. $TFP_{T,i,t}$ is constructed by aggregating 1-digit sectoral TFP of traded sectors (agriculture is excluded due to issues caused by Common Agricultural Policy) using sectoral output as weights. *Pool* is a pooled regression with all countries and periods sharing the same estimate of a constant and a slope coefficient. Fixed effects is a panel regression with countries as cross-sections. Random effects is a random effects panel estimation with countries as cross sections. Cross-section is a regression which uses the time-average value for each country and runs a cross sectional regression. All standard errors (except for $Cross-section$) are computed using a Panel corrected standard errors method (Beck and Katz, 1995) under the assumption of period correlation (cross-sectional clustering). The standard errors in $Cross-section$ are Newey-West standard errors. $t-statistics$ in parentheses. The estimate of the constant is not reported. A * denotes a 10%, ** 5% and *** 1% significance. $\triangle$: UK, Denmark and Sweden. $\dagger$: UK, Denmark, Sweden, Czech Republic, Hungary, Slovenia. Rejection of the null at 5% in Hausman test (HT) implies no difference between FE and RE, viewed as a preference for FE.

Table 6. *pn* **- TFP regression**

	Pool	**Fixed effects**	**Random effects**
		Eurozone	
	1	2	3
TFP	-0.03	0.05	0.04
	(0.05)	(0.09)	(0.08)
$\overline{R}^2$	-0.006	0.73	-0.005
N	117	117	117
Hausman test	–	–	not reject
		Floating currency countries$^{\triangle}$	
	4	5	6
TFP	0.05	**-0.41*****	**-0.35*****
	(0.05)	(0.08)	(0.07)
$\overline{R}^2$	-0.01	0.67	0.33
N	39	39	39
Hausman test	–	–	reject
		Floating currency countries 2†	
	4	5	6
TFP	**-0.87*****	**-0.32*****	**-0.33*****
	(0.16)	(0.08)	(0.08)
$\overline{R}^2$	0.32	0.97	0.20
N	66	66	66
Hausman test	–	–	not reject

Dependant variable: *pn* is the log of the relative price of nontraded to traded goods (all expenditure-weighted) in country i, relative to EU15 average ($pn \equiv q_N - q_T$). TFP_{it} is the log of TFP levels of traded relative to non-traded sector in country i, relative to $\log(TFP_{T,EU12,t}/TFP_{N,EU12,t})$. $TFP_{T,i,t}$ is constructed by aggregating 1-digit sectoral TFP of traded sectors (agriculture is excluded due to issues caused by Common Agricultural Policy) using sectoral output as weights. Eurozone countries are: Austria, Belgium, Germany, France, Finland, Italy, Ireland, the Netherlands, and Spain. △: UK, Denmark and Sweden. † : UK, Denmark, Sweden, Czech Republic, Hungary, Slovenia. *Pool* is a pooled regression with all countries and periods sharing the same estimate of a constant and a slope coefficient. *Fixed effects* is a panel regression with countries as cross-sections. *Random effects* is a random effects panel estimation 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). $t-statistics$ are in parentheses. The estimate of the constant is not reported. A * denotes a 10%, ** 5% and *** 1% significance. Rejection of the null at 5% in Hausman test (HT) implies no difference between FE and RE, viewed as a preference for FE.

Table 7. Properties of model Real Exchange Rates

	Fixed - sticky	Flexible prices	Data
	1	2	3
STD	0.037	0.042	0.033
(Time Series)	(0.030, 0.042)	(0.036, 0.050)	
STD	0.101	0.106	0.113
(Cross Section)	(0.071, 0.125)	(0.085, 0.131)	
Serial	0.794	0.663	0.670
Correlation	(0.720, 0.880)	(0.570, 0.759)	

Regression of Real Exchange Rate on Relative Nontraded Price

	4	5	6
Time series	1.606	1.586	0.70
	(1.567, 1.628)	(1.558, 1.617)	
Cross section	0.942	0.967	0.60
	(0.791, 1.052)	(0.877, 1.068)	

Description

Table 8.
Regression of Real Exchange Rates on Productivity and ULC

	Fixed - sticky	Flexible prices	Data
	Time Series		
	1	2	3
Traded TFP	-0.131	-0.185	-0.18
	(-0.162, -0.065)	(-0.201, -0.169)	
Nontraded TFP	0.512	0.194	0.36
	(0.423, 0.580)	(0.155, 0.218)	
ULC	0.421	1.399	0.46
	(0.284, 0.580)	(1.320, 1.470)	

Cross Section

	4	5	6
Traded TFP	-0.601	-0.588	-0.93
	(-0.662, -0.498)	(-0.654, -0.545)	
Nontraded TFP	0.410	0.581	0.27
	(0.015, 1.150)	(0.143, 0.955)	
ULC	0.831	0.597	0.43
	(-0.364, 1.608)	(-0.128, 1.471)	

Description

Table 9.
Properties of model Real Exchange Rates under different pricing assumptions

	LCP	**PCP**	**LCP – PCP**
	1	2	3
STD	0.081	0.067	0.076
(Time Series)	(0.070, 0.096)	(0.061, 0.076)	(0.065, 0.086)
STD	0.101	0.101	0.112
(Cross Section)	(0.073, 0.131)	(0.076, 0.135)	(0.080, 0.136)
Serial	0.593	0.652	0.600
Correlation	(0.502, 0.677)	(0.581, 0.729)	(0.522, 0.650)

Regression of Real Exchange Rate on Relative Nontraded Price

	4	5	6
Time series	0.790	1.583	2.458
	(0.296, 1.293)	(1.550, 1.612)	(2.041, 2.840)
Cross section	0.835	0.956	0.990
	(0.612, 1.113)	(0.829, 1.094)	(0.798, 1.129)

Table 10.
Regression of Real Exchange Rates on Productivity and ULC under different pricing assumptions

	LCP	**PCP**	**LCP – PCP**
	Time Series		
	1	2	3
Traded TFP	-0.050	-0.113	-0.082
	(-0.292, 0.267)	(-0.206, 0.032)	(-0.284, 0.078)
Nontraded TFP	2.193	1.224	1.747
	(1.787, 2.602)	(1.131, 1.307)	(1.611, 1.974)
ULC	-2.650	-0.900	-1.895
	(-3.095, -2.135)	(-0.963, -0.835)	(-2.070, -1.705)

Cross Section

	4	5	6
Traded TFP	-0.359	-0.503	-0.462
	(-0.576, -0.138)	(-0.557, -0.445)	(-0.547, -0.363)
Nontraded TFP	2.851	1.313	1.934
	(1.408, 4.298)	(1.216, 1.461)	(1.601, 2.139)
ULC	-3.745	-0.929	-1.940
	(-6.193, -1.142)	(-1.055, -0.730)	(-2.532, -1.484)

A Appendix: Construction of the panel of sectoral TFP levels across Europe

This section documents the construction of the TFP level panel dataset at sectoral level. The reason for the construction of this dataset to provide the perfect match to the level data of real exchange rates across Europe. To construct the dataset, we construct a concordance between the sectors included in the Groningen Growth and Development Center's (GGDC thereafter) 1997 TFP level database, and the sectors included in the KLEMS time-series database. These two databases are meant to be used in conjunction, as outlined in Inklaar and Timmer (2008). Then, the cross-sectional TFP database and the time-series TFP database are linked using the constructed concordance to obtain annual sectoral panel TFP level data.
Table A1 lists the sectors included in the TFP 1997 level database and Table A2 the sectors in the TFP time-series sectoral growth rate database. Table A3 shows the concordance between the two, the names of the 21 overlapping sectors, and their tradability descriptor.

A.1 1997 TFP levels

The construction of the 1997 GDDC TFP level database[12] is described in Inklaar and Timmer (2008) (IT thereafter). The database is constructed for 30 OECD countries using an improved version of the methodology of Jorgenson and Nishmizu (1978)[13]. We use the output-based measure of TFP which IT argue better reflects technology differences than the two other value-added measures (see IT pp. 23).
TFP 1997 level estimates are constructed vis-à-vis the U.S. levels in two stages. First, symmetric Input-Output Tables and input PPPs are constructed for 45 sub-industries. The second stage consists of two steps. First, PPPs for capital, labour and intermediate inputs for 29 industries (based on 45 sub-industries) are constructed using a price-variant of index number approach in Caves et al. (1982) known as the CCD method. These are used to implicitly derive quantities of all inputs and outputs. The second step, known as primal level accounting, sees industry comparative productivity levels constructed on the basis of input and output quantities in a bilateral Tornqvist model as in Jorgenson and Nishimizu (1978). Specifically, for sector i in

[12] See `http://www.rug.nl/research/ggdc/data/ggdc-productivity-level-database`.

[13] The improvements include the use of sectoral IO measures that exclude intra-industry flows, the application of multilateral indices at the industry level, and the use of relative output prices from the production side and the use of the exogenous approach to capital measurement.

country j in 1997, IT estimate the level of sectoral TFP as:

$$\ln A_{i,j} \equiv \ln TFP_{i,j}^{SO} = \ln \frac{Q_{i,j}^{SO}}{Q_{i,US}^{SO}} - \hat{\nu}_K \ln \frac{Q_{i,j}^{K}}{Q_{i,US}^{K}} - \hat{\nu}_L \ln \frac{Q_{i,j}^{L}}{Q_{i,US}^{L}} - \hat{\nu}_{II} \ln \frac{Q_{i,j}^{II}}{Q_{i,US}^{II}} \quad \text{(A.9)}$$

where Q_j^K is a quantity index of capital services, Q_c^L is a quantity index of labour services and Q_j^{II} is a quantity index of intermediate input services. $\hat{\nu}_K$ is the share of capital services in total costs averaged over the two countries: $\hat{\nu}_K = 0.5(\nu_j^K + \nu_j^{US})$ where $\nu_j^K \equiv \frac{V_j^K}{V_j^K + V_j^L + V_j^{II}}$ and V_j^K is the nominal value of capital services. In order to facilitate quantity measure comparisons, $Q_j^{SO} = \frac{V_j^{SO}}{PPP_j^{SO}}$ where V_j^{SO} is the nominal value of output in country j. Similarly for intermediate inputs Q_j^{II}. For labour input Q_j^L, the same ratio measure is justified by the need to aggregate various labour types (high- vs. low-skill), and the construction of PPP_j^L which is constructed based on relative wages. For capital input, $Q_j^K = \frac{\tilde{V}_j^K}{PPP_j^K}$ where $\tilde{V}_j^K$ is the ex-ante nominal compensation of capital $\tilde{V}_j^K = V_j^K - V_j^R$ where V_j^R is "supra-normal profits" (see IT section 4.1 for a detailed discussion).

A.2 TFP time series

A European Commission-funded project, EU KLEMS data contains annual observations for 25 European countries, Japan and the US from 1970 onwards. The data is described in detail in O'Mahony and Timmer (2009, OT thereafter). We use KLEMS' Total factor productivity growth March 2011 update to the November 2009 release[14]. The TFP is estimated in the growth accounting approach as a measure of disembodied technological change[15]. The growth accounting in KLEMS proceeds under standard neoclassical assumptions of constant returns to scale and perfect competition[16] allows a full decomposition of industry i output:

$$\begin{aligned} \Delta \ln Y_{it} &= \bar{\nu}_{it}^X \bar{\omega}_{it}^E \Delta \ln X_{it}^E + \bar{\nu}_{it}^X \bar{\omega}_{it}^M \Delta \ln X_{it}^M + \bar{\nu}_{it}^X \bar{\omega}_{it}^S \Delta \ln X_{it}^S \\ &+ \bar{\nu}_{it}^K \bar{\omega}_{it}^{ICT} \Delta \ln K_{it}^{ICT} + \bar{\nu}_{it}^K \bar{\omega}_{it}^N \Delta \ln K_{it}^N \\ &+ \bar{\nu}_{it}^L \Delta \ln LC_{it} + \bar{\nu}_{it}^L \Delta \ln H_{it} + \Delta \ln B_{it}^Y \end{aligned} \quad \text{(A.10)}$$

where Y is output, K is an index of capital service flows, L is an index of labour service flows, X is an index of intermediate inputs, H is hours worked, LC is labour

[14]See http://www.euklems.net/euk09ii.shtml.

[15]Technical change embodied in new capital goods is excluded from TFP due to the KLEMS' use of quality-adjusted prices.

[16]Consequently, negative TFP growth can be observed in some service industries, which OT is a consequence of well-known measurement issues surrounding corporate reorganization and institutional changes (see Basu et al. 2004 and Hulten, 2001).

composition[17] and B is an index of disembodied (Hicks-neutral) technological change. Intermediate inputs are further split into energy (E), materials (M) and services (S), each with a respective period-average share $\bar{\omega}$ in total input costs. Each of the inputs K, L, X^E, X^M, X^S is constructed as a Törnqvist quantity index of individual sub-types ($\Delta \ln I_{it} = \sum_l \bar{\omega}^I_{l,it} \Delta \ln I_{l,it}$). $\bar{\nu}$ are two-period average shares of each input in the nominal output.

A.3 Construction of the TFP level sectoral panel dataset

The construction of TFP level sectoral panel dataset proceeds in four steps. First, the sectors in the 1997 cross-section dataset are matched to the sectors in the TFP growth-rate dataset. Second, a level TFP series is constructed for each sector and country. Third, TFP level is expressed relative to EU12 average, to match the construction of the real exchange rate dataset as closely as possible[18]. Fourth, the sectors are aggregated into Traded and Nontraded aggregates using sectoral output data.

Let A_{ij} be the 1997 GDDC sectoral-output and PPP based TFP of sector i in country j, relative to the US. Let B_{ijt} be the EU KLEMS sectoral-output and PPP based TFP index of sector i in country j and year t, re-scaled so that $B_{i,j,1997} = 100\ \forall i, j$. Both A and B are synchronized to the 21 sectors as in Table A3. Let also $B_{i,US,t}$ be the TFP index for each sector in the US, also with the base of 100 in 1997. Then, sectoral TFP level C_{ijt} is constructed as:

$$C_{ijt} = \frac{A_{ij} B_{ijt}}{B_{i,US,t}} \tag{A.11}$$

and similarly for the EU15 aggregate:

$$C_{i,EU12,t} = \frac{A_{i,EU12} B_{i,EU12,t}}{B_{i,US,t}} \tag{A.12}$$

The TFP level index expressed vis-a-vis EU12. It is the ratio of (3) and (4):

$$TFP_{ijt} = \frac{C_{ijt}}{C_{i,EU12,t}} = \frac{A_{ij} B_{ijt}}{A_{i,EU12} B_{i,EU12,t}} \tag{A.13}$$

The aggregate traded and nontraded TFP levels are computed as follows:

$$TFP_{T,j,t} \quad = \quad \frac{\sum_{i \in T} \gamma_{ij,T} C_{ijt}}{\frac{1}{12} \sum_{j \in EU12} (\sum_{i \in T} \gamma_{i,j,T} C_{i,j,t})} \tag{A.14}$$

[17] Labour composition is growth literature's measure of "labour quality" (see Jorgenson et al. 2005). It consists of labour characteristics such as educational attainment, age and gender.

[18] Only 12 of the EU15 countries have TFP data: Belgium, Germany, Spain, France, Ireland, Italy, the Netherlands, Austria, Finland, Sweden, Denmark and the United Kingdom.

$$TFP_{N,j,t} = \frac{\sum_{i\in N}\gamma_{ij,N}C_{ijt}}{\frac{1}{12}\sum_{j\in EU12}(\sum_{i\in N}\gamma_{i,j,N}C_{i,j,t})} \quad \text{(A.15)}$$

where $\gamma_{ij,T}$ ($\gamma_{ij,N}$) is a 1997 sectoral output weight of sector i in traded (nontraded) output of country j (s.t., $\sum_i \gamma_{ij} = 1\ \forall j$). The agriculture sector is omitted from the analysis because of the EU's Common Agricultural Policy's distortion of many assumption used to calculate sectoral TFP measures.
Consequently, the relative productivity measure in Traded to Nontraded sectors is constructed as a ratio of (5) and (6). In our empirical analysis we always work with the logarithms of these constructed productivity measures.

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Table A1. Sectors in the GGDC 1997 TFP level database

1	TOTAL INDUSTRIES
2	MARKET ECONOMY
3	ELECTRICAL MACHINERY, POST AND COMMUNICATION SERVICES
4	Electrical and optical equipment
5	Post and telecommunications
6	GOODS PRODUCING, EXCLUDING ELECTRICAL MACHINERY
7	TOTAL MANUFACTURING, EXCLUDING ELECTRICAL
8	Consumer manufacturing
9	Food products, beverages and tobacco
10	Textiles, textile products, leather and footwear
11	Manufacturing nec; recycling
12	Intermediate manufacturing
13	Wood and products of wood and cork
14	Pulp, paper, paper products, printing and publishing
15	Coke, refined petroleum products and nuclear fuel
16	Chemicals and chemical products
17	Rubber and plastics products
18	Other non-metallic mineral products
19	Basic metals and fabricated metal products
20	Investment goods, excluding hightech
21	Machinery, nec.
22	Transport equipment
23	OTHER PRODUCTION
24	Mining and quarrying
25	Electricity, gas and water supply
26	Construction
27	Agriculture, hunting, forestry and fishing
28	MARKET SERVICES, EXCLUDING POST AND TELECOMMUNICATIONS
29	DISTRIBUTION
30	Trade
31	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel
32	Wholesale trade and commission trade, except of motor vehicles and motorcycles
33	Retail trade, except of motor vehicles and motorcycles; repair of household goods
34	Transport and storage
35	FINANCE AND BUSINESS, EXCEPT REAL ESTATE
36	Financial intermediation
37	Renting of m. eq. and other business activities
38	PERSONAL SERVICES
39	Hotels and restaurants
40	Other community, social and personal services
41	Private households with employed persons
42	NON-MARKET SERVICES
43	Public admin, education and health
44	Public admin and defence; compulsory social security
45	Education
46	Health and social work
47	Real estate activities

`http://www.rug.nl/research/ggdc/data/ggdc-productivity-level-database`

Table A2. Sectors in the March 2009 edition of the KLEMS TFP time-series database

1	TOTAL INDUSTRIES
2	AGRICULTURE, HUNTING, FORESTRY AND FISHING
3	MINING AND QUARRYING
4	TOTAL MANUFACTURING
5	FOOD , BEVERAGES AND TOBACCO
6	TEXTILES, TEXTILE , LEATHER AND FOOTWEAR
7	WOOD AND OF WOOD AND CORK
8	PULP, PAPER, PAPER , PRINTING AND PUBLISHING
9	CHEMICAL, RUBBER, PLASTICS AND FUEL
10	Coke, refined petroleum and nuclear fuel
11	Chemicals and chemical
12	Rubber and plastics
13	OTHER NON-METALLIC MINERAL
14	BASIC METALS AND FABRICATED METAL
15	MACHINERY, NEC
16	ELECTRICAL AND OPTICAL EQUIPMENT
17	TRANSPORT EQUIPMENT
18	MANUFACTURING NEC; RECYCLING
19	ELECTRICITY, GAS AND WATER SUPPLY
20	CONSTRUCTION
21	WHOLESALE AND RETAIL TRADE
22	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel
23	Wholesale trade and commission trade, except of motor vehicles and motorcycles
24	Retail trade, except of motor vehicles and motorcycles; repair of household goods
25	HOTELS AND RESTAURANTS
26	TRANSPORT AND STORAGE AND COMMUNICATION
27	TRANSPORT AND STORAGE
28	POST AND TELECOMMUNICATIONS
29	FINANCE, INSURANCE, REAL ESTATE AND BUSINESS SERVICES
30	FINANCIAL INTERMEDIATION
31	REAL ESTATE, RENTING AND BUSINESS ACTIVITIES
32	Real estate activities
33	Renting of m. eq. and other business activities
34	COMMUNITY SOCIAL AND PERSONAL SERVICES
35	PUBLIC ADMIN AND DEFENCE; COMPULSORY SOCIAL SECURITY
36	EDUCATION
37	HEALTH AND SOCIAL WORK
38	OTHER COMMUNITY, SOCIAL AND PERSONAL SERVICES
39	PRIVATE HOUSEHOLDS WITH EMPLOYED PERSONS
40	EXTRA-TERRITORIAL ORGANIZATIONS AND BODIES

`http://www.euklems.net/euk09ii.shtml`

Table A3. Sectoral concordance

	GGDC sector ID	KLEMS sector ID	Tradability	Names of sectors
1	27	2	T	Agriculture, hunting, forestry and fishing
2	24	3	T	Mining and quarrying
3	9	5	T	Food , beverages and tobacco
4	10	6	T	Textiles, textile , leather and footwear
5	13	7	T	Wood and of wood and cork
6	14	8	T	Pulp, paper, paper , printing and publishing
7	16	9	T	Chemical, rubber, plastics and fuel
8	18	13	T	Other non-metallic mineral
9	19	14	T	Basic metals and fabricated metal
10	21	15	T	Machinery, nec
11	4	16	T	Electrical and optical equipment
12	22	17	T	Transport equipment
13	11	18	T	Manufacturing nec; recycling
14	25	19	N	Electricity, gas and water supply
15	26	20	N	Construction
16	29	21	N	Wholesale and retail trade
17	39	25	N	Hotels and restaurants
18	34	27	N	Transport and storage
19	5	28	N	Post and telecommunications
20	36	30	N	Financial intermediation
21	37	31	N	Real estate, renting and business activities