# *** WORKING DRAFT NOT PUBLIC *** Deviations in real exchange rate levels across the OECD members and their structural determinants

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**Abstract**

We study the validity of an augmented Balassa-Samuelson theory using a panel of real exchange rate levels across 17 OECD countries in conjunction with a unique panel of total factor productivity (TFP) levels across sectors. We find that real exchange rate dynamics can be explained by relative productivity levels both across countries and over time. We also show that other relative fundamentals such as structural labour market differences matter for real exchange rates.

*JEL classification:* F41, F31
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# 1 Introduction

Most papers that investigate the link between real exchange rates and productivity focus on the time dimension (using growth rates of productivity) but typically neglect the cross-sectional (level differences across countries) dimension. Usually, time series studies use labour productivity or real income per capita to proxy productivity for data availability reasons. The underlying theoretical framework for many studies that consider the relationship between the real exchange rate and productivity is the Balassa-Samuelson (BS) model, which is based on total factor productivity (TFP). The 'BS' model suggests that over the long term there should be a relationship between the real exchange rate and relative traded and non-traded TFP across countries. However, evidence for BS effects tends to be weak in the time series dimension, although there is slightly stronger evidence in cross sectional studies, particularly when comparing rich and poor economies.[1] An exception is Berka et al. (2014), who construct estimates of cross-country levels of TFP and prices and find support for a BS relationship for 9 eurozone economies between 1995 and 2009, conditional on controlling for differences in unit labour costs (ULC).

To enable empirical evaluation of the level of real exchange rate through the lens of the BS hypothesis, this paper constructs a unique panel of levels of sectoral TFP, real exchange rates, as well as unit labour costs, labour market proxies, terms of trade and real interest rate levels to account for structural differences in economy-wide costs by country and year for 17 OECD economies.

Based on an augmented BS framework, a range of time-series panel models are estimated to assess the misalignment of real exchange rates over a long term horizon. We show that while the simple BS model is rejected by the data, there is a link between the real exchange and sectoral TFP in both a time series and cross-sectional dimensions, provided that structural factors such as labour market differences are controlled for. Nonetheless, large unexplained differences in real exchange rates remain across countries.

Empirical tests for BS-type effects typically look for a price wedge between tradables and non-tradables[2] and evidence of a positive correlation between the relative

[1]See De Gregorio et al. (1994), Canzoneri et al. (1999), Lothian and Taylor (2008) or Chong et al. (2012)). Examples of studies that consider a cross-sectional dimension include Rogoff (1996) and Bergin et al. (2006). Few studies apply panel tests, although exceptions includes Ricci et al. (2013) who look for cointegration between the real exchange rate and a set of explanatory variables.

[2]For example, Engel (1999) shows that real exchange rates exhibit large and persistent deviations

productivity differentials between the two sectors across trading partners and their real bilateral exchange rate.[3]

Violations of the assumptions implicit in the BS framework, such as perfect substitutability of goods, may cause relative prices to change for reasons unrelated to productivity. We show that in a model incorporating imperfect substitutability, labour market imperfections can significantly affect real exchange rates, both over time and across countries. Likewise, our empirical estimates show that controlling for the possibility of structural labour market differences can help explain relative price levels and their changes over time.

# 2 Description of the data

This is the first study that jointly considers the time-series and the cross-sectional variation in real exchange rates and sectoral TFP in a panel of OECD countries. We construct panel datasets of levels of TFP by sector, real exchange rates, unit labour costs, terms of trade and indicators of structural labour market differences for 17 OECD countries, all vis-a-vis the US.[4] Eight of these countries included in the dataset were amongst the founding members of the eurozone in 1999. The unbalanced annual panel covers the period of 1970 to 2012, with the length of data varying from a minimum of 13 years to a maximum of 42 years, both across countries and variables (see Table 16). Results for both balanced and unbalanced panels are presented. Appendix C provides detailed descriptions of the approaches used to construct the dataset and Tables 1 to 2 report the descriptive statistics of the main variables used for all countries in the unbalanced panel.

The construction of the panel of sectoral TFP estimates is described in detail in Steenkamp (2015); we only outline our approach here. Drawing on different sources of industry data requires matching of industry classifications. Using concordances, we construct a panel of annual estimates of TFP and real exchange rate by com-

from the 'law of one price' for tradables, while Chen et al. (2015) find that relative non-traded prices are responsible for a large proportion of the variation in real exchange rate levels.

[3]Bordo et al. (2014) identify a long-run relationship between real exchange rates and relative income when estimating a model incorporating a time trend, which they argue could pick up the impact of changes in trade costs.

[4]The countries are: Australia, Austria, Belgium, Czech Republic, Denmark, Spain, Finland, France, Germany, Hungary, Ireland, Italy, Japan, the Netherlands, New Zealand, Sweden, and the United Kingdom.

bining cross-sectional TFP and PPP *levels* for given benchmark years to *indices* of industry productivity and prices as in Berka et al. (2014). Industry TFP levels are are constructed based on the Groningen Growth and Development Centre (GGDC) Productivity Level database (1997 benchmark year), expressed relative to the US.[5] We aggregate 11 industry $a_{i,j,t}$ into traded and non-traded aggregates ($a_{i,T,t}$ and $a_{i,N,t}$ respectively) using constant 1997 gross value added (GVA) country-specific weights. Figure 6 plots the levels of traded and non-traded TFP for each country compared to the US. Over the unbalanced panel, the level of TFP in traded sector has been the highest in the Netherlands and Ireland, and the lowest in Eastern Europe. TFP in non-traded sector has also been the highest in the Netherlands, followed by New Zealand, while it is the lowest Japan, the Czech Republic and Hungary.[6] Table 3 shows that traded good TFP is more volatile than non-traded TFP for all countries. Figures 9 to 11 compare our estimates of TFP levels to the labour productivity level estimates from **?**, with all series expressed relative to the US.[7] For many countries the relative levels and trends correspond with those in relative labour productivity. Exceptions for tradables TFP include: Austria (lower than relative labour productivity vs the US), Denmark (lower), Hungary (lower), Netherland (higher), New Zealand (lower). However, relative tradable TFP generally shows larger changes than labour productivity. While many countries have had relatively flat labour productivity compared with the US, Belgium, Japan, Spain and Italy have seen their relative non-tradable TFP decline. The ratio of tradable to non-tradable TFP relative to the US is most different from that of labour productivity in Japan (the TFP ratio is higher), Belgium (higher), New Zealand (lower and declining) and Denmark (lower

[5]Since New Zealand is not included in the GGDC database, industry TFP level comparisons to the US from Steenkamp (2015) are used. These estimates were constructed using Mason (2013)'s 2009 year benchmark comparisons between New Zealand and Australia (as Australia is in the GGDC database and can be used to express New Zealand figures relative to the US). The construction of the panel of TFP levels $a_{i,j,t}$ is as follows: $a_{i,j,t} = \frac{TFPlevel_{i,j} \times TFPindex_{i,j,t}}{TFPindex_{i,US,t}}$ where $TFPlevel$ is the relative level of TFP of country $i$ relative to US in sector $j$, in 1997, and $TFPindex$ are the time-series indices of sectoral TFP, normalized to = 1 in 1997.

[6]New Zealand's high ranking for non-tradables reflects the inclusion of real estate, renting and business services because of differing treatment of owner-occupied dwellings in New Zealand compared with the other countries in th e sample (discussed in Steenkamp (2015)). We follow the methodology of Berka et al. (2014) in order to be comparable to their estimates for euro zone economies, but provide alternative aggregations in the Appendix.

[7]Note that there are some comparability issues between the New Zealand estimates and those for other countries, which relate to the PPPs used to compare the value of outputs. For all countries except New Zealand these estimates are based on data in 2005 PPPs for USD, while for New Zealand the estimates are based on data in 2005 current USD (see discussion in **?**).

and declining) and France (higher).

Our panel of real exchange rate levels is constructed using bilateral nominal exchange rates and estimates of relative price levels. $q_{i,t}$ is the logarithm of the level of the bilateral real exchange rate of country $i$ relative to the US, defined as $q_{i,t} = NER_{i:US,t} + p_{i,t} - p_{US,t}$. The $NER$ is the log of nominal exchange rate to the US dollar (defined as the foreign currency price of one unit of domestic currency relative to the US dollar so that an increase represents appreciation), and $p_{i,t}$ and $p_{US,t}$ denote logs of aggregate consumer price levels in country $i$ and the $US$, respectively. Aggregate price levels for each economy are created using International Comparison Program (ICP) aggregate consumer price PPPs. Estimates of tradable and non-tradable price levels are also constructed using ICP price parities and goods and services CPI series as proxies for tradables and non-tradables price timeseries.[8] We define the relative price of non-traded goods as $p_N = q_N - q_T$, the difference between tradables real exchange rate $q_{T,i:US,t} = NER_{i:US,t} + p^T_{i,t} - p^T_{US,t}$ and the non-tradable real exchange rate for each economy relative to the US $q_{N,i:US,t} = NER_{i:US,t} + p^N_{i,t} - p^N_{US,t}$ using tradable and non-tradable price levels, created as $p^T_{i,t} = PPP_{i,T} \times CPI^T_{i,t}$ and $p^N_{i,t} = PPP_{i,N} \times CPI^N_{i,t}$ where PPPs have been adjusted by the nominal exchange rates to get them in common terms. Over the full unbalanced panel, the Eastern European countries in our sample have the lowest $q$ level, Denmark, Sweden and Finland the highest.

We also consider other variables that may impact the real exchange rate through their impact on relative sectoral prices or the terms of trade (see for example Figure 8).

The first is relative Unit Labour Cost *levels* ($ULC$), which are constructed from the OECD data, expressed as average $ULC$ in country $i$ relative to $ULC$ in the US (the same way as the sectoral productivity and real exchange rate data) after conversion into the same currency. To remove the impact of nominal exchange rate variability on

[8] There are very few papers that use consumer prices to construct relative prices. Most papers in the literature focus exclusively on value added deflators as price proxy (see for example, Drozd and Nosal (2010), Mihaljek and Klau (2008), Mihaljek and Klau (2004), Engel 1999) or measure the real exchange rate simply as the nominal rate adjusted for differences in aggregate CPI (see Bordo et al. (2014), Chong et al. (2012), Gubler and Sax (2011), Ricci et al. 2013). Papers that use value-added based relative prices tend to find a positive relationship between relative sectoral prices and real exchange rates (see Steenkamp (2013) or Drozd and Nosal 2010). Using value-added based sectoral prices produces very different inflation measures than those based on consumer prices, especially for tradable prices (see Steenkamp 2013).

the $ULC$ measures, $ULC$ is orthogonalised to the $NER$ for each country by regressing the $ULC$ measure on a constant and the $NER$. The orthogonalised ULC measure ($OULC$) is calculated as the residual from this regression plus the sample average of ULC for each country.[9] The lowest unit labour costs on average have been found in the Czech Republic and the UK, and the highest in Ireland, Austria and Germany (see also Figure 7).

Relative terms of trade ($TOT_{i,t}$) is measured as the difference between export and import price *levels* from Feenstra et al. (2015) (constructed as export and import PPPs divided by the nominal exchange rate) relative to the same expression for the US in logarithms. Over the full unbalanced sample, the Czech Republic, Hungary, New Zealand and Sweden had the most favourable terms of trade compared to the US, Australia the least favourable over the full sample.

Lastly, bilateral long-run real interest rate differentials relative to the US ($RIRDIFF_{i,t}$) are based on 10 year government bond yields obtained from Bloomberg. Relative interest rate levels are expressed as the home country rate less the US rate, adjusted by relative CPI inflation rates. Over the full sample, real interest rates are highest in New Zealand and Finland, lowest in Hungary and Japan.

## 2.1 Institutional labour market differences

We also construct a panel of variables capturing institutional labour market differences across the countries in our sample. We use several indicators from the Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts (ICTWSS) dataset (Visser 2013). Unlike the ULC variable, these institutional variables better capture labour market aspects that are both relevant to wage determination that also orthogonal to productivity. Many of these characteristics of wage bargaining have evolved over long periods of history and can be viewed as exogenous within our sample. Specifically, we choose summary variables that best capture institutional differences in wage-setting (described in greater detail in Appendix subsection C.6). Indicators of union density or co-ordination would be expected to affect the bargaining power of unions and real wage flexibility. Indicators of employment

[9] Specifically, since the residuals are mean-zero by construction, we add to them the average ($ULC$) to preserve the correct average level difference. This avoids introducing bias in fixed effects estimation (as the residuals alone will be mean zero). None of our results hinge on the use of either ULC measure. The results are naturally stronger when nominal exchange rate variation is not removed from ULC.

protection, on the other hand, should capture the labour market's ability to adjust to changes in labour demand, while replacement rates should affect the willingness of labour to transition from unemployment into the workforce and therefore also the stickiness in the labour market.

As far as we are aware, this is the first study of the importance of labour market frictions in real exchange rates using these indicators.[10] These indicators of labour market institutions have recently been shown to be related to cyclical movements in real wages, labour productivity and unemployment in OECD economies by Gnocchi et al. (2015).

The variables considered include: $CONC_{i,t}$ (summary measure of concentration of unions at aggregate and sectoral levels), $AUTH_{i,t}$ (summary measure of formal authority of unions regarding wage setting at aggregate and sectoral levels), $CENT_{i,t}$ (centralisation of wage bargaining measured by weighting national and sectoral concentration of unions by level of importance)[11] and $UD_{i,t}$ (the union density rate) obtained from the ICTWSS dataset. We include replacement rates, $RR_{i,t}$ (ratio of disposable income when unemployed to expected disposable income) provided by Gnocchi et al. (2015), along with $EPRC_{i,t}$ (the strictness of employment protection legislation), $EPR_{i,t}$ (the strictness of employment protection on individual contracts), $EPT_{i,t}$ (employment protection on temporary contracts) from the OECD. Each indicator is expressed as a log difference to the level of the US indicator. A higher value of each of these indicators implies a relative more rigid labour market compared to the US.[12]

## 2.2 Developments in relative prices and sectoral productivity

The Balassa-Samuelson hypothesis predicts that there will be a positive relationship between sectoral price and productivity differentials and the real exchange rate. This section describes differences in price and productivity levels across countries, and the

[10]**?** produce labour productivity growth rates for tradable and non-tradables for a selected group of OECD economies using EU KLEMS for a balanced panel of 1970-2007. They find that while a rise in the traded to non-traded labour productivity ratio domestically tends to be associated with higher relative non-traded to traded prices, relative wages tend to fall.

[11]$CENT$ is a broader measure than $CONC$, as $CENT$ also incorporates internal and external demarcations between union confederations.

[12]Several labour market indicators are highly significant in explaining both ULCs and real exchange rates. This suggests that labour market rigidities may contribute to differences in real exchange rates that are orthogonal to productivity.

changes observed over time.

Overall, our data show that there is a positive relationship between sectoral price changes and sectoral TFP changes domestically (Figure 1) and also across countries (Figure 3) over the full sample.[13] Relative non-tradable to tradable prices ($p_N$) rose domestically in all countries (although the increase in New Zealand is negligible according to our price proxies). When expressed relative to the US (as in Figure 3), relative sectoral price increases are smaller than in the US for many countries.[14] Although the there is a positive relationship between relative productivity and the real exchange rate in both levels and changes over time internationally, a positive relationship is only observed for relative tradable to non-tradable price levels across countries and not over time. In our unbalanced panel, real exchange rates rose the most in Japan, Australia and Eastern Europe and the least in France. The relative price of non-traded goods compared to the US grew the most in the UK and the least in Australia. Relative traded to non-traded TFP grew the most in Japan and the least in Denmark (again, in an unbalanced panel).[15] Unit labour costs grew the most in Czech Republic, followed by Spain, and the least in Sweden, Germany and France (see Figure 7 or 8). Overall, the timeseries correlation between relative TFP levels ($a_T - a_N$) and $q$ levels is 0.34 (while only 0.26 between $a_T - a_N$ and $p_N$). The correlation between $OLUC$ and $q$ levels is 0.65.

In cross-section, the relative price of non-traded to traded goods has been highest in Australia, Germany and Spain. The ratio of traded to non-traded TFP has been the highest in Ireland and Belgium, and the lowest in New Zealand and Hungary. The correlation between $a_T - a_N$ and $q$ is 0.61 in cross-section, compared to only 0.26 between $a_T - a_N$ and $p_N$. However, as Table 7 in the Appendix demonstrates, the prediction from the BS model that there is a positive relationship between real exchange rates and relative non-traded to traded prices holds according to our data. The correlation between $OLUC$ and $q$ is 0.29 in cross section using an unbalanced panel.

[13]Note that the domestic relationship is weak for the period 1995 to 2007 (Figure 2), although the positive correlation holds across countries in both time and cross section (Figure 5).

[14]Our proxies for tradable prices grew faster in most countries than in the US, while the non-tradable price proxies grew at slower rates than in the US (Figure 5 in the Appendix).

[15]In an unbalanced panel, traded TFP rose the most in Sweden and Finland, and non-traded TFP the most in Finland, Czech Republic and the US (Figure 5 in the Appendix).

# 3 Real Exchange Rates in a Theoretical Model

## 3.1 A Basic New Keynesian model

Here we present a simple adaptation of a New Keynesian model of real exchange rates in the spirit of Balassa-Samuelson. The model is a variation of Berka et al. (2014) that incorporates labour market differences across sectors and countries that explain differences in wages and therefore real exchange rates. There are two countries, each populated by an infinitely-lived representative agent maximizing:

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

where $C_t$ is a composite consumption bundle and $N_t$ is the supply of labour, and $\chi$ is a country-specific time-varying labour supply disutility. The composite consumption good is a CES aggregator of traded and nontraded composite consumption ($C_T$ and $C_N$, respectively). While the nontraded consumption is home-made, traded consumption is a composite of home or foreign traded consumption goods, denoted as $C_H$ and $C_F$. Importantly, and in line with a voluminous literature, we these traded consumption goods at the retail level as CES aggregates of pure wholesale traded product and a retail input $V$ which is assumed to be nontraded. Hence, at home:

$$\begin{aligned}
C_t &= \left( \gamma^{\frac{1}{\theta}} C_{Tt}^{1-\frac{1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_{Nt}^{1-\frac{1}{\theta}} \right)^{\frac{\theta}{\theta-1}} \\
C_{Tt} &= \left( \omega^{\frac{1}{\lambda}} C_{Ht}^{1-\frac{1}{\lambda}} + (1-\omega)^{\frac{1}{\lambda}} C_{Ft}^{1-\frac{1}{\lambda}} \right)^{\frac{\lambda}{\lambda-1}} \\
C_{Ht} &= \left( \kappa^{\frac{1}{\phi}} I_{Ht}^{1-\frac{1}{\phi}} + (1-\kappa)^{\frac{1}{\phi}} V_{Ht}^{1-\frac{1}{\phi}} \right)^{\frac{\phi}{\phi-1}} \\
C_{Ft} &= \left( \kappa^{\frac{1}{\phi}} I_{Ft}^{(1-\frac{1}{\phi}} + (1-\kappa)^{\frac{1}{\phi}} V_{Ft}^{1-\frac{1}{\phi}} \right)^{\frac{\phi}{\phi-1}}
\end{aligned}$$

In the above equations, $\theta$, $\lambda$ and $\phi$ represent elasticities of substitution between traded and nontraded goods, home and foreign tradables, and the wholesale traded good and nontraded input in retail sectors, respectively. $\gamma$, $\omega$ and $\kappa$ represent steady-state shares of traded consumption in overall consumption, home bias in traded goods, and the weight of wholesale consumption in overall traded retail bundle, respectively.

The optimal price indexes then are:

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

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

where $P_T$ and $P_N$ are home country's price indexes of traded and nontraded aggregates, $\tilde{P}_H$ and $\tilde{P}_F$ are price indexes of Home and Foreign retail traded goods, and $P_H$ and $P_F$ are prices of Home and Foreign wholesale traded goods, measured at Home.

We assume that law of one price holds in traded goods at wholesale level, and so $P_H = P_H^*$ and $P_F = P_F^*$. The real exchange rate is defined as

$$Q_t = \frac{S_t P_t^*}{P_t}$$

In our world of complete risk sharing, marginal utilities of consumption must equal between countries, when expressed in the same currency:

$$\frac{C_t^{-\sigma}}{P_t} = \frac{C_t^{*-\sigma}}{P_t^*} \tag{2}$$

The first order conditions imply the usual sets of equations. The implicit labour supply is governed by:

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

Where $W_t$ is the nominal wage. The demand equations for consumption components are given by:

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

Foreign consumption bundles, foreign prices, and demand first order conditions, are determined in an analogous fashion, and denoted with an $^*$.

Firms in each sector produce using labour and a fixed capital stock: $Y_{Nt} = A_{Nt} N_{Nt}^{\alpha}$, $Y_{Ht} = A_{Ht} N_{Ht}^{\alpha}$. **Shall we instead use $A_T$ as notation to keep things simple?**

We allow for the existence of unions in each sector. Labour unions move bargaining power to workers and result in wages that are higher than the marginal product of labour. We model this with a wage markup $\mu$ that is potentially sector-specific. The consequence of such labour market imperfection in this model is that real wages equal a markup ($\mu \geq 1$) on marginal product of labour:

$$\frac{W_t}{P_{T,t}} = \mu_T MPL_{T,t} = \mu_T A_{T,t} \alpha N_{T,t}^{\alpha-1} \qquad \frac{W_t}{P_{N,t}} = \mu_N MPL_{N,t} = \mu_N A_{N,t} \alpha N_{N,t}^{\alpha-1} \tag{3}$$

So $\mu$ raises labour cost and appreciates home country's q.

There are many papers that feature a wedge between the marginal rate of substitution in consumption and the marginal product in production. This literature is largely focused on understanding how labour market inefficiencies might affect labour supply. Sources of 'labour wedge' could include search costs, monopoly power in wage-setting, sticky nominal wages etc. Hall (1997), Chari et al. (2002), Gali et al. (2007), Shimer (2009), Karabarbounis (2014). However, irrespective of the underlying source of the wedge, we argue that they translate into price changes that are independent of TFP.

We assume that prices are flexible and firm engage in monopolistic competition that yields the usual markup-pricing rule. Monetary policy in each country is characterized by a Taylor-type rule which adjusts nominal interest rates at home as follows:

$$r_t = \rho + \sigma_p \pi_t + \sigma_q (q_t - u_t)$$

where $\sigma_p$ and $\sigma_q$ are weights on inflation and real exchange rate stability, respectively, and $u_t$ is a monetary policy shock (see Steinsson (2008)).[16] A similar monetary policy is followed by a foreign country. It can be shown that this implies that nominal exchange rate in a symmetric equilibrium is a linear function of the differential monetary policy shocks $s_t = x(u_t^* - u_t)$ where $x$ is a constant.[17]

## 3.2 Model of real exchange rates

We solve the model around a symmetric steady state, and study the implications for the determination of real exchange rates. There are four fundamental forces in each

[16] **The Steinsson paper seems to highlight the empirical importance of MP shocks to business cycle dynamics, while not really providing much theoretical justification for the specification used, perhaps we should also cite a theoretical paper?**

[17] **How important is this model feature for the properties of RERs obtained when simulating the model?**

country that drive real exchange rates in the model: productivity of traded sector, productivity of the nontraded sector, disutility of labour and the wage markup. We focus here on the role of wage markups, both between sectors and between countries, in driving the real exchange rate dynamics. We later argue that the institutional differences in labour markets that cause these markups are empirically highly significant determinants of real exchange rates, both over time and across countries.

The Balassa-Samuelson mechanism implies that sectoral productivity differences influence real exchange rates. An increase in Home relative (traded vs. nontraded) productivity over Foreign appreciates Home real exchange rate. An additional mechanism exists in models where traded goods are imperfect substitutes (such as here): There, increase in traded productivity additionally lowers the price of home exportables, thus depreciating terms of trade and the real exchange rate. In usual model calibrations, as well as in empirical studies, the former effect dominates the latter, and relative technological improvements are associated with real exchange rate appreciations.

At the core of both of these mechanisms lies the assumption that labour markets are perfectly competitive, and factors of production receive their marginal products. But there are clear differences in the efficiency of labour market institutions over time (due to reforms) and also between countries. Such institutional differences play a prominent role in the discussions of international competitiveness. Here, the assumption of wage markups implies that wages can rise not only because higher productivity, but also due to increases in the bargaining power of workers, over time and across countries. When $\alpha = 1$, first order conditions of firms operating in both sectors and in both countries can be expressed, in logs:

$$\begin{aligned} w - p_H &= a_H + \mu_T \qquad & w^* - p^* &= a_F^* - \mu_T^* \\ w - p_N &= a_N + \mu_N \qquad & w^* - p^* &= a_N^* - \mu_N^* \end{aligned}$$

The traded sector conditions imply that an international wage difference can be decomposed into endogenous terms of trade movements, productivity differences, and wage markup differences:

$$w^* + s - w = \tau + a_F^* - a_H + \mu_T^* - \mu_T$$

where $\tau \equiv p_F^* - p_H + s$ is the terms of trade. A similar condition can be expressed using the nontraded sectors' first order conditions. With intra-national labour market integration, wages must equal between sectors, which consequently implies that:

$$p_N^* - p_N + s = \tau + [a_T^* - a_T - (a_N^* - a_N)] + [\mu_T^* - \mu_T - (\mu_N^* - \mu_N)]$$

Thus, the real exchange rate for non-traded goods is a function of terms of trade, relative productivities (the Balassa-Samuelson effect) and the relative markup differences. If we further assumed that $\kappa = 1$ and $\omega = 0.5$, so that the retail sector does not use non-traded inputs and there is no home bias in traded consumption, we could rewrite the above condition as:

$$p_n = [a_T^* - a_T - (a_N^* - a_N)] + [\mu_T^* - \mu_T - (\mu_N^* - \mu_N)]$$

where $p_n \equiv p_N^* - p_N - (p_T - p_T^*)$ is the relative price of non-traded to traded goods between the countries. In contrast to the standard Balassa-Samuelson model, the 'relative-relative price' of non-traded to traded goods between countries is not equally a function of the deviations in relative productivities, as it is a function of relative differences in sectoral markups. These two drivers, however, obviously have a different influences on the equilibrium real exchange rate in a more complete model, because productivity directly increases output as well as relative prices, while the wage markups do not.

**Insert equation for q in terms of $\chi$ and $\mu$.**

**Show ULC and TOT equations.**

The importance of the *relative* difference of markups is intuitively clear. If Home country has a 10% higher markups than Foreign country in both sectors, wages will obviously be higher by 10%, ceteris paribus. But the relative price of nontraded goods, a key driver of the real exchange rate, will be 0, since prices of *both* traded and nontraded goods are higher by the same proportion.

We may then ask whether this implies that labour market imperfections have no influence on the real exchange rate in the case when $\mu_T^* - \mu_T - (\mu_N^* - \mu_N) = 0$, that is, when there are *no sectoral* but only *national* differences in labour markups. It turns out that such direct effect also exists, irrespective of whether sectoral wage markups differ. This markup level channel operates in exactly the opposite direction of the channel due to disutility of labour $\chi$. Algebraically, this can be seen from a combination of first order conditions. In logs, we can write the implicit labour supply condition as $w^R - q = \sigma c^R + \psi n^R + \chi^R$ where ”$.^R$” denotes a value of Foreign relative to Home variable, expressed in the same currency if necessary. Applying the complete risk sharing condition, this reduces to $w^R = \psi n^R + \chi^R$. We can then use firm's first order conditions (in either sector) to substitute for $w^R$, yielding (after substituting for $p_N^R$):

$$\frac{1}{1-\gamma\kappa} q + a_N^R - \mu^R = \psi n^R + \chi^R$$

where we assume $\mu_N^R = \mu_T^R = \mu^R$. This condition is the only place in the model where $\mu^R$ as well as $\chi^R$ enter. Consequently, if we define $\tilde{\chi}^R \equiv \chi^R - \mu^R$ we can solve the log-linearized model in the same manner as without labour markups by writing $\tilde{\chi}^R$ instead of $\chi^R$. Then, by construction, coefficient on $\mu^R$ in model's solution (for any variable) must equal the negative of that variable's coefficient on $\tilde{\chi}^R$, while the coefficient on $\chi^R$ must equal that on $\tilde{\chi}^R$.

The reason behind the opposite signs is intuitively obvious. We can think of an increase in the disutility of labour parameter in a country as contracting its labour supply curve, while a higher markup on wages expands labour supply curve (this effect is equivalent to a wage subsidy). Thus, while a country with a higher parameter $\chi$ will be expected to have lower employment and higher wage, the opposite will be the case for a country which has a higher parameter $\mu$.

The solution of the model around a symmetric steady state equilibrium sees the real exchange rate determined as follows:

$$q = \frac{1}{D}[\beta_T a_T^R + \beta_N a_N^R + \beta_\chi \chi^R + \beta_{\mu^R}\mu^R + \beta_{\mu_{Diff}}\mu_{Diff}] \tag{4}$$

Where

$$\begin{aligned}
\beta_T &= (1-\gamma\kappa)\left(1+\frac{1}{D}\left[(1-\gamma)\left(1-\frac{\psi}{\sigma}(\gamma\kappa(\sigma-1)+1)\right)-\gamma\psi\right]\right) \\
\beta_N &= -(1-\gamma\kappa)\left(1+\frac{1}{D}\left[1+(1-\gamma)(1+\psi-\frac{\psi}{\sigma}(1+\gamma\kappa(\sigma-1)))\right]\right) \\
\beta_\chi &= \frac{1-\gamma\kappa}{D} \\
\beta_{\mu_R} &= \frac{1-\gamma\kappa}{D} \\
\beta_{\mu_{Diff}} &= (1-\gamma\kappa)\left(1+\frac{1}{D}\left[(1-\gamma)(1-\frac{1}{\sigma}\left(\gamma(\sigma-1)+1\right))\right]\right) \\
D &= \frac{1}{\sigma}\left[\sigma-\psi(\gamma\kappa(\sigma-1)+1)(\gamma-1)\right]+\gamma\psi(\kappa(\lambda-1)+1)
\end{aligned}$$

Under standard calibrations (such as in Berka et al. (2014)), the model predicts $\beta_T$, $\beta_\chi$ and $\beta_{\mu_{Diff}}$ are positive, while $\beta_N$ and $\beta_{\mu_R}$ are negative. In absolute magnitude, these calibrations imply that nontraded TFP and the wage markup differential elasticities are the largest, followed by traded TFP, with the level wage markup coefficient being the smallest.

# 4 Empirical Methodology

We estimate the reduced-form regression of the model, equation (5) below using pooled OLS:

$$q_{i,t} = \alpha + \beta a_{T,i,t} + \gamma a_{N,i,t} + \delta oulc_{i,t} + \omega x_{i,t} + \epsilon_{i,t} \tag{5}$$

where $q_{i,t}$ is the logarithm real exchange rate of country $i$ in year $t$, $a_{T,i,t}$ and $a_{N,i,t}$ are similarly log-differences in traded and nontraded productivity, respectively, and $oulc_{i,t}$ is the relative unit labour cost of country $i$, and $x_{i,t}$ is a vector of variables describing institutional characteristics of country's individual labour markets. All variables are bilateral, expressed relative to the US.

We also estimate versions of the model that incorporate either fixed or random effects:

$$q_{i,t} = \alpha + \beta a_{T,i,t} + \gamma a_{N,i,t} + \delta oulc_{i,t} + \omega x_{i,t} + \eta_i + \epsilon_{i,t} \tag{6}$$

where $\eta_i$ are cross-sectional country effects. The pooled regressions ignore the possibility of heterogeneity in the relationship between TFP and the real exchange rate for different countries (i.e. all countries are assumed to have the same intercepts in which case $\eta_i$ is not estimated). In our fixed effect regressions, on the other hand, we allow for different intercepts (i.e. include $\eta_i$), but they are assumed to be fixed over the sample. Estimation with random effects implies assuming that the intercepts can vary across countries, but that countries still have a common mean. We also consider including slope dummies (i.e a country dummy interacted with $a^T_{i:US,t}$ and $a^N_{i:US,t}$), to check whether the impact of TFP on the real exchange rate is different for some countries.

# 5 Model calibration/simulation results

# 6 Empirical results

In this section we report results from pooled regressions in which all countries share the same constant and the same slope coefficients, fixed effects panel regressions in which each country has an individual intercept, random effects regressions where country intercepts can differ (under the assumption that they are independent random variables) and a cross-sectional regressions (based on the sample average for each variable) without any time-dimension. The time-series aspect of these relationships is best identified in the fixed-effects regressions. The pool regression combines the cross-sectional and time-series aspects and the random effects regression is a combination of fixed effects and pool estimators.

The Balassa-Samuelson model predicts a positive relationship between the real exchange rate and relative non-tradable to tradable prices. Table 7 shows that there is a robust statistical relationship between real exchange rates and relative prices.

**Benchmark results now in Table 8.**

The benchmark results of our estimation of the relationship between relative TFP and real exchange rates (equations 5 and 6) are reported in Table 9. We proceed by sequentially relaxing assumptions by first assuming that only relative sectoral TFP matters for $q$, then allowing traded and non-traded TFP to influence $q$ with different magnitudes, and finally adding unit labour costs as a separate determinant of $q$ levels in our panel.

In a pool regression, relative TFP is highly significant with an elasticity of 0.57. That is, a 1% improvement in relative productivity of the traded sector relative to non-tradables, relative to the US, appreciates a country's $q$ by 0.57%. Allowing traded and nontraded to influence $q$ separately raises the $\bar{R}^2$ of the regression as the two variables have significantly different elasticities **(do we need to report this differently, eg as deviations from sample mean in FE? Alternatively we should mention high Rs are to be expected for low frequency data.)**. *The addition of orthogonalized ULC nearly quadruples the $\bar{R}^2$, without influencing the productivity coefficients. This indicates that relative unit labour costs are a significant source of $q$ variation overall, in addition to productivity.*

In fixed effects regressions, no total factor productivity variable is significant individually. This lack of productivity-$q$ co-movement in time-series among OECD countries is a standard result in the literature. $OULC$ is highly significant in the fixed effect regressions and raises $\bar{R}^2$ increases by more than 0.3. Thus, unit labour costs variation is particularly important in explaining time-series movements of $q$ and non-productivity-related growth in labour costs between countries over the sample accounted for a substantial amount of real currency appreciation.

Random effects regressions broadly mimic the results of fixed-effects, with very similar sizes of the coefficient estimates. Again, there is a lack of significance even when ULC is added to the regression.[18]

In cross-sectional regressions, relative TFP is highly significant, as is traded TFP. $OULC$ is again highly significant and adds substantially to the $\bar{R}^2$ of the regression. Non-traded TFP is only significant when $OULC$ is added to the regression, but the overall explanatory power remains substantial.

To summarize, our results indicate that real exchange rates in high-income OECD countries accord with an augmented Balassa-Samuelson theory which explicitly considers the levels of sectoral TFP and $q$ amongst floating currency OECD countries. We show that that labour market differences orthogonal to TFP are a key additional driver of RER differences both in cross-section and over time, and secondly that their inclusion helps to elicit the Balassa-Samuelson TFP-$q$ relationship.

## 6.1 Robustness

This section discusses several robustness checks that have been performed. Table 18 in Appendix D summarises the impacts on coefficient estimates and statistical significance when varying the sample, dataset and aggregation approaches used.

### 6.1.1 Possible spurious effect of nominal exchange rate

It is possible that our baseline results could be spuriously driven by the explicit or implicit inclusion of nominal exchange rate in our dependent variables as $OULC$ or $TOT$. In the case of $OULC$, we effectively take care of this problem by using $ULC$ orthogonalized to $NER$ in all regressions. But to highlight the point that our baseline results are not spuriously driven by nominal exchange rates, we add $NER$ as a stand-

[18] Hausman tests indicate a preference for random effects over the fixed effects regression. Under random effects, country-specific intercepts are assumed to be randomly distributed variables, and the slope coefficients are weighted averages of fixed effect estimator and a pool estimator.

alone variable to our regressions, and present the results in Table 11. Naturally, we expect $NER$ to be highly significant in the time-series regressions, as it is part of the dependent variable by construction. The goal is to establish whether $OULC$ remains significant after the inclusion of $NER$. In all four regressions, $OULC$ stays highly significant. *TFP variables are now also significant in fixed and random effect regressions, which they are not in our benchmark results.*

#### 6.1.2 Country slope dummy variables

**Are we still going to focus on slope dummy results?**

Industrial structure and institutional differences exist even between the rich OECD countries included in our study. However, our empirical methodology above assumes common slope coefficients for all variables. If that assumption is false, estimates of the fixed effects we rely on to calculate $q$ over/under-valuation may be biased. We relax this assumption by introducing a full set of country slope dummy variables for all three of our variables in the baseline case 2c in Table **??**. The resulting estimates of the average unexplained $q$ levels are reported in column 1b in Table 10. For most countries[19], relaxation of the common-slope-assumption doesn't materially change the estimate of the mean unexplained $q$ deviation. For others (Austria, Czech Republic, Hungary, Japan and the UK), the estimated mean unexplained $q$ deviation increases in absolute value. The average absolute unexplained mean $q$ deviation declines to 0.19, which is insignificantly different from the mean absolute $q$ in the data (0.18). We therefore conclude that our estimates of the average unexplained $q$ deviations are robust to the assumption of a common slope, for most countries.

#### 6.1.3 Inclusion of terms of trade differentials

The basic Balassa-Samuelson model assumes that both countries produce the same basket of tradable goods. Relaxing this assumption, so that domestic and foreign tradable goods are imperfect substitutes (as in our model), then changes in relative terms of trade could affect the real exchange rate. An improvement in home tradable productivity, for example, would reduce the price of domestically produced tradables. While this would increase the relative price of non-tradables in terms of tradables (the Balassa-Samuelson effect), it would also cause the home country's terms of trade

[19]These are: Australia, New Zealand, Belgium, Denmark, Spain, Finland, Ireland, Italy and Sweden.

to fall. The effect of terms of trade on the real exchange rate can be ambiguous, depending on whether the income effect (higher demand for all products, but especially for non-tradables) is offset by demand substitution towards imports when the currency appreciates. Unless the Balassa-Samuelson effect dominates the terms of trade effect, improvements in traded sector productivity changes may cause the real exchange rate to depreciate (see Benigno and Thoenissen (2003)). As reported in Table 12, adding relative terms of trade to the benchmark model yields highly significant coefficient estimates in the pooled, fixed effect and random effect regressions but not in the cross-section, although the sign is negative (which is also the case if $OULC$ is omitted from the regressions).

#### 6.1.4 Inclusion of long-run interest rate differentials

Unlike the basic Balassa-Samuelson model, some theories argue that aggregate demand considerations may influence real exchange rates (for an overview, see e.g., Froot and Rogoff (1995)). Bergstrand (1991) shows that when income elasticity of demand for services exceeds unity, demand plays an important role in causing $q$. De Gregorio et al. (1994), Chinn and Johnson (1996) and others suppose that concentration of government expenditures in nontraded sector should give aggregate demand components a channel through which they influence the relative price of nontraded goods and hence the real exchange rate. We control for the role of aggregate demand by adding long-run real interest rate differentials ($RIRDIFF$) into our regressions. A decrease in real interest rates at home, ceteris paribus, may cause an increase in the demand for nontraded consumption goods, and hence a real exchange rate appreciation: an expected negative coefficient. Table shows that the inclusion of an interest rate differential does not change our baseline results. In the pool regression, there is a negligible change in coefficient sizes and no change in their significance, while the $RIRDIFF$ has a positive and significant sign. Qualitatively, these results carry through in the fixed- and random-effect regressions. While we cannot explain the positive coefficient on the interest rate differential variable (in line with the findings in Berka et al. (2014)), we conclude that our standard coefficient estimates remain unaffected by the addition of this demand-side variable. To that extent, demand-side variables are not driving our results.

#### 6.1.5 Alternative measure of institutional labour market differences

Institutional differences between economies matters for competitiveness. Table 15 shows that most of the labour market indicators are significant when added to the benchmark model for the pooled, fixed effect and random effect versions of the model, but not in the cross-section. *However, only $CONC$ and the average of four indicators $LAB4avg$ have positive coefficients in both timeseries and cross-sectional dimensions. The other indicators are either insignificant,*[20] *or suggest, contrary to expectation, that tighter labour market conditions relative to the US would be associated with a less appreciated currency. That said, the coefficients on a couple of labour markets indicators switch sign and are significant when $RULC$ is dropped from the model.*

*When excluding ULCs and using the RER based on aggregate CPI (or the alternative series for non-tradable TFP) the labour market indicators are only significant and have the correct signs in a handful of the pooled regressions. Adding relative terms of trade does not improve the results in general.*

*An alternative interpretation could be that the relationship between labour market flexibility and the real exchange rate is in the other direction. For example, it may be that centralization of wage bargaining (eg measured using conc) helped Germany and other European countries stay competitive in spite of appreciating real exchange rates (or helped moderate wage growth). It is also conceivable that reforms that imply less flexibility in labour market structure may actually improve labour market efficiency by offsetting some of the increased bargaining power of employers (or rising mark-ups if deregulation is associated with consolidation within industries). On the contrary, concentration of union membership (eg $UD$), and also the power of unions (auth), could result in increased labour market inefficiency and increases in wages not associated with increased productivity. These variables are significant, at least in a timeseries dimension.*

#### 6.1.6 5-year averages

The literature finds more empirical support for the Balassa-Samuelson hypothesis in cross-section than in the time-series. This implies that lowering the frequency of our observations should result in stronger regression results. To assess the robustness of our results to a lower frequency of the data, we construct a dataset of 5-year non-

[20] $UD$ and $RR$ are not significant in fixed effects or random effects models.

overlapping averages of all our variables and repeat our baseline regressions. Table shows that the main difference in the coefficient estimates is that non-traded TFP is no longer significant in the pooled regressions and that coefficient estimates change slightly. *The* $\bar{R}^2$ *of our regressions increases in all cases. We can conclude that our main results are not driven by higher-frequency movements.*

Additional robustness tests are provided in Section D, which provides a summary of the impacts of varying the sample, dataset and aggregation approaches used.

## 6.2 Conditional real exchange rate deviations

We next want to understand the extent to which $q$ deviations remain unexplained by the estimated augmented Balassa-Samuelson model, and the variation of these unexplained deviations across countries. To shed light on this issue, we collect fixed-effect estimates for all 17 countries from our baseline regression, and use them to construct residual unexplained real exchange rate levels. Table reports the mean values of these unexplained $q$ levels by country, from 4 different specifications[21]. These represent the residual mean $q$ deviations conditional on each country's fundamentals. The fifth column reports their average, and the sixth column reports the Root Mean Square Error (RMSE) by country. The last column reports the mean $q$ in the data.

Although the standard deviation of the conditional residual $q$ deviations across countries is smaller than that of unconditional $q$ deviations (0.23 vs. 0.16), the average absolute deviation increases from 0.18 to 0.21. That is, augmented Balassa-Samuelson model results in a larger average absolute $q$ deviations than those present in the data. In many countries, average $q$ deviation changes from 'undervalued' to 'overvalued', after conditioning on TFP and ULC differences. One way of interpreting this finding is that the augmented Balassa-Saumelson model over-explains the average $q$ deviation. Another is that the model misses some important time-invariant $q$ determinants.

Figure 12 plots the actual, predicted, and unexplained $q$ deviations by country. For some countries, such as Germany, Spain and the UK, total factor productivity differences and differences in unit labour costs account for nearly all of the $q$ deviations, resulting in little unexplained $q$ (-0.6%, -0.4% and 1.6%, respectively, in our preferred specification on average). On the contrary, unexplained $q$ are on average the

[21]The specifications are: two unbalanced panel estimates (one for each of our two measures of nontraded TFP), and two balanced 1995-2012 panels. The values are sums of the fixed effect estimate and the constant.

largest in Hungary (-53%), Denmark (46%), Australia (36%), New Zealand (35%), Japan (31%), Sweden (27%), Ireland (28%) and Czech Republic (-25%). The RMSE is largest in Hungary (0.51), followed by Denmark (0.44), New Zealand (0.37), Australia (0.34), Ireland (0.33), Sweden (0.294) and Czech Republic (0.29), while the lowest in Spain (0.01), Germany (0.04), Belgium (0.05), Austria (0.07) and France (0.09).

Let us consider the example of New Zealand. Its average $q$ conditional on traded and nontraded TFP, and its ULC relative to the U.S. is 0.35. That is, New Zealand's real exchange rate is approximately 35% "overvalued" relative to the U.S., if we only consider TFP and orthogonal labour cost differences as the determinants of its $q$. The change from the New Zealand's unconditional average $q$ of -0.15 is substantial: while the raw data indicates that New Zealand's price level is around 15% below the U.S. price level on average, after considering the differences between New Zealand's productivity levels and labour cost levels, the price level turns out to be actually 35% above the U.S. price level. Statistically speaking, this is caused by New Zealand's traded TFP being well below the US levels, while the nontraded TFP on average being higher than that in the US. While New Zealand's unit labour costs are the second lowest in our sample, on average, given the estimated coefficient on ULC in our benchmark specification they do not eliminate the $q$ gap, resulting in the "overvaluation" by 35%.

New Zealand is not unique. In fact, for 12 out of 17 countries, augmented Balassa-Samuelson model 'over-explains' the role of the fundamentals, in the sense that the conditional unexplained mean $q$ deviations are further from parity in their absolute values than the unconditional $q$ data. The only countries with lower conditional $q$ deviations are Germany, UK, Spain, Czech Republic and Hungary.

# 7 Conclusion

This paper develops the data necessary for an evaluation of the level of real exchange rate over medium to long run using the standard supply-side model of exchange rate determination that emphasizes productivity differentials of traded and non-traded sectors.

We show that the standard model fails to explain relative price differences and their changes over time. However, relaxing the assumptions about wage determination and the role of labour market differences across sectors and countries helps improve the performance of the model. We show theoretically and empirically that when controlling for structural labour market differences across countries, there is a link between the real exchange and sectoral TFP in OECD economies. There remains, however, large unexplained differences in real exchange rates across countries.

# References

**Australian Bureau of Statistics**, "Estimates of Industry Multifactor Productivity: Table 1 (Quality adjusted hours worked), 5260.0.55.002," 2014. Retrieved 17 December 2014: `http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/5260.0.55.0022013-14?OpenDocument`,.

_ , "Gross Value Added (GVA) by Industry, Table 5 in 5204.0 Australian System of National Accounts," 2014. Retrieved December 17 2014: `http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/5204.02013-14?OpenDocument`.

**Benigno, Gianluca and Christoph Thoenissen**, "Equilibrium Exchange Rates and Supply-Side Performance," *Economic Journal*, March 2003, *113* (486), C103–C124.

**Bergin, Paul R., Reuven Glick, and Alan M. Taylor**, "Productivity, tradability, and the long-run price puzzle," *Journal of Monetary Economics*, November 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, Michael B. Devereux, and Charles Engel**, "Real Exchange Rates and Sectoral Productivity in the Eurozone," Working Paper 20510, National Bureau of Economic Research September 2014.

**Bordo, Michael D., Ehsan U. Choudhri, Giorgio Fazio, and Ronald MacDonald**, "The Real Exchange Rate in the Long Run: Balassa-Samuelson Effects Reconsidered," Working Paper 20228, National Bureau of Economic Research June 2014.

**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.

**Chen, Lein-Lein, Seungmook Choi, and John Devereux**, "Explaining price level differences: New evidence on the BalassaSamuelson effect," *Southern Economic Journal*, 2015, *82* (1), 81–99.

**Chinn, Menzie and Louis Johnson**, "Real exchange rate levels, productivity and demand shocks: evidence from a panel of 14 countries," Working Paper 5709, NBER 1996.

**Chong, Yanping, Oscar Jorda, and Alan M. Taylor**, "The Harrod-Balassa-Samuelson Hypothesis: Real Exchange Rates and Their Long-Run Equilibrium.," *International Economic Review*, 2012, *53* (2), 609 – 633.

**Drozd, Lukasz A. and Jaromir B. Nosal**, "The Nontradable Goods' Real Exchange Rate Puzzle," in "NBER International Seminar on Macroeconomics 2009" NBER Chapters, National Bureau of Economic Research, Inc, August 2010, pp. 227–249.

**Engel, Charles**, "Accounting for U.S. Real Exchange Rate Changes," *Journal of Political Economy*, June 1999, *107* (3), 507–538.

**EU KLEMS Growth and Productivity Accounts**, "Appendix tables to Robert Inklaar and Marcel P. Timmer (2008), GGDC Productivity Level Database: International Comparisons Of Output, Inputs And Productivity At The Industry Level, GGDC Research Memorandum GD-104, Groningen: University of Groningen.," 2014. Retrieved November 12 2014: `http://www.euklems.net/`.

**Feenstra, Robert C., Robert Inklaar, and Marcel P. Timmer**, "The Next Generation of the Penn World Table," *American Economic Review*, October 2015, *105* (10), 3150–82.

**_ , _ , and Marcel Timmer**, "The Next Generation of the Penn World Table," NBER Working Papers 19255, National Bureau of Economic Research, Inc July 2013.

**Froot, Kenneth A. and Kenneth Rogoff**, "Perspectives on PPP and Long-Run Real Exchange Rates," in G. M. Grossman and K. Rogoff, eds., *Handbook of International Economics*, Elsevier Science, 1995, pp. 1647 – 1688.

**Gnocchi, Stefano, Andresa Lagerborg, and Evi Pappa**, "Do labor market institutions matter for business cycles?," *Journal of Economic Dynamics and Control*, 2015, *51* (C), 299–317.

**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.

**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.

**Gubler, Matthias and Christoph Sax**, "The Balassa-Samuelson Effect Reversed: New Evidence from OECD Countries," Working papers 2011/09, WWZ Discussion Paper 2011.

**Lothian, JamesR. and MarkP. Taylor**, "Real Exchange Rates Over the Past Two Centuries: How Important is the Harrod-Balassa-Samuelson Effect?," *Economic Journal*, October 2008, *118* (532), 1742–1763.

**Mason, Geoff**, "Investigating New Zealand-Australia Productivity Differences: New Comparisons at Industry Level (Industry Dataset 1997-2010)," New Zealand Productivity Commission Working Paper 2013/02 2013.

**Mihaljek, Dubravko and Marc Klau**, "The Balassa Samuelson Effect in Central Europe: A Disaggregated Analysis," *Comparative Economic Studies*, March 2004, *46* (1), 63–94.

**_ and _** , "Catching-up and inflation in transition economies: the Balassa-Samuelson effect revisited," BIS Working Papers 270, Bank for International Settlements December 2008.

**OECD**, "Quarterly benchmarked Unit Labour Cost indicators," 2015. Retrieved 24 February 2015, `http://stats.oecd.org/Index.aspx?DataSetCode=ULC_QUA`,.

— , "Unit Labour Costs - Annual Indicators," 2015. Retrieved 24 February 2015, `http://stats.oecd.org/Index.aspx?DataSetCode=ULC_ANN#`,.

**OECD and Eurostat**, "Purchasing Power Parities and Real Expenditures 2007: 2005 Benchmark year," 2008. Retrieved 24 February 2015, `http://dx.doi.org/10.1787/248602622754.`,.

**O'Mahony, Mary and Marcel P. Timmer**, "Output, Input and Productivity Measures at the Industry Level: The EU KLEMS Database," *Economic Journal*, 06 2009, *119* (538), F374–F403.

**Ricci, Luca Antonio, Gian Maria Milesi-Ferretti, and Jaewoo Lee**, "Real Exchange Rates and Fundamentals: A Cross-Country Perspective," *Journal of Money, Credit and Banking*, 08 2013, *45* (5), 845–865.

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

**Statistics Japan**, "Consumer Price Index (CPI), Table 751-790," 2015. Retrieved 17 February 2015: `http://www.e-stat.go.jp/SG1/estat/ListE.do?bid=000001033700&cycode=0`.

**Statistics New Zealand**, "Productivity Statistics: 1978 to 2012," 2013. Retrieved 6 December 2013, `www.stats.govt.nz/browse_for_stats/economic_indicators/productivity/ProductivityStatistics_HOTP78-12/Definitions.aspx`,.

— , "National Accounts - SNA 2008, GDP(P), Nominal, ANZSIC06 industry groups (Annual-Mar)," 2014. Retrieved 17 December 2014.

**Steenkamp, Daan**, "Productivity and the New Zealand Dollar: Balassa-Samuelson tests on sectoral data," Reserve Bank of New Zealand Analytical Notes series AN2013/01, Reserve Bank of New Zealand June 2013.

— , "Constructing cross country estimates of relative industry MFP levels," Reserve Bank of New Zealand Analytical Notes series AN2015/04, Reserve Bank of New Zealand July 2015.

**The World Bank**, "International Comparison Program," 2011.

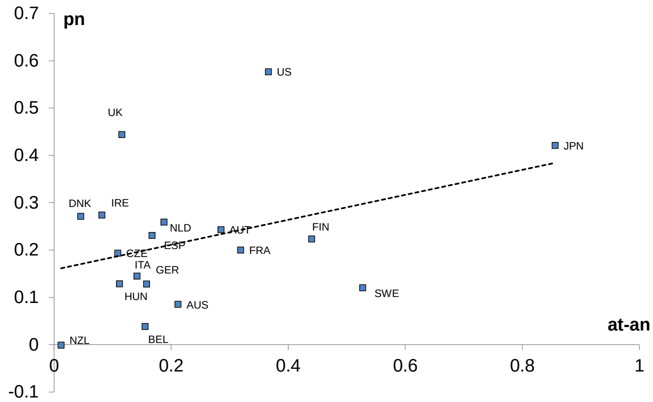
**Timmer, Marcel, Gerard Ypma, and Bart van van Ark**, "PPPs for Industry Output: A New Dataset for International Comparisons," Technical Report 2007.

**Visser, J**, "ICTWSS: Database on Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts in 34 Countries Between 1960 and 2012," Technical Report, Amsterdam Institute for Advanced labour Studies 2013.

**WorldKLEMS database**, 2014. Retrieved November 12 2014: http://www.worldklems.net/data.htm.

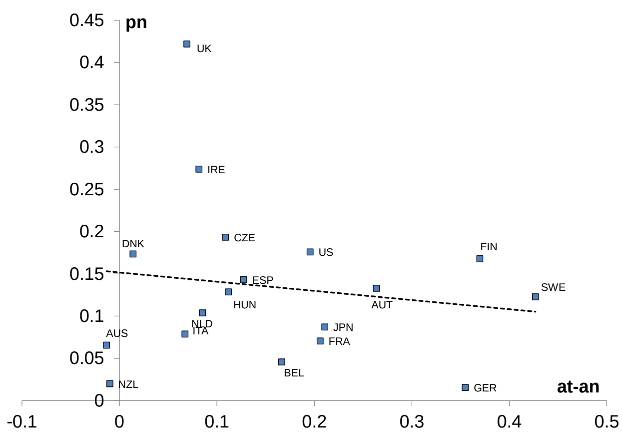
# A Data and Figures

Figure 1: Domestic sectoral price and productivity ratios (Unbalanced panel, changes)



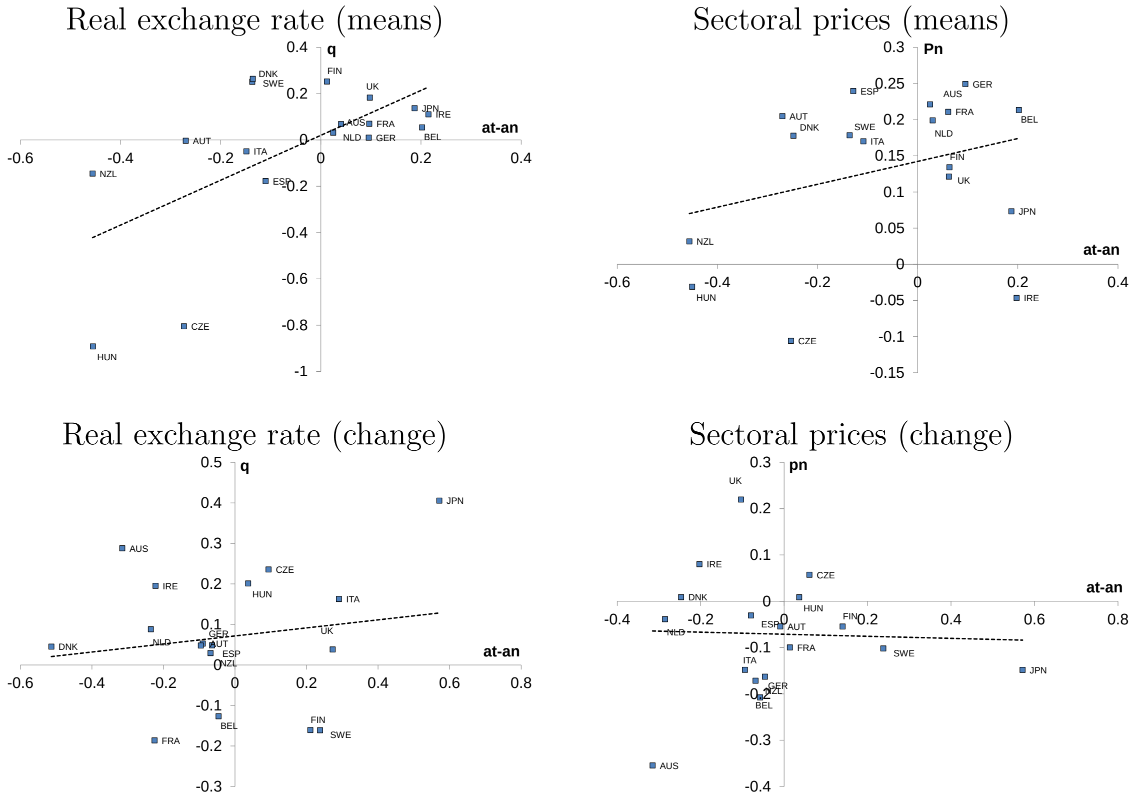

Note: All variables specified in logs. $a_T$ and $a_N$ traded and non-traded TFP indices, and $p_N = P_N - P_T$ where $P_T$ and $P_N$ are indices of traded and non-traded consumer prices. Unbalanced sample described in Table 16. Note that for the Czech Republic the $p_N$ chart sample starts in 1999 and for Hungary in 2000, while for New Zealand, $a_N$ starts in 1996.

Figure 2: Domestic sectoral price and productivity ratios (1995-2007, changes)



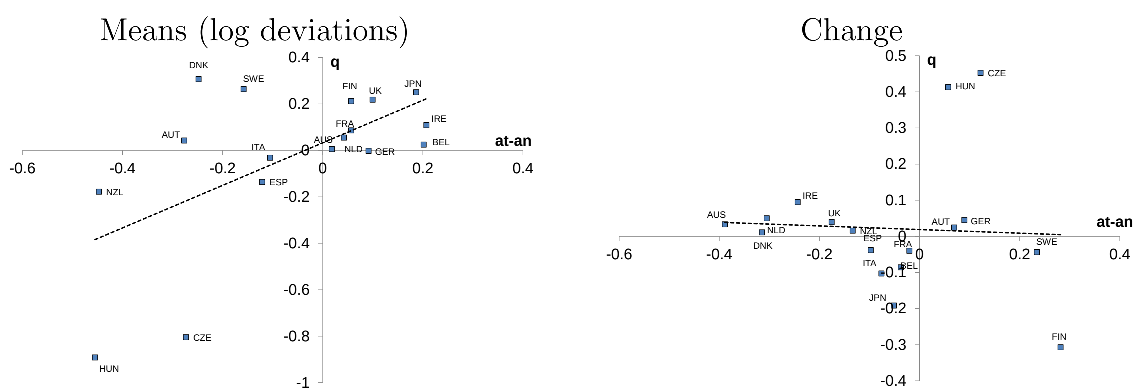

Note: All variables specified in logs. $a_T$ and $a_N$ traded and non-traded TFP indices, and $p_N = P_N - P_T$ where $P_T$ and $P_N$ are indices of traded and non-traded consumer prices. Unbalanced sample described in Table 16. Note that for the Czech Republic the $p_N$ chart sample starts in 1999 and for Hungary in 2000, while for New Zealand, $a_N$ starts in 1996.

Figure 3: Cross country sectoral prices and productivity ratios (Unbalanced panel)



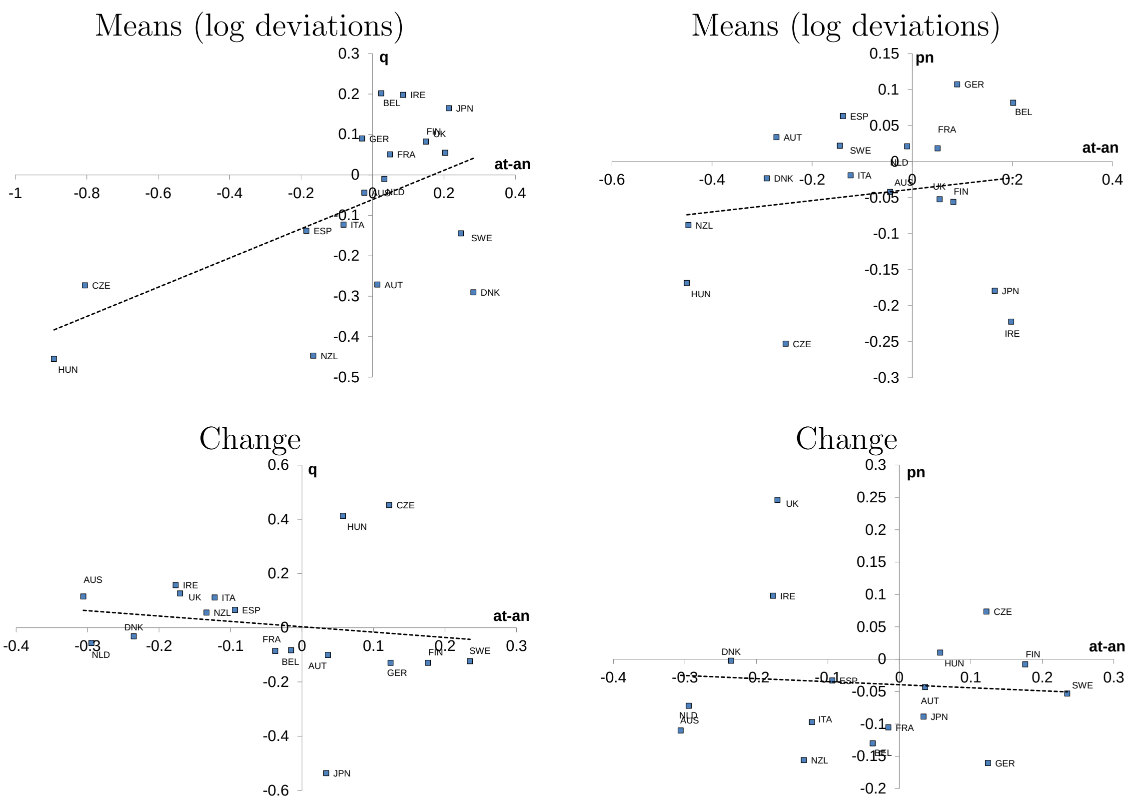

Note: All variables specified in log deviations from US levels. $q$ is the bilateral real exchange rate in levels against the US based on aggregate CPI, $a_T$ and $a_N$ traded and non-traded TFP levels relative to the US. $p_N = q_N - q_T$ where $q_T$ and $q_N$ are the traded and non-traded real exchange rate against the US. The sample for charts with $p_N$ is shorter for most countries, see Table 16.

Figure 4: Cross country sectoral prices and productivity ratios (1990-2007)




Note: All variables specified in log deviations from US levels. $q$ is the bilateral real exchange rate in levels against the US based on aggregate CPI, $a_T$ and $a_N$ traded and non-traded TFP levels relative to the US. $p_N = q_N - q_T$ where $q_T$ and $q_N$ are the traded and non-traded real exchange rate against the US. The sample for charts with $p_N$ is shorter for most countries, see Table 16.

Figure 5: Cross country sectoral prices and productivity ratios (1995-2007)




Note: $q$ is the bilateral real exchange rate in levels against the US based on aggregate CPI, $a_T$ and $a_N$ traded and non-traded TFP levels relative to the US ($a_{N2}$ is an alternative non-traded TFP measure that excludes sector 11 as described in Appendix section C.1). All variables specified in log deviations from US levels. The sample for charts with $p_N$ is shorter for most countries, see Table 16.

Table 1: Summary statistics: average levels (Unbalanced panel)

| Country | Sample | $\overline{a_T}$ | $\overline{a_N}$ | $\overline{a_T - a_N}$ | $\overline{q}$ | $\overline{oulc}$ | $\overline{conc}$ | $\overline{tot}$ | $\overline{rirdiff}$ |
|---|---|---|---|---|---|---|---|---|---|
| AUS | 1983-2010 | -0.06 | -0.09 | 0.02 | 0.03 | -0.35 | 0.21 | 0.00 | 1.03 |
| AUT | 1990-2009 | -0.48 | -0.21 | -0.27 | 0.06 | -0.05 | 0.60 | 0.08 | 0.60 |
| BEL | 1995-2010 | 0.02 | -0.18 | 0.20 | 0.05 | -0.10 | -0.03 | 0.10 | 0.44 |
| CZE | 1995-2007 | -0.71 | -0.43 | -0.27 | -0.81 | -0.53 | 0.25 | 0.11 | 0.30 |
| DNK | 1990-2007 | -0.28 | -0.03 | -0.25 | 0.31 | -0.16 | -0.03 | 0.07 | 1.22 |
| ESP | 1980-2009 | -0.26 | -0.15 | -0.11 | -0.18 | -0.09 | -0.33 | 0.09 | 0.08 |
| FIN | 1975-2010 | -0.16 | -0.17 | 0.01 | 0.25 | -0.07 | -0.18 | 0.10 | 1.64 |
| FRA | 1980-2009 | -0.14 | -0.23 | 0.10 | 0.07 | -0.23 | -0.96 | 0.06 | 0.50 |
| GER | 1991-2009 | -0.07 | -0.17 | 0.10 | 0.01 | -0.07 | 0.34 | 0.05 | 0.41 |
| HUN | 1995-2007 | -0.72 | -0.26 | -0.45 | -0.89 | -0.13 | -0.64 | 0.13 | -1.53 |
| IRE | 1988-2007 | 0.15 | -0.06 | 0.21 | 0.11 | -0.01 | 0.56 | 0.08 | 0.35 |
| ITA | 1972-2009 | -0.14 | 0.01 | -0.15 | -0.05 | -0.24 | -0.39 | 0.05 | -0.29 |
| JPN | 1973-2009 | -0.34 | -0.53 | 0.19 | 0.14 | -0.32 | -0.28 | 0.05 | -1.08 |
| NLD | 1988-2009 | 0.18 | 0.14 | 0.04 | 0.07 | -0.11 | 0.05 | 0.03 | 0.54 |
| NZL | 1996-2010 | -0.36 | 0.10 | -0.46 | -0.15 | -0.31 | 0.35 | 0.10 | 1.61 |
| SWE | 1993-2010 | -0.13 | 0.00 | -0.14 | 0.26 | -0.15 | -0.06 | 0.10 | 1.46 |
| UK | 1972-2009 | -0.13 | -0.23 | 0.10 | 0.18 | -0.46 | 0.34 | 0.04 | 0.07 |

Each variable $x$ is in logarithmic form (except real interest rates which are in levels), expressed as a bilateral difference of country $i$ value minus the US value. A $\overline{x}$ represents a time-series average. $a_T$ is the Traded TFP, $a_N$ is the non-traded TFP, $q$ is the real exchange rate, $oulc$ is the orthogonalised bilateral unit labour cost difference, $CONC$ is a measure of the centralization of wage bargaining, expressed as the log difference relative to the US, $TOT$ is export over import price *levels* expressed relative to the US, $RIRDIFF$ is real long run interest rate differentials to the US.

Table 2: Summary statistics: time-series volatility (std) (Unbalanced panel)

| Country | Sample | $s(a_T)$ | $s(a_N)$ | $s(a_T\text{-}a_N)$ | $s(q)$ | $s(oulc)$ | $s(conc)$ | $s(tot)$ | $s(rirdiff)$ |
|---|---|---|---|---|---|---|---|---|---|
| AUS | 1983-2010 | 0.13 | 0.03 | 0.15 | 0.14 | 0.24 | 0.16 | 0.07 | 1.71 |
| AUT | 1990-2009 | 0.06 | 0.02 | 0.05 | 0.13 | 0.27 | 0.22 | 0.03 | 0.65 |
| BEL | 1995-2010 | 0.08 | 0.05 | 0.04 | 0.15 | 0.14 | 0.25 | 0.03 | 0.59 |
| CZE | 1995-2007 | 0.08 | 0.06 | 0.06 | 0.19 | 0.28 | 0.14 | 0.04 | 1.35 |
| DNK | 1990-2007 | 0.12 | 0.03 | 0.10 | 0.12 | 0.13 | 0.17 | 0.03 | 1.56 |
| ESP | 1980-2009 | 0.14 | 0.10 | 0.05 | 0.19 | 0.16 | 0.21 | 0.07 | 2.34 |
| FIN | 1975-2010 | 0.16 | 0.08 | 0.10 | 0.16 | 0.16 | 0.21 | 0.06 | 1.69 |
| FRA | 1980-2009 | 0.06 | 0.03 | 0.07 | 0.15 | 0.45 | 0.19 | 0.05 | 1.67 |
| GER | 1991-2009 | 0.06 | 0.03 | 0.06 | 0.13 | 0.26 | 0.24 | 0.03 | 0.80 |
| HUN | 1995-2007 | 0.05 | 0.02 | 0.05 | 0.20 | 0.19 | 0.21 | 0.04 | 2.74 |
| IRE | 1988-2007 | 0.08 | 0.07 | 0.10 | 0.13 | 0.23 | 0.18 | 0.05 | 2.05 |
| ITA | 1972-2009 | 0.14 | 0.11 | 0.13 | 0.14 | 0.43 | 0.18 | 0.05 | 2.67 |
| JPN | 1973-2009 | 0.13 | 0.08 | 0.16 | 0.20 | 0.32 | 0.20 | 0.11 | 2.48 |
| NLD | 1988-2009 | 0.11 | 0.03 | 0.12 | 0.12 | 0.34 | 0.25 | 0.03 | 1.29 |
| NZL | 1996-2010 | 0.05 | 0.02 | 0.05 | 0.19 | 0.30 | 0.35 | 0.04 | 0.97 |
| SWE | 1993-2010 | 0.11 | 0.03 | 0.09 | 0.13 | 0.19 | 0.20 | 0.04 | 1.26 |
| UK | 1972-2009 | 0.06 | 0.05 | 0.09 | 0.11 | 0.28 | 0.20 | 0.08 | 2.30 |

$s(x)$ represents a the time-series standard deviation of variable $x$ in country $i$ (which has been expressed as a bilateral difference of country $i$ value minus the US value). A $\overline{x}$ represents a time-series average. $a_T$ is the Traded TFP, $a_N$ is the non-traded TFP, $q$ is the real exchange rate, $oulc$ is the orthogonalised bilateral unit labour cost difference, $CONC$ is a measure of the centralization of wage bargaining, expressed as the log difference relative to the US. $TOT$ is export over import price *levels* expressed relative to the US, $RIRDIFF$ is real long run interest rate differentials to the US.

Table 3: Summary statistics: average growth rates (Unbalanced panel)

| Country | Sample | $g(a_T)$ | $g(a_N)$ | $g(a_T\text{-}a_N)$ | $g(q)$ | $g(oulc)$ |
|---|---|---|---|---|---|---|
| AUS | 1983-2010 | -1.18 | 0.06 | -1.24 | 0.87 | 1.41 |
| AUT | 1990-2009 | 0.24 | 0.30 | -0.06 | 0.17 | -1.34 |
| BEL | 1995-2010 | -1.38 | -1.14 | -0.25 | -0.69 | -0.43 |
| CZE | 1995-2007 | 0.30 | -0.71 | 1.02 | 3.84 | 6.85 |
| DNK | 1990-2007 | -1.90 | -0.07 | -1.83 | 0.06 | 0.02 |
| ESP | 1980-2009 | -1.10 | -0.85 | -0.25 | 0.17 | -0.36 |
| FIN | 1975-2010 | 1.17 | 0.55 | 0.62 | -0.34 | -0.17 |
| FRA | 1980-2009 | -0.46 | 0.18 | -0.64 | -0.50 | 0.76 |
| GER | 1991-2009 | -2.04 | -0.33 | -1.71 | 0.37 | 0.88 |
| HUN | 1995-2007 | 1.02 | 0.53 | 0.48 | 3.50 | -0.75 |
| IRE | 1988-2007 | 0.22 | 1.24 | -1.01 | 0.80 | -1.26 |
| ITA | 1972-2009 | 0.00 | -1.15 | 1.17 | 0.43 | 0.78 |
| JPN | 1973-2009 | 0.48 | -1.20 | 1.70 | 1.11 | 2.14 |
| NLD | 1988-2009 | -0.83 | 0.27 | -1.10 | 0.36 | 0.53 |
| NZL | 1996-2010 | -1.07 | -0.31 | -0.77 | 0.20 | -4.82 |
| SWE | 1993-2010 | 1.99 | 0.42 | 1.57 | -0.69 | 1.04 |
| UK | 1972-2009 | 0.28 | -0.49 | 0.77 | 0.09 | -0.45 |

$g(x)$ represents a the compound average annual growth rate of variable $x$, in %. Each variable $x$ in country $i$ has been expressed as a bilateral difference of country $i$ value minus the US value. A $\overline{x}$ represents a time-series average. $a_T$ is the Traded TFP, $a_N$ is the non-traded TFP, $q$ is the real exchange rate, *oulc* is the orthogonalised bilateral unit labour cost difference, $TOT$ is export over import price *levels* expressed relative to the US, $RIRDIFF$ is real long run interest rate differentials to the US.

Table 4: Summary statistics: average levels (Unbalanced panel, pn) **DROP?**

| Country | Sample | $\overline{a_T}$ | $\overline{a_N}$ | $\overline{a_T - a_N}$ | $\overline{q}$ | $\overline{p_n}$ | $\overline{oulc}$ | $\overline{tot}$ | $\overline{rirdiff}$ |
|---|---|---|---|---|---|---|---|---|---|
| AUS | 1983-2010 | -0.06 | -0.09 | 0.02 | 0.03 | 0.02 | -0.35 | 0.00 | 1.03 |
| AUT | 1990-2009 | -0.48 | -0.21 | -0.27 | 0.06 | 0.02 | -0.05 | 0.08 | 0.60 |
| BEL | 1995-2010 | 0.02 | -0.18 | 0.20 | 0.05 | 0.06 | -0.10 | 0.10 | 0.44 |
| CZE | 1999-2007 | -0.72 | -0.47 | -0.25 | -0.77 | -0.25 | -0.43 | 0.11 | 0.30 |
| DNK | 1990-2007 | -0.28 | -0.03 | -0.25 | 0.31 | -0.02 | -0.16 | 0.07 | 1.22 |
| ESP | 1993-2009 | -0.36 | -0.22 | -0.13 | -0.15 | 0.06 | -0.08 | 0.09 | 0.11 |
| FIN | 1975-2010 | -0.16 | -0.17 | 0.01 | 0.25 | -0.04 | -0.07 | 0.10 | 1.64 |
| FRA | 1990-2009 | -0.17 | -0.23 | 0.06 | 0.10 | 0.03 | -0.05 | 0.05 | 1.07 |
| GER | 1995-2009 | -0.08 | -0.18 | 0.10 | -0.01 | 0.09 | -0.13 | 0.05 | 0.63 |
| HUN | 2000-2007 | -0.70 | -0.25 | -0.45 | -0.83 | -0.17 | -0.18 | 0.12 | -1.15 |
| IRE | 1995-2007 | 0.18 | -0.01 | 0.20 | 0.09 | -0.22 | -0.08 | 0.07 | -0.71 |
| ITA | 1990-2009 | -0.18 | -0.07 | -0.11 | -0.02 | -0.01 | -0.24 | 0.04 | 1.28 |
| JPN | 1973-2009 | -0.34 | -0.53 | 0.19 | 0.14 | -0.15 | -0.32 | 0.05 | -1.08 |
| NLD | 1990-2009 | 0.17 | 0.14 | 0.03 | 0.07 | 0.02 | -0.12 | 0.04 | 0.43 |
| NZL | 1996-2010 | -0.36 | 0.10 | -0.46 | -0.15 | -0.11 | -0.31 | 0.10 | 1.61 |
| SWE | 1993-2010 | -0.13 | 0.00 | -0.14 | 0.26 | 0.02 | -0.15 | 0.10 | 1.46 |
| UK | 1990-2009 | -0.16 | -0.22 | 0.06 | 0.20 | -0.04 | -0.44 | 0.03 | 0.99 |

Each variable $x$ is in logarithmic form (except real interest rates which are in levels), expressed as a bilateral difference of country $i$ value minus the US value. A $\overline{x}$ represents a time-series average. $a_T$ is the Traded TFP, $a_N$ is the non-traded TFP, $q$ is the real exchange rate, the relative price of non-traded to traded goods is $p_n$, *oulc* is the orthogonalised bilateral unit labour cost difference, $TOT$ is export over import price *levels* expressed relative to the US, $RIRDIFF$ is real long run interest rate differentials to the US.

Table 5: Summary statistics: time-series volatility (std) (Unbalanced panel,pn) **DROP?**

| Country | Sample | $s(a_T)$ | $s(a_N)$ | $s(a_T\text{-}a_N)$ | $s(q)$ | $s(p_n)$ | $s(oulc)$ | $s(tot)$ | $s(rirdiff)$ |
|---|---|---|---|---|---|---|---|---|---|
| AUS | 1983-2010 | -0.06 | -0.09 | 0.02 | 0.03 | 0.02 | -0.35 | 0.00 | 1.03 |
| AUT | 1990-2009 | -0.48 | -0.21 | -0.27 | 0.06 | 0.02 | -0.05 | 0.08 | 0.60 |
| BEL | 1995-2010 | 0.02 | -0.18 | 0.20 | 0.05 | 0.06 | -0.10 | 0.10 | 0.44 |
| CZE | 1999-2007 | -0.72 | -0.47 | -0.25 | -0.77 | -0.25 | -0.43 | 0.11 | 0.30 |
| DNK | 1990-2007 | -0.28 | -0.03 | -0.25 | 0.31 | -0.02 | -0.16 | 0.07 | 1.22 |
| ESP | 1993-2009 | -0.36 | -0.22 | -0.13 | -0.15 | 0.06 | -0.08 | 0.09 | 0.11 |
| FIN | 1975-2010 | -0.16 | -0.17 | 0.01 | 0.25 | -0.04 | -0.07 | 0.10 | 1.64 |
| FRA | 1990-2009 | -0.17 | -0.23 | 0.06 | 0.10 | 0.03 | -0.05 | 0.05 | 1.07 |
| GER | 1995-2009 | -0.08 | -0.18 | 0.10 | -0.01 | 0.09 | -0.13 | 0.05 | 0.63 |
| HUN | 2000-2007 | -0.70 | -0.25 | -0.45 | -0.83 | -0.17 | -0.18 | 0.12 | -1.15 |
| IRE | 1995-2007 | 0.18 | -0.01 | 0.20 | 0.09 | -0.22 | -0.08 | 0.07 | -0.71 |
| ITA | 1990-2009 | -0.18 | -0.07 | -0.11 | -0.02 | -0.01 | -0.24 | 0.04 | 1.28 |
| JPN | 1973-2009 | -0.34 | -0.53 | 0.19 | 0.14 | -0.15 | -0.32 | 0.05 | -1.08 |
| NLD | 1990-2009 | 0.17 | 0.14 | 0.03 | 0.07 | 0.02 | -0.12 | 0.04 | 0.43 |
| NZL | 1996-2010 | -0.36 | 0.10 | -0.46 | -0.15 | -0.11 | -0.31 | 0.10 | 1.61 |
| SWE | 1993-2010 | -0.13 | 0.00 | -0.14 | 0.26 | 0.02 | -0.15 | 0.10 | 1.46 |
| UK | 1990-2009 | -0.16 | -0.22 | 0.06 | 0.20 | -0.04 | -0.44 | 0.03 | 0.99 |

$s(x)$ represents a the time-series standard deviation of variable $x$ in country $i$ (which has been expressed as a bilateral difference of country $i$ value minus the US value). A $\overline{x}$ represents a time-series average. $a_T$ is the Traded TFP, $a_N$ is the non-traded TFP, $q$ is the real exchange rate, the relative price of non-traded to traded goods is $p_n$, $oulc$ is the orthogonalised bilateral unit labour cost difference, $TOT$ is export over import price *levels* expressed relative to the US, $RIRDIFF$ is real long run interest rate differentials to the US.

Table 6: Summary statistics: average growth rates (Unbalanced panel,pn) **DROP?**

| Country | Sample | $g(a_T)$ | $g(a_N)$ | $g(a_T\text{-}a_N)$ | $g(q)$ | $g(p_n)$ | $g(oulc)$ |
|---|---|---|---|---|---|---|---|
| AUS | 1983-2010 | -1.18 | 0.06 | -1.24 | 0.87 | -1.19 | 1.41 |
| AUT | 1990-2009 | 0.24 | 0.30 | -0.06 | 0.17 | -0.29 | -1.34 |
| BEL | 1995-2010 | -1.38 | -1.14 | -0.25 | -0.69 | -1.01 | -0.43 |
| CZE | 1999-2007 | 1.27 | 0.62 | 0.65 | 4.41 | 0.61 | 4.60 |
| DNK | 1990-2007 | -1.90 | -0.07 | -1.83 | 0.06 | 0.05 | 0.02 |
| ESP | 1993-2009 | -0.94 | -0.64 | -0.30 | 0.48 | -0.16 | 0.18 |
| FIN | 1975-2010 | 1.17 | 0.55 | 0.62 | -0.34 | -0.07 | -0.17 |
| FRA | 1990-2009 | -0.22 | -0.26 | 0.04 | -0.14 | -0.34 | 0.76 |
| GER | 1995-2009 | -0.46 | -0.16 | -0.30 | -0.72 | -1.06 | 0.00 |
| HUN | 2000-2007 | 0.61 | 0.14 | 0.47 | 5.51 | 0.09 | 3.99 |
| IRE | 1995-2007 | -0.68 | 0.25 | -0.93 | 0.83 | 0.52 | -2.96 |
| ITA | 1990-2009 | -0.99 | -0.71 | -0.29 | -0.25 | -0.41 | 0.78 |
| JPN | 1973-2009 | 0.48 | -1.20 | 1.70 | 1.11 | -0.49 | 2.14 |
| NLD | 1990-2009 | -1.15 | 0.15 | -1.30 | 0.27 | -0.18 | -0.83 |
| NZL | 1996-2010 | -1.07 | -0.31 | -0.77 | 0.20 | -1.31 | -4.82 |
| SWE | 1993-2010 | 1.99 | 0.42 | 1.57 | -0.69 | -0.59 | 1.04 |
| UK | 1990-2009 | -0.27 | -0.03 | -0.24 | -0.27 | 0.63 | 0.47 |

$g(x)$ represents a the compound average annual growth rate of variable $x$, in %. Each variable $x$ in country $i$ has been expressed as a bilateral difference of country $i$ value minus the US value. A $\overline{x}$ represents a time-series average. $a_T$ is the Traded TFP, $a_N$ is the non-traded TFP, $q$ is the real exchange rate, the relative price of non-traded to traded goods is $p_n$, $oulc$ is the orthogonalised bilateral unit labour cost difference, $TOT$ is export over import price *levels* expressed relative to the US, $RIRDIFF$ is real long run interest rate differentials to the US.

Figure 6: TFP levels (relative to US, log)

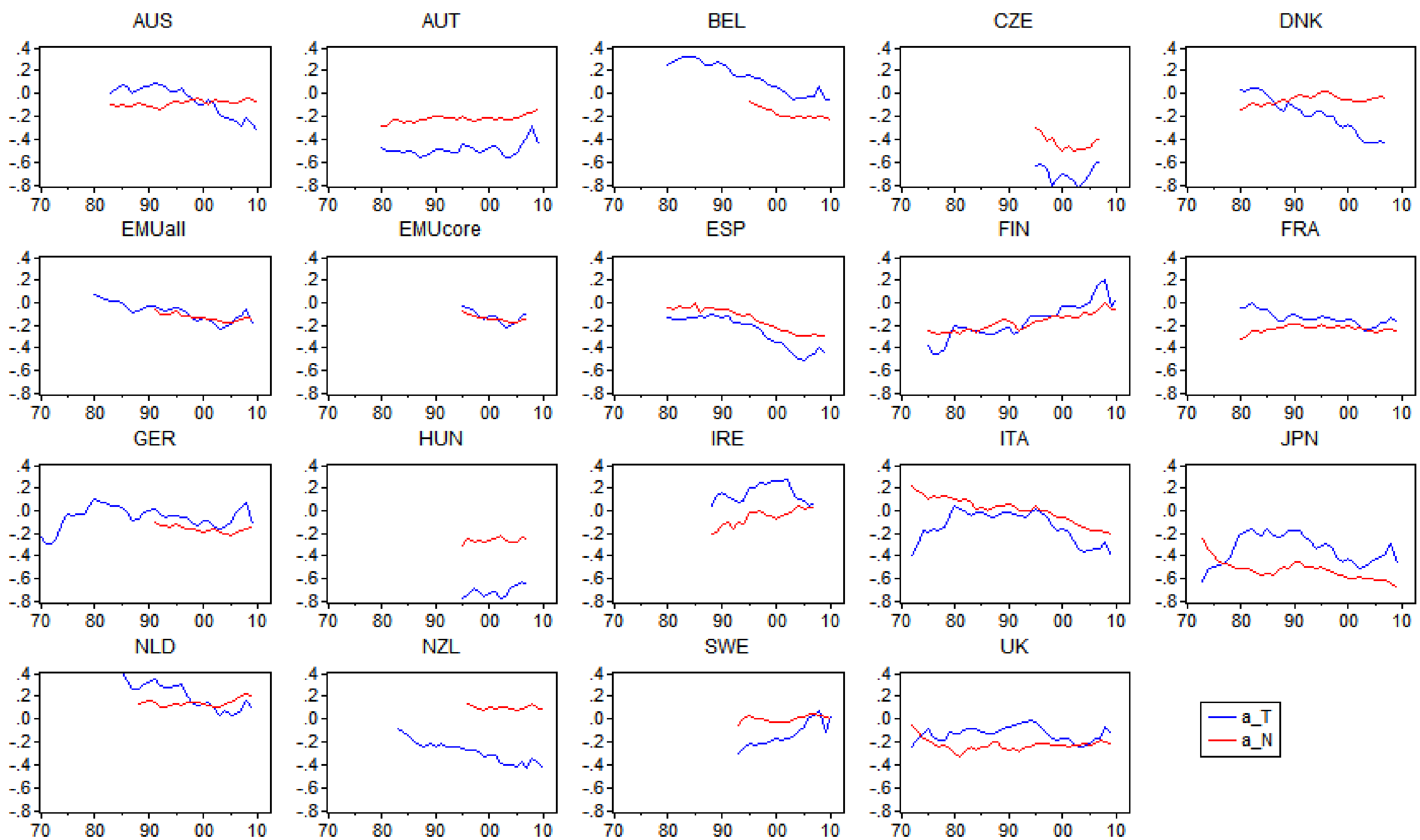


Figure 7: Levels of orthogonalized ULC ($OULC$) and ULC (relative to US, log)

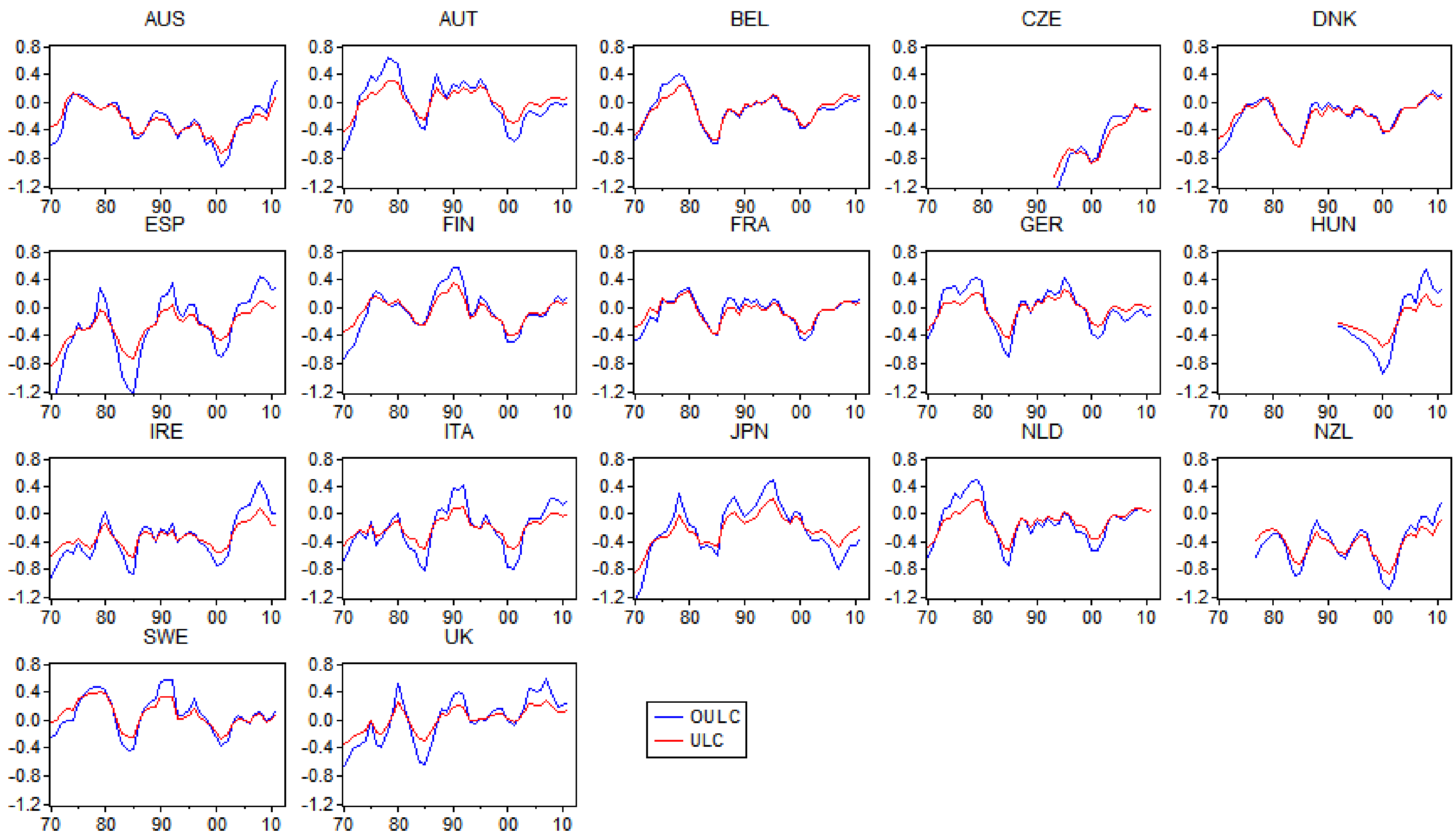


Figure 8: Levels of real exchange rates, orthogonalized ULCs and terms of trade (relative to US, logs)

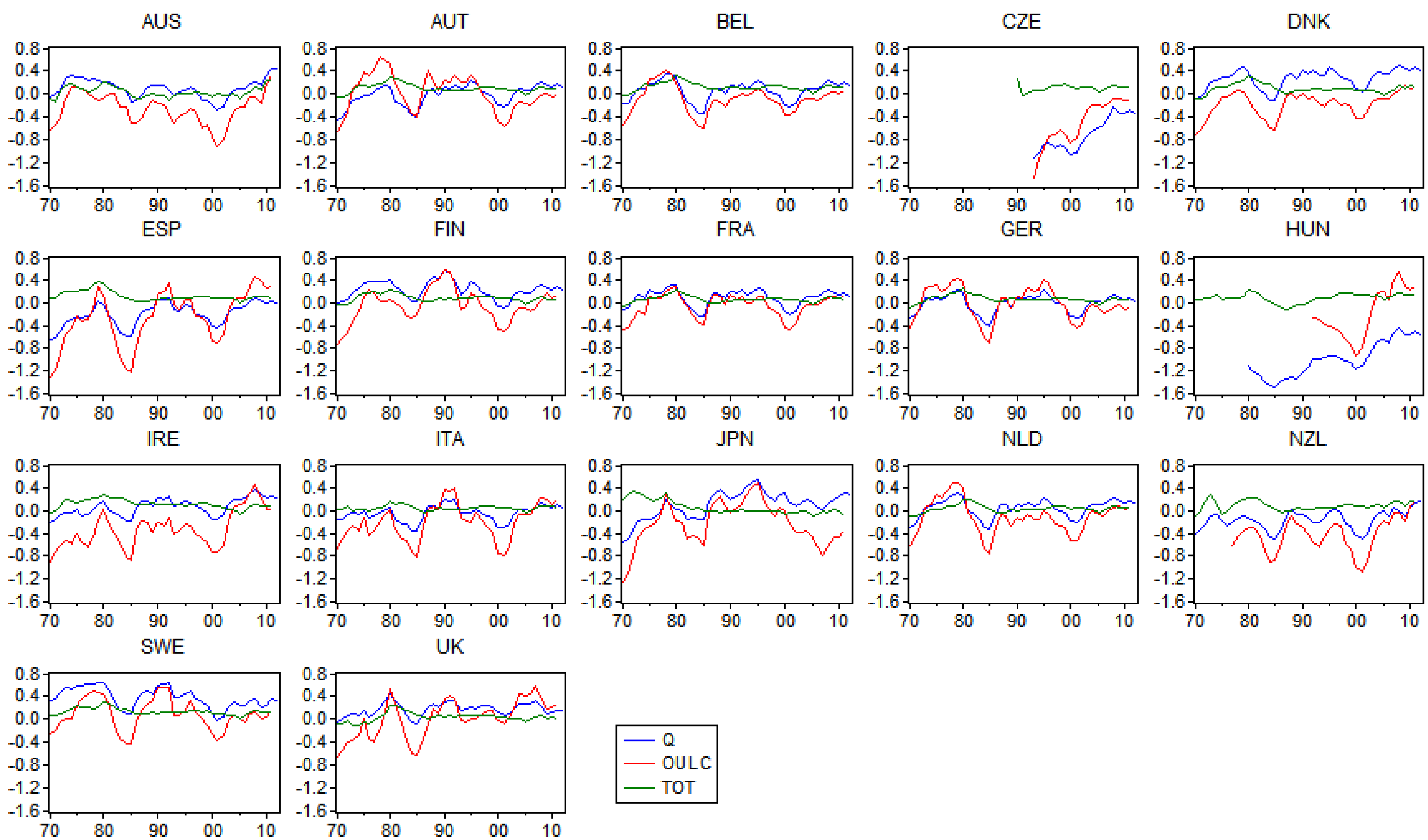
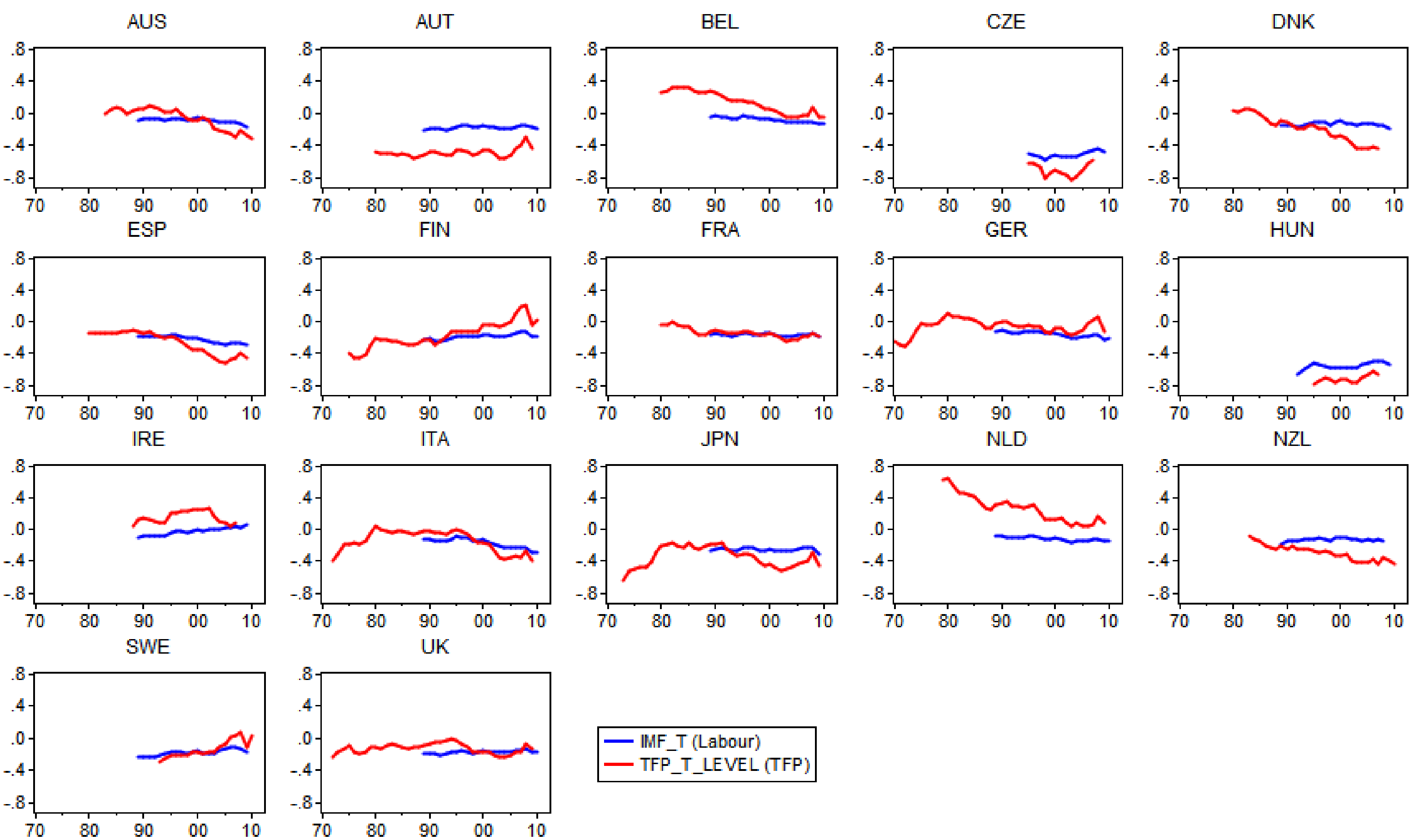
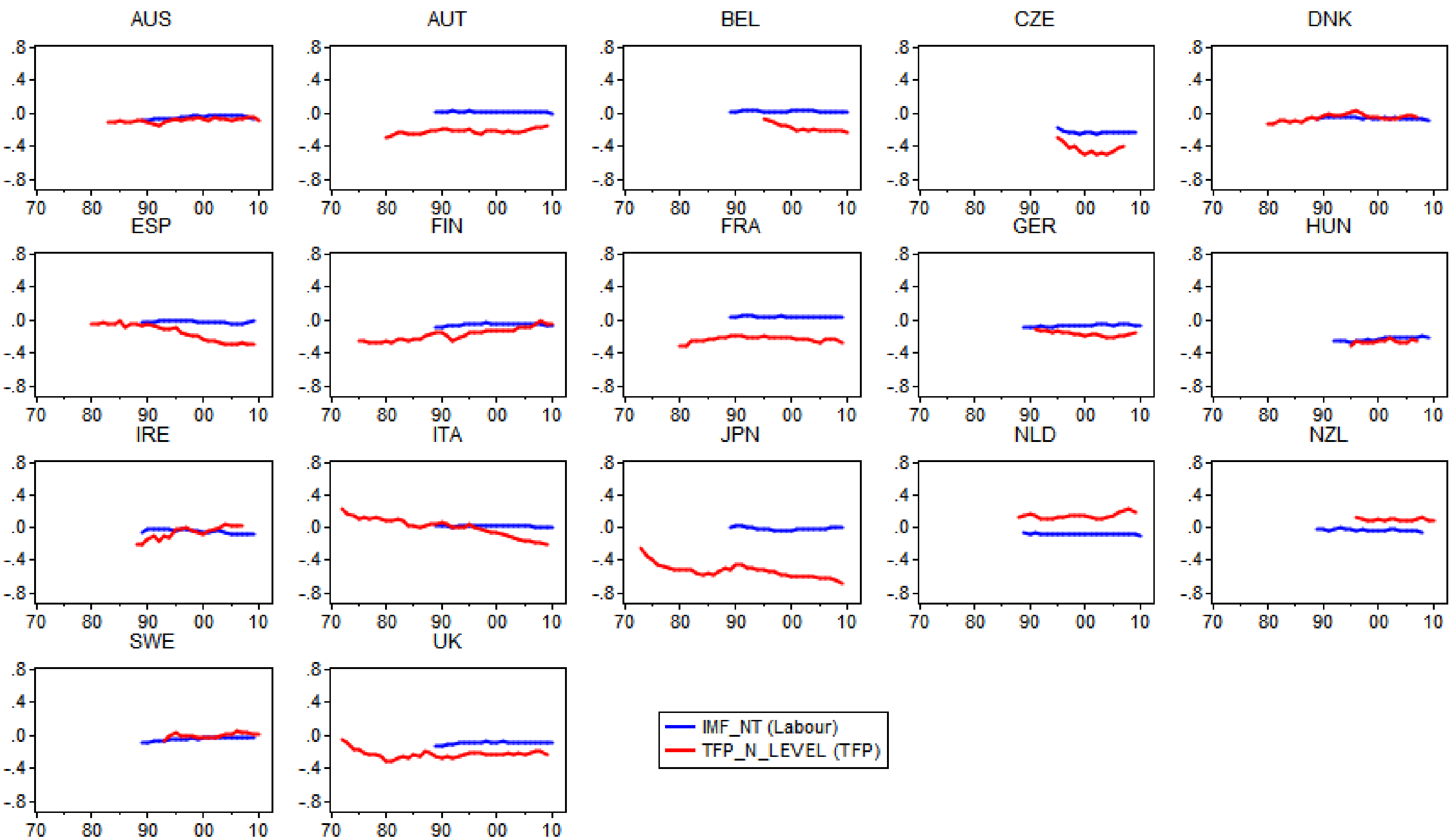


Figure 9: Labour productivity vs TFP (Tradable levels, relative to US)



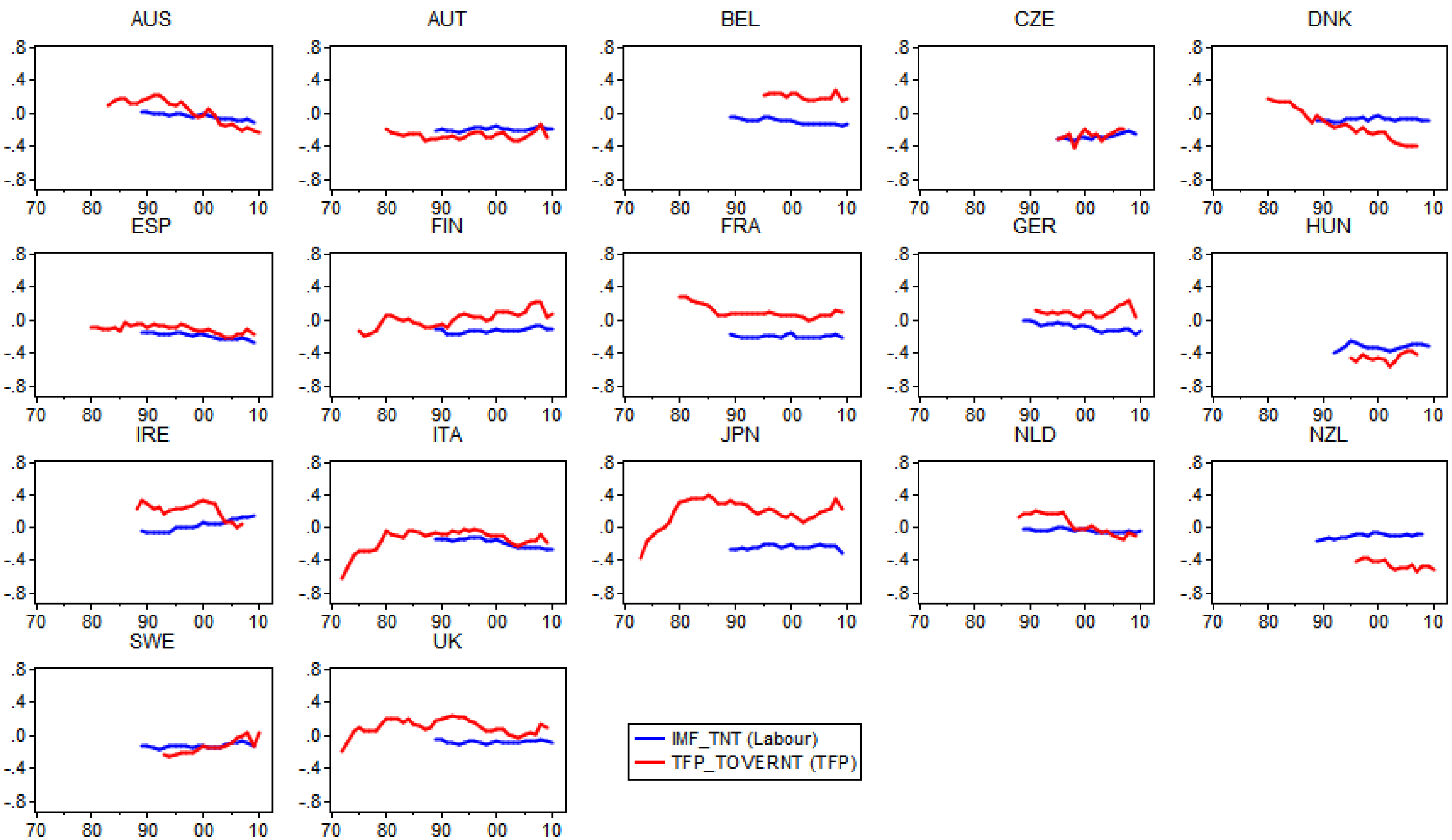

Source: ? and author's calculations

Figure 10: Labour productivity vs TFP (Non-Tradable levels, relative to US)




Source: **?** and author's calculations

Figure 11: Labour productivity vs TFP (Tradable-to-non-tradable levels, relative to US)




Source: ? and author's calculations

# B Empirical results

Table 7: Price regressions (Unbalanced, full sample)

| **Dependent variable:** $q$ | **Pool** | **FE** | **RE** | **XS** |
|---|---|---|---|---|
| $p_n$ | 0.75*** | 0.30*** | 0.35** | 1.66** |
| | 0.11 | 0.12 | 0.11 | 0.72 |
| **Adjusted R-squared** | 0.64 | 0.64 | 0.02 | 0.21 |
| **N** | 392 | 392 | 392 | 17 |
| **HT** | NA | NA | Rejected | NA |

Note: Based on the decomposition of $p_n$ in equation 3.2 as $p_n \equiv p_N^* - p_N - (p_T - p_T^*)$. * denotes a 10 percent, ** 5 percent and *** 1 percent significance. $q$ is the bilateral real exchange rate levels against the US based on aggregate price levels created based on weighted tradable and non-tradable prices using country specific sector weights, $q_T$ and $q_N$ are the traded and non-traded real exchange rate against the US. All variables defined in Appendix section C.2. All variables specified in log deviations. Standard errors are in parentheses. *FE* denotes a fixed effects panel regression (countries as cross sections). *RE* denotes random effects regression (countries as cross sections). *XS* is a cross-sectional regression (time-averages of variables in each country). Rejection of the null at 5 percent in Hausman test (HT) implies no difference between FE and RE, viewed as preference for FE. **Have left out the regressions of $q_T$ on $p_n$ or $q_T$ on $q$ since we construct these series differently to the way you do in your other paper.** *Should we adjust SErrors?*

Table 8: RER - TFP regressions (1990-2007)

| | Textbook model | | | | Berka et al model | | | | Augmented model | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Pool** | **FE** | **RE** | **XS** | **Pool** | **FE** | **RE** | **XS** | **Pool** | **FE** | **RE** | **XS** |
| $a_T$ | 0.78*** | −0.03 | 0.10 | 0.99*** | 0.62*** | 0.17*** | 0.19*** | 0.64** | 0.62*** | 0.19*** | 0.20*** | 0.62* |
| **s.e.** | 0.08 | 0.11 | 0.1 | 0.3 | 0.06 | 0.04 | 0.04 | 0.29 | 0.06 | 0.04 | 0.04 | 0.3 |
| $a_N$ | −0.23** | 0.67*** | 0.50** | -0.28 | −0.07 | −0.17* | −0.15* | -0.1 | −0.09 | −0.17* | −0.16* | -0.08 |
| **s.e.** | 0.12 | 0.23 | 0.2 | 0.46 | 0.09 | 0.09 | 0.09 | 0.42 | 0.09 | 0.09 | 0.08 | 0.42 |
| **OULC** | | | | | 0.59*** | 0.50** | 0.50*** | 0.85** | 0.60*** | 0.50*** | 0.50*** | 0.88** |
| **s.e.** | | | | | 0.04 | 0.01 | 0.01 | 0.33 | 0.04 | 0.01 | 0.01 | 0.35 |
| **CONC** | | | | | | | | | 0.06** | 0.06*** | 0.06*** | 0.08 |
| **s.e.** | | | | | | | | | 0.03 | 0.02 | 0.02 | 0.14 |
| $Wald \beta = -\gamma$ | R*** | R*** | R*** | R* | R*** | N | N | R** | R*** | N | N | R* |
| $LR$ | R*** | R*** | R*** | R** | R*** | R*** | R*** | N | - | - | - | - |
| *observations* | 281 | 281 | 281 | 17 | 281 | 281 | 281 | 17 | 281 | 281 | 281 | 17 |

Here $x$ proxied using $CONC$, defined as the centralization of wage bargaining (weighting of sectoral and aggregate), specified as up for a more centralised labour market. Sample here is 1990-2007. The null for the likelihood ratio test is that the coefficients of the additional regressors are jointly zero.

## Table 9: RER - TFP regressions (unbalanced sample)

| | **Pool** | | | | **Fixed effects** | | | | **Random effects** | | | | **Cross section** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| $a_T - a_N$ | 0.57*** | | | 0.48*** | -0.10 | | | 0.02 | -0.02 | | | 0.04 | 0.86** | | | 0.81** |
| | 0.06 | | | 0.05 | 0.08 | | | 0.04 | 0.07 | | | 0.05 | 0.33 | | | 0.33 |
| $a_T$ | | 0.67*** | 0.59*** | | | -0.12 | 0.02 | | | -0.02 | 0.05 | | | 0.97*** | 0.96*** | |
| | | 0.06 | 0.04 | | | 0.08 | 0.04 | | | 0.07 | 0.04 | | | 0.29 | 0.31 | |
| $a_N$ | | -0.26*** | -0.14** | | | -0.05 | 0.00 | | | 0.00 | 0.02 | | | -0.12 | -0.14 | |
| | | 0.08 | 0.06 | | | 0.13 | 0.08 | | | 0.12 | 0.08 | | | 0.43 | 0.46 | |
| $OULC$ | | | 0.59*** | 0.58*** | | | 0.48*** | 0.48*** | | | 0.49*** | 0.49*** | | | 0.12 | 0.49 |
| | | | 0.03 | 0.03 | | | 0.01 | 0.01 | | | 0.02 | 0.02 | | | 0.47 | 0.48 |
| **N** | 431 | 431 | 431 | 431 | 431 | 431 | 431 | 431 | 431 | 431 | 431 | 431 | 17 | 17 | 17 | 17 |
| **HT** | NA | NA | NA | NA | NA | NA | NA | NA | R | R | R | R | NA | NA | NA | NA |

Based on equations 5 and 5. Dependant variable: log RER based on aggregate CPI levels expressed as country $i$ relative to the US. $a_i$ is the log of TFP level of traded relative to non-traded sector in country $i$ ($a_{T,i,t} - a_{N,i,t}$) relative to the US. $a_{T,i,t}$ is an aggregation of 1-digit sectoral TFP of traded sectors using sectoral outputs as weights. $a_{N,i,t}$ is a TFP aggregation of nontraded sectors. $OULC_{it}$ is orthogonalized relative unit labour costs calculated as are the residuals of a relative ULC regression on nominal exchange rate (expressed at the correct average level). The data sample is 1970-2012 (unbalanced across countries, see 16). 'Pool' is a pooled regression with all countries and periods sharing the same estimate of a constant and a slope. 'Fixed effects' is a panel regression with countries as cross-sections. 'Random effects' is a random effects panel 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. The estimate of the constant is not reported. A * denotes a 10%, ** 5% and *** 1% significance. Rejection of the null in Hausman test (HT) implies no difference between FE and RE, viewed as a preference for FE. **How should I report R squareds for FE? As deviations from mean?**

Table 10: Average unexplained RER levels, Root mean square error (needs updating)

| | Unbalanced (1970-2012) | | | Balanced, 1995-2012 | | Average | RMSE | Data: |
|---|---|---|---|---|---|---|---|---|
| | base. | slope dum. | alt. $a_N$ | base. | alt. $a_N$ | | | mean RER |
| | 1 | 1b | 2 | 3 | 4 | 5 | 6 | 7 |
| AUS | 0.34 | 0.34 | 0.36 | 0.36 | 0.37 | 0.36 | 0.343 | -0.06 |
| AUT | 0.05 | 0.39 | 0.09 | 0.10 | 0.12 | 0.09 | 0.067 | 0.01 |
| BEL | 0.05 | 0.07 | 0.02 | 0.07 | 0.04 | 0.04 | 0.053 | 0.01 |
| CZE | -0.29 | 0.13 | -0.26 | -0.23 | -0.23 | -0.25 | 0.292 | -0.77 |
| DNK | 0.44 | 0.45 | 0.47 | 0.45 | 0.47 | 0.46 | 0.442 | 0.23 |
| ESP | 0.00 | 0.00 | 0.03 | 0.02 | 0.04 | 0.02 | 0.013 | -0.20 |
| FIN | 0.19 | 0.20 | 0.21 | 0.22 | 0.23 | 0.21 | 0.196 | 0.09 |
| FRA | 0.09 | 0.14 | 0.14 | 0.11 | 0.14 | 0.12 | 0.092 | 0.02 |
| GER | -0.01 | -0.13 | -0.01 | 0.00 | -0.01 | -0.006 | 0.036 | -0.008 |
| HUN | -0.51 | -0.09 | -0.59 | -0.47 | -0.55 | -0.53 | 0.506 | -0.71 |
| IRE | 0.31 | 0.29 | 0.23 | 0.32 | 0.25 | 0.28 | 0.313 | 0.04 |
| ITA | 0.15 | 0.13 | 0.06 | 0.17 | 0.10 | 0.12 | 0.147 | -0.08 |
| JPN | 0.25 | -0.02 | 0.30 | 0.35 | 0.36 | 0.31 | 0.255 | 0.22 |
| NLD | 0.14 | 0.07 | 0.11 | 0.12 | 0.10 | 0.12 | 0.138 | -0.01 |
| NZL | 0.37 | 0.37 | 0.30 | 0.39 | 0.33 | 0.35 | 0.371 | -0.15 |
| SWE | 0.29 | 0.30 | 0.25 | 0.29 | 0.25 | 0.27 | 0.294 | 0.23 |
| U K | 0.02 | 0.15 | 0.02 | 0.04 | 0.03 | 0.02 | 0.029 | 0.15 |

The table reports total fixed effect estimates from four regressions. Each number represents the sum of the constant and the fixed effect estimates for a given country. Columns 1, 1b and 2 are based on an estimation using an unbalanced sample 1970 - 2012, where in column 2 we use an alternative measure of nontraded TFP (see the appendix). Column 1b reports results based on a regression which includes country slope dummy variables for every variable in the regression, to allow country-specific elasticities. Columns 3 and 4 are based on a balanced sample of 1995 - 2012, with column 4 using an alternative measure of non-traded TFP. Column 5 reports the average values of columns 1, 2, 3, and 4. Column 6 reports the root mean square error from based on the baseline unbalanced panel estimation, by country. Finally, column 7 reports the mean RER from the data (unbalanced sample).

Table 11: Robustness of RER - TFP regressions to the inclusion of NER

| | Pool | | Fixed effects | | Random effects | | Cross-section | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| $a_T - a_N$ | 0.52*** | | 0.11*** | | 0.13*** | | 0.84** | |
| | 0.05 | | 0.04 | | 0.04 | | 0.34 | |
| $a_T$ | | 0.77*** | | 0.09*** | | 0.11*** | | 0.95** |
| | | 0.05 | | 0.04 | | 0.04 | | 0.32 |
| $a_N$ | | -0.13*** | | -0.29*** | | -0.26*** | | -0.09 |
| | | 0.08 | | 0.07 | | 0.07 | | 0.51 |
| $OULC$ | 0.55*** | 0.59*** | 0.43*** | 0.41*** | 0.43*** | 0.42*** | 0.43 | 0.51 |
| | 0.03 | 0.03 | 0.01 | 0.01 | 0.01 | 0.01 | 0.51 | 0.13 |
| $NER$ | 0.11*** | -0.00*** | 0.21*** | 0.23*** | 0.21*** | 0.22*** | 0.22 | -0.12 |
| | 0.03 | 0.04 | 0.02 | 0.02 | 0.02 | 0.02 | 0.53 | 0.51 |
| **N** | 431 | 431 | 431 | 431 | 431 | 431 | 17 | 17 |
| **Adjusted** $R^2$ | 0.55 | 0.60 | 0.95 | 0.95 | 0.82 | 0.83 | 0.22 | 0.34 |

Dependant variable: $q$ is log RER using aggregate CPI expressed as country $i$ relative to the US and $NER$ is the nominal exchange rate vis-a-vis the US (up as appreciation). $a_i$ is the log of TFP level of traded relative to non-traded sector in country $i$ ($a_{T,i,t} - a_{N,i,t}$) relative to the US. $a_{T,i,t}$ is an aggregation of 1-digit sectoral TFP of traded sectors using sectoral outputs as weights. $a_{N,i,t}$ is a TFP aggregation of nontraded sectors. $OULC_{it}$ is orthogonalized relative unit labour costs calculated as are the residuals of a relative ULC regression on nominal exchange rate (expressed at the correct average level). $TOT$ is export over import price *levels* expressed in logs relative to the US. The data sample is 1970-2012 (unbalanced across countries, see 16). 'Pool' is a pooled regression with all countries and periods sharing the same estimate of a constant and a slope. 'Fixed effects' is a panel regression with countries as cross-sections. 'Random effects' is a random effects panel 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. Standard errors are in parentheses. The estimate of the constant is not reported. A * denotes a 10%, ** 5% and *** 1% significance.

Table 12: Robustness of RER - TFP regressions to adding terms of trade

| | **Pool** | | **Fixed efffects** | | **Random effects** | | **Cross section** | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| $a_T - a_N$ | 0.44*** | | 0.02 | | 0.04 | | 0.49 | |
| | 0.05 | | 0.04 | | 0.04 | | 0.36 | |
| $a_T$ | | 0.55*** | | 0.04 | | 0.03 | | 0.72* |
| | | 0.05 | | 0.04 | | 0.04 | | 0.40 |
| $a_N$ | | -0.12** | | -0.00 | | -0.00 | | -0.11 |
| | | 0.06 | | 0.07 | | 0.07 | | 0.46 |
| $OULC$ | 0.59*** | 0.60*** | 0.48*** | 0.49*** | 0.49*** | 0.49*** | 0.74 | 0.36 |
| | 0.03 | 0.03 | 0.01 | 0.01 | 0.01 | 0.01 | 0.47 | 0.59 |
| $TOT$ | -0.42*** | -0.42*** | -0.30*** | -0.31*** | -0.31*** | -0.31*** | -4.00 | -2.49 |
| | 0.12 | 0.13 | 0.07 | 0.07 | 0.07 | 0.07 | 2.40 | 2.61 |
| **N** | 431 | 431 | 431 | 431 | 431 | 431 | 17 | 17 |
| **Adjusted** $R^2$ | 0.55 | 0.61 | 0.94 | 0.94 | 0.77 | 0.77 | 0.35 | 0.39 |

Dependant variable: $q$ is log RER using aggregate CPI expressed as country $i$ relative to the US. $a_i$ is the log of TFP level of traded relative to non-traded sector in country $i$ ($a_{T,i,t} - a_{N,i,t}$) relative to the US. $a_{T,i,t}$ is an aggregation of 1-digit sectoral TFP of traded sectors using sectoral outputs as weights. $a_{N,i,t}$ is a TFP aggregation of nontraded sectors. $OULC_{it}$ is orthogonalized relative unit labour costs calculated as are the residuals of a relative ULC regression on nominal exchange rate (expressed at the correct average level). $TOT$ is export over import price *levels* expressed in logs relative to the US. The data sample is 1970-2012 (unbalanced across countries, see 16). 'Pool' is a pooled regression with all countries and periods sharing the same estimate of a constant and a slope. 'Fixed effects' is a panel regression with countries as cross-sections. 'Random effects' is a random effects panel 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. Standard errors are in parentheses. The estimate of the constant is not reported. A * denotes a 10%, ** 5% and *** 1% significance.

Table 13: Robustness of RER - TFP regressions to the inclusion of interest rate differential

| | Pool | | Fixed efffects | | Random effects | | Cross section | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| $a_T - a_N$ | 0.40*** | | -0.01 | | 0.02 | | 0.86*** | |
| | 0.05 | | 0.04 | | 0.04 | | 0.26 | |
| $a_T$ | | 0.49*** | | 0.00 | | 0.04 | | 0.90*** |
| | | 0.05 | | 0.04 | | 0.04 | | 0.27 |
| $a_N$ | | -0.10*** | | 0.09 | | 0.11 | | -0.61 |
| | | 0.06 | | 0.08 | | 0.08 | | 0.46 |
| $OULC$ | 0.47*** | 0.50*** | 0.46*** | 0.46*** | 0.46*** | 0.46*** | 0.36 | 0.47 |
| | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 | 0.38 | 0.47 |
| $RIRDIFF$ | 0.02*** | 0.02*** | 0.02*** | 0.02*** | 0.02*** | 0.02*** | 0.20* | 0.17** |
| | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.08 |
| **N** | 409 | 409 | 409 | 409 | 409 | 409 | 17 | 17 |
| **Adjusted** $R^2$ | 0.53 | 0.56 | 0.92 | 0.92 | 0.76 | 0.77 | 0.54 | 0.52 |

Dependant variable: $q$ is log RER using aggregate CPI expressed as country $i$ relative to the US. $a_i$ is the log of TFP level of traded relative to non-traded sector in country $i$ ($a_{T,i,t} - a_{N,i,t}$) relative to the US. $a_{T,i,t}$ is an aggregation of 1-digit sectoral TFP of traded sectors using sectoral outputs as weights. $a_{N,i,t}$ is a TFP aggregation of nontraded sectors. $OULC_{it}$ is orthogonalized relative unit labour costs calculated as are the residuals of a relative ULC regression on nominal exchange rate (expressed at the correct average level). $RIRDIFF$ is real long run interest rate differentials to the US. The data sample is 1970-2012 (unbalanced across countries, see 16). 'Pool' is a pooled regression with all countries and periods sharing the same estimate of a constant and a slope. 'Fixed effects' is a panel regression with countries as cross-sections. 'Random effects' is a random effects panel 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. Standard errors are in parentheses. The estimate of the constant is not reported. A * denotes a 10%, ** 5% and *** 1% significance.

Table 14: Robustness of RER - TFP regressions to sampling frequency: 5-year averages

| | Pool | | Fixed effects | | Random effects | |
|---|---|---|---|---|---|---|
| | 1a | 1b | 2a | 2b | 3a | 3b |
| $a_T - a_N$ | 0.48*** | | 0.04 | | 0.11 | |
| | 0.11 | | 0.10 | | 0.08 | |
| $a_T$ | | 0.62*** | | -0.04 | | 0.09 |
| | | 0.11 | | 0.11 | | 0.10 |
| $a_N$ | | -0.15 | | 0.12 | | 0.10 |
| | | 0.15 | | 0.21 | | 0.18 |
| **OULC** | 0.57*** | 0.61*** | 0.47*** | 0.47*** | 0.48*** | 0.48*** |
| | 0.08 | 0.08 | 0.04 | 0.04 | 0.04 | 0.04 |
| **Adjusted** $R^2$ | 0.46 | 0.55 | 0.93 | 0.94 | 0.65 | 0.65 |
| **N** | 91 | 84 | 91 | 84 | 91 | 84 |

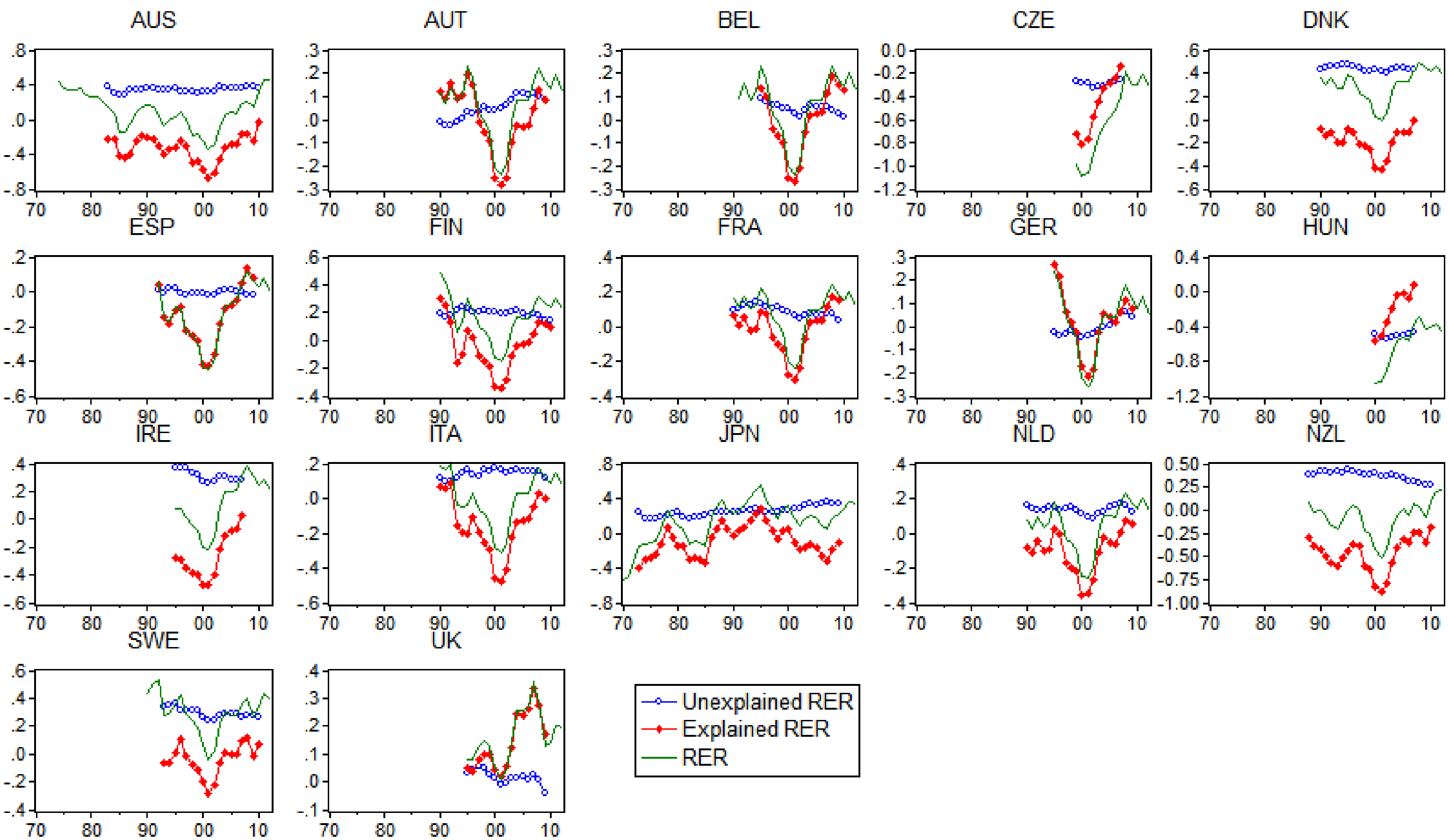
All variables in this table are 5-year non-overlapping average values of their annual values. Dependant variable: $q$ is log RER using aggregate CPI expressed as country $i$ relative to the US. $a_i$ is the log of TFP level of traded relative to non-traded sector in country $i$ ($a_{T,i,t} - a_{N,i,t}$) relative to the US. $a_{T,i,t}$ is an aggregation of 1-digit sectoral TFP of traded sectors using sectoral outputs as weights. $a_{N,i,t}$ is a TFP aggregation of nontraded sectors. $OULC_{it}$ is orthogonalized relative unit labour costs calculated as are the residuals of a relative ULC regression on nominal exchange rate (expressed at the correct average level). The data sample is 1970-2012 (unbalanced across countries, see 16). 'Pool' is a pooled regression with all countries and periods sharing the same estimate of a constant and a slope. 'Fixed effects' is a panel regression with countries as cross-sections. 'Random effects' is a random effects panel 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. Standard errors are in parentheses. The estimate of the constant is not reported. A * denotes a 10%, ** 5% and *** 1% significance.

Table 15: Robustness of RER - TFP regressions to the inclusion of labour indicators

| | **Pool** | | **Fixed effects** | | **Random effects** | | **Cross-section** | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| $a_T - a_N$ | 0.49*** | | 0.03 | | 0.05 | | 0.80** | |
| | 0.05 | | 0.04 | | 0.04 | | 0.34 | |
| $a_T$ | | 0.59*** | | 0.04 | | 0.04 | | 0.94** |
| | | 0.05 | | 0.06 | | 0.05 | | 0.32 |
| $a_N$ | | -0.16*** | | -0.00 | | 0.00 | | -0.17 |
| | | 0.07 | | 0.10 | | 0.09 | | 0.49 |
| $OULC$ | 0.57*** | 0.58*** | 0.47*** | 0.49*** | 0.48*** | 0.48*** | 0.50 | 0.14 |
| | 0.03 | 0.03 | 0.01 | 0.01 | 0.01 | 0.01 | 0.49 | 0.50 |
| $CONC$ | 0.09*** | 0.07*** | 0.07*** | 0.07*** | 0.07*** | 0.07*** | 0.13 | 0.06 |
| | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.17 | 0.17 |
| **N** | 431 | 431 | 431 | 431 | 431 | 431 | 17 | 17 |
| **Adjusted** $R^2$ | 0.56 | 0.62 | 0.94 | 0.94 | 0.76 | 0.76 | 0.25 | 0.35 |

Dependant variable: $q$ is log RER using aggregate CPI expressed as country $i$ relative to the US. $a_i$ is the log of TFP level of traded relative to non-traded sector in country $i$ $(a_{T,i,t} - a_{N,i,t})$ relative to the US. $a_{T,i,t}$ is an aggregation of 1-digit sectoral TFP of traded sectors using sectoral outputs as weights. $a_{N,i,t}$ is a TFP aggregation of nontraded sectors. $OULC_{it}$ is orthogonalized relative unit labour costs calculated as are the residuals of a relative ULC regression on nominal exchange rate (expressed at the correct average level). $CONC$ is a measure of the centralization of wage bargaining, expressed as the log difference relative to the US. The data sample is 1970-2012 (unbalanced across countries, see 16). 'Pool' is a pooled regression with all countries and periods sharing the same estimate of a constant and a slope. 'Fixed effects' is a panel regression with countries as cross-sections. 'Random effects' is a random effects panel 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. Standard errors are in parentheses. The estimate of the constant is not reported. A * denotes a 10%, ** 5% and *** 1% significance.

Figure 12: Actual and predicted, and unexplained RER



# C Data Appendix

Table 16: Time series used

| **Country** | **Series** | **Main source** | **Updated/backdated** | **Start** | **End** |
|---|---|---|---|---|---|
| **Australia** | $TFP$ | Australian Bureau of Statistics (2014b) | | 1983 | 2012 |
| | GVA | Australian Bureau of Statistics (2014a) | EUKLEMS(Rev.3,March 2011) | 1971 | 2012 |
| | $CPI_G$ and $CPI_S$ | Haver (ANZ) | | 1998 | 2012 |
| **Austria** | $TFP$ | EUKLEMS(Rev.4,July 2012) | | 1980 | 2009 |
| | GVA | EUKLEMS(Rev.4,July 2012) | | 1970 | 2010 |
| | $CPI_G$ and $CPI_S$ | Haver (EUDATA) | | 1998 | 2012 |
| **Belgium** | $TFP$ | EUKLEMS(Rev.4,December 2012) | | 1970 | 2011 |
| | GVA | EUKLEMS(Rev.4,December 2013) | | 1970 | 2011 |
| | $CPI_G$ and $CPI_S$ | Haver (EUDATA) | | 1991 | 2011 |
| **Czech Republic** | $TFP$ | EUKLEMS(Rev.3,March 2011) | | 1995 | 2007 |
| | GVA | EUKLEMS(Rev.3,March 2011) | | 1995 | 2007 |
| | $CPI_G$ and $CPI_S$ | Haver (EUDATA) | | 1999 | 2012 |
| **Denmark** | $TFP$ | EUKLEMS(Rev.3,March 2011) | | 1980 | 2007 |
| | GVA | EUKLEMS(Rev.3,March 2011) | | 1970 | 2007 |
| | $CPI_G$ and $CPI_S$ | Haver (EUDATA) | | 1990 | 2012 |
| **Finland** | $TFP$ | EUKLEMS(Rev.4,December 2013) | | 1975 | 2012 |
| | GVA | EUKLEMS(Rev.4,December 2013) | | 1975 | 2012 |
| | $CPI_G$ and $CPI_S$ | Haver (EUDATA) | | 1990 | 2012 |
| **France** | $TFP$ | EUKLEMS(Rev.4,July 2012) | | 1980 | 2009 |
| | GVA | EUKLEMS(Rev.4,July 2012) | | 1970 | |
| | $CPI_G$ and $CPI_S$ | Haver (EUDATA) | | 1990 | 2012 |
| **Germany** | $TFP$ | EUKLEMS(Rev.4,October 2012) | | 1970 | 2009 |
| | GVA | EUKLEMS(Rev.4,October 2012) | | 1970 | 2010 |
| | $CPI_G$ and $CPI_S$ | Haver (EUDATA) | | 1995 | 2012 |
| **Hungary** | $TFP$ | EUKLEMS(Rev.3,March 2011) | | 1995 | |
| | GVA | EUKLEMS(Rev.3,March 2011) | | 1991 | 2007 |
| | $CPI_G$ and $CPI_S$ | Haver (EUDATA) | | 2000 | 2012 |
| **Ireland** | $TFP$ | EUKLEMS(Rev.3,March 2011) | | 1988 | 2007 |
| | GVA | EUKLEMS(Rev.3,March 2011) | | 1970 | 2007 |
| | $CPI_G$ and $CPI_S$ | Haver (EUDATA) | | 1995 | 2012 |
| **Italy** | $TFP$ | EUKLEMS(Rev.4,October 2012) | | 1972 | 2010 |
| | GVA | EUKLEMS(Rev.4,October 2012) | | 1970 | 2010 |
| | $CPI_G$ and $CPI_S$ | Haver (EUDATA) | | 1990 | 2012 |
| **Japan** | $TFP$ | EUKLEMS(Rev.4,May 2013) | | 1973 | 2009 |
| | GVA | EUKLEMS(Rev.4,May 2013) | | 1973 | 2009 |
| | $CPI_G$ and $CPI_S$ | Statistics Japan (2015) | | 1970 | 2012 |
| **Netherlands** | $TFP$ | EUKLEMS(Rev.4,November 2012) | | 1970 | 2009 |
| | GVA | EUKLEMS(Rev.4,November 2012) | | 1970 | 2011 |
| | $CPI_G$ and $CPI_S$ | Haver (EUDATA) | | 1990 | 2012 |
| **New Zealand** | $TFP$ | Statistics New Zealand (2013) | | 1978 | 2012 |
| | GVA | Statistics New Zealand (2014) | | 1972 | 2012 |
| | $CPI_G$ and $CPI_S$ | Haver (ANZ) | | 1988 | 2012 |
| **Spain** | $TFP$ | EUKLEMS(Rev.4,July 2012) | | 1980 | 2009 |
| | GVA | EUKLEMS(Rev.4,July 2012) | | 1970 | 2009 |
| | $CPI_G$ and $CPI_S$ | Haver (EUDATA) | | 1992 | 2012 |
| **Sweden** | $TFP$ | EUKLEMS(Rev.4,December 2013) | | 1993<br>2011 | |
| | GVA | EUKLEMS(Rev.4,December 2013) | | 1993 | 2011 |
| | $CPI_G$ and $CPI_S$ | Haver (EUDATA) | | 1990 | 2012 |
| **United Kingdom** | $TFP$ | EUKLEMS(Rev.4,October 2012) | | 1972 | 2009 |
| | GVA | EUKLEMS(Rev.4,October 2012) | | 1970 | 2010 |
| | $CPI_G$ and $CPI_S$ | Haver (EUDATA) | | 1995 | 2012 |
| **United States** | $TFP$ | WorldKLEMS(April 2013 update) | | 1970 | 2010 |

| | | | | |
|---|---|---|---|---|
| **All countries** | GVA | WorldKLEMS(April 2013 update) | 1970 | 2010 |
| | $CPI_G$ and $CPI_S$ | Haver (USECON) | 1970 | 2012 |
| | $CPI_{Aggregate}$ | OECD (CPI: All groups), except Japan from Haver (G10 database) | 1970 | 2012 |
| | $RIRDIFF_{i,t}$ | Bloomberg (generic 10Y government bonds)[22] and Haver (CPI: All items (year on year percentage change) | 1970[23] | 2012 |
| | $ULC$ | OECD (2015b), except OECD (2015a) and series SUNZZZI from SNZ for NZ. | 1970[24] | 2012[25] |
| | Exchange rates | IMF (IFS) | 1970[26] | 2012[27] |
| | EPRC, EPR, EPT | OECD Indicators of Employment Protection (version 1) | 1985 | 2012[28] |
| | AUTH, CONC, CENT, UD, AdjCov | Visser (2013) | 1970 | 2011 |
| | RR | Gnocchi et al. (2015) | 1970 | 2008[29] |

Table 17: Cross section data used

| **Series** | **Data Source** | **Description** | **Industry coverage** |
|---|---|---|---|
| TFP levels, 1997 | GGDC (EU KLEMS Growth and Productivity Accounts (2014)) | Multifactor productivity (value added based, double deflated) | 48 industry categories |
| Gross value added levels, 1997 | GGDC (EU KLEMS Growth and Productivity Accounts (2014)) | Gross value added at current basic prices | 48 industry categories |
| Consumer expenditure shares, 2011 | ICP (The World Bank (2011)) | Expenditure shares (GDP = 100) | 13 expenditure categories |
| Consumer PPPs, 2011 | ICP (The World Bank (2011)) | PPPs (USD=1) by category | 13 expenditure categories |
| CPI PPPs, 2011 | ICP (The World Bank (2011)) | PPP (USD=1) for actual individual consumption | |
| NZ:AU TFP levels, 2009 | Mason (2013) | Based on aligned industry data | 26 industry categories |
| Terms of trade levels | Feenstra et al. (2015) | Based on export and import price levels relative to US GDP(output) in 2005=1 | Not applicable |

[22] Except for the Czech Republic and Hungary for which rates are based on the series CZGB10YR and GHGB10YR.

[23] Cze data starts in 2000, 1999 for HUN, EMU starts in 1997.

[24] 1990 for NZ, 1992 for CZE,HUN.

[25] 2011 for the US, JPN, AUS.

[26] 1993 for the Czech Republic, 1995 for Russia.

[27] 2011 for the US, Japan, Australia.

[28] CZE only starts in 1993, HUN and NZL from 1990.

[29] No data for CZE, HUN, FIN, ITA, SWE only to 2003, NETH to 2007.

## C.1 Total factor productivity

The construction of the panel of industry TFP levels (compared to the US as numeraire) is described in Steenkamp (2015). Industries are matched at the 1-digit level for each data type across data sources and aggregated into 11 sectors for each economy. Thereafter, the 11 industries are categorised as tradable and non-tradable and aggregated. The industry concordances used in this paper are discussed in greater detail in Steenkamp (2015) and summarised in Table 3 of that paper.

All TFP estimates in this paper are based on GVA data. To compare the value of output across countries, adjustment for relative price levels is required. To account for price differences in across countries, output values are adjusted using PPPs specifying relative prices for a good/service or bundle of these between economies. The GGDC, EU KLEMS and World KLEMS TFP level comparisons used in this study are constructed from double deflated GVA (i.e. gross output and intermediate inputs are deflated by their own PPPs).[30] The panel of sectoral TFP levels is constructed by linking GGDC TFP level comparisons to the US for the benchmark year of 1997 (EU KLEMS Growth and Productivity Accounts 2014) to time series TFP estimates from EU KLEMS (O'Mahony and Timmer 2009) and the World KLEMS database (WorldKLEMS database 2014). Tradable and non-tradable aggregations of industry data are constructed by weighting each industry by its share in 1997 constant price GVA. As New Zealand is not included in these datasets, estimates of New Zealand industry TFP levels are constructed using Mason (2013)'s 2009 year benchmark comparisons between New Zealand and Australia (as Australia is in the GGDC database and can be used to express New Zealand figures relative to the US).[31] To update Mason (2013)'s industry TFP levels, nominal gross value added is converted to common currency using Mason (2013)'s update of the GGDC PPP exchange rates expressed in USD in 2009.

Several alternative sets of TFP estimates are also constructed to assess the sen-

[30]Defined as follows: $lnTFP_i^{GVA} = ln\frac{GVA_i/PPP_i^{GVA}}{GVA_{US}} - \hat{w}_L ln\frac{L_i/PPP_i^L}{L_{US}} - (1-\hat{w}_K) ln\frac{K_i/PPP_i^K}{K_{US}}$ where $GVA_i$ is GVA-based output in volumes, $K_i$ a quantity index of capital services, $L_i$ is a quantity index of labour services, $\hat{w}_K$ denotes the average share of capital services in total costs between country $i$ and the US, $\hat{w}_L$ is the average labour share in value added labour compensation between the countries defined similarly. Each bilateral PPP for country pair $i$ and $US$ are aggregated taking a geometric mean of all Tornqvist indices and applying an EKS procedure to $lnPPP_i^{GVA} - lnPPP_{US}^{GVA}] = \frac{1}{1-\hat{w}_{II,i,US}}[(lnPPP_i^{GO} - lnPPP_{US}^{GO}) - \hat{w}_{II,i,US}(lnPPP_i^{II} - lnPPP_{US}^{II})$ where $\hat{w}_{II,i,q}$ is the share of intermediate inputs in output averaged over the relevant countries and $PPP^{II}$ is PPP for intermediate inputs aggregated over input types for each country (expressed relative to the geometric average over all countries) and $PPP^{GO}$ is likewise defined for gross output. The impact of PPP measures used is discussed in more detail in Timmer et al. (2007) and OECD and Eurostat (2008).

[31]Mason (2013) estimates TFP as $lnTFP_{i,NZ:AU} = ln(GVA_{i,NZ:AU}) - \hat{\alpha}_{i,NZ:AU} ln(L_{i,NZ:AU}) - (1-\hat{\alpha}_{i,NZ:AU}) ln(K_{i,NZ:AU})$ where $GVA_{i,NZ:AU}$ is relative value added with nominal output converted to common currency, $L_{i,NZ:AU}$ is relative labour inputs , $K_{i,NZ:AU}$ denotes relative capital inputs, $\hat{\alpha}_{i,NZ:AU}$ denotes the average share of labour in value added across the two countries.

sitivity of the empirical results to the use of different datasets or different aggregation approaches (see Steenkamp (2015) for more detail). These include alternative TFP estimates based on different vintages of data (such as the older ISIC Rev.3 datasets available for all economies except New Zealand), different industry concordances, and different weighting schemes when aggregating industries into tradable and non-tradable categories. An aggregation of core European Monetary Union (EMU) economies (Austria, Spain, France, Germany, Italy and the Netherlands) is also created using industry GVA weights for the period 1991 to 2009.[32] An alternative EMU aggregation is also created from all of the EMU countries for which data are available, which has a shorter sample of 1995 to 2007.[33]

## C.2 Relative price levels

A cross-country panel of tradable and non-tradable consumer price levels is constructed using a similar approach as with TFP above. The cross-sectional sectoral price parity and expenditure shares for the 18 countries considered are taken from the International Comparison Program (Feenstra et al. (2013)) for a 2011 year benchmark.

The cross-section of industry expenditure PPPs is created by categorising expenditures into tradables and non-tradables. Tradable categories are taken to be food and nonalcoholic beverages, alcoholic beverages, tobacco, and narcotics, clothing and footwear, net purchases abroad (and half-weights on furnishings, household equipment and maintenance and miscellaneous goods and services), while the non-tradable categories are health, transport, communication, recreation and culture, education, restaurants and hotels (and half-weights on furnishings, household equipment and maintenance and miscellaneous goods and services), and their respective PPP levels relative to the US are aggregated using their expenditure shares.

Goods- and services consumer price indices were sourced from Haver (and directly from the statistical agency for Japan) are used as proxies for tradables and non-tradables price timeseries. For the US, the 'Commodities' category, which corresponds to the 'goods' category for other countries is used.[34] These series may not be good

[32]Since TFP growth for the financial intermediation category for Germany is only available from 1991.

[33]Although estimates of GVA-based MFP growth rates are available for Korea from the Asia KLEMS project, Korea is not included in this comparison as it is not in the 1997 GGDC productivity levels comparison.

[34]There are some differences between expenditure categories for some countries. For instance, 'Commodities' in the US series includes nondurables, food (which includes food away from home), and durables, as well as energy (including services like utilities and gas, but excludes water and sewer and trash collection services). For Australia on the other hand, the 'goods' CPI series does include both gas and other household fuels and water and sewage, while excluding restaurant meals. For countries in the EMU, water supply, electricity, gas, solid fuels and heat energy are included in the goods category, while refuse and sewerage collection and restaurants and canteens are included in services.

proxies of trade exposure, but alternative proxies have conceptual problems of their own. Value-added deflators, for example, capture prices of the output by domestic production industries, but will not pick up import price effects. Some statistical agencies, such as those in Australia and New Zealand, publish official tradables and non-tradables CPI series but these unfortunately do not have a long sample.

The benchmark series for real exchange rates relative to the US ($q$) are constructed for 17 economies using nominal exchange rates (period average, market rates) and aggregate CPI series and aggregate consumer price PPPs. Exchange rates are constructed as:

$$q_{i:US,t} = \frac{NER_{i:US,t} \times p_{aggCPI,i,t}}{p_{aggCPI,US,t}} \times PPP_{aggCPI,i,t} \tag{7}$$

where the nominal rate ($NER_{NZ:i,t}$) defined as the foreign currency price of one New Zealand dollar relative to country $i$ at time $t$[35] and where aggregate price levels are created for each country by weighting $p_t^T$ and $p_t^N$ using ICP price parities for aggregate consumer prices $PPP_{aggCPI,i,t}$. To create the panel of relative consumer price levels, each country's relative PPP levels are multiplied by the ratio of their CPI timeseries vis-a-vis the US (which have been re-scaled to 2011 = 100), which are converted to common currency to generate the tradable real exchange rate. The tradable and non-tradable real exchange rate are defined as follows:

$$q_{T,i:US,t} = NER_{i:US,t} + p_{i,t}^T - p_{US,t}^T \tag{8}$$

and the non-tradable real exchange rate for each economy relative to the US:

$$q_{N,i:US,t} = NER_{i:US,t} + p_{i,t}^N - p_{US,t}^N \tag{9}$$

Tradable and non-tradable price levels are created as $p_{i,t}^T = PPP_{i,T} \times CPI_{i,t}^T$ and $p_{i,t}^N = PPP_{i,N} \times CPI_{i,t}^N$ where PPPs have been adjusted by the nominal exchange rates to get them in common terms. Nominal exchange rates are re-based to an index where 2011 = 1. Exchange rates here are specified as up for appreciation against the US, so appreciation makes a country more expensive relative to the US. The relative price of non-traded goods is $p_{N,t} = q_t^N - q_t^T$.

## C.3 Unit labour costs

Unit labor costs (ULC) series are obtained from the OECD (2015b), and defined as nominal total economy labour costs over real output (2005 base year), adjusted for exchange rate change.[36] ULCs are expressed relative to the US (which only has

[35] Constant euro conversion rates are applied to the exchange rates of euro zone economies before 1999.

[36] To convert nominal unit labour costs into common currency, the series was divided by nominal exchange rates after indexing each exchange rate to 1 in 2010, the base year for the OECD's GDP data. For New Zealand, official total economy ULC series stop in 2009 and have been updated using the nominal ULC index from SNZ to 2012.

data to 2011), in logarithms (see Figure C.3). To remove nominal exchange rate variability from the $ULC$ measures, $ULC$ is orthogonalised to the $NER$ for each country by regressing the $ULC$ measure on the $NER$ and the residuals added to the mean of the $ULC$ to avoid introducing bias in fixed effects estimation (as the residuals alone will be mean zero). Consequently, the orthogonalised $OULC_i$ series identify the difference in ULC between country $i$ and the US at any point of time.

## C.4 Terms of trade

Relative terms of trade levels are measured using Feenstra et al. (2015)'s quality-adjusted price levels of exports and imports which are obtained by dividing export and import PPPs by the nominal exchange rate.[37] These price levels are then normalised to the US using the US national accounts deflator relative to 2005. We construct relative terms of trade level as the difference between export to import levels relative to the same expression for the US in logarithms.

## C.5 Real long run interest rate differentials

Bilateral long-run real interest rate differentials ($RIRDIFF_{i,t}$) to the US are based on 10 year government bond yields obtained from Bloomberg. We calculate the real interest rate differentials as the difference between a 10-year government bond yields in country $i$ minus in the US, in a given year, and then adjusted for CPI inflation differentials.

## C.6 Labour market indicators

A large number of indicators of structural differences between countries' labour markets were considered. The OECD provide three indicators of employment protection that are available from 1985 onwards, while the Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts (ICTWSS) dataset (Visser (2013)) provides 182 indicators of various characteristics of labour markets for a large cross-section of countries for a long time span.

Several of these indicators have been shown to perform well in characterizing wage setting and labour market developments. For example, Gnocchi et al. (2015) show that these labour market indicators are related to cyclical movements in real wages, labour productivity and unemployment in OECD economies.[38]

On this basis, the following ICTWSS indicators are considered individually: $CONC_{i,t}$ (summary measure of concentration of unions at aggregate and sectoral levels), $AUTH_{i,t}$

[37]The quality adjustment is necessary since export and import prices are calculated as unit values (as opposed to prices as in the ICP), see Feenstra et al. (2015) for details. Note also that these export and import prices are based on merchandise trade only.

[38]The indicators they investigate are $RR$, $UD$, $CONC$, $CENT$, $Minwage$, $Ext$, $Wcoord$, $Govint$, $Level$, $EPRC$, $EPR$, $EPT$ and $UC$.

(summary measure of formal authority of unions regarding wage setting at aggregate and sectoral levels), $CENT_{i,t}$ (centralisation of wage bargaining measured by weighting national and sectoral concentration of unions by level of importance)[39], $UD_{i,t}$ (the union density rate), $haff_{i,t}$ (measure of authority of unions in wage setting at national and industry level), $hcf_{i,t}$ (membership concentration at the industry level within confederations). Indicators that do not range between 0 and 100 are scaled up by multiplying by 100. These indicators are then expressed as natural log differences to US levels.

We also consider the following categorical variables from ICTWSS: $coord_{i,t}$ (coordination of wage-setting), $ext_{i,t}$ (existence of mandatory extension of collective agreements by public law), $govint_{i,t}$ (government intervention in wage bargaining), $level_{i,t}$ (degree of centralisation in wage bargaining), $tc_{i,t}$ (the existence of a tripartite council) and $sector_{i,t}$ (a measure of sectoral organization of employment relations) and express them as the value for country $i$ less that of the US.

We also include replacement rates, $RR_{i,t}$ (ratio of disposable income when unemployed to expected disposable income) provided by Gnocchi et al. (2015), along with $EPRC_{i,t}$ (the strictness of employment protection legislation), $EPR_{i,t}$ (the strictness of employment protection on individual contracts), $EPT_{i,t}$ (employment protection on temporary contracts) from the OECD. All of these individual indicators are expressed as log differences to the US.

For all of the individual variables, higher values imply a relative more rigid labour market compared to the US.

Apart from including individual indicators, we also created our own summary measures of the various indicators in the ICTWSS dataset. The first summary measure $Lab4avg_i$ is a simple average of the unadjusted values of $UD$, $AUTH$, $CONC$ and $AdjCov_{i,t}$ (Bargaining (or Union) Coverage) for each economy $i$, and then logged and expressed relative to the US.

The second is the first principal component extracted from indicators for each economy.[40] Before principal components were extracted, variables which are not available for any years for all of the countries in our sample were excluded, as were similar indicators that were very highly correlated with other variables. Out of the 182 indicators, 53 are selected, most of which are ranked categorical variables. Table 20 lists the ICTWSS indicators that are available for a large time span for the countries in the sample.[41]. To enhance interpretability of results, we transformed the ICTWSS

[39] $CENT$ is a broader measure than $CONC$, as $CENT$ also incorporates internal and external demarcations between union confederations.

[40] Gnocchi et al. (2015) also extract principal components from their various indicators to obtain a summary measure of overall labour market rigidity, unionisation and wage setting. They use four principal components capturing over 75 percent of the variation of their indicators. To control for endogeneity with other macroeconomic variables, they use start period values for the principal components and period averages for macroeconomic variables.

[41] *Govint* was not considered for the principal component as it implies no scale or rank-order, while *Length* and *UnionCov* are excluded as they are not available for all countries for full sample. $CENT$

series where necessary to ensure that a higher value of each of indicator implies a relatively more rigid labour market compared to the US. Principal components for each economy are expressed relative to the value of the US equivalent and denoted $LabPC_{i,t}$. All numerical series are expressed as log differences vs US and all categorical series are expressed simply as differences to the US. All indicators standardised to prevent series with larger variances dominating the principal component. A high value of $LabPC_{i,t}$ implies a relatively inflexible labour market compared to the US. Figure 15 plots $AUTH_{i,t}$, $CONC_{i,t}$, as $CENT_{i,t}$, Figure 16 shows the principal component and $Lab4avg_i$.[42] *Also consider a principal component or simple average of just the indicators that are in log differences (i.e. 10 indicators).*

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is a broader measure than $CONC$, as $CENT$ also incorporates internal and external demarcations between union confederations.

[42] The first principal component seems to be picking up the big drop in $AdjCov$ (Bargaining (or Union) Coverage) in 1992 in New Zealand (even after being standardised), since there is very little other variation in the other indicators. But $AUTH$ and $CENT$ (formal authority of unions regarding wage setting and centralisation of wage bargaining respectively) show a similar drop in 1991/2, although they tighten relative to the US over the 2000 by more than the principal component for New Zealand.

# D Impact of data source selection, construction choices and sample selection

Table 18 summarises the impacts on coefficient estimates and statistical significance when varying the sample, dataset and aggregation approaches used. The alternative data series include:

- Using a common sample of 1995-2007;
- Including EMU countries individually as opposed to using an aggregation of these economies;
- Using an alternative exchange rate definition ($q_{secp}$);
  - The benchmark results are based on real exchange rates constructed using aggregate CPI from the OECD and aggregate consumer price PPPs. Alternatively, aggregate price levels could be measured by weighting our tradable and non-tradable price measures together. For each economy, relative aggregate price levels compared to the US are created by weighting $p_{i,t}^{T}$ and $p_{i,t}^{N}$ using country specific weights for each sector as follows:

$$p_{i:US,t} = \alpha_i p_{i,t}^{T} + (1 - \alpha_i) p_{i,t}^{N} \tag{10}$$

$$p_{US,t} = \alpha_{US} p_{US,t}^{T} + (1 - \alpha_{US}) p_{US,t}^{N} \tag{11}$$

    where $p_{i:US,t}^{T}$ and $p_{i:US,t}^{N}$ have been adjusted using 2011 $PPP_{i,N}$ (where adjusted by nominal exchange rates to get them in common terms) to convert them into levels relative to the US, $\alpha_i$, represents the share of tradables in total output of each country[43] and components are in logarithms.

    The real exchange rate based on sectoral prices ($q_{secP,i,t}$) is then defined as the relative price of domestic and foreign goods, measured in domestic currency terms:

$$q_{secP,i,t} = NER_{i:US,t} + p_{i,t} - p_{US,t} \tag{12}$$

  - A comparison of the three different relative price measures constructed is plotted in Figure 14.

[43] The value of alpha is calculated for each country as the 2011 share of tradables in expenditure based on ICP weights.

- Using alternative construction choices of TFP measures (e.g. using continuous weighting ($a_{continiousweighting}$), or including Finance in tradables ($FinanceinT$), or excluding sector 11 when constructing non-tradables TFP ($a^N_{exsec11}$).);[44]

- Using alternative datasets and industrial classifications (e.g. the ISIC Revision 3 and 4 industrial classifications for all countries ($Rev3all$), or updating Revision 3 data using Revision 4 to obtain longer samples($Rev3 + 4$), or using Revision 3 for just the US ($USRev3$)).

[44]Timeseries of TFP growth for some industries are only available from 1996 for New Zealand, so an alternative non-traded TFP measure ($a^N_{exSec11}$) which excludes real estate, renting and business services is also constructed for all countries. There are also some potentially serious comparability issues for the New Zealand comparisons to other countries because of differing treatment of owner-occupied dwellings in New Zealand and Australia compared with the other countries in the sample, see Steenkamp (2015) for more details.

Table 18: Impact of using alternative data on textbook BS model vs Berka et al version

| | Pool | | Fixed Effects | | Random Effects | | Cross section | |
|---|---|---|---|---|---|---|---|---|
| | q on a_T-a_N | q on a_T-a_N and OULC | q on a_T-a_N | q on a_T-a_N and OULC | q on a_T-a_N | q on a_T-a_N and OULC | q on a_T-a_N | q on a_T-a_N and OULC |
| Using 1995 to 2007 | + | + | - | + | - | + | + | + |
| Using EMUcore (1995 to 2007) | + | + | - | + | + | + | NA | NA |
| Using EMUcore (full unbalanced panel) | + | + | - | + | + | + | NA | NA |
| Using q_secp (1995 to 2007) | + | + | - | + | + | + | + | + |
| Using q_secp (full unbalanced panel) | + | + | + | + | + | + | + | + |
| Using a_{N_exsec11} (1995 to 2007) | - | - | - | + | - | + | - | - |
| Using a_{N_exsec11} (full unbalanced panel) | - | - | - | - | - | - | - | - |
| Using a_{USREV3} (1995 to 2007) | + | + | - | + | - | + | + | + |
| Using a_{USREV3} (full unbalanced panel) | + | + | - | - | - | - | + | + |
| Using a_{REV3all} (1995 to 2007) | + | + | - | + | - | + | + | + |
| Using a_{REV3all} (full unbalanced panel) | + | + | - | - | - | - | + | + |
| Using a_{REV3+4} (1995 to 2007) | + | + | + | + | + | + | + | + |
| Using a_{REV3+4} (full unbalanced panel) | + | + | + | - | + | - | + | + |
| Using a_{T=Manuf} (1995 to 2007) | + | + | - | + | - | + | + | + |
| Using a_{T=Manuf} (full unbalanced panel) | + | + | - | + | - | + | + | + |
| Using a_{Continious weighting} (1995 to 2007) | + | + | + | + | + | + | + | + |
| Using a_{Continious weighting} (full unbalanced panel) | + | + | + | + | + | + | + | + |
| Using a_{Finance in T} (1995 to 2007) | + | + | + | + | + | + | + | + |
| Using a_{Finance in T} (full unbalanced panel) | + | + | + | + | + | + | + | + |

Note: '+' indicates positive coefficient, '-' a negative coefficient, shading indicates statistical significance at 10 percent.

Table 19: Impact of using alternative data from augmented model

| | q on a_T-a_N and OULC and CONC | | | |
|---|---|---|---|---|
| | Pool | FE | RE | XS |
| 1990-2007 | + | + | + | + |
| Unbalanced panel | + | + | + | + |
| EMUcore (1995 to 2007) | + | + | + | NA |
| EMUcore (full unbalanced panel) | + | + | + | NA |
| q_secp (1995 to 2007) | + | + | + | + |
| q_secp (full unbalanced panel) | + | + | + | + |
| a_{N_exsec11} (1995 to 2007) | - | + | + | - |
| a_{N_exsec11} (full unbalanced panel) | - | - | - | - |
| a_{USREV3} (1995 to 2007) | + | + | + | + |
| a_{USREV3} (full unbalanced panel) | + | - | - | + |
| a_{REV3all} (1995 to 2007) | + | + | + | + |
| a_{REV3all} (full unbalanced panel) | + | - | - | + |
| a_{REV3+4} (1995 to 2007) | + | + | + | + |
| a_{REV3+4} (full unbalanced panel) | + | - | - | + |
| a_{T=Manuf} (1995 to 2007) | + | + | + | + |
| a_{T=Manuf} (full unbalanced panel) | + | + | + | + |
| a_{Continous weighting} (1995 to 2007) | + | + | + | + |
| a_{Continous weighting} (full unbalanced panel) | + | + | + | + |
| a_{Finance in T} (1995 to 2007) | + | + | + | + |
| a_{Finance in T} (full unbalanced panel) | + | + | + | + |

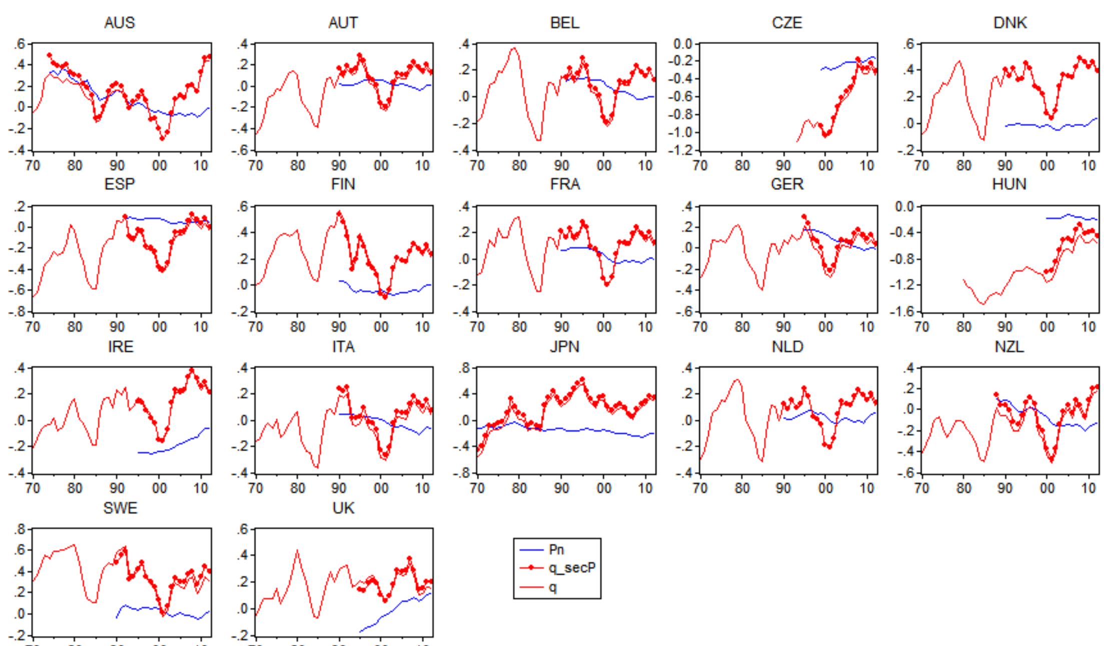
Note: '+' indicates positive coefficient, '-' a negative coefficient, green shading indicates statistical significance at 10 percent.

Figure 13: (Absolute) bias in textbook model

| | Δa_T-a_N | | | |
|---|---|---|---|---|
| | **Pool** | **FE** | **RE** | **XS** |
| **1990-2007** | 0.17 | -0.18 | -0.08 | 0.38 |
| **1995-2007** | 0.17 | -0.41 | -0.23 | 0.33 |
| **Unbalanced panel** | 0.08 | -0.13 | -0.07 | 0.05 |
| **EMUcore (1995-2007)** | 0.30 | -0.11 | 0.02 | NA |
| **EMUcore (full unbalanced panel)** | 0.34 | 0.05 | 0.12 | NA |
| **q_secp (1995-2007)** | 0.09 | -0.48 | -0.25 | 0.31 |
| **q_secp (full unbalanced panel)** | 0.07 | -0.25 | -0.12 | 0.32 |
| **a_{N_exsec11} (1995-2007)** | -0.08 | -0.71 | -0.67 | 0.27 |
| **a_{N_exsec11} (full unbalanced panel)** | -0.04 | -0.34 | -0.33 | 0.30 |
| **a_{USREV3} (1995-2007)** | 0.09 | -0.72 | -0.56 | 0.02 |
| **a_{USREV3} (full unbalanced panel)** | 0.09 | -0.33 | -0.24 | 0.05 |
| **a_{REV3all} (1995-2007)** | 0.07 | -0.63 | -0.50 | 0.30 |
| **a_{REV3all} (full unbalanced panel)** | 0.09 | -0.27 | -0.20 | 0.32 |
| **a_{REV3+4} (1995-2007)** | 0.75 | 0.99 | 0.94 | 0.45 |
| **a_{REV3+4} (full unbalanced panel)** | 0.71 | 0.54 | 0.56 | 0.46 |
| **a_{T=Manuf} (1995-2007)** | 0.15 | -0.44 | -0.29 | 0.33 |
| **a_{T=Manuf} (full unbalanced panel)** | -0.01 | -0.09 | -0.04 | 0.41 |
| **a_{Continous weighting} (1995-2007)** | 0.19 | 0.17 | 0.21 | 0.28 |
| **a_{Continous weighting} (full unbalanced panel)** | 0.13 | -0.09 | -0.03 | 0.32 |
| **a_{Finance in T} (1995-2007)** | 0.09 | 0.67 | 0.60 | 0.09 |
| **a_{Finance in T} (full unbalanced panel)** | 0.04 | 0.30 | 0.33 | 0.11 |

Shading indicates statistical significance at 10 %.

Figure 14: Three different relative price measures (up as appreciation, log)



## D.1 Summarising information from labour market indicators

Table 20: ICTWSS series and transformations used for principal component

| Number | Mnemonic | Description | Transformation | Binary |
|---|---|---|---|---|
| 1 | $RA_m$ | Right of Association, market sector | 4 | 2 |
| 2 | $RA_g$ | Right of Association, government | 4 | 2 |
| 3 | $RCB_m$ | Right of Collective bargaining, market sector | 4 | 2 |
| 4 | $RCB_g$ | Right of Collective bargaining, government sector | 4 | 2 |
| 5 | $RS_m$ | Right to Strike, market sector | 4 | 2 |
| 6 | $RS_g$ | Right to Strike, government | 4 | 2 |
| 7 | $Coord$ | Coordination of wage-setting | 1 | 2 |
| 10 | $LEVEL$ | The predominant* level(s) at which wage bargaining takes place | 1 | 2 |
| 11 | $Art$ | Articulation of sectoral bargaining | 3 | 2 |
| 13 | $EXT$ | Mandatory extension of collective agreements by public law to non-organised | 3 | 2 |
| 15 | $NMW$ | Length of collective (wage) agreements | 3 | 2 |
| 16 | $MWS$ | Minimum Wage Setting | 3 | 2 |
| 17 | $PACTNEG$ | A social pact | 1 | 1 |
| 18 | $PACTSIGN$ | A (tripartite) social pact | 3 | 2 |
| 19 | $AGRSIGN$ | A (nation-wide) agreement | 3 | 2 |
| 20 | $AUT-W$ | The (central) agreement is autonomously negotiated | 1 | 1 |
| 21 | $AUT-NW$ | The (central) agreement is autonomously negotiated | 1 | 1 |
| 22 | $SPONSOR-W$ | The (central) agreement is negotiated | 1 | 1 |
| 23 | $SPONSOR-NW$ | The (central) agreement is autonomously negotiated | 1 | 1 |
| 25 | $PACTSTRUCT$ | Pact or agreement is negotiated by all or some of the (possible) actors | 3 | 2 |
| 26 | $PACTSCOPE$ | Scope of social pact | 3 | 2 |
| 27 | $PACTTYPE$ | Type of social pact | 3 | 2 |
| 28 | $WAGE$ | pact or agreement is about wage issues | 1 | 1 |
| 29 | $NON-WAGE$ | pact or agreement is about non-wage issues | 1 | 1 |
| 30 | $PACTAPPLIES$ | Wage clause in pact | 1 | 1 |
| 31 | $AGGRAPPLIES$ | Wage clause in central agreement applies in specified year | 1 | 1 |
| 32 | $WAGEPROC$ | pact or agreement is about procedure for wage setting: articulation of levels, conflict procedures, etc. | 1 | 1 |
| 33 | $WAGEMAX$ | pact or agreement contains a norm or ceiling regarding maximum wage rise | 1 | 1 |
| 34 | $TAXBUDGET$ | Pact or agreement contains, and/or is predicated on, concessions (or promises) regarding taxation and/or budgetary decisions | 1 | 1 |
| 35 | $WRKHRS$ | Pact or agreement contains, and/or is predicated on, concessions (or promises) regarding working hours | 1 | 1 |
| 36 | $EMPLPOL$ | Pact or agreement contains, and/or is predicated on, concessions (or promises) regarding employment policies (job creation, subsidies, etc.) | 1 | 1 |
| 37 | $EMPLLEG$ | Pact or agreement contains, and/or is predicated on, concessions (or promises) regarding employment protection legislation (labour law) | 1 | 1 |
| 38 | $SOCSEC$ | Pact or agreement contains, and/or is predicated on, concessions (or promises) regarding social security | 1 | 1 |
| 39 | $PENSIONS$ | Pact or agreement contains, and/or is predicated on, concessions (or promises) regarding (old age, retirement) pensions | 1 | 1 |
| 40 | $TRAINING$ | Pact or agreement contains, and/or is predicated on, concessions (or promises) regarding vocational training | 1 | 1 |
| 41 | $UNIONRIGHT$ | Pact or agreement contains, and/or is predicated on, concessions (or promises) regarding unions (representation, recognition) rights, including employee representation, works councils, bargaining rights, etc. | 1 | 1 |
| 42 | $Instconc$ | Pact or agreement sets up or changes nation-wide councils for concertation | 1 | 1 |

| | | | | |
|---|---|---|---|---|
| 43 | $TC$ | existence of a standard (institutionalized) tripartite council | 3 | 2 |
| 44 | $BC$ | existence of a standard (institutionalised) bipartite council | 1 | 1 |
| 45 | $RI$ | routine involvement of unions | 1 | 2 |
| 46 | $WC$ | status of works council | 3 | 2 |
| 47 | $WCSTRUCT$ | structure of works council representation | 3 | 2 |
| 48 | $WCRIGHTS$ | rights of works councils | 3 | 2 |
| 49 | $WCNEGOT$ | involvement of works councils (or similar structures) in wage negotiations | 3 | 2 |
| 50 | $Sector$ | sectoral organization of employment relations | 3 | 2 |
| 56 | $Cfautority$ | authority of confederation over its affiliates | 1 | 2 |
| 62 | $Unauthority$ | authority of union (affiliate) over their local or workplace branches and representatives | 2 | 0 |
| 92 | $UD$ | Union density rate | 2 | 0 |
| 95 | $AdjCov$ | Bargaining (or Union) Coverage, adjusted | 2 | 0 |
| 108 | $Hcf$ | Membership concentration at central or confederal level (Herfindahl index at central or peak level) | 2 | 0 |
| 109 | $Haff$ | Membership concentration at the industry level, within confederations (Herfindahl index at sectoral level) | 2 | 0 |
| 110 | $AUTH$ | Summary measure of formal authority of unions regarding wage setting at peak and sectoral level | 2 | 0 |
| 111 | $CONC$ | Summary measure of concentration of unions at peak and sectoral level | 2 | 0 |
| 112 | $CENT$ | Summary measure of centralisation of wage bargaining, taking into account both union authority and union concentration at multiple levels. | 2 | 0 |

Note: Transformations applied: '1' for no transformation, '2' for natural logarithm (standardised), '3' for scale increased to eliminate zero value and '4' for scale increased to eliminate zero value and re-expressed to be increasing in labour market inflexibility. The column binary classifies variables as '0' when 'not binary', '1' for 'binary' (not standardised) and '2' for 'ranked categorical'.

Figure 15: Selected labour market indicators

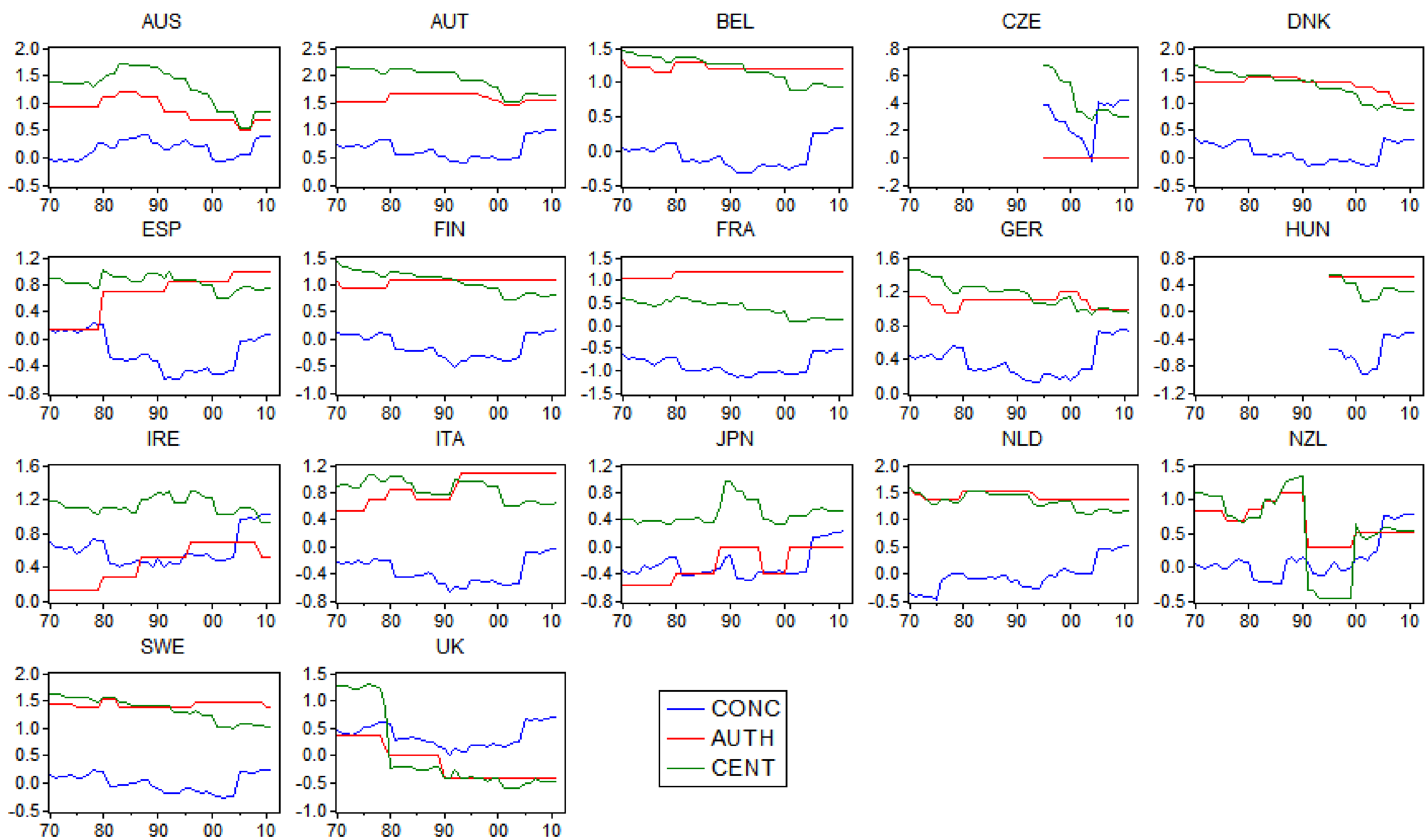


Figure 16: Principal component of labour market indicators vs simple average