Disaggregate Real Exchange Rate Behaviour.

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Abstract

In this paper, we re-examine the "PPP Puzzle" using sectoral disaggregated data. Specifically, we first analyse the mean reversion speeds of real exchange rates for a number of different sectors in eleven industrial economies and then focus on relating these rates to variables identified in the literature as key determinants of CPI-based real exchange rates, namely: the *trade balance*, *productivity* and the *mark up*. In particular, we seek to understand to what extent the relationships existing at the aggregate level are borne out at the disaggregate level. We believe that this analysis can help shed light on the PPP puzzle.

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Introduction

There has recently been a huge resurgence of interest in testing the purchasing power parity (PPP) hypothesis, and this has led to the emergence of the so-called PPP puzzle of Rogoff (1996). The PPP puzzle concerns the evident slow adjustment speed of real exchange rates (reported half-lives are in the range of three to five years) coupled with the high short-run volatility of real and nominal exchange rates. If the latter were a consequence of liquidity effects in the presence of sticky prices, the real exchange rate would be expected to have a much faster adjustment speed than the stylised range (i.e. to mean-revert with a half life of around one year).

A number of modifications to the PPP construct have been offered to explain the relatively low mean reversion speeds of real exchange rates. One explanation, consistent with the spirit of PPP, concerns the existence of transaction costs and their ability to impart non-linear adjustment into the real exchange rate; once such non-linearities are modelled, adjustment speeds consistent with PPP are reported (e.g., Obstfeld and Taylor (1997)). Other explanations, less consistent with the PPP proposition, emphasise the role of productivity effects in producing systematic movements of the real exchange rate (e.g., MacDonald and Ricci (2001)) or, the role of pricing to market and adjustments to the mark up as a key determinant of the slow mean reversion of real exchange rates (e.g., Cheung, Chinn and Fujii (2001)).

Another approach to understanding violations of PPP involves focussing on disaggregating the prices contained in CPI-based real exchange rates. One of the first studies in this vein is that of Engel (1993), who takes a standard decomposition of the real exchange rate into a relative price of traded goods and the relative price of non-traded to traded goods across countries:

$$q_t = q_t^T + q_t^{NT,T} , \quad (1)$$

where q_t^T is the relative price of traded goods and $q_t^{NT,T}$ is the relative price of non-traded to traded goods. Engel (1993) calculated the relative importance of the two components in (1) by comparing the conditional variances of relative prices within countries and across countries, calculated using four disaggregated indexes of the CPI - energy, food, services and shelter - from the OECD. These indexes were chosen to capture different degrees of tradability, with food taken to be the traded good and the remaining components the non-traded elements. The startling result to emerge from Engel's work is that out of a potential 2400 variance comparisons, in 2250 cases the variance of the relative price within the country is significantly smaller than the variance across countries for the same type of good. This would seem to indicate that it is violations in the LOOP that are responsible for the major part of the volatility of CPI-based real exchange rates. Rogers and Jenkins (1995) reconfirm Engel's result using even finer levels of price disaggregation for 11 OECD countries.[†]

The above-noted price-based tests support the view that it is the q^T component of the real exchange rate that is responsible for the majority of the variability and systematic movement in the overall CPI-based real exchange rate. However, disaggregate prices have also been used to directly tackle the PPP puzzle. For example Imbs et al. (2005a) argue that differentiated goods prices mean revert at different rates and aggregating across goods can introduce a positive bias into aggregate half-lives. Using CPI-based real exchange rates and the sectoral

[†] Engel (1999) provides an update of his original study and reports, using output prices from the OECD and personal consumption deflators from national income accounts to construct the q_t^T and $q_t^{NT, T}$ terms, that over 95% of US dollar bilateral real exchange rates are explained by the q_t^T component of the real exchange rate.

disaggregate components of these prices collected from Eurostat, for a sample period 1975 to 1996, Imbs et al. estimate half-lives for the CPI-based real exchange rates of around 4 years, which is in the usual range. But they also demonstrate that the half-lives for constituent components of the CPIs (i.e. the disaggregate data) is between four months and two years. Imbs et al. also demonstrate that the degree of heterogeneity is more marked for the relative price of traded goods than the relative price of non-traded to traded goods and, indeed, homogeneity restrictions on the persistence properties of real exchange rates cannot be rejected.

Chen and Engel (2005) provide a number of criticisms of the methods of Imbs et al.: they argue that the equal weighting given to goods prices places too much weight on the prices of goods which adjust relatively rapidly; allowing for non-zero correlation between the series implies the bias term can be positive or negative; in the context of a simulation exercise, if q_t^T is constrained to be non-explosive, that small sample bias offsets the aggregation bias and, indeed correcting for small sample bias produces half-lives which are much closer to the consensus estimates; in the presence of measurement error in q_t^T which is additive, and not very persistent, this can make relative prices appear less persistent than they actually are. Using the same data set as Imbs et al, but with corrections for data entry errors, Chen and Engel show that half-life estimates are in fact in line with Rogoff's consensus estimates.

In response to Chen and Engel, Imbs et al. (2005b) concede that the aggregation bias can be positive or negative, but argue that the examples used by Chen and Engel to generate negative bias are unrealistic and therefore conclude that the positive bias case is the relevant one. Using a simulation exercise, Imbs et al. (2005b) show that an aggregation bias exists even if explosive roots are ruled out and, in terms of the existence of aggregation bias in actual data samples, it still exists even if the data is cleaned of measurement error. They further argue that Chen and Engel do not find empirical evidence of aggregation bias in their data sets because they use an inappropriate estimator and one which is rejected by the data: when an appropriate estimator is used results consistent with Imbs et al. (2005a) original findings are recovered.

In order to study the dynamic behaviour of the real exchange rate in a setting that is free of the product aggregation bias of Imbs et al (2005a), and also to reassess Engel proposition that deviations from the LOOP are the key explanation for real exchange rate variability, Parsley and Wei (2004) use the Economist's data set on the price of a Big Mac in a number of capital cities. In particular, they match Big Mac prices with the prices of the underlying ingredients of a Big Mac across countries, which then allows them to decompose Big Mac real exchange rates into tradable, q^T, and non-tradable, q^{NT}, components. Parsely and Wei (2004) demonstrate that adjustment speeds for real exchange rates calculated using the tradable components of the Big Mac are much lower than that for non-tradables (average half-lives of 1.4 years and 3.4 years, respectively) and the half-life of Big Mac deviations is 1.8 years which is, as we have seen, much smaller than the kind of half-lives reported in the literature using CPI-based real exchange rates.[‡]

[‡] Cheung, Chinn and Fujii (2001) seek to explore the consequences of market structure for the persistence of deviations from PPP. They capture persistence using the mean reversion coefficient for industry *i* of country *j* and this is then regressed onto two measures of market structure and a number of macroeconomic variables. The first measure of market structure is the price cost margin (PCM) which approximates profits of an industry and is intended to give a measure of how competitive an industry is and the intra-industry trade index (IIT), which is a measure

In this paper, we seek to build on recent research using disaggregate price data by constructing real exchange rates for a number of different sectors in eleven industrial economies. The sectors included produce a number of goods ranging from Food Products to Textiles and Transport Equipment. Although the goods considered are normally regarded as traded, they will nonetheless contain important non-traded elements, which may have a bearing on our results (arguably, Food Products are more tradable than Transport Equipment). As a first step, we present some evidence on the time series properties of sectoral real exchange rates and the ability of disaggregated prices to explain the PPP puzzle. We then go on to explore the relationship at the sectoral level between exchange rates and certain variables which have been identified in the exchange rate literature as key determinants of CPI-based real exchange rates (see, for example, MacDonald (2007)): the *trade balance*, *productivity* and the *mark up*. The trade balance is usually seen as a key determinant of a country's long run, or equilibrium, exchange rate and it should therefore have a powerful impact on relative prices. Productivity differences are also thought to introduce a systematic bias into real exchange rates, although their sign is contentious.[§] Adjustments in the

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of market power due to product differentiation. Using sectoral real exchange rate data (for nine manufacturing sectors) from 15 OECD countries over the period 1970-1993 Cheung *et al* show that both market structure effects are significantly positively related to the mean reversion speed and robust to different specifications; the macro variables are, however, not robust to different specifications. They also show that industries with high PCMs have slowest mean reversion.

[§] Taking a standard Balassa-Samuelson perspective a positive shock to total factor productivity should appreciate an exchange rate. However, more recent approaches mark-up arising from pricing-to-market behaviour, and other supply-side distortions, can also introduce systematic biases and wedges into the dynamics of real exchange rates (e.g., Cheung, Chinn and Fujii (2001)).

Given these determinants, we ask: to what extent are the relationships existing at the aggregate level borne out at the disaggregate level? For example, do sectors respond in a similar way at the disaggregate level to movements in the trade balance, productivity, and the mark-up? We view our work as an extension of the studies referred to above which focus solely on the behaviour of the disaggregate real exchange rate. We believe that our analysis can help shed light on the PPP puzzle, and, to our knowledge, it has not been undertaken in previous studies.

The remainder of the paper proceeds as follows. In the next section, we describe the disaggregate data set used in the paper and then go on, in Section 2, to present our empirical work, which includes an analysis of the time series properties of the sectoral real exchange rates and panel estimates of the relationship between such real exchange rates and the three conditioning variables. Our findings are summarised in a concluding section.

1. The data set.

The data used in this study are drawn from the *Structural Analysis* (or "STAN")[**] database for Industrial Analysis, which is made available on a rolling updated basis by

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which rely on New Trade Theory suggest an exchange rate depreciation because the law of one price does not hold (see, for example, MacDonald and Ricci (2007)).

[**] We thank Focco Vijselaar (previously of the ECB) and Bill Cave and Colin Webb (both of the OECD) for discussions on the STAN database.

the OECD (e.g., OECD (2005)). Despite the potential availability of a large number of sectors, our desire to work with balanced panels limited the number of sectors used in the analysis.

Accordingly, our study focuses on sectoral data for 12 countries: Austria, Belgium, Canada, Denmark, Finland, Germany, Italy, Japan, Netherlands, Norway, UK, and the USA (the *numeraire*) observed over the period 1980 to 1997.[††] For this group of countries and sample period, the STAN data set has four composite indicators with full coverage for 11 sub-sectors in manufacturing. Namely:

(1) *Food Products, Beverages And Tobacco;*

(2) *Textiles, Textile Products, Leather And Footwear*;

(3) *Wood And Products of Wood And Cork*;

(4) *Pulp, Paper, Paper Products, Printing and Publishing*;

(5) *Coke, Refined Petroleum Products and Nuclear Fuel*;

(6) *Chemicals and Chemical Products*;

(7) *Rubber and Plastics Products*;

(8) *Other Non-Metallic Mineral Products;*

(9) *Machinery and Equipment*;

(10) *Transport Equipment;*

[††] Data beyond 1997 is clearly available (although for the current vintage of the STAN database, the consistent coverage of key variables declines). The choice of the sample period is in line with the purposes of the present study. Since our sample contains many exchange rates of countries that have joined EMU, we prefer to limit the study to the period ahead of the introduction of the Euro. Indeed, after the Euro, with a common nominal exchange rate vis-à-vis the US dollar, we would be picking up only price differentials.

(11) *Manufacturing Nec; Recycling.*

For each of these sectors we construct the respective price deflator (used in the computation of the real exchange rate), trade balance, productivity and mark-up. A full description of the dataset and the variables construction can be found in the Data Appendix. In terms of the STAN categorisation, all of these sectors are regarded as traded. Unfortunately, it is not possible to obtain data for non-traded sectors for the kind of sample needed to implement the econometric methods used here. Of course, all of the above-noted sectors will have some non-traded input(s), although it is not possible to unravel the extent of this in each case.

2 Empirical results

In this section we present our empirical results. We focus first on some panel unit root tests for our disaggregate real exchange rates and then move on to the relationship between these real exchange rates and the sectoral fundamentals.

2.1 Panel unit root results for the disaggregate real exchange rate series.

The first step in our empirical testing is to check the time series properties of our sectoral real exchange rates. For this purpose, we perform a series of panel unit root tests to assess the stationarity of the series and have computed the implied speed of mean-reversion. Recently, a plethora of tests have become widely available in the literature on panel unit root testing.[‡‡] Here, we use two of the most widely used tests,

[‡‡] Accordingly, a number of applications have been written in the most widely available econometric software. In this paper, we have performed the PUR test using *Matlab* version 7 with the codes developed by Christophe Hurlin and by Serena Ng. We are grateful to both for making their code available online.

namely the Levin, Lin and Chu (2002) [LLC] and the Im, Pesaran and Shin (2003) [IPS] tests.

The LLC test can essentially be seen as a pooled Augmented Dickey-Fuller (ADF) test when lags of the dependent variable are included to account for serial correlation in the errors:

$$\Delta q_{it} = \alpha_{1i} + \alpha_{2t} + \alpha_3 q_{it-1} + \sum_{j=1}^{p} \alpha_{4j} \Delta q_{it-j} + \varepsilon_{it}, \qquad (2)$$

where α_{1i} is an individual effect, α_{2t} is a time effect, and α_3 is the mean-reversion parameter. As in the univariate ADF, non-stationarity holds under the null hypothesis. LLC construct their test by estimating equation (2) and deriving a t^* statistic, which follows a standard normal distribution. IPS, on the other hand, perform univariate unit root tests and then base their test on the average of the t-statistics, $\bar{t}$, from the individual ADF regressions. After adjusting for the size of NxT, they derive a $W[\bar{t}]$ statistic, which again follows a standard normal distribution under the null of non-stationarity.

It is important to note that although the LLC and IPS tests have the same null hypothesis, the alternatives are different: in the LLC test all the individual series are assumed to be stationary with identical first-order autoregressive coefficients under the alternative; in the IPS test the individual first order autoregressive coefficients are allowed to vary under the alternative. Clearly, if the stationary alternative with identical cross-sectional autoregressive coefficients is correct, the LLC test is more appropriate than the IPS test.

Table 1 presents the results of these tests for the series of sectoral real exchange rates. In particular, three sets of results are shown; statistics which are pooled across sectors and countries (labelled ‘Full’ in the table), statistics which are pooled for each sector and across countries, and statistics which are pooled for each country and across sectors.

[Insert table 1 about here]

The evidence from the four tests is not unambiguous. The LLC test strongly rejects the non-stationarity null for the full sample. However, when we consider different levels of aggregation, this test highlights how results may differ from sector-to-sector or from country-to-country. The LLC test leads to rejection of the null in 7 cases for the sectoral aggregations (non-stationarity is rejected for the Minerals, Paper, Rubber, Textile and Transport Equipment sectors at the 1 or 5 % significance levels, and Chemicals and Food at the 10% level) and in 6 cases for the country level aggregations (Austria, Belgium, Italy and Netherlands at the 5% level, Denmark and Japan at the 10% levels). Similarly for the full sample, the IPS test rejects the null at the 1% level of significance. However, at the sectoral and country level aggregations, IPS qualitatively confirms the LLC evidence for the Chemicals, Paper, Food and Transport Equipment sectors and produces alternative evidence for the Minerals, Rubber and Textile (nonstationary) and for the Coke and Wood (stationary) sectors, although at the country level, rejection of the null is confirmed for only Austria and Belgium.

2.2 Implied Half Lives

In order to shed light on the PPP puzzle we compute the implied half-lives using the formula:

$$HL = \frac{\log(0.5)}{\log(1+\hat{\alpha}_3)}$$

For the full sample, the estimated half-life is 2.7 years. The half-lives of the real exchange rates disaggregated by sectors across countries, when non-stationarity is rejected by at least two of the tests, are quite heterogeneous, falling in a range between 1.18 and 4.6 years. So, while for some sectors evidence seems to be supportive of the LOOP, in the sense of producing half-lives of around one year to eighteen months (Chemicals (≈1.2), Food (≈1.5), Paper (≈1.5) and Transport (≈1.6)), for the others half-lives seem to be too slow and are therefore not supportive of the LOOP (Minerals (≈3), Rubber (≈4.6), and Textile (≈2.8)). The country-by-country rates disaggregated by sector produce less support against the puzzle with half-lives ranging between approximately 2.2 years for Belgium and 4 years for Denmark.

In summary, the panel unit root tests display mixed evidence – some sectors and countries produce evidence of strong mean reversion, whereas others produce weak or no evidence of mean reversion. It is interesting to note that for the country results which do produce evidence of stationarity, the half-lives are, in general, in the range defined by the PPP puzzle of between 3 and 5 years. As far as we are aware this is a new result: the standard result for the univariate properties of the CPI-based real exchange rates considered here is that they are non-stationary, so using sectoral data would seem to have advantages in producing evidence of stationarity, although not sufficiently fast to be consistent with the PPP hypothesis. Interestingly, however, some of the sectoral results produce evidence which is more in conformity with the PPP hypothesis and this would seem to lend support to the findings of Imbs et al. (2005a, 2005b.) How do these results change if we condition our different measures of the real exchange rate onto the fundamentals?

2.3 The fundamentals

In our empirical investigation of the relationship between the sectoral exchange rates and the fundamentals we use three conditioning variables, which have been popular in the empirical literature analysing CPI-based real exchange rates, namely the trade balance, relative productivity and the mark-up. A country's net foreign asset position is usually taken to be the key tie down relationship for an equilibrium exchange rate (see, for example, MacDonald (2007)). Lane and Milesi Ferretti (2001) have demonstrated, from the standard balance of payments condition, that the counterpart to the real exchange rate net foreign asset relationship is between the real exchange rate and the trade balance, where the relationship is expected to be negative. Given that we have access to precise trade balance data which matches the level of disaggregation in our price series, we can investigate whether a similar relationship holds in the disaggregate data.

The relationship between a CPI-based real exchange and the productivity differential is usually predicted to be negative (given our definition of the real exchange rate) on the basis of the Balassa-Samuelson proposition. Clearly, though, if one is considering the relative price of traded goods, which most of our series broadly are, then there is no reason why the relationship should not be the opposite in the absence of the law of one price. For example, in the standard Balassa-Samuelson example the law of one price is assumed to hold for traded goods and so, by assumption, the relative price of traded goods cannot change as a result of a total factor productivity shock in the traded sector; the resulting appreciation of the real exchange rate is due to the resulting wage equalisation between the traded and non traded sectors and the rise in the relative price of non-traded to traded goods. Clearly, in the absence of the LOOP, movements in the relative price of traded goods are feasible, although the net effect on the CPI-based real exchange rate may still produce a real exchange rate appreciation if the relative price of non-traded goods dominates.

The mark-up is central to the literature on pricing to market. Firms operating in an imperfectly competitive market price to market in order to protect their market share and adjust the mark-up to achieve this. Equally, exogenous changes in the mark-up should have implications for the real exchange rate and an increase in the mark-up is expected to produce an appreciation of the real exchange rate and the converse for a decrease in the mark-up. We would expect similar relationships to hold at the disaggregate level since these are effectively firm-specific decisions. Indeed the mark-up relationship may be expected to be even clearer at the disaggregate level.

Before we proceed to the estimation of the role of fundamentals in explaining real exchange rate behaviour, we pre-test the series for stationarity. In table 5, we report PUR results for the trade balance, productivity and the mark-up differentials. In the majority of cases, these tests indicate that all three variables are nonstationarity. Given this, we have estimated all of our equations using an estimator robust to the presence of nonstationary variables. In particular, we have adopted the panel dynamic OLS estimator, which has been shown by Kao and Chiang (1999) to have better finite sample properties compared to the panel OLS and fully modified OLS estimators. The chosen specification accounts for fixed effects, heterogeneity and cross-sectional dependence[§§] through sectoral or country dummies and time effects:

$$q_{it} = \gamma_{1i} + \gamma_{2t} + \boldsymbol{\gamma}_3' \mathbf{X}_{it} + \sum_{j=-p}^{n} \theta_j \Delta \mathbf{X}_{it+j} + \eta_{it}, \qquad (3)$$

where q_{it} is the sector i real exchange rate series, γ_{1i} is an individual fixed effect, γ_{2t} is a time effect, $\mathbf{X}_{it}$ is a matrix containing the conditioning variables (the trade balance as a proportion of nominal value added, productivity and the mark up), and η_{it} is a normally distributed random error.[***] As for the PUR tests discussed above,

[§§] Due, for example, to the *numeraire* currency.

[***] Given that we use annual data, we have considered a leads and lags structure of one year only.

estimation is pooled for the full sample of sectors and countries and for the sectoral disaggregation across all countries and the country disaggregation across sectors. The relative Panel DOLS estimates are reported in tables 2 and 3.

[Insert table 2 about here]

[Insert table 3 about here]

Starting with the full sample results, the trade balance is the only fundamental variable which does not produce a statistically significant coefficient. Productivity enters positively and is strongly significant while the coefficient on the mark-up is negative and also strongly significant. The former result is, as noted above, contrary to the standard BS prediction that productivity changes in the tradable sector do not affect the real exchange rate for tradables (because the LOOP is assumed to hold). Here they clearly do and this finding would seem to be consistent with recent theoretical work which suggests that the kind of goods entering international trade are differentiated rather than homogeneous (see, for example, MacDonald and Ricci (2007). It is worth noting that the relationship between the productivity differential and the real exchange rate is essentially proportional: prices move on a one-to-one basis in response to productivity changes. The mark-up results accord with simple intuition: an increase in the mark-up produces a less than proportional rise in the domestic price level.

Turning to the sector-by-sector regressions, we find the trade balance to be significant in at least four cases at the 1 or 5% confidence levels (Machinery (-), Manufacturing (+), Paper (-), Transport Equipment (-)). Productivity differentials continue to be an important determinant of the sectoral real exchange rate at the disaggregated level, and the coefficients are all positive and close to unity, confirming the results for the full sample. The positive sign suggests that increased productivity in the traded sector induces currency depreciation. This result is, of course, the opposite of that expected in the standard neo-classical Balassa-Samuelson framework where an improvement in tradable productivity leads to an exchange rate appreciation. Our results for productivity therefore suggest that in order to understand the influence of productivity on the real exchange rate, it is necessary to move to models of international trade in which the law of one price assumption is relaxed and the heterogeneity of goods which enter international trade is explicitly recognised.

The coefficient on the mark-up term is highly significant in the sectoral estimates although, interestingly, with contrasting signs depending on the sector. For example, for the Chemicals and Rubber sectors, higher mark ups seem to cause a depreciation of the real exchange rate, whilst for the Coke, Food, Machinery, Manufacturing, Minerals, Paper, Textile, Transport Equipment, and Wood an increase in the mark-up causes an appreciation as in the full sample case. We take these differential results as reflective of differing market structures across our sectors and in the spirit of the pricing to market literature, reflective of differing elasticities of demand in the two groups.

In contrast to the full sample and the sector-by-sector regressions, the trade balance enters the country regressions significantly in most cases (7 out of 11), but again with alternate signs (positive for Austria, Belgium, Denmark, and negative for Finland, Japan, Norway and the UK). Perhaps this result simply reflects the fact that the trade balance is a country-wide phenomenon and therefore not an important determinant of the sectoral behaviour of real exchange rates. As in the full sample and in the sector-by-sector regressions, productivity enters positively and significantly in the country estimates and with a coefficient which is above one in the majority of cases. The mark-up is significant in all cases except for Austria and the Netherlands and it is negative in all cases aside from the UK, with coefficients which are again significantly different from unity.

2.4 Residuals and Implied Adjustment Speeds from Panel DOLS.

Interestingly, the residuals from the Panel DOLS estimations are all stationary (PUR tests are not reported, but are available from the authors upon request). In table 4 we compare adjustment speeds calculated using the half-life formula for the raw sectoral real exchange rates with the rates of mean reversion of the residuals of the panel DOLS estimation of real exchange rate on fundamentals.

[Insert table 4 about here]

Overall, for the sector-by-sector regressions the results show a very marked improvement of half-lives, with the average half-life going from 2.75 to 1.88. It is interesting to note that the adjustments speeds for the three sectors which produced significant but relative slow mean reversion with the univariate PUR tests - Minerals, Rubber and Textiles – now produce half-lives of around two years and sectors which produced essentially non-stationary univariate real exchange behaviour – Machinery and Manufacturing - also produce respectable half-lives once the set of conditioning variables is used. The country-by-country regressions are also interesting and, in general, contrast with the univariate results. For example, the adjustment speeds for five countries - Canada, Denmark, Japan, Netherlands, Norway – are markedly faster than in the univariate case and these results suggests that the PPP puzzle is perhaps not that surprising: in order to understand systematic movements in real exchange rates, it is necessary to consider the systematic determinants of real exchange rates.

3. Conclusions

This paper builds on recent research which uses disaggregated price indices to shed light on the real exchange rates behaviour and real exchange rate determinants at the sectoral level. In particular, we use price data disaggregated at the sectoral level to construct real exchange rates for eleven sectors in eleven industrialised economies.

As a first step, we have examined the time series properties of the sectoral real exchange rates and the ability of disaggregated prices to explain the PPP puzzle using the Levin, Lin and Chu (2002) and Im, Pesaran and Shin (2003) panel unit root tests. We have two main findings here. First, the sectoral results produce evidence which is closer in conformity to the PPP hypothesis than that obtained with aggregate data and this would seem to lend support to the findings of Imbs et al. (2005a, 2005b). Second, for the univariate country results we find clear evidence of stationarity in a number of cases and although the half-lives are in the range defined by the PPP puzzle, this is a very different result compared to that found using country CPI-based real exchange rates which always prove to be non-stationary. This would seem to reinforce the argument for using sectoral data.

The following conclusions emerge from the second part of our work, in which we concentrate on the ability of some of the critical variables proposed in the exchange rates literature to determine real exchange rates at the sectoral level. In particular, the sectoral rates are regressed against the respective trade balances, productivities and mark-ups using a cointegration-based framework which builds of a panel dynamic OLS technique. These regressions seem to provide mixed evidence with respect to the relationship between the real exchange rate and the fundamentals. A first result worth mentioning is that there seems to be a weak relationship between the real exchange rate and the trade balance, a variable indicated in open economy macro models as a determinant of long run equilibrium real exchange rates. A clearer result is found with respect to the mark-up, which enters most of the regressions with a negative and significant sign. A particularly interesting result is found for the productivity differential, which enters the regressions always significantly and with a positive sign. Hence, a productivity increase produces a currency depreciation. This result is opposite to what expected in the standard neo-classical Balassa-Samuelson framework and seems to suggest that it is necessary to move to models of international trade in which the law of one price assumption is relaxed and the heterogeneity of goods which enter international trade is explicitly recognised. Our analyses of adjustment speeds and half-lives suggests that in order to understand the relatively low mean reversion speeds of real exchange rates it is necessary to understand and model the determinants of real exchange rates.

4. Data Appendix

The data used in this study are drawn from the *Structural Analysis* (or “STAN”) database for Industrial Analysis, which is made available on a rolling updated basis by the OECD (e.g., OECD (2005)). This is an annual data base that provides a number of standard macro time series for the main industrialized countries at an aggregate and industry-specific level (using the *ISIC Rev. 3* industrial classification scheme). Sectors covered include: Manufacturing; Agriculture; Mining; Utilities; Construction; Wholesale; Hotels and Restaurants; Transport; Communications; Finance; Real Estate; Public Services. STAN is primarily based on member countries' annual National Accounts by activity tables but also uses data from other sources, such as national industrial surveys/censuses.

As discussed in the text, we have selected the sectors used in this paper in order to preserve the balance nature of the data (i.e. all countries having the same number and coverage of indicators along the same time dimension). For example, trade data (exports and imports) are essentially unavailable for the non-manufacturing and public sectors for the main industrial economies and the same holds, though to a lesser extent, for productivity. In order to maximise the available data we used excel codes to search through all the available individual country data sheet files and dimension the largest complete data panel for a sufficiently long time horizon and country range (these programs are available on request).

Accordingly, our study focuses on sectoral data for 12 countries: Austria, Belgium, Canada, Denmark (excluding the coke sector), Finland, Germany (comprising West-Germany plus East Germany after 1992; Germany prior to unification was calculated using growth rates derived from West German data), Italy, Japan, Netherlands, Norway, UK, and the USA (the *numeraire*). The sample period is

1980 to 1997. For this group of countries and sample period, the STAN data set has four composite indicators with full coverage for 11 sub-sectors in manufacturing. The composite series are (table acronyms and STAN data codes given in square brackets):

1. Food: Food Products, Beverages And Tobacco [15-16];
2. Textiles: Textiles, Textile Products, Leather And Footwear [17-19];
3. Wood: Wood And Products Of Wood And Cork [20];
4. Paper: Pulp, Paper, Paper Products, Printing And Publishing [21-22];
5. Coke: Coke, Refined Petroleum Products and Nuclear Fuel [23];
6. Chemicals: Chemicals and Chemical Products [24];
7. Rubber: Rubber and Plastics Products [25];
8. Minerals: Other Non-Metallic Mineral Products [26];
9. Machinery: Machinery and Equipment [29-33];
10. Transport: Transport Equipment [34-35];

Our constructed variables, and transformations used, are:

- Trade balance = (*expo* - *impo*) / *valu*
- Price [Implicit Price Deflator**]** = 100*(*valu*/*valuk_1995*)
- Productivity = *valuk_1995*/*empn*
- Markup = *valu*/*labr*

Where, following STAN mnemonics, *Valu* = nominal value added; *Valuk* = real value added; *Labr* = labor costs; *Empn* = total employment, *expo* and *impo* are nominal export and nominal imports and *valuk_1995* is *valuk* in 1995 currency - this ensures that at *t=1995* the "Implicit Price deflator" = 100.

References

Chen, Shiu-Shen and Charles Engel (2005) “Does 'Aggregation Bias' Explain The PPP Puzzle?,” Pacific Economic Review, 10, 49-72

Cheung, Yin-Wong, Menzie D. Chinn, and Eiji Fujii (2001) “Market Structure and the Persistence of Sectoral Real Exchange Rates,” International Journal of Finance & Economics, 6, 95-114.

Engel, Charles (1993) “Real exchange rates and relative prices: An empirical Investigation,” Journal of Monetary Economics, 32, pages 35-50

Engel, Charles (1999) “Accounting for U.S. real exchange rate changes,” Journal of Political Economy, 107, 507-538.

Im, Kyung So, M. Hashem Pesaran, and Yongcheol Shin, (2003) “Testing for unit roots in heterogeneous panels,” Journal of Econometrics, 115, July, 53-74.

Imbs, Jean M., Haroon Mumtaz, Morten O. Ravn, and Helen M. Rey (2005a) “PPP Strikes Back: Aggregation and the Real Exchange Rate,” The Quarterly Journal of Economics, 120, 1-43

Imbs, Jean M., Haroon Mumtaz, Morten O. Ravn, and Helen M. Rey (2005b) “Aggregation Bias' DOES Explain the PPP Puzzle,” CEPR Discussion Paper #5237

Kao, Chihwa and Min-Hsien Chiang (1999) “On the Estimation and Inference of a Cointegrated Regression in Panel Data”, mimeo.

Lane, Philip R. and Gian Maria Milesi-Ferretti (2002) “External wealth, the trade balance, and the real exchange rate”, European Economic Review, 46, 1049-1071

Levin, Andrew, Chien-Fu Lin, and James Chu (2002) “Unit-root test in panel data: asymptotic and finite sample properties,” Journal of Econometrics, 108, 1-24.

MacDonald, Ronald, (2007), *Exchange Rate Economics: Theories and Evidence*, London: Taylor-Francis.

MacDonald, Ronald (1995) "Long-Run Exchange Rate Modeling - A Survey of the Recent Evidence," IMF Working Paper #95/14,

MacDonald, Ronald (1985) "Buffer Stocks, Exchange Rates and Deviations from Purchasing Power Parity," Empirical Economics, 10, 163-75.

MacDonald, Ronald. and Luca A. Ricci (2007), "Real Exchange Rates, Imperfect Substitutability, and Imperfect Competition", *Journal of Macroeconomics*, forthcoming.

MacDonald, Ronald and Luca A. Ricci (2001) "PPP and the Balassa Samuelson Effect: The Role of the Distribution Sector," IMF Working Papers 01/38

Obstfeld, Maurice and Alan M. Taylor (1997) "Nonlinear Aspects of Goods-Market Arbitrage and Adjustment: Heckscher's Commodity Points Revisited," Journal of the Japanese and International Economies, 11, 441-479,

OECD STAN Database (2005) Directorate for Science, Technology and Industry, OECD Publications: Paris.

Parsley, David and Shang-Jin Wei (2004) "A Prism into the PPP Puzzles: The Micro-Foundations of Big Mac Real Exchange Rates," CEPR Discussion Paper #4486.

Rogers, John H. and Michael Jenkins (1995) "Haircuts or hysteresis? Sources of movements in real exchange rates," Journal of International Economics, Vol. 38(3-4), 339-360

Rogoff, Kenneth (1996). "The Purchasing Power Parity Puzzle," Journal of Economic Literature, Vol. 34, No. 2., 647-668.

Table 1 – Real Exchange Rates Panel Unit Root Tests

	$\hat{\rho}$	**HL**	LLC (2002) t^*	IPS (2003) $W[\bar{t}]$
Full Sample	-0.2260	2.7	-3.915***	-3.466***
Chemicals	-0.4437	1.18	-1.491*	-4.086***
Coke	-0.2965	1.97	2.017	-2.501***
Food	-0.3609	1.54	-1.418*	-1.620*
Machinery	-0.0932	7.08	0.943	3.057
Manufacturing	-0.1912	3.26	-0.868	0.547
Minerals	-0.2021	3.07	-3.052***	-0.288
Paper	-0.3786	1.48	-1.945**	-2.187**
Rubber	-0.1385	4.65	-2.568***	0.014
Textile	-0.2217	2.77	-2.219**	-0.726
Transport	-0.3448	1.64	-3.112***	-1.938**
Wood	-0.3576	1.57	1.056	-1.920**
Austria	-0.2411	2.88	-1.923**	-1.426*
Belgium	-0.3152	2.2	-1.915**	-3.221***
Canada	-0.3034	2.29	-0.407	-1.196
Denmark	-0.1709	4.05	-1.406*	0.179
Finland	-0.4279	1.62	1.359	-0.981
Germany	-0.2646	2.62	-1.018	-0.491
Italy	-0.3207	2.16	-1.733**	-1.247
Japan	-0.2412	2.87	-1.497*	-0.973
Netherlands	-0.1953	3.55	-2.086**	-0.199
Norway	-0.2492	2.78	-0.572	-1.014
UK	-0.2769	2.50	-0.923	-0.872

***,**,* denote significance at the 1, 5, 10 % confidence level

Table 2: Real Exchange Rate Panel DOLS Regressions on Trade Balance (TB), Productivity (X) and Mark-up (K) Differentials.

Full Sample and Sectoral Disaggregation

$q=\ln(S*P^f/P)$	Full	Chemicals	Coke	Food	Machinery	Manufacturing	Minerals	Paper	Rubber	Textile	Transport	Wood
TB	0.005	-0.084	0.009	0.170	-0.182***	0.208**	0.097	-0.392*	-0.113	-0.025	-0.040*	0.057
	(0.005)	(0.055)	(0.007)	(0.168)	(0.050)	(0.096)	(0.139)	(0.216)	(0.077)	(0.034)	(0.023)	(0.077)
X	0.946***	0.510***	0.984***	0.729***	1.011***	0.727***	0.627***	0.697***	0.515***	0.757***	0.702***	0.855***
	(0.031)	(0.100)	(0.060)	(0.113)	(0.098)	(0.140)	(0.105)	(0.100)	(0.088)	(0.139)	(0.096)	(0.102)
K	-0.496***	0.329**	-0.943***	-0.351**	-0.843***	-0.877***	-1.242***	-0.615**	0.898***	-0.501	-0.401**	-0.563***
	(0.029)	(0.158)	(0.056)	(0.162)	(0.198)	(0.234)	(0.228)	(0.247)	(0.204)	(0.306)	(0.170)	(0.136)
Observations	1810	165	160	165	165	165	165	165	165	165	165	165
R^2-Within	0.72	0.78	0.86	0.75	0.94	0.86	0.90	0.76	0.93	0.86	0.82	0.76
R^2-Overall	0.00	0.01	0.07	0.08	0.03	0.01	0.03	0.00	0.31	0.01	0.01	0.02
R^2-Between	0.02	0.31	0.02	0.58	0.10	0.14	0.28	0.17	0.04	0.12	0.20	0.06
F-test	166.83	17.31	28.67	14.61	76.30	30.76	42.35	15.52	63.70	30.18	23.18	15.71
RMSE	0.14	0.08	0.16	0.10	0.09	0.10	0.10	0.09	0.10	0.10	0.10	0.12

Standard errors in parentheses

Constant, time and id fixed effects, leads and lags are omitted.

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 3: Real Exchange Rate Panel DOLS Regressions on Trade Balance (TB), Productivity (X) and Mark-up (K) Differentials

Country by Country Disaggregation

$q=\ln(S*P^f/P)$	Austria	Belgium	Canada	Denmark	Finland	Germany	Italy	Japan	Netherlands	Norway	UK
TB	0.096**	0.067**	0.001	0.149***	-0.071**	0.033	-0.059	-0.189*	-0.009	-0.029***	-0.728***
	(0.048)	(0.027)	(0.033)	(0.020)	(0.034)	(0.072)	(0.061)	(0.103)	(0.011)	(0.007)	(0.136)
X	0.626***	1.292***	1.133***	1.519***	1.595***	1.353***	1.123***	1.089***	0.660***	1.035***	0.282**
	(0.053)	(0.090)	(0.095)	(0.118)	(0.086)	(0.082)	(0.077)	(0.084)	(0.172)	(0.089)	(0.122)
K	-0.044	-0.565***	-0.423***	-0.713***	-0.972***	-0.716***	-0.564***	-0.374***	-0.166	-0.247***	0.237**
	(0.095)	(0.115)	(0.060)	(0.099)	(0.059)	(0.057)	(0.075)	(0.062)	(0.152)	(0.081)	(0.110)
Observations	165	165	165	160	165	165	165	165	165	165	165
R^2-Within	0.93	0.89	0.88	0.95	0.91	0.93	0.90	0.94	0.91	0.92	0.76
R^2-Overall	0.54	0.20	0.05	0.06	0.00	0.05	0.31	0.18	0.26	0.33	0.05
R^2-Between	0.25	0.12	0.07	0.01	0.07	0.00	0.26	0.08	0.00	0.43	0.00
F-test	64.39	39.86	34.87	87.06	48.65	61.33	44.88	81.72	47.27	57.53	15.53
RMSE	0.09	0.09	0.07	0.08	0.08	0.09	0.09	0.07	0.11	0.07	0.11

Standard errors in parentheses.
Constant, time and id fixed effects, leads and lags are omitted.
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 4: Implied Half Lives

	q	$\hat{\eta}_{it}$
Full Sample		
	2.7	2.33
Sector by Sector		
Chemicals	1.18	1.23
Coke	1.97	2.09
Food	1.54	2.43
Machinery	7.08	1.98
Manufacturing	3.26	1.58
Minerals	3.07	2.08
Paper	1.48	2.14
Rubber	4.65	1.87
Textile	2.77	1.93
Transport	1.64	1.18
Wood	1.57	2.16
Average	2.75	1.88
Country by Country		
Austria	2.88	3.48
Belgium	2.2	2.61
Canada	2.29	1.33
Denmark	4.05	1.74
Finland	1.62	1.58
Germany	2.62	2.69
Italy	2.16	2.09
Japan	2.87	1.86
Netherlands	3.55	2.33
Norway	2.78	1.80
UK	2.50	5.46
Average	2.68	2.45

Table 5 –Panel Unit Root Tests of Fundamentals

	Trade Balance Differentials		Productivity Differentials		Mark-Up Differentials	
	LLC (2002)	IPS (2003)	LLC (2002)	IPS (2003)	LLC (2002)	IPS (2003)
	t^*	$W[\bar{t}]$	t^*	$W[\bar{t}]$	t^*	$W[\bar{t}]$
FULL SAMPLE	1.357	-5.141***	10.496	0.640	9.284	1.962
CHEM	0.599	-1.422*	-0.973	-3.431***	4.572	1.835
COKE	1.176	-2.977***	-0.054	-5.985	2.661	-4.815***
FOOD	2.239	-2.039**	5.046	0.516	6.640	-2.541***
MACH	0.638	-0.643	6.873	6.139	6.803	8.013
MANU	-1.235	-1.913**	1.542	-2.184**	0.198	-0.868
MINE	-1.136	-0.807	6.077	-1.246	6.927	3.954
PAPE	3.071	-1.967**	5.091	4.175	9.559	0.862
RUBB	-0.923	-1.226	4.751	1.605	4.413	2.894
TEXT	0.296	-0.004	-0.689	0.266	-2.274	0.965
TRAN	1.272	-2.997***	2.585	-0.568	-0.913	-3.666***
WOOD	-0.033	-1.055	3.253	2.575	-0.868	-0.070
AUSTRIA	3.234	-1.218	2.278	1.058	3.144	0.391
BELGIUM	-1.352*	-2.548***	2.989	-0.723	4.292	-1.130
CANADA	-0.611	-1.688**	2.618	0.443	0.481	-1.276
DENMARK	0.492	-3.470***	4.103	0.567	3.134	0.980
FINLAND	1.137	0.833	5.238	1.046	2.307	-0.998
GERMANY	-2.708***	-2.275**	3.733	-0.105	3.411	1.689
ITALY	1.982**	-1.785**	2.340	0.655	2.927	1.372
JAPAN	-1.251	-0.641	1.417	-2.116**	4.366	3.134
NETHERLANDS	3.639	-0.614	5.000	2.412	4.601	1.559
NORWAY	-2.213**	-1.900**	2.948	-2.145**	1.295	-0.096
UK	4.168	-1.749**	2.328	1.054	1.898	0.906

***,**,* denote significance at the 1, 5, 10 % confidence level