# What determines European real exchange rates?

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**Abstract**

We study a newly created panel data set of relative prices for a large number of consumer goods among 31 European countries over a 15 year period. The data set includes Eurozone members both before and after the inception of the euro, floating exchange rate countries of western Europe, and emerging market economies of Eastern and Southern Europe. We find that there is a substantial and continuing deviation from PPP at all levels of aggregation, both for traded and non-traded goods, even among Eurozone members. Real exchange rates exhibit two clear properties in the sample; a) they are closely tied to GDP per capita relative to the European average, at all levels of aggregation and for both cross country time series variation, b) they are highly positively correlated with cross country and time series variation in the relative price of non-traded goods. We then construct a simple two-sector endowment economy model of real exchange rate determination which exhibits these two properties, calibrated to match the data. Simulating the model using the historical relative GDP per capita for each country, we find that for most countries, there is a very close fit between the actual and simulated real exchange rate.

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# 1 Introduction

This paper examines the behaviour of real exchange rates, both at aggregate and disaggregate levels, across a large sample of European countries over a fifteen year period, ending in 2009. Our starting point is to document the size of deviations from PPP for all categories of goods in the sample. We go on to explore the determinants of the deviations from PPP. Finally, we ask to what extent a simple theoretical open economy model can mimic the pattern of real exchange rate movements among European countries.

Many studies have established that there are persistent deviations from equality of prices across countries, at all levels of aggregation. Equivalently, real exchange rates display large and persistent departures from PPP, whether measured at the level of individual goods, or in terms of aggregate price indices. Despite consensus on the broad facts, however, there is no agreement on the explanation of these departures from PPP. Many competing theories have been put forward, highlighting nominal price rigidities, trade costs, non-traded goods, compositional effects, aggregation bias, and other features, as well as combinations of these elements[1]. One of the difficulties in providing a convincing account of the source of relative price movements across countries is the absence of a large panel of detailed comparable data on goods prices at the disaggregated level. Without such a panel, it is difficult to explore the sources of time variation in real exchange rates across countries. A parallel problem is that most disaggregated time series of price data used in international studies are in the form of indices, rather than price levels. This rules out the possibility of comparing prices across countries at a moment in time, instead allowing only studies of the movement in cross-country relative prices over time. With a large panel of prices of comparable goods across countries, it is possible to jointly explore the determination of the level and the rate of change of real exchange rates among countries.

The data in our study are comprised of prices for a large number of categories of consumer goods across 31 European countries over a 15 year period. The panel contains the high income countries of Western Europe, including the Eurozone countries, both before and after the inception of the euro, as well as the floating exchange rate countries of Western and Northern Europe. In addition, for a slightly shorter sample period, the data includes the emerging countries of Eastern and Southern Europe.

From these data we can construct measures of real exchange rates at both disaggregated and aggregate levels. We find large and persistent deviations from absolute PPP among all European countries. These deviations hold for all categories of goods, but

[1] Recent contributions include Engel (1999), Imbs et al. (2005), Burstein et al. (2003), Crucini, Telmer and Zachariadis (2005), Carvalho and Nechio (2008), Drodz and Nosal (2008), among many others.

are much more pronounced for non-traded than for traded goods. The deviations have not been eliminated by membership of the single currency area. Even among Eurozone members, there are persistent departures from PPP that show no obvious signs of erosion within the sample. For emerging Eastern and Southern Europe countries, the conclusions are somewhat nuanced. For these countries, the deviations from PPP are much larger, but there is much greater evidence of convergence in price levels towards the European average, while still, at least in the sample, remaining quite far away from PPP.

What explains these persistent departures from PPP? In cross country studies, it has long been noted that aggregate price levels tend to be higher in richer countries (e.g. Summers and Heston, 1988). In our data we find that real exchange rates are very closely tied to GDP per capita relative to the European average, *both* in comparisons across countries, and in movement over time. It is notable that is pattern holds, even though the per-capita GDP differential among European countries is of far smaller magnitude than in that between developed and developing countries. Moreover, the data show that some countries displayed declining relative GDP per capita, combined with persistent depreciation in their real exchange rate, while other countries displayed substantial appreciation combined with increasing relative GDP.

Relative GDP per capita is an important determinant of the real exchange rate not just in the aggregate, but also at the level of individual goods. Almost 50 percent of the variation in individual product-based real exchange rates - i.e. real exchange rates at the most disaggregated level, measured across time and countries, is explained by relative GDP per capita differences across countries and movements over time. Quantitatively we find that, on average, a one percent increase in the relative GDP per capita for a given country towards the European mean leads to a 0.35 to 0.40 percent appreciation of the real exchange rate to the European mean. When broken down into non-traded and traded goods separately, the real appreciation coefficient becomes 0.5 percent and 0.2 percent, respectively.

A second feature of real exchange rates in the data is that they are highly positively correlated with the internal relative price of non-traded to traded goods. This relationship holds true both across countries and over time. Over the whole sample, the cross country correlation between the real exchange rate and the relative price of non-traded goods is 0.89, while the time series correlation is 0.84. Moreover, even when we break down the sample into country groupings (Eurozone, floaters, and Eastern and Southern Europe), the correlation still prevails.

We develop a theoretical model of real exchange rate determination based on these two features of the data. We deliberately employ a 'minimalist' model of the real exchange rate based on a two-sector endowment economy with traded and non-traded goods. In our model, the time series and cross country properties of real exchange rates are identical. Real exchange rates are determined by differences in the levels and rates of growth of relative GDP across countries. In addition, in the model, real exchange rates are associated with movements in internal relative prices. The mechanism in the model is broadly consistent with a number of theoretical models of real exchange rates.

For each country, we simulate the model by choosing a path for GDP that matches the historical sample. We calibrate the sectoral growth process in the model to replicate the observed relationship between real exchange rates and GDP. We find that the simulated real exchange rate from the model very closely tracks the sample real exchange rate, in levels and rates of change, for almost all countries in the dataset. We interpret this finding as an encouraging consistency check - the pattern of real exchange rate levels and trends in European countries is consistent with a standard general equilibrium model of the real exchange rate. Moreover, the results may be seen as a contrast to the large literature on exchange rate determination, which emphasizes the difficulty in linking exchange rates to fundamentals of any kind (e.g. Engel, Mark and West 2008 and references therein).

Many previous papers have studied the properties of real exchange rates and relative price comparisons across countries, using both aggregate and disaggregated data. Engel and Rogers (1996) look at movements in price indices across Canadian and US cities, and find that both distance and border matter for relative price variability. Engel and Rogers (2001) use European data, and separate the border into two factors; a) "real barriers" effect caused by barriers to market integration and b) a "sticky consumer price-volatile exchange rate" factor. Similar to our findings below, Engel and Rogers (2004) find no evidence for prices in Europe to converge after euro's introduction in 1999.

Crucini, et al. (2005) present a study quite similar to that of our paper, using a more disaggregated data set on European prices, for four separate sample years for up to 13 EU countries. They argue that PPP holds quite well in these data, when adjusting for GDP per capita. Our paper differs from theirs in that we have a panel covering up to fifteen years, we focus on a more aggregated sample of consumer products (see the discussion below for the differences in aggregation levels), and we examine a much larger set of countries, including both EU countries and non-EU countries, emerging economies in Eastern and Southern Europe, floating and fixed exchange rate countries, and pre-and post Eurozone countries. Our results are generally supportive of Crucini et al. (2005). In particular, we report a measure of 'conditional' deviations from PPP, measuring the mean and variance of departures from PPP, after adjusting for real GDP per capita. Similar to their study, we find that conditional deviations from PPP are substantially lower than unconditional deviations.

Faber and Stokman (2009) also study price level convergence in Europe using HICP data for the EU15 countries, but over a longer time period than we study. They construct price levels from HICP data by mapping the indices from the HICP into absolute price levels from surveys at various intervals. They show that the EU15 countries exhibited substantial absolute price convergence from 1980 onwards, but not much convergence after the late 1990's. Their study differs from ours in a number of ways. They focus on a smaller group of countries. In addition, they employ quite a different data at a different level of aggregation than ours. Their data is based on a small bundle of HICP categories at a relatively high level of aggregation. Most importantly, because our data begins in the mid 1990's, we cannot study that type of long run price convergence that they find.

Crucini and Telmer (2007), using EIU data on city prices find that cross-sectional variance in long-run absolute deviations from LOP is large relative to time-series variance and time series variance in changes in LOP deviations is dominated by idiosyncratic variation, rather than country-specific variation (such as would be driven by nominal exchange rate movements). Our findings are consistent with their paper in the sense that, when we focus on the volatility of real exchange rates at the disaggregated level, we find much less difference in the average volatility between Eurozone countries (or euro-pegging countries) and floating exchange rate countries than the equivalent volatility at the level of the aggregate real exchange rate.

Finally, our paper is related the literature documenting a relationship between price levels and GDP per capita (sometimes called the 'Penn' effect, after Summers and Heston (1991)). While this property seems to be robust when looking across countries, it is not so clear that it holds in time series data (see e.g. Summers and Heston 1988). Many papers, both theoretical and empirical, have explored the 'Balassa-Samuelson' mechanism (e.g. Asea and Mendoza 1994, De Gregario et al. 1994), which rationalizes the relationship between real exchange rates and GDP based on asymmetric productivity growth rates across sectors, although the relationship may also be explained through differences in factor intensities (Bhagwati 1984). An alternative explanation is explored by Bergstrand (1991). He argues that a 'demand-side' explanation, due to the property that the income elasticity of demand for services exceeds unity, plays an important role in explaining the relationship. Our paper provides a further documentation of the nature of the relationship between relative prices and GDP per capita for European countries. We argue that the relationship holds almost in the same way both across countries and over time. Moreover, our findings are notable in the sense that the link between real exchange rates and GDP per capita is very strong, despite that the magnitude of differences in GDP per capita across European countries is much smaller than that in the Penn World Tables.

The following section discusses the data in detail. Section 3 describes the properties of real exchange rates, both at the aggregate level and the disaggregated level. Section 4 discusses the relationship between real exchange rates and relative GDP. Section 5 shows that a simple structural model based on relative GDP, distance, and euro membership can account for a large part of the variation in real exchange rates both at the aggregate and disaggregated level. Finally, section 6 discusses the extent to which the empirical findings are consistent with a simple general equilibrium model of exchange rate determination. Some conclusions follow.

# 2 Data-Description

## 2.1 Annual Price Level Indices

We use a dataset on prices for a large number of European countries over the 1995-2009 period. The data are annual Price Level Indices, or PLI's, constructed by Eurostat as part of the Eurostat-OECD PPP Programme. They give the price of the good heading at a given time and for a given country, relative to the price in the reference country. The level of aggregation of the PLI is at the 'Basic Heading'. Basic Headings are constructed as unweighted averages of product level observations in each country. Basic Headings are then aggregated using expenditure weights to form HICP categories used at a higher level of aggregation. For our purposes, for the full sample 1995-2009, PLI's are available for 146 consumer expenditure headings on goods and services, 36 government expenditure headings, and 32 headings for expenditures on gross fixed capital formation. In this paper, we focus on consumer PLI's. Table A1 gives a list of good categories included in the consumer PLI's. The 1995-2009 sample extends across 18 western European countries. The countries are: Belgium, Germany, Greece, Spain, France, Ireland, Italy, Luxembourg, the Netherlands, Austria, Portugal, Finland, Denmark, Sweden, UK, Iceland, Norway, and Switzerland. In addition, for 1999-2009, we have an identical sample for 13 additional countries, mostly Eastern European[2]. PLI's are derived from Basic Heading-level PPP's, and are measured relative to 15 members of the EU area[3]. The PPP for any country and good is just the ratio of the good price for that country to the average price of that good for the EU15. For the euro area countries (after the euro was launched in 1999), the PLI is just equal to the PPP (multiplied by 100). For non-euro area members, the PLI for the country-good is obtained by dividing the PPP by the exchange rate, relative to the euro, so as to obtain the price in the same units. In each year, the EU15 price for each good is scaled to 100, so prices above 100 for a country-good in any year represents a price above

[2] The countries are Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia, Bulgaria, Romania, and Turkey.

[3] That is, Austria, Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Spain, Sweden, Portugal, Finland, and the United Kingdom.

the EU15 average price. Thus, for each country-good-year, the PLI gives us a measure of the good-level real exchange rate against the EU15. Denote the individual PLI for good $i$, country $j$, time $t$ as $p_{i,j,t}$. Thus, from our definition, we have that:

$$p_{i,j,t} = PPP_{i,j,t}/S_{j,t} = \frac{P_{i,j,t}}{S_{j,t}P^*_{i,t}},$$

where $S_{j,t}$ is the exchange rate of country $j$ against the EU15, $P_{i,j,t}$ is price of good $i$ for country $j$, and $P^*_{i,t}$ is the price of good $i$ for the EU15.

# 3 Characteristics of PLI's

## 3.1 Mean Comparisons across Countries

We first focus on the properties of average (within-country) PLI's. PLI's can be thought of as good-level real exchange rates. Average PLI's then represent a measure of aggregate real exchange rates. Define the aggregate real exchange rate for country j as:

$$p_{j,t} = \frac{1}{N}\sum_{i}^{N} p_{i,j,t}. \tag{1}$$

where $N$ is the number of goods in the aggregate. In this definition, aggregate real exchange rates are unweighted. Eurostat does provide expenditure weights for good categories, but since we wish to focus on deviations from PPP (or the law of one price) at the micro level, we find it more compelling to report unweighted averages of PLI's. In the Appendix, it is shown that the properties of the weighted averages, using expenditure weights, are very similar to those of the unweighted averages.

We also show two measures of the movement in the dispersion of $p_{j,t}$ across countries over time. The first measure is simply the standard deviation:

$$SD_t = \sqrt{\frac{1}{M}\sum_{j}\left(\frac{1}{N}\sum_{i} p_{i,j,t} - \frac{1}{MN}\sum_{j}\sum_{i} p_{i,j,t}\right)^2}.$$

where $M$ is the number of countries in the grouping. Since the PLI's are measured relative to the EU15 scaled average of 100 however, it is possible that the standard deviation for a given group of countries is small, but there is still a significant departure of parity with the EU15. Therefore, we define an alternative measure of dispersion across countries as

$$MAD_t = \text{mean}_j(\text{ABS}(p_{jt} - 100)).$$

If the sample of countries are evenly dispersed above and below the EU15 average, then the two measures will be very close. But $MAD_t$ may be considerably higher than $SD_t$ for a group of countries whose price is far above or below the EU15 average.

We begin by reporting the characteristics of $p_{j,t}$ for the sample of 18 Western European countries. The top left panel of Figure 1 describes the path of $p_{j,t}$ for all 12 countries in the Eurozone, while the bottom left panel shows the prices for the group of 6 countries with independent currencies and floating exchange rates.

It is clear that, even within the Eurozone, and particularly outside the Eurozone, there is a substantial and continuing departure from PPP in the aggregated data. Although there is some tendency for price differentials across countries to narrow over time (as discussed below), this fall in dispersion across countries is very small relative to the departures from overall PPP. The Mean Absolute Deviation for the Eurozone countries goes from 11 percent at the start of the sample to about 6.5 percent by the end, but between the highest price country (Finland) and the lowest (Portugal) there is still a 30 percent real exchange rate differential at the end of the sample. Moreover, all of the fall in real exchange rate dispersion within the Eurozone took place before the euro came into effect in 1999. There has been no significant change in dispersion between 2000 and 2009.[4]

An inspection of Figure 1 reveals interesting patterns among the Eurozone countries and the nature of the convergence in average price levels. Six of the high real exchange rate countries at the beginning of the sample - Germany, France, Belgium, Austria, Luxembourg, and the Netherlands, have persistently depreciating real exchange rates over the sample. Two countries with initially low real exchange rates, Ireland and Italy, have substantial real appreciations over the sample. Ireland went from being below the EU average in 1995 to being considerably above the average by 2007. On the other hand, Greece, Spain, and Portugal show little convergence, with real exchange rates 10-15 percent below the European average for the full sample. Finally, Finland remains an outlier, remaining 15-20% above the EU average over the whole sample.

For the non-Eurozone countries of Western Europe, there is no evidence at all of convergence over time in real exchange rates. For almost all of the sample, these countries have higher prices than the EU average. This leads to the $MAD_t$ measure of dispersion being significantly larger than the $SD_t$ measure. Moreover, as to be anticipated, year to year variation in real exchange rates for the freely floating countries over the sample is much higher than that for the Eurozone countries.

Figure 2 illustrates the PLI's for the additional, Eastern and Southern European countries for the shorter sample of 1999-2009. The key feature of these countries is that their real exchange rates are far lower than the EU average. Nevertheless, there was

[4]A similar point, using a different data-set, is made in Engel and Rogers (2004), and Faber and Stokman (2009). Interestingly however, this conclusion depends solely on the presence of one country: Ireland. Without Ireland, it may be shown that the average dispersion across the Eurozone countries continued to fall slowly even after 1999.

substantial upwards convergence over the sample. The Figure shows that the average deviation from PPP relative to the EU average fell progressively over the sample. This still remains considerably larger than the equivalent measure for the Western European countries however - on average the Western European countries were about 15 percent away from PPP over the whole sample. For the Eastern and Southern European countries, the average was over 34 percent.

Figure 3 describes the full distribution of prices across all goods for the same three groups of countries as in Figures 1 and 2, for three separate periods; 1995 (for EU12 and floaters only), 1999, and 2009, as well as the mean distribution across all years for the three groups[5] . It is clear from the Figure that the differences in the mean PLI's across country groups are quite representative of the full distribution of prices across the groups. The distribution for the floating countries is significantly to the right of the Eurozone countries, and the distribution for the Eastern and Southern European countries is significantly to the left. The dispersion of prices among both the floating economies and the Eastern and Southern European economies is significantly higher than those in the Eurozone. We also see the trends in the distribution over time. For the Eurozone, there is a significant narrowing of the distribution in the pre-euro period (from 1995 to 1999), but not much change afterwards. For the Eastern and Southern European countries, there is a rightward shift in the distribution between 1999 and 2009, as suggested in Figure 2. Finally, we see that the floating economies had a significant shift leftward in 2009 relative to 1999, and a slight tendency to bimodality. This obviously reflects the sharp exchange rate depreciations of some of the floating exchange rate countries (UK and Iceland) after 2008.

Table 1 reports the sample average PLI for each country, the coefficient of variation (CV) over time of aggregate PLI's for each country, as well as the mean of the CV of individual prices within countries. The former CV measures the volatility of the aggregate real exchange rate, while the latter CV measures the average within-country dispersion of prices. The within-country CV for country $j$ for year $t$ is defined as:

$$cv_{j,t} = \frac{\sqrt{\frac{1}{N}\sum_i^N (p_{i,j,t} - p_{j,t})^2}}{p_{j,t}}.$$

The Table confirms the results of Figure 1 and 2; the average departure from PPP for the Eastern and Southern European countries is substantially greater than for either the Eurozone countries or the floating exchange rate economies. Real exchange rate volatility is substantially higher for the floating countries, and for the Eastern and Southern European countries. It is also apparent that the dispersion of prices within countries is much

[5]The distributions in Figure 3 are Kernel density estimates. Note that this distribution treats each good separately, so it contains more disaggregated information than Figure 1 or Figure 2.

greater for Eastern and Southern European countries. The mean CV for these countries is twice that of the Eurozone countries.

Figures 1-3 and Table 1 makes clear that, at both the mean level and at the level of individual goods, there is substantial and continuing deviation from equality within European consumer goods prices. Moreover, average departures from PPP are strongly representative of departures from price parity at the individual good level, for most countries. If a country's average real exchange rate is far above (below) PPP relative to the EU average, almost all individual real exchange rates are above (below) PPP.

Figure 1 indicates that aggregate real exchange rate variability is greater for the floating exchange rate countries. This is consistent with much theoretical and empirical work in international macroeconomics. Interestingly, however, this difference is much less pronounced at the micro level. Table 2 illustrates the average standard deviation over time of real exchange rate changes first for the aggregate real exchange rate, and then at the micro level, across all 146 consumer goods over the full sample, for all countries. At the aggregate level, the standard deviation for euro area members is 1.9 percent, while the standard deviation for the floaters is 4.2 percent By contrast, at the micro level, the average standard deviation across euro area members is 6.7 percent, while among the floating rate countries of Western Europe the average volatility is 8.9 percent. Thus, the proportional difference in real exchange rate adjustment among euro area members and floaters at the disaggregated level is much less than at the aggregate level.[6]

## 3.2 Decomposition into Traded and Non-Traded

Price differentials across countries should be limited by the ability to trade. Although we cannot directly align the individual PLI categories with trade flows, we can roughly decompose categories separately into tradable and non-tradable groups. The Appendix describes how tradability is defined at the good level. Although there is clear evidence that real exchange rate movements are driven by price differentials in all types of goods, both traded and non-traded, there should still be a theoretical presumption that the departures from PPP in real exchange rates are lower in traded goods than in non-traded goods.

Figure 4 shows the separate breakdown of the country level PLI's for traded and non-traded goods for the Eurozone countries. The properties of average traded and non-traded goods PLI's, in terms of deviations from the EU average, are similar to the overall PLI's. Even for traded goods, there is significant and continued departure from PPP in both directions.

[6]This accords with the results of Crucini and Telmer (2007) for city data from EIU.

For the non-traded goods categories we see essentially the same features, except that the magnitude of departures from PPP are substantially greater for the countries both above and below the EU average. Both in cross country comparisons, and in movements over time within countries, the PLI's for non-traded goods follow the pattern displayed both by the aggregate real exchange rate and that for traded goods. For both categories of goods, there is a significant convergence of prices just prior to the euro, and little convergence thereafter. But the key difference is that the average departure from PPP for the Eurozone countries is twice as great for the non-traded goods category as that for traded goods.

Figure 5 show the same results for the floating exchange rate countries of Western Europe. The average departure from PPP is much higher for the non-traded category, although again, there are significant departures from PPP for the traded category, and the time series properties of real exchange rates are essentially identical for both traded and non-traded categories. In terms of convergence in average real exchange rates across countries for these group of countries, the Figure shows that in non-traded goods, there is significant divergence over time, while in traded goods, there is no convergence at all over the whole sample path.

Finally, Figure 6 describes the pattern of movement in traded and non-traded categories for the countries of Eastern and Southern Europe. As for the other groups of countries, there are large and persistent departures from PPP in both categories of goods, but those for traded goods are roughly 50 percent less than for non-traded goods.

Given that retail prices of all goods should contain some non-traded component, the pattern of persistent departures from PPP in both traded and non-traded categories is still consistent with a theory in which the underlying driving force for the real exchange rate is the price adjustment of non-traded relative to traded inputs into production. But if this is true, then we should see that in cross country comparisons, countries with a higher real exchange rate should have higher relative prices of non-traded to traded goods, and correspondingly, in time series observations, countries with a higher rate of real exchange rate appreciation should have a faster rate of increase in non-traded goods to traded goods. Figure 7 and 8 provide very clear confirmation of these two features. Figure 7 illustrates the relationship between the mean real exchange rate over the whole sample, and the mean ratio of the price level for non-traded goods relative to traded goods, on a country by country basis. There is a strong positive relationship in the cross country dimension. The raw correlation between the two series is 0.89. Thus, countries with higher real exchange rates have higher relative prices of non-traded goods, on average. Figure 8 illustrates the equivalent relationship in the time series dimension. It shows the connection between the average rate of real exchange rate appreciation and the average rate of growth of the price of non-traded goods to traded goods over the sample, where each observation represents a different country. Again, there is a strong positive relationship, with the correlation equal to 0.84. This gives us evidence that the real exchange rates among European countries is driven by within-country relative price differentials - both as a comparison among countries, and over time within countries. Moreover, the correlation is very similar in the cross country and time series relationship. These two observations provides key empirical support for the theoretical model we develop below.[7]

## 3.3 Real Exchange Rates and Relative GDP per capita

It is well known that richer countries have higher price levels. This is the 'Penn Effect' (Summers and Heston, 1991). This leads to a positive cross country relationship between real GDP per capita and real exchange rates. Whether the equivalent relationship holds over time is not so clear (see, e.g. Summers and Heston 1988) - do fast growing countries experience trend real exchange rate appreciation? In this section, we investigate the relationship between PLI based real exchange rates and GDP for the European sample. We find that the relationship holds quite closely, both in cross section *and* time series.

Figure 9 illustrates the relationship between relative GDP per capita and country level average real exchange rates for each of the countries in the sample. Relative GDP is defined as US dollar GDP per capita, relative to the EU15 average US dollar GDP per capita[8]. Then, if real exchange rate differentials were driven primarily by differences in income per capita, we should anticipate that countries with GDP per capita equal to the EU average should have real exchange rates at the EU average (i.e. PPP should hold when compared to the EU15). Figure 9 shows that this principle holds fairly accurately for the Western European sample. Belgium, Germany, France, Austria and the Netherlands all have GDP per capita close to the EU average, and the same holds for their real exchange rates. For Greece, Spain and Portugal, real exchange rates and relative GDP's are considerably below the EU average, while the Scandinavian countries, both real GDP per capita and real exchange rates are substantially above the EU average. For most countries, the deviation of GDP per capita from the EU average exceeds that of the real exchange rate, in absolute terms. That is, for the relative poorer countries of Greece, Spain and Portugal, the deviation from PPP is far less than the deviation of GDP per capita. A similar characteristic is seen in the opposite direction for Luxembourg, Switzerland, Norway and the Netherlands; real GDP per capita is proportionally more

[7] The only exception to this is in the *cross country correlation* group of floating exchange rate countries, which separately we find is negative.

[8] Since the purpose is to explore the relationship between GDP per capita and real exchange rates, we use actual GDP per capita rather than PPP adjusted GDP per capita.

above the EU average that are their real exchange rates.

Likewise, for the Eastern and Southern European countries, real GDP per capita is far below the EU average, as is the real exchange rate for these countries, and again, the deviation of the relative price from the EU average is substantially less than that of GDP per capita.

Figures 9 suggests that the relationship between GDP per capita and real exchange rates holds both in the cross section and over time. Across countries, high real exchange rates are associated with higher GDP per capita. But also within countries, movements in relative GDP per capita tend to be associated with movements in real exchange rates in the same direction. This is particularly true for the floating exchange rate countries; i.e. Sweden, UK, Iceland, Norway and Switzerland[9] . Moreover, both across countries and over time, there is a less than proportional response of the real exchange rate to movements in relative GDP.

Figure 10 gives a broader illustration of the relationship between relative GDP and real exchange rates. The figure presents a scatter plot of real exchange rates and GDP per capita over all countries and time periods in the sample. We see a close association, aside from outliers due to Luxembourg, which, from Figure 10, has a relative GDP per capita substantially out of proportion to its real exchange rate[10]. The Figure also supports the observation made above that, unconditionally, the real exchange rate increases by less than in proportion to relative GDP.

# 4 Structural Determinants of Real Exchange Rates

Figure 9 suggests that relative GDP is an important factor in the determination of country-level real exchange rates. This is consistent with a number of alternative theories of real exchange rate determination. The Balassa-Samuelson model (Balassa 1964, Samuelson 1964) predicts that a higher real exchange rate is generated by a higher productivity in the traded relative to the non-traded sectors, expressed relative to the average relative sectoral productivity in the rest of the world (e.g. Obstfeld and Rogoff, 1995). Analogously in the time dimension, faster productivity growth in the traded sector implies

[9]Note, because we are using relative GDP per capita, rather than PPP adjusted GDP, there is a tendency for movements in GDP to follow relative nominal exchange rates, given slow movements in GDP deflators. Hence it is not surprising to see a high correlation between relative GDP per capita and real exchange rates for the floating exchange rate countries. But, as is seen in the Appendix, the relationship between the nominal and real exchange rates for the floating countries is not perfect. This caveat does not apply to the Eurozone countries, of course.

[10]The case of Luxembourg is unique, since most workers in Luxembourg do not live in the country. If we were to use GDP per worker rather than per capita, we would have a much smaller estimate of GDP for Luxembourg.

trend real appreciation. In both cases, higher relative productivity in traded goods implies simultaneously higher relative GDP per capita and a higher real exchange rate. But there are alternative explanations for the link between relative GDP and real exchange rates. Even without differences in productivity sectoral productivity, a country may have a higher real exchange rate if it has higher average productivity, relative to the rest of the world, and the non-traded goods sector is relatively labor intensive. This argument was originally made by Bhagwati (1984).

Both of these arguments are based on 'supply side' models of the real exchange rate. There are alternative 'demand side' models of the relationship between real exchange rates and relative GDP. If the income elasticity of demand for non-traded goods is above unity, at least within a certain range of income per capita comparisons, then growth in national income will tend to push up the relative price of non-traded goods, and lead to a real exchange rate appreciation. This view is developed and tested in Bergstrand (1991). Other demand side determinants of real exchange rates may come from fiscal policy. Government spending in most countries is highly biased towards domestic goods. Other things equal, a higher government spending to GDP ratio should be associated with a higher real exchange rate. An exploration of alternative views of real exchange rates in the cross section is given in Neary (1988), and De Gregario et al. (1994).

Real exchange rates may also be influenced by trade barriers or trade costs. While PPP should hold for pure traded goods in the absence of any restrictions to international trade, empirical studies have identified the existence of significant trade costs (Anderson and Van Wincoop, 2005). As a proxy measure for trade costs, we use distance of the national capital from Frankfurt. To the extent that trade costs are proportional to the shipping distance involved, this should be a roughly accurate representation of the costs of arbitrage over traded goods[11]. As a related measure of the importance of trade, we also allow for trade openness (imports plus exports over GDP) to play a role. Like reduced trade barriers, trade openness is likely to be associated with smaller deviations from PPP. [12].

Finally, we allow for a euro area dummy. The transparency of price comparisons implied by membership of the European single currency area may impart forces towards

[11] Of course it must be noted that the PLI's we are examining are not pure traded goods, but represent measures of retail level prices paid by consumers, which incorporate local service content for distribution, marketing, etc. We do not have information on differences in marketing and distribution across countries however.

[12] Since the PLI measures the price level relative to the EU 15 countries, we should anticipate that reduced openness (or distance) would lead to deviations in the average PLI from the EU 15. But it is not clear in which direction the real exchange rate should deviate. To test for the possibility that openness may have different effects on the real exchange rate for low or high income countries, we also allowed for an interaction term in openness and relative GDP per capita, in addition to openness itself. But this term was insignificant.

price convergence that do not operate for other countries, even if they maintain stable exchange rates vis a vis the euro. Eleven countries entered the euro area at its inception in 1999, followed by 4 more at various dates up to the end of our sample. The Euro variable introduces a dummy for the year and country for which euro membership applies.

Retail prices also include expenditure taxes, notably the VAT, which is levied in all countries in our sample. VAT rates differ among European countries, even for countries within the Eurozone. Because over the sample period, VAT rates have been fixed for most countries, the presence of differential expenditure taxes should be picked up in regressions allowing for fixed effects. In the numerical simulations of the theoretical model developed in Section 5 below, we incorporate differential rates of VAT into the analysis. From the results of that Section, we find that differential rates of VAT can explain at best only a small part of the real exchange rate differentials among European economies.

Table 3 reports results from an OLS regression of country log real exchange rates on log relative GDP per capita, and these other variables, for the full sample[13]. The elasticity of the real exchange rate to relative GDP is highly significant. Relative GDP has an influence on real exchange rates that is important in both the cross section and over time. When country or time fixed effects are included separately, the coefficient on relative GDP is essentially unchanged. A 1 percent increase in relative GDP per capita is associated with a 0.35 percent increase in the real exchange rate. Euro membership is significantly negative, but from an economic point of view, the coefficient is very small. Moreover, the significance of the euro dummy is eliminated when including country fixed effects. This is consistent with the pattern in the figures above, showing that most of the price convergence among euro members took place before entry into the euro system. Distance has a significantly positive coefficient, but again quite small. The government spending ratio is uniformly insignificant. Openness is associated with a lower real exchange rate. Again however, this effect is small.

Table 3 also provides a breakdown of these regressions separately into traded and non-traded goods. The simplest Balassa Samuelson model assumes full PPP in tradable goods. Here we see however that the traded goods real exchange rate is positively associated with relative GDP per capita. Nevertheless, the estimates support the traditional view of the real exchange rate as being driven by relative movements in non-traded to traded goods prices. The traded goods coefficient on relative GDP falls to approximately 0.26, while the analogous coefficient for non-traded rises to 0.57. For tradables, Euro and Distance are still significant in the basic specification, but again, Euro loses significance when country

[13]Table 3's regressions are run in (log) levels. Although the majority of panel unit root tests rejected the null hypothesis of a unit root in the real exchange rate and relative real GDP per capita, we also run the regression in differences in Table 6 below.

fixed effects are allowed. In the non-tradables case, Euro is insignificant even without the inclusion of fixed effects.

Table 4 decomposes the regressions separately for Western Europe and Eastern and Southern Europe. The main message from here is that the relationship between GDP and the real exchange rate is stronger for Western European countries, although still, in all cases, the coefficient is highly significant, both for all goods and for traded and non-traded goods separately. For both sets of countries, the relationship is very similar in time series and cross section, and again for both sets of countries, the coefficient on non-traded goods is substantially higher than that for traded goods.

In the aggregate then, the relationship between real exchange rates and real GDP per capita is very close. But real exchange rates in the aggregate mask considerable heterogeneity among different consumer categories of goods. How much variability at the disaggregated level can be explained by relative GDP per capita? Table 5 reports the results of a regression using all the individual PLI's across all countries and dates. The coefficient on RGDP is very significant, and even higher than before. With or without fixed effects, the elasticity is about 0.4. The striking feature of this regression however is that even at this disaggregated level, the $R^2$ is 0.5. Thus, even at level of disaggregated individual prices, relative GDP, Euro, and Distance can explain 50 percent of the price variability across countries and over time. Moreover, as before, the key message of the averaged regressions prevails; the relationship between relative GDP and the real exchange rate is essentially the same in the time series and cross section dimension.

## 4.1 Conditional Deviations from PPP

In section 2 we noted that there existed substantial and continuing deviations from PPP at all levels of aggregation, both within the Eurozone and between the Eurozone and other European countries. Crucini et al. (2005) argue that, after accounting for GDP per capita, PPP represented a good approximation in European price data, using quite a different data-set than ours, involving a series of non-concurrent cross-samples. Here we revisit this question by asking how the distribution of real exchange rates, *conditioning on relative GDP per capita*, compares with the unconditional distribution. We do this by comparing the unconditional distribution of prices from Figure 3 with the residuals from a projection of prices on relative GDP per capita for each country. Figure 11 illustrates the results. The Figure shows two quite striking characteristics. First, by comparison with Figure 3, the empirical densities of the price distributions are all centred around PPP [14]. That is, conditional on relative GDP, on average there is no deviation from PPP

[14]Note this does not hold by construction. While the residuals from the projection of all prices on income sum to zero, this is not true of the three subgroups of countries individually

across all three groups of countries. The second feature is that among the three groups of countries, the variability of conditional deviations from PPP is substantially smaller than the unconditional variability in Figure 3. That is, within each group, a lot of the deviations from PPP can be attributed to a country's GDP per capita being higher or lower than the average level. This point is further supported by Table 1. The Table reports conditional means of the aggregate PLI's, and the traded and non-traded goods prices[15] . We see that after conditioning on GDP per capita, each country's price level is significantly closer to 100 (PPP). The coefficient of variation of the PLI across time and countries moves from an unconditional value of 26 percent to a conditional value of 12 percent - a fall of 56 percent[16].

### 4.2 Robustness

Tables 6-7 report the results of some alternative specifications. To investigate whether the relationship between relative GDP and real exchange rates is driven by non-stationarity in the series, Table 6 redoes the regressions of Table 3, except now in first differences. The coefficient on relative GDP is still highly significant, and even larger in magnitude, and holds strongly both in time series and cross section[17] Again, the coefficient is very similar across the two frequencies. Table 7 provides regression support for the perspective on the real exchange rate discussed in Section 3. It shows the relationship between the relative price of non-traded goods and relative per capita GDP directly. As suggested by the previous evidence, this relationship is positive and highly significant. Both in time series and cross section, countries with higher levels of relative GDP per capita have higher internal relative price on non-traded to traded goods.

## 5 A Simple General Equilibrium Model

The key features of the data are the strong cross-country and time-series relationship between real exchange rates and relative GDP, and the relationship between real exchange

[15]The conditional means are computed for each country as the average over time of $P_{it} - a - bY_{it} + P_{EU15_t}$, where $a$ and $b$ represent the estimates of a projection of all countries PLIs on relative income per capita (specifically, $P_{ijt} = a + bY_{it} + e_{ijt}$). If relative income per capita could exactly explain each country's real exchange rate, then each conditional mean would be equal to the PLI for the EU15, which is scaled to 100.

[16]This is a magnitude similar to the effects of income adjustment in the Crucini et al (2005), although their absolute measures of departures from PPP differ significantly from ours.

[17]If real exchange rates and relative GDP are non-stationary but cointegrated, then first differencing is not an appropriate specification. However, tests did not support cointegration between real exchange rates and relative GDP in our data set. We did estimate a dynamic model, allowing for lagged values of relative GDP and real exchange rates. The implied long run elasticity of the real exchange rate with respect to relative GDP from this estimation is very close to that of Table 3.

rates, relative GDP, and the relative price of non-traded goods. In general, countries with relative GDP above (below) the EU average have higher (lower) real exchange rates than the EU average, with the deviation in the real exchange rate from the EU average being 35-40 percent of the deviation in relative GDP. The data indicate that the relationship between the real exchange rate and GDP when compared across countries seems to be very similar to the relationship observed over time for any country. In addition, the real exchange rate itself seems to be substantially accounted for by movements in the relative price of non-traded goods.

Are these relationships consistent with a theoretical model of real exchange rate determination? We construct a rudimentary structural model of the real exchange rate to ask this question. To be consistent with the data, the model should be capable of reproducing the relationship between relative GDP per capita and the real exchange rate, in both cross-country and time series dimensions, and have the real exchange rate associated with country differences and movements over time in the relative price of non-traded goods. In the discussion above, we described three models of the relationship between GDP per capita and real exchange rates. The Balassa-Samuelson model relies on differential productivity levels (and growth rates) in the traded relative to the non-traded sector. The Bhagwati model emphasizes GDP differentials (or GDP growth differentials) with non-traded goods being relatively more labour intensive, so that rising domestic wages tend to push up the relative price of non-traded goods in a faster growing economy. Alternatively, a demand side explanation for the relationship is given in Bergstrand (1991), where growing income, combined with an income elasticity of demand for non-traded goods that exceeds unity, leads to a progressive real appreciation associated with growth in per capita GDP.

In all three models, the movement in real exchange rates is accounted for by movements in the relative price of non-traded goods. As discussed above, there has been some empirical support for all of these approaches. The Balassa Samuelson model has received the most attention in empirical studies, with researchers focusing on the link between real exchange rates and different measures of sectoral productivity growth. Evidence in support of the Balassa Samuelson hypothesis is mixed (see, e.g. Asea and Mendoza 1994 and De Gregario et al. 1994). Bergstrand (1991) finds evidence in support of both the demand side hypothesis and the factor intensities hypothesis, while De Gregario et al. (1994) also find links between relative prices of non-traded and demand variables.

With the data on real exchange rates alone, we cannot directly identify the mechanism driving the real exchange rate-relative GDP per capita relationship. We lack adequate data on sectoral productivity measures and factor intensities for all countries in our sample. Moreover, a mechanism based on non-homothetic preferences and differential income elasticities is hard to reconcile with the large variation in incomes per capita across countries in our sample. What matters for our analysis is that relative GDP growth is associated with excess demand for non-traded goods at a given real exchange rate. To this effect, we employ a simple endowment-based assumption for inducing this excess demand and linking it to relative GDP per capita.

Both the Balassa Samuelson model, or the Bhagwati factor-intensity models imply that trend growth increases the relative supply of traded goods to non-traded goods over time. We introduce this link in an endowment economy framework, allowing for differential sectoral growth. Our approach is as follows. We choose the differential sectoral growth in the model so as to be consistent with the estimated elasticity of the real exchange rate to relative GDP over the whole sample. Then, with the other calibrated estimates, we simulate the model for each country in our sample, and compare the simulated real exchange rate to that in the sample. We emphasize that this procedure does not represent a test of a particular model of real exchange rate determination. It may be seen rather as a consistency check. It allows us to investigate whether the properties of real exchange rates across time and countries in a simple theoretical model is consistent with the historical path of real exchange rates. To the extent that model simulations and actual real exchange rate series are close, we may infer that the pattern of European real exchange rates is consistent with basic theories of equilibrium real exchange rates. The essential value added of the exercise is to show that, given a calibration drawn from empirical estimates for *all countries together*, real exchange rates in *each separate country* seem to be driven by the same equilibrium forces [18].

A second insight that this approach can offer is the degree to which the variation of real exchange rates across countries resembles that over time. The theoretical model by construction has the property that the two are the same. To the extent that the implied exchange rates from the model represent the observed path of exchange rates on a country by country basis, the model offers theoretical support for this isomorphism as a property of the data. The particular mechanism that is used in the calibration is discussed at greater length below.

[18] Given the extremely poor performance of almost all models of nominal exchange rates (e.g. Frankel and Rose 1996), it may be seen as a step forward to have a theoretical model which can account for both real exchange rate levels and trends, even if it is calibrated to a specific data set.

## 5.1 The model

We take a two country endowment economy model. Denote the countries as 'Home' and 'Rest of World', with the Home country consumption aggregate defined as

$$C = \left(\gamma^{\frac{1}{\theta}} C_T^{1-\frac{1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_N^{1-\frac{1}{\theta}}\right)^{\frac{\theta}{\theta-1}},$$

where $C_T$ and $C_N$ represent respectively, the composite consumption of tradable and non-tradable goods. The elasticity of substitution between tradable and non-tradable goods is $\theta$. Tradable consumption in turn is decomposed into consumption of home goods (exportable), and foreign goods (importables), as follows:

$$C_T = \left(\omega^{\frac{1}{\lambda}} C_X^{1-\frac{1}{\lambda}} + (1-\omega)^{\frac{1}{\lambda}} C_M^{1-\frac{1}{\lambda}}\right)^{\frac{\lambda}{\lambda-1}},$$

where $\omega$ represents the relative size of the home country, in both population terms, and in the measure of total tradable goods produced in the world economy, and $\lambda$ is the elasticity of substitution between home and foreign traded goods.

These consumption aggregates imply the following price index definitions:

$$P = \left(\gamma P_T^{1-\theta} + (1-\gamma) P_N^{1-\theta}\right)^{\frac{1}{1-\theta}},$$

$$P_T = \left(\omega P_X^{1-\lambda} + (1-\omega) P_M^{1-\lambda}\right)^{\frac{1}{1-\lambda}},$$

where $P_T$ and $P_N$ represent traded and non-traded price levels, and $P_X$ and $P_M$ are retail prices of home exportables and foreign importables. The analogue of the real exchange rate variable $p_{j,t}$ above is defined as the price of the home good, relative to the rest of the world. Thus we define the real exchange rate as:

$$RER = \frac{P}{P^*}$$

where an asterisk indicates the 'Rest of World' price level. Since we are focusing purely on a flexible price model, we abstract from nominal exchange rates. Given that we are primarily interested in accounting for relative prices, and not quantities, we also abstract from endogenous labour supply and capital accumulation. Introducing a single, consistent calibration of growth in the factors of production for all countries in our sample would be infeasible, given the numbers of countries involved. Instead, we take a simpler approach where the output of non-tradable and tradable goods are assumed to evolve exogenously[19].

[19]In fact, this assumption is not so restrictive as it appears at first glance. In the Appendix, we show how the model can be extended to allow for endogenous capital accumulation and inter-sectoral labour mobility, with similar implications for the real exchange rate real GDP per capita relationship as in this simpler model.

While the evidence presented above indicated that real exchange rate movements were associated with movements in the relative price of non-traded, we also found that relative GDP was positively correlated with traded goods prices, although less strongly than for non-traded goods. In order to account for this, we allow for a difference between wholesale and retail prices. Retail goods in the tradable sector are produced using a combination of raw wholesale goods and non-tradable goods as inputs. This captures the presence of a marketing or distribution sector. There is strong evidence for the role of distribution costs in retail pricing of tradable goods (e.g. Corsetti et al. 2008, and references therein). Here, we assume that the production of consumption retail goods in sectors $X$ and $M$ are assembled according to:

$$\begin{aligned} C_X &= \left(\kappa_1 I_X^{(1-\phi_1)} + (1-\kappa_1) I_{XN}^{1-\phi_1}\right)^{\frac{1}{1-\phi_1}} \\ C_M &= \left(\kappa_2 I_M^{(1-\phi_2)} + (1-\kappa_2) I_{MN}^{1-\phi_2}\right)^{\frac{1}{1-\phi_2}} \end{aligned}$$

where $I_X$ $(I_M)$, represents the direct use of wholesale tradable goods in producing retail consumables for $X$ and $M$, respectively, and $I_{XN}$ $(I_{MN})$ represents the use of non-tradable distribution services.

The model is closed with the addition of a home country budget constraint, and goods market clearing conditions. The home budget constraint is given by:

$$PC = P_X Y_X + P_N Y_N, \tag{2}$$

where $Y_X$ $(Y_N)$ indicates output of good $X$ $(N)$, and it is assumed that there is no borrowing or lending across countries.[20]

Goods market clearing conditions are given as:

$$\begin{aligned} \omega Y_X &= \omega I_X + (1-\omega) I_X^*, \qquad (3) \\ (1-\omega) Y_M &= \omega I_M + (1-\omega) I_M^*, \\ Y_N &= C_N + I_{XN} + I_{MN}, \\ Y_N^* &= C_N^* + I_{XN}^* + I_{MN}^*. \end{aligned}$$

[20] It is useful to clarify the nature of the simplification regarding capital markets. In the classic Balassa-Samuelson model, as represented in Obstfeld and Rogoff (1995) for instance, capital is fully mobile, the real interest rate is determined in world capital markets, and the real exchange rate is determined by factor markets, independent of demand considerations. But this model also has the unrealistic implication that there is no necessary link between movements in aggregate consumption and movements in GDP. The model here, by limiting capital mobility, ensures that aggregate consumption and GDP move together. Then the trend in the real exchange rate is determined by the combination of differential endowment growth in combination with growth in consumer demand. We could make the model consistent with the conventional factor market equilibrium interpretation of the Balassa Samuelson model by introducing factor mobility and endogenous capital accumulation as described in footnote 19. This would not alter the essential results of the paper however.

We use the model to look at the relationship between different real exchange rate measures, as defined above, and relative GDP. In the model without investment or government spending, relative GDP is just defined as relative real consumption, or

$$\frac{C}{C^*} = \frac{P_X Y_X + P_N Y_N}{P_M^* Y_M^* + P_N^* Y_N^*} \frac{P^*}{P}. \tag{4}$$

The relationship between the real exchange rate and relative GDP will obviously depend on the calibration of the model, as well as the assumptions about the drivers of GDP growth. Our approach here is to choose the path of endowments $Y_X$, $Y_N$, $Y_M^*$, and $Y_N^*$ to exactly replicate the relative GDP per capita position for each country over the historical sample path. Given the calibration, and simulating the two country equilibrium model, this will imply a path of the real exchange rate for each country. We can then compare the simulated path for the real exchange rate with that of the historical sample path, for each country.

For our calibration, we take a very standard set of parameter values. As regards sectoral shares, we set $\gamma = 0.7$ so that the non-tradable goods sector would represent thirty percent of consumption in a steady state with $P_N = P_T = 1$. Assume that the home country is relatively small as a part of the European economy, so that $\omega = 0.1$. We assume that distribution services make up approximately 30 percent of the value-added in the consumption of retail tradable goods, so that $\kappa_1 = \kappa_2 = 0.7$. This, in combination with $\gamma = 0.7$, implies that in total, non-traded goods would make up 50 percent of total production in a steady state with $P_N = P_T = 1$.

We use the standard assumption of a low elasticity of substitution between tradable and non-tradable goods, in both final consumption and in distribution services. Following Mendoza (1995), we use an elasticity of 0.65. Thus, we set $\lambda = \phi_1 = \phi_2 = 0.65$. Finally, we need to determine the elasticity of substitution between home and foreign goods. If this elasticity is too low, then economic growth will lead to a large terms of trade deterioration and a real exchange rate depreciation, even if growth is quite concentrated in the traded goods sector. The recent literature has emphasized a distinction between short run and long run elasticities of substitution (e.g. Ruhl 2008). For annual data, the international business cycle literature has typically used elasticities lower than the long run estimates. We follow this lead, and set $\theta = 2$. This is lower than estimates of 5 or 6 found in long run trade estimates, but in the range of the estimates used in the macro literature. In fact, the results are not particularly sensitive to different values of $\theta$ in the range of 2 to 5.

We wish to examine the implications of differential *levels* and *growth rates* of relative GDP on real exchange rates. The key requirement is that growth in relative income per capita give rise to excess demand for non-tradables, at given real exchange rates. We introduce this by assuming differential growth rates at the sectoral level. Given all other parameters in the model, the real exchange rate will depend on *cross-country differences* in the relative supply of exportables to non-tradables *within* a country. Even if the home country's GDP per capita was lower than that of the rest of the world, in an endowment economy this would not necessarily imply a lower real exchange rate unless it also implied that the ratio of tradable goods to non-tradable goods, at the wholesale level, was also less than that in the rest of the world. Likewise, growth over time in relative GDP per capita will be associated with real appreciation only if the growth rate of tradable goods exceeds that of non-tradable goods. We emphasize again that, although our model does not include endogenous labour mobility or capital accumulation, a similar dynamic involving relative sectoral output levels would be implied by the Balassa-Samuelson or Bhagwati models with open capital markets (although as noted in footnote 20, the consumption trend in those models would be counterfactual).

Our results above indicate an *empirical* elasticity of the real exchange rate to relative GDP per capita of 0.35 to 0.4, *both* across countries and over time. We use the model to reproduce this elasticity in both dimensions. Since there is no physical capital and no borrowing or lending, then the comparison of two periods with different values of GDP per capita is equivalent to a comparison of two small countries, both interacting with the rest of the world, but one country having the same difference in GDP per capita relative to the other country. While this isomorphism between cross section and time series perspective is not *a priori* an obvious choice, the evidence for our sample, both in Figure 10 and in Table 3, provides quite strong support for taking such a perspective.

The key aspect of the model calibration is to determine the relationship between growth in real GDP per capita and movements in the real exchange rate. Without loss of generality, we set the ratio of $Y_M$ to $Y_N^*$ in the rest of the world to unity, and assume a zero growth rate in $Y_M$ and $Y_N^*$. This is simply a benchmark for comparison with the home economy, and conveniently accords with the data, which is expressed in relative terms. Then, we assume that process for $Y_N$ in the home economy is given by:

$$Y_N = aY^b, \tag{5}$$

where $a$ is a constant, $Y$ is real GDP per capita, relative to the rest of the world, and $b$ satisfies $0 \leq b \leq 1$. The solution procedure involves pre-assigning $Y$, substituting for (5), and then solving (2),(3), and (4) for the 6 variables $C$, $C^*$, $P_N$, $P_N^*$, $P_M^*$, and $Y_X$, with the home traded good $Y_X$ taken as the numeraire. The combination of parameters $a$ and $b$ determine the level and the slope of the real exchange rate locus as a function of $Y$, for any given time, or the evolution of the real exchange rate over time, as $Y$ moves along its historical path. More specifically, if we take the case $a = Y_M = Y_N^* = 1$, then for $Y = 1$, it must be that $RER = 1$, since all endowments are equal across sectors and countries in this case, and by symmetry, full PPP holds. On the other hand, if $b = 1$ then the real exchange rate is constant (not necessarily equal to unity, unless $a = 1$ also), since $Y_N$ and $Y_X$ then move in proportion to one another as relative GDP per capita ($Y$) moves. The model simulation then involves choosing the path of $Y_X$ to reproduce the historical series for $Y$, given the condition (5). Lower values of $b$ reduce the proportionate response to $Y_N$ to changes in $Y$ as $Y_X$ changes, and as a consequence, involve a *higher* elasticity of the real exchange rate to $Y$. Intuitively, for a low value of $b$, movements in $Y_X$ are not accompanied by proportional movements in $Y_N$ and hence must be accompanied by greater relative price change.

Since the evidence suggests that, on average, countries with GDP per capita above the EU average (below the EU average) have real exchange rates above (below) unity, in what follows, we choose $a = 1$ as a level benchmark. This ensures that the average country has a real exchange rate equal to unity. This leaves the parameter $b$ to be chosen. The estimates above suggest that the elasticity of the real exchange rate to relative GDP in the cross section and time dimension is between 0.35 and 0.4. The choice of $b$ will determine this elasticity in the model. The elasticity is not independent of the value of $Y$ itself however. For given $b$, the elasticity is higher, for higher $Y$[21]. We choose $b = .7$. This value reproduces an elasticity of 0.39 at the symmetric point $Y = RER = 1$.

Figure 12 illustrates the workings of the model for a case where the home economy is growing relative to the rest of the world at 4 percent per year. The Figure illustrates the path of the home country's relative GDP and the real exchange rate. The second panel of the Figure illustrates the analogue of the empirical elasticity of the real exchange rate to relative GDP. It is the ratio of the rate of change of the real exchange rate to the rate of change of relative GDP per capita, as a function of relative GDP per capita (on the x-axis) [22].

We now take this calibration and apply it to the observed GDP data for all countries in the sample. We use exactly the same calibration for all countries, but solve the model as described above so as to reproduce the observed movements in relative GDP per capita for each country. As discussed above, the point of the exercise is to explore whether a rudimentary model, calibrated in line with the aggregate estimated relationship between real exchange rates and relative GDP, is consistent with the cross country and time series pattern of real exchange rates for all countries in the sample.

Figures 13-15 report the results for the three groups of countries. Figure 13 gives the

[21]This is in fact consistent with the estimates from Table 3 and 4. The estimated elasticities are higher for countries with higher relative GDP per capita.

[22]Note that the model implies that (as we found in the data) the elasticity is higher for higher levels of relative GDP per capita.

path of relative GDP per capita, the historical sample path of the real exchange rate, and the simulated model-generated real exchange rate for the Eurozone countries. The evaluation of the model hinges on the closeness of the sample path and the simulated real exchange rates. For all countries except Finland and Luxembourg, the average simulated model real exchange rate is close to the sample average. That is, the model gets the levels right in most cases. In particular, Greece, Spain and Portugal, with relative GDP per capita significantly below the European average, have real exchange rates about 15-20 percent below the European average. The model represents this very accurately. Likewise the average sample and simulated real exchange rates are very close for the Western European countries.

Of key interest however is the question of how the model tracks the time path of real exchange rate movements. That is, can the model track the dynamics of the real exchange rate? For most countries, the answer is yes. The Western European countries that experienced persistent depreciation for most of the sample were Belgium, Germany, Austria, France, and the Netherlands. The simulated real exchange rates very closely track the historical sample for Belgium Germany and Austria, and are quite close for France and somewhat less close for the Netherlands. As these countries experienced declines in their relative GDP per capita, the magnitude of real exchange rate depreciation implied by the model is very accurately accounted for by the model. At the end of the sample, these declines in relative GDP were reversed somewhat (after 2008), resulting in real exchange rate appreciations, which are also reflected by the model. Conversely, the model very accurately tracks the sustained path of real appreciation in Ireland, following the transition in relative GDP from below the European average to above the European average. The post-2008 real depreciation is also seen in the model simulation. In both cases (i.e. for Western European countries and for Ireland), we see exactly the same transition in the model as in the data - for countries moving from below (above) the European average to above (below) the European average, the real exchange rate follows the same process, and the relative GDP line cuts the RER locus from below (above).[23]

Figure 14 presents the same information for the floating exchange rate countries. The model-generated real exchange rate for Switzerland is very close to that in the data. For the UK, the model real exchange rate follows the rising income over the sample path, but fails to account for the extent of the UK real appreciation in the late 1990's, but then does capture the post 2008 real depreciation. For the Scandinavian countries: Iceland, Sweden, Norway, and Denmark, the sample real exchange rate is substantially above that

[23]Italy presents a puzzle, from the point of view of the model. Italy experienced considerable real appreciation over the sample, almost as much as Ireland. But Italy's relative per capita GDP growth stalled in the late 1990's, and thereafter fell back. This is not seen in the path of the Italian real exchange rate.

produced by the model simulation - as was the case for Finland in Figure 20. It seems that prices in these countries are much higher than could be accounted for by the basic sectoral demand effects generated by our model. When we extend the analysis to allow for differential rates of VAT below however, the model offers an improved picture for these countries.

Figure 15 illustrates the path of real GDP, simulated and sample real exchange rates for the countries of Eastern and Southern Europe over the shorter, 1999-2009 sample. As we noted previously, these countries have very low real exchange rates relative to the EU15. Despite this, the model-simulated exchange rate fits remarkably well for most countries. With the exception of Cyprus, Turkey, and Malta, in all cases, the average real exchange rate produced by the model over the sample is very close to that in the data, so that, in level terms, the model can quite accurately account for the real exchange rates for Eastern and Southern European countries. But in addition, in all cases, the model quite accurately captures the process of real appreciation over the sample path. In the model, this is driven by the catch-up process of economic growth, reflected by the historical sample path of increasing relative GDP per capita for these countries.

From these three groups of countries we may conclude that a bare-bones, rudimentary endowment economy model of real exchange rate determination, driven by differential sectoral growth rates, produces a real exchange rate path remarkably close to the observed historical sample path of real exchange rates for most of the 31 European countries in our sample. It is worth noting again that the model simulations are not calibrated country by country. In each case, the simulated model is based on exactly the same calibration. Moreover, the key driver of the real exchange rate in all cases is the assumption implicit in equation (5), which contains only a single parameter - the elasticity of the growth rate of non-tradable goods to changes in real GDP. We set this parameter to 0.7, the same for all 31 countries, independently of substantial differences in per capita GDP levels across countries. Despite this extreme simplicity in calibration, the model does a very good job of reproducing both the levels and time paths of most countries' real exchange rates. Our interpretation of these results is not necessarily as a test of a model of exchange rate determination, but rather as a consistency check, indicating that the pattern of real exchange rates in European countries is consistent with a basic economic model. We emphasize that the results of these simulations are not automatically implied from the regression evidence from section 3. The key value added is that the single calibration based on aggregate data works well for almost all countries separately.

One important issue we have not dealt with up to now is the presence of differential tax rates on goods across European countries. VAT rates and other expenditure taxes are not identical in the 31 economies in our sample. This will make a difference to the price comparisons, since retail prices are measured inclusive of taxes. In the initial simulations reported in Figures 13-15, we ignored expenditure taxes. While all countries make extensive use of VAT as a revenue raising device, the tax rates differ considerably across countries. Southern European countries such as Greece, Spain and Portugal generally have low rates of VAT, while Scandinavian countries have high VAT rates. Table A2 of the Appendix shows estimates of VAT rates for the full sample of countries.

How does the presence of VAT affect our results for the real exchange rate? In the Appendix, we explore this by incorporating VAT explicitly into the model. We make the simplifying assumption that VAT is set at a uniform rate on all goods, domestic and imported. Thus, taxes do not affect the relative price of any good faced by consumers in the model. It then follows that we can adjust the real exchange rates implied by the model by the difference between each countries effective VAT rate and that of the European average.

Figures A6 - A8 of the Appendix illustrate the results when the model is extended to allow for differential VAT rates. The adjustment affects only the levels, and not the rate of changes of the simulated real exchange rates. Broadly speaking, the results are as before. The main difference is that the real exchange rates of the Scandinavian countries no longer look so anomalous, relative to the model-generated real exchange rates. In particular, Norway's model generated real exchange rate is very close to that of the historical sample. On the other hand, for some European countries (e.g. France, and Germany) the model generated real exchange rate is somewhat less than that of the historical sample. Among the floating exchange rate countries, Switzerland's real exchange rate now looks somewhat anomalous, since Switzerland has a relatively low VAT rate. Finally, the results for the Eastern and Southern European countries are not much changed. Overall, we can conclude that the incorporation of differential VAT rates into the model does not substantially change the good performance of the model in accounting for the pattern of real exchange rates in Europe.

We have assumed that relative GDP is positively correlated with the relative supply of traded goods to non-traded goods. How reasonable is this assumption? It is difficult to answer this question accurately because we do not have good measures of sectoral output levels arranged by the degree of tradability of each sector. But we may obtain partial information by looking at differences across countries in relative sectoral growth rates. We constructed sectoral measures using the main aggregates tables of the OECD Structural Analysis Database for 25 countries in our sample. Traded goods are defined as the national-currency real sectoral output of agriculture, fishing, industry and construction (sectors A, B, C, D, E and F). Non-traded goods output is the national-currency real output of wholesale and retail trade, repair, hotels and restaurants, transport, financial intermediation, real estate, and other service activities (sectors G, H, I, J, K, L, M, N, O and P). As with our measure of relative GDP, sectoral output of traded to non-traded goods is expressed relative to the EU15 average. Figure 16 shows that, on average, faster growing countries have higher growth rates of traded goods relative to non-traded goods. There is a positive correlation between the average growth rate in relative sectoral output of traded to non-traded goods, and the average growth rate of GDP. The correlation is 0.59.

# 6 Conclusions

This paper has explored the characteristics of European real exchange rates at both an aggregated and disaggregated level, using a new data set on prices of a large number of consumer goods for a broad sample of European countries over a thirteen year period. The key advantage of the data-set is that it allows for an explicit comparison of price levels across countries, so that we can explore the characteristics of real exchange rates in the cross section and the time series. Our results showed that there is a substantial departure from the PPP at both the aggregate and disaggregate levels, both in the euro area countries and the non-euro countries. Moreover, with the exception of the emerging Eastern European countries, there is little in the data to suggest that departures from PPP are diminishing over time.

While real exchange rates display continuing departure from PPP, we find that both in the cross section and time series, relative GDP per capita can explain a substantial part of the variation in European real exchange rates, for both the Eurozone countries, the floating exchange rate countries, and the emerging countries of Eastern Europe. Moreover, while the data indicate substantial departures from PPP for all categories of goods, both traded and non-traded, the departures are uniformly greater for the non-traded category. Moreover, movements in real exchange rates are strongly positively with growth in the relative price of non-traded to to traded goods.

We employed a simple textbook general equilibrium model of the real exchange rate, in which real exchanges were driven by differential growth rates in traded relative to non-traded sectors. When we simulate the model to match the historical sample path of relative GDP for each country in our sample, we find that, for most countries, the implied path of the real exchange rate is remarkably close to the sample real exchange rate, both in levels and rates of change over time. While the mechanism driving real exchange rates in our model is of a reduced form type, the success of the model in accounting for levels and trends in real exchange rates suggests that there is good potential for further research directed at uncovering the specifics of real exchange rate determination in European countries.

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**Table 1. Average price level, dispersion of prices, and income**

| | $\bar{P}_i$ | $\bar{P}_{i,T}$ | $\bar{P}_{i,NT}$ | $\tilde{P}_i$ | $\tilde{P}_{iT}$ | $\tilde{P}_{iN}$ | CV($P_i$) | $\overline{CV}(p_{ij})$ | $\bar{Y}$ |
|---|---|---|---|---|---|---|---|---|---|
| Belgium | 100 | 100 | 102 | 101.6 | 99.4 | 106.0 | 2.2 | 15 | 109 |
| Germany | 101 | 98 | 106 | 101.7 | 97.8 | 109.4 | 3.7 | 17 | 109 |
| Greece | 87 | 94 | 73 | 106.3 | 107.2 | 104.6 | 4.1 | 25 | 61 |
| Spain | 86 | 89 | 82 | 101.3 | 98.4 | 107.1 | 3.1 | 18 | 73 |
| France | 102 | 100 | 107 | 103.6 | 99.6 | 111.8 | 3.6 | 17 | 104 |
| Ireland | 107 | 107 | 108 | 103.1 | 102.7 | 103.9 | 6.1 | 19 | 123 |
| Italy | 97 | 99 | 93 | 105.1 | 104.1 | 107.2 | 4.3 | 20 | 91 |
| Luxembourg | 103 | 99 | 110 | 58.9 | 65.2 | 46.5 | 2.4 | 21 | 230 |
| Netherlands | 96 | 96 | 98 | 94.9 | 93.1 | 98.3 | 2.3 | 17 | 116 |
| Austria | 103 | 100 | 109 | 102.3 | 98.4 | 109.9 | 3.6 | 16 | 114 |
| Portugal | 86 | 91 | 75 | 107.7 | 106.4 | 110.3 | 1.4 | 23 | 54 |
| Finland | 116 | 114 | 122 | 116.8 | 112.8 | 124.7 | 1.9 | 18 | 111 |
| Sweden | 118 | 114 | 125 | 113.2 | 109.4 | 120.7 | 5.6 | 20 | 124 |
| Denmark | 130 | 128 | 136 | 118.9 | 118.0 | 120.7 | 1.3 | 20 | 143 |
| United Kingdom | 104 | 100 | 112 | 105.8 | 100.1 | 117.1 | 9.2 | 23 | 107 |
| Iceland | 129 | 134 | 120 | 121.4 | 126.6 | 111.2 | 12.0 | 27 | 133 |
| Norway | 139 | 136 | 145 | 115.0 | 116.9 | 111.3 | 4.6 | 24 | 178 |
| Switzerland | 124 | 117 | 138 | 105.0 | 101.3 | 112.3 | 5.5 | 23 | 161 |
| Cyprus | 94 | 101 | 78 | 110.7 | 112.9 | 106.4 | 0.8 | 28 | 68 |
| Czech Republic | 62 | 74 | 40 | 91.4 | 94.2 | 85.9 | 11.5 | 40 | 35 |
| Estonia | 68 | 76 | 50 | 99.0 | 98.7 | 99.4 | 7.4 | 34 | 29 |
| Hungary | 64 | 74 | 45 | 95.3 | 95.9 | 94.0 | 9.2 | 36 | 30 |
| Latvia | 66 | 76 | 47 | 100.2 | 100.0 | 100.5 | 8.0 | 38 | 22 |
| Lithuania | 61 | 71 | 43 | 95.5 | 95.0 | 96.3 | 7.9 | 39 | 22 |
| Malta | 83 | 92 | 65 | 108.0 | 109.7 | 104.6 | 3.1 | 38 | 46 |
| Poland | 65 | 73 | 49 | 98.2 | 96.7 | 101.1 | 8.5 | 35 | 24 |
| Slovakia | 61 | 73 | 39 | 93.7 | 95.6 | 90.0 | 16.2 | 41 | 27 |
| Slovenia | 79 | 86 | 64 | 101.0 | 101.4 | 100.2 | 4.3 | 23 | 54 |
| Bulgaria | 53 | 64 | 31 | 91.1 | 91.5 | 90.5 | 7.3 | 51 | 11 |
| Romania | 56 | 67 | 33 | 93.0 | 93.9 | 91.2 | 13.0 | 53 | 13 |
| Turkey | 71 | 83 | 47 | 106.1 | 108.1 | 102.1 | 9.2 | 50 | 19 |
| Average | 91 | 94 | 84 | 102.1 | 101.6 | 103 | 5.9 | 28 | 73 |
| C.V. | 26% | 20% | 39% | 12% | 11.4% | 14.5% | | | |

$P_i$ is the real exchange rate of country $i$ relative to EU15 (=100). $P_N$ and $P_{NT}$ represent the average price of traded and non-trade goods, respectively. $p_{ij}$ is the price of good j in country i. $\tilde{P}_i$ is the average RER conditional on differences in GDP per capita (similarly for $\tilde{P}_{iT}$ and $\tilde{P}_{iN}$). $CV(P_i)$ is the coefficient of variation (CV) of the aggregate real exchange rate, and $\overline{CV}(p_{ij})$ is the average (over time) CV of all relative prices in a country $i$. $Y_i$ is GDP per capita of country $i$ relative to the average of EU15 (=100). C.V. in last row refers to coefficient of variation across both time and countries. For $\tilde{P}$ measures this row reports STD (the average value of $\tilde{P}$ is 0 by construction). The sample period is 1995-1999 for the first 18 countries, and 1999-2009 for the last 13 countries.

**Table 2**

**Panel A: Standard deviations of aggregate real exchange rates**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Belgium | 1.8 | Netherlands | 2.0 | Cyprus | 1.1 | Slovenia | 1.1 |
| Denmark | 1.3 | Austria | 1.3 | Czech Rep. | 4.9 | Bulgaria | 2.7 |
| Germany | 1.2 | Portugal | 0.8 | Estonia | 2.9 | Romania | 6.5 |
| Greece | 2.7 | Finland | 1.7 | Hungary | 5.1 | Turkey | 12.5 |
| Spain | 1.8 | Sweden | 3.3 | Latvia | 5.8 | | |
| France | 1.7 | United Kingdom | 5.6 | Lithuania | 4.3 | | |
| Ireland | 3.3 | Iceland | 8.1 | Malta | 2.6 | | |
| Italy | 3.0 | Norway | 3.8 | Poland | 9.3 | | |
| Luxembourg | 1.6 | Switzerland | 3.4 | Slovakia | 4.0 | | |

**Panel B: Mean standard deviation of disaggregated real exchange rates**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Belgium | 6.2 | Netherlands | 7.1 | Cyprus | 6.5 | Slovenia | 7.5 |
| Denmark | 7 | Austria | 5.7 | Czech Rep. | 6.9 | Bulgaria | 5.8 |
| Germany | 5.5 | Portugal | 7.8 | Estonia | 5.5 | Romania | 7.8 |
| Greece | 7.7 | Finland | 6.1 | Hungary | 7.8 | Turkey | 6.1 |
| Spain | 6.1 | Sweden | 8.2 | Latvia | 5.9 | | |
| France | 6.3 | United Kingdom | 9.7 | Lithuania | 6.7 | | |
| Ireland | 7.7 | Iceland | 13.2 | Malta | 7.2 | | |
| Italy | 7.6 | Norway | 8.8 | Poland | 7.1 | | |
| Luxembourg | 6.5 | Switzerland | 6.4 | Slovakia | 6.9 | | |

## Table 3. Price level regressions, average country price

| | All goods and services | | | Traded goods | | | Non-traded goods | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pooled | Country FE | Period FE | Pooled | Country FE | Period FE | Pooled | Country FE | Period FE |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| log(RGDP) | **0.35***** | **0.33***** | **0.36***** | **0.26***** | **0.3***** | **0.26***** | **0.57***** | **0.51***** | **0.57***** |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| Euro dummy | **-0.06***** | -0.01 | **-0.08***** | **-0.07***** | -0.001 | **-0.07***** | -0.03 | -0.01 | -0.04 |
| | (0.00) | (0.58) | (0.00) | (0.00) | (0.94) | (0.00) | (0.17) | (0.46) | (0.16) |
| log(Distance) | **0.08***** | – | **0.08***** | **0.1***** | – | **0.1***** | **0.05*** | – | **0.05*** |
| | (0.00) | | (0.00) | (0.00) | | (0.00) | (0.07) | | (0.09) |
| G/Y | 0.06 | 0.04 | 0.07 | – | – | – | 0.06 | 0.09 | 0.06 |
| | (0.4) | (0.63) | (0.37) | | | | (0.54) | (0.43) | (0.55) |
| Openness | **-0.04***** | **-0.07**** | **-0.04***** | **-0.02**** | **-0.05*** | -0.02 | **-0.09***** | **-0.11**** | **-0.09***** |
| | (0.00) | (0.03) | (0.00) | (0.02) | (0.07) | (0.2) | (0.00) | (0.00) | (0.00) |
| $\overline{R}^2$ | 0.95 | 0.98 | 0.95 | 0.91 | 0.96 | 0.92 | 0.96 | 0.99 | 0.96 |
| N | 397 | 365 | 397 | 408 | 408 | 397 | 397 | 397 | 397 |

Dependant variable: Logarithm of price level relative to EU15. All standard errors computed using Arellano (1987) adjustment of White's HCCM. p-values in parentheses. A * denotes 10%, ** 5% and *** 1% significance.

## Table 4. Price level regressions (average price) by country group

| | Western Europe | | | | | | Southern and Eastern Europe | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | All | | Traded goods | | Non-traded goods | | All | | Traded goods | | Non-traded goods | |
| | Pool | FE | Pool | FE | Pool | FE | Pool | FE | Pool | FE | Pool | FE |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| log(RGDP) | **0.46***** | **0.44***** | **0.40***** | **0.38***** | **0.6***** | **0.58***** | **0.29***** | **0.32***** | **0.23***** | **0.29***** | **0.48***** | **0.48***** |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| Euro dummy | **-0.03***** | -0.004 | **-0.03***** | -0.002 | **-0.04**** | -0.01 | **0.08***** | **0.05***** | **0.05***** | **0.03***** | **0.17***** | **0.08***** |
| | (0.00) | (0.7) | (0.01) | (0.9) | (0.02) | (0.43) | (0.00) | (0.00) | (0.00) | (0.38) | (0.00) | (0.00) |
| log(Distance) | **0.09***** | – | **0.11***** | – | 0.03 | – | **0.11***** | – | **0.1***** | – | **0.17***** | – |
| | (0.00) | | (0.00) | | (0.21) | | (0.00) | | (0.00) | | (0.00) | |
| G/Y | 0.12 | 0.08 | 0.11 | 0.02 | **0.16*** | **0.19***** | 0.005 | 0.002 | – | – | 0.03 | -0.07 |
| | (0.11) | (0.34) | (0.15) | (0.85) | (0.08) | (0.00) | (0.96) | (0.99) | | | (0.82 | (0.8) |
| Openness | **-0.06***** | **-0.07*** | **-0.04**** | -0.05 | **-0.1***** | **-0.11**** | **-0.03**** | -0.05 | **-0.04*** | -0.04 | **-0.08*** | **-0.11*** |
| | (0.00) | (0.07) | (0.03) | (0.2) | (0.00) | (0.03) | (0.05) | (0.34) | (0.07) | (0.38) | (0.08) | (0.08) |
| $\overline{R}^2$ | 0.88 | 0.95 | 0.84 | 0.93 | 0.88 | 0.96 | 0.92 | 0.93 | 0.86 | 0.89 | 0.91 | 0.96 |
| N | 265 | 265 | 265 | 265 | 265 | 265 | 132 | 132 | 143 | 143 | 132 | 132 |

Dependant variable: Logarithm of price level relative to EU15. "FE" denotes a country fixed effect regression. All standard errors computed using Arellano (1987) adjustment of White's HCCM to remove problems related to serially correlated error terms. p-values in parentheses. Data sources: *PLI*: OECD-Eurostat PPP program; *RGDP*: IMF World Economic Outlook, October 2010; $G/Y$ and *Openness*: OECD STAN database, online.

**Table 5. Price level regressions, all prices**

| | All goods | | | Traded | | Non-Traded | |
|---|---|---|---|---|---|---|---|
| | Pooled | Country dummies | | Pooled | CD | Pooled | CD |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| log(RGDP) | **0.39**$^{***}$ | **0.42**$^{***}$ | **0.42**$^{***}$ | **0.28**$^{***}$ | **0.35**$^{***}$ | **0.62**$^{***}$ | **0.58**$^{***}$ |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| Euro dummy | **-0.04**$^{***}$ | -0.001 | -0.001 | **-0.05**$^{***}$ | -0.0002 | -0.01 | -0.004 |
| | (0.00) | (0.7) | (0.7) | (0.00) | (0.96) | (0.11) | (0.60) |
| log(Distance) | **0.1**$^{***}$ | – | 0.21 | **0.1**$^{***}$ | – | **0.11**$^{***}$ | – |
| | (0.00) | | (0.15) | (0.00) | | (0.00) | |
| $R^2$ | 0.47 | 0.49 | 0.49 | 0.43 | 0.45 | 0.69 | 0.72 |
| N | 60,298 | 60,298 | 60,298 | 40,061 | 40,061 | 20,237 | 20,237 |

Dependant variable: Logarithm of price level relative to EU15. p-values in parentheses, computed using Newey-West standard errors. A * denotes 10%, ** 5% and *** 1% significance.

**Table 6. Price level regressions in differences**

| | Pooled | Country FE | Period FE |
|---|---|---|---|
| | 1 | 2 | 3 |
| d(log(RGDP)) | **0.52**$^{***}$ | **0.58**$^{***}$ | **0.53**$^{***}$ |
| | (0.00) | (0.00) | (0.00) |
| Euro dummy | **0.0006**$^{***}$ | **0.0007**$^{**}$ | **0.0006**$^{**}$ |
| | (0.01) | (0.01) | (0.03) |
| log(Distance) | **-0.004**$^{**}$ | – | **-0.004**$^{**}$ |
| | (0.03) | | (0.05) |
| d(log(G/Y)) | 0.09 | **0.11**$^{*}$ | 0.09 |
| | (0.11) | (0.08) | (0.15) |
| d(log(Open)) | **-0.17**$^{***}$ | **-0.15**$^{**}$ | **-0.15**$^{**}$ |
| | (0.01) | (0.03) | (0.03) |
| $\bar{R}^2$ | 0.61 | 0.61 | 0.62 |
| N | 367 | 367 | 367 |

Dependant variable: Difference of logarithm of price level relative to EU15. "FE" denotes a country fixed effect regression. p-values in parentheses. A * denotes 10%, ** 5% and *** 1% significance. All standard errors computed using Arellano (1987) adjustment of White's HCCM, which is robust to serial correlation of error terms. Data sources: *PLI*: OECD-Eurostat PPP program; *RGDP*: IMF World Economic Outlook, October 2010; *G/Y* and *Openness*: OECD STAN database, online.

**Table 7. Relative price ($P_N/P_T$) regressions**

| | Pooled 1 | Country FE 2 | Period FE 3 |
|---|---|---|---|
| log(RGDP$_t$) | **0.30**$^{***}$ | **0.20**$^{***}$ | **0.29**$^{***}$ |
| | (0.00) | (0.00) | (0.00) |
| Euro dummy | 0.022 | -0.005 | 0.03 |
| | (0.28) | (0.39) | (0.21) |
| log(Distance) | -0.04 | – | -0.04 |
| | (0.12) | | (0.15) |
| log(G/Y) | -0.0004 | 0.05 | -0.003 |
| | (0.99) | (0.52) | (0.96) |
| log(Open) | **-0.12**$^{***}$ | **-0.12**$^{***}$ | **-0.12**$^{***}$ |
| | (0.00) | (0.01) | (0.00) |
| LR elast. | **0.30**$^{***}$ | **0.20**$^{***}$ | **0.29**$^{***}$ |
| $\bar{R}^2$ | 0.92 | 0.98 | 0.92 |
| N | 397 | 397 | 397 |

Dependant variable: Logarithm of $P_N/P_T$ relative to EU15. "FE" denotes a country fixed effect regression. p-values in parentheses. A * denotes 10%, ** 5% and *** 1% significance. All standard errors computed using Arellano (1987) adjustment of White's HCCM, which is robust to serial correlation of error terms. Data sources: *PLI*: OECD-Eurostat PPP program; *RGDP*: IMF World Economic Outlook, October 2010; $G/Y$ and *Openness*: OECD STAN database, online.

Figure 1: Average PLI's in the countries of western Europe

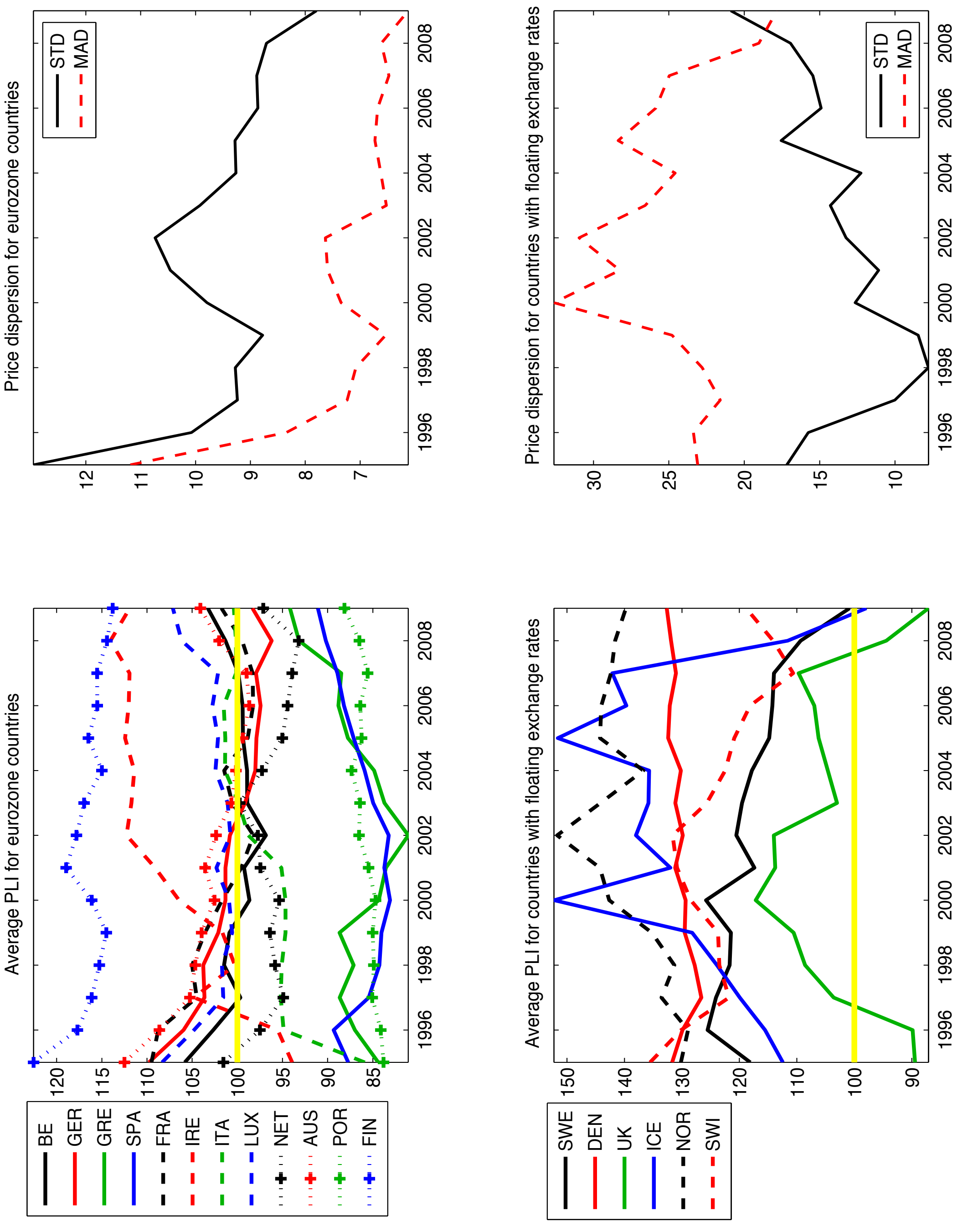

Figure 2: Average PLI's in Southern and Eastern Europe

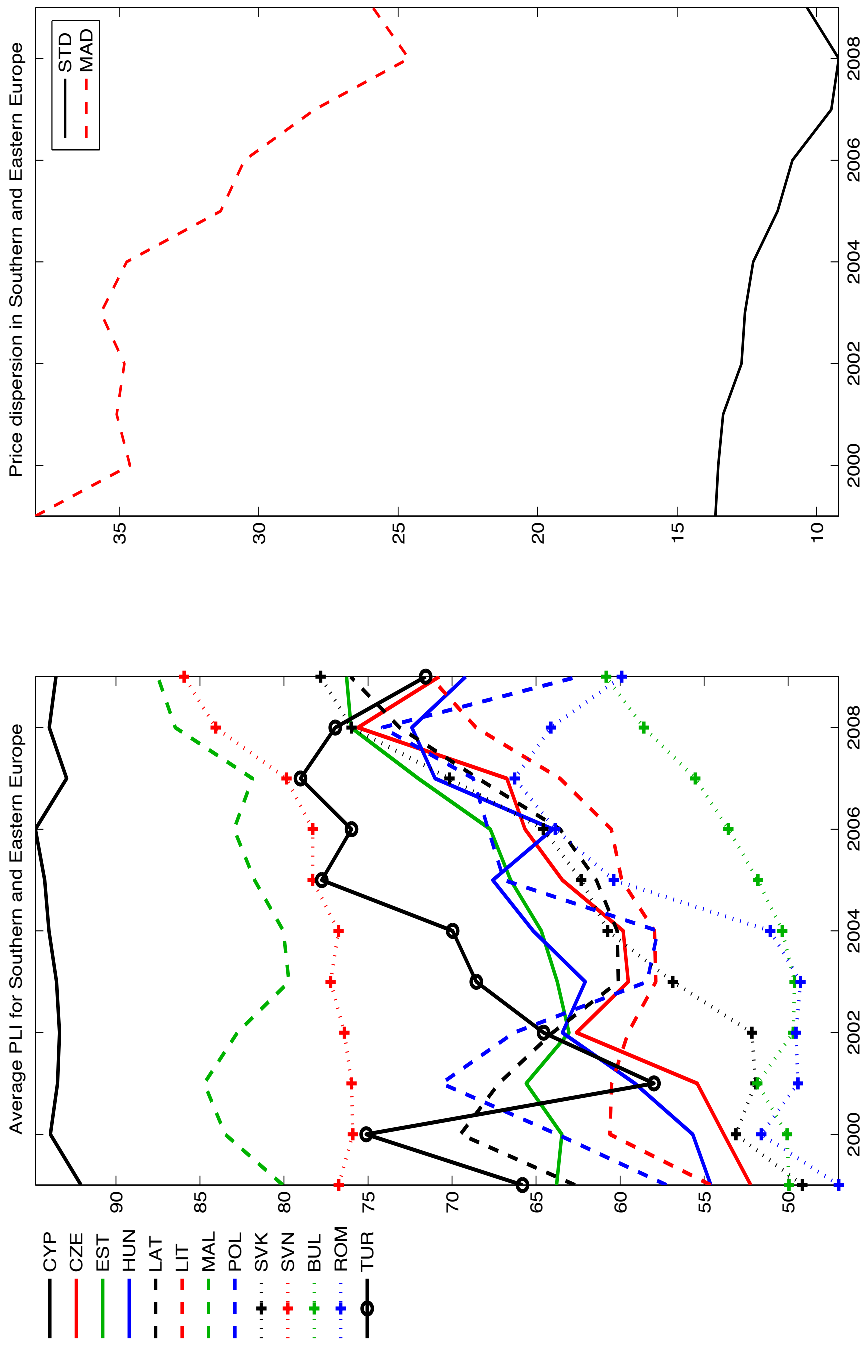

Figure 3: Kernel density estimates of prices for all goods within a country group by year

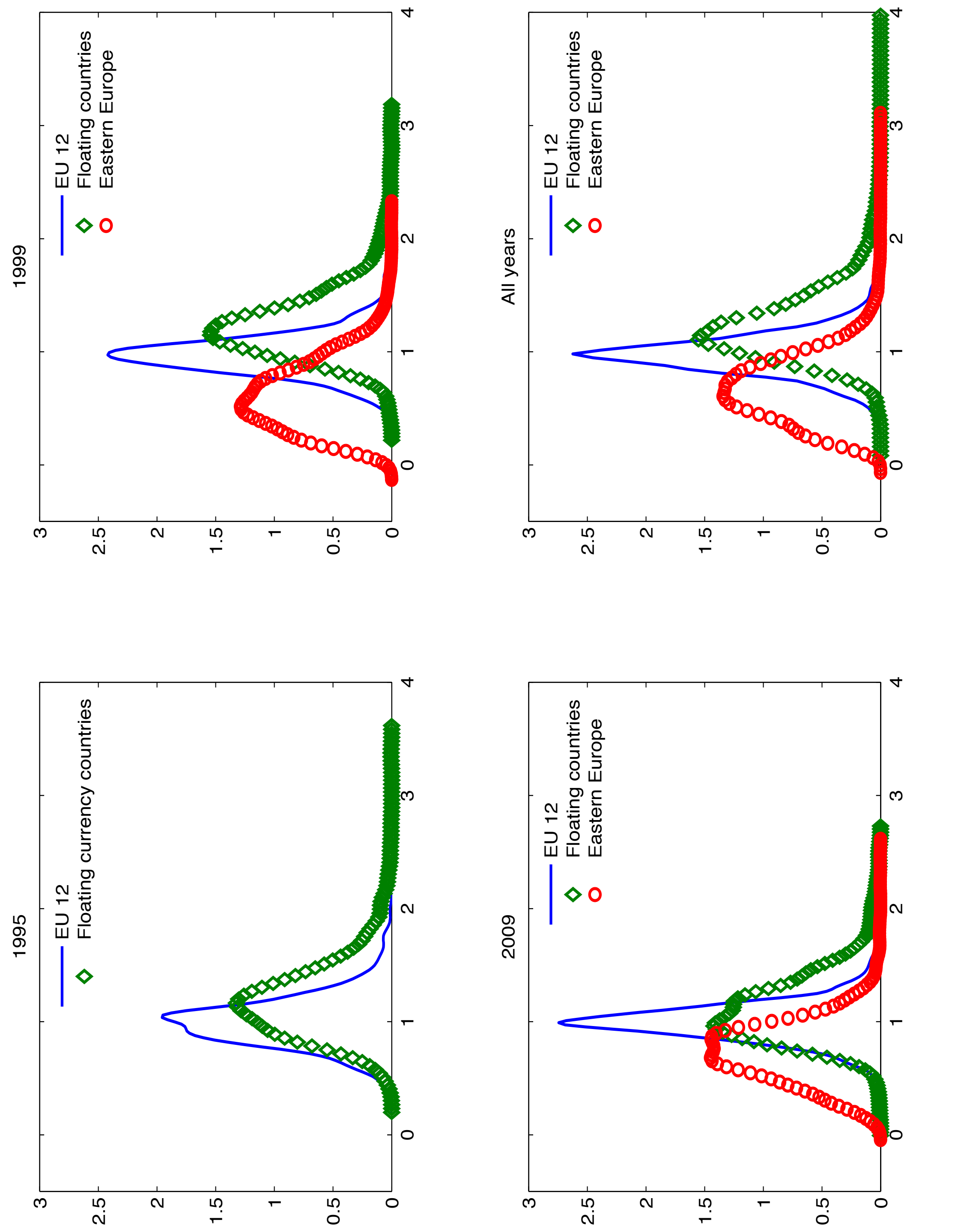

Figure 4: Decomposition into Traded and Non-Traded, Eurozone countries

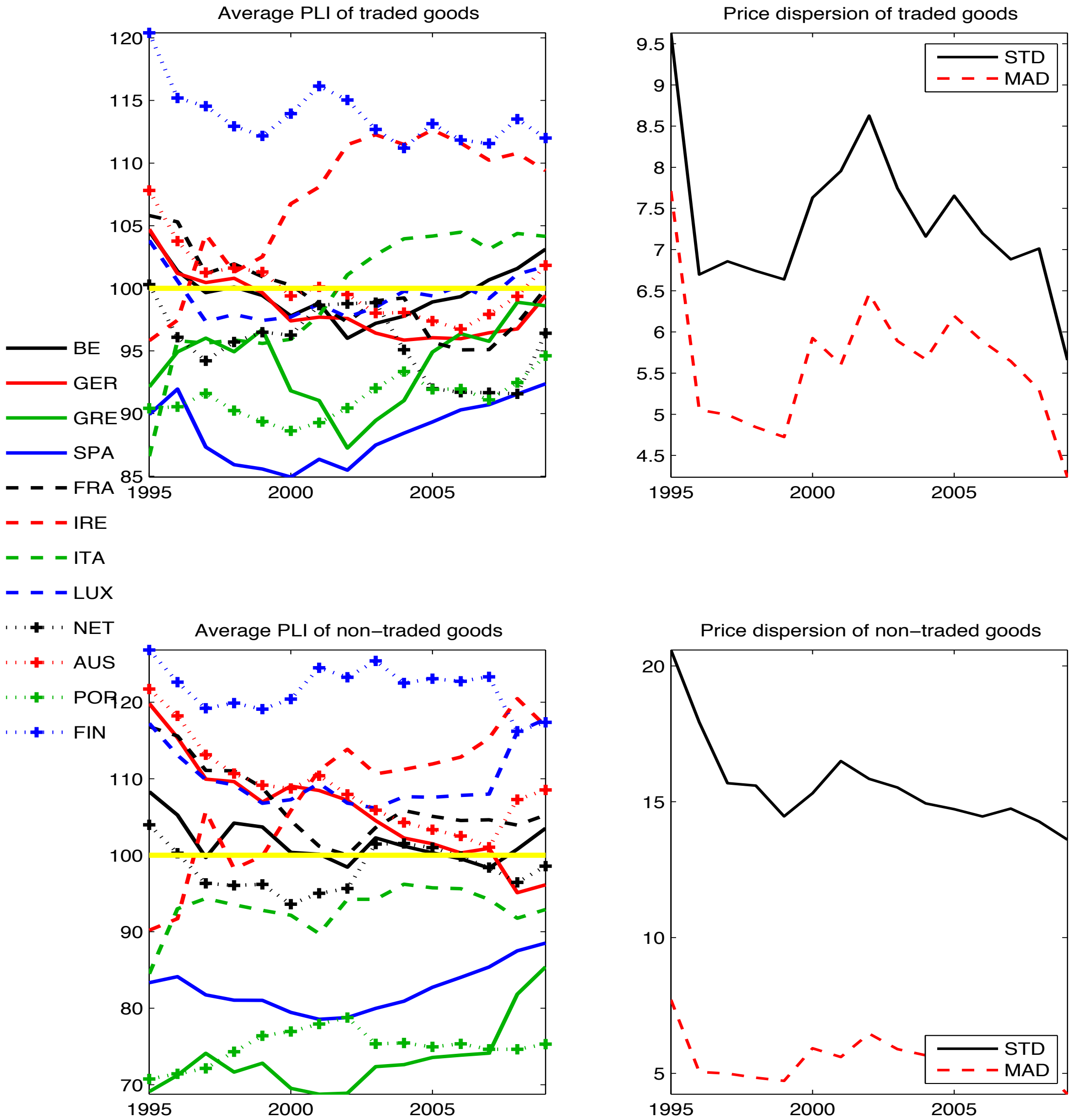

Figure 5: Decomposition into Traded and Non-Traded, countries in Western Europe with floating exchange rates

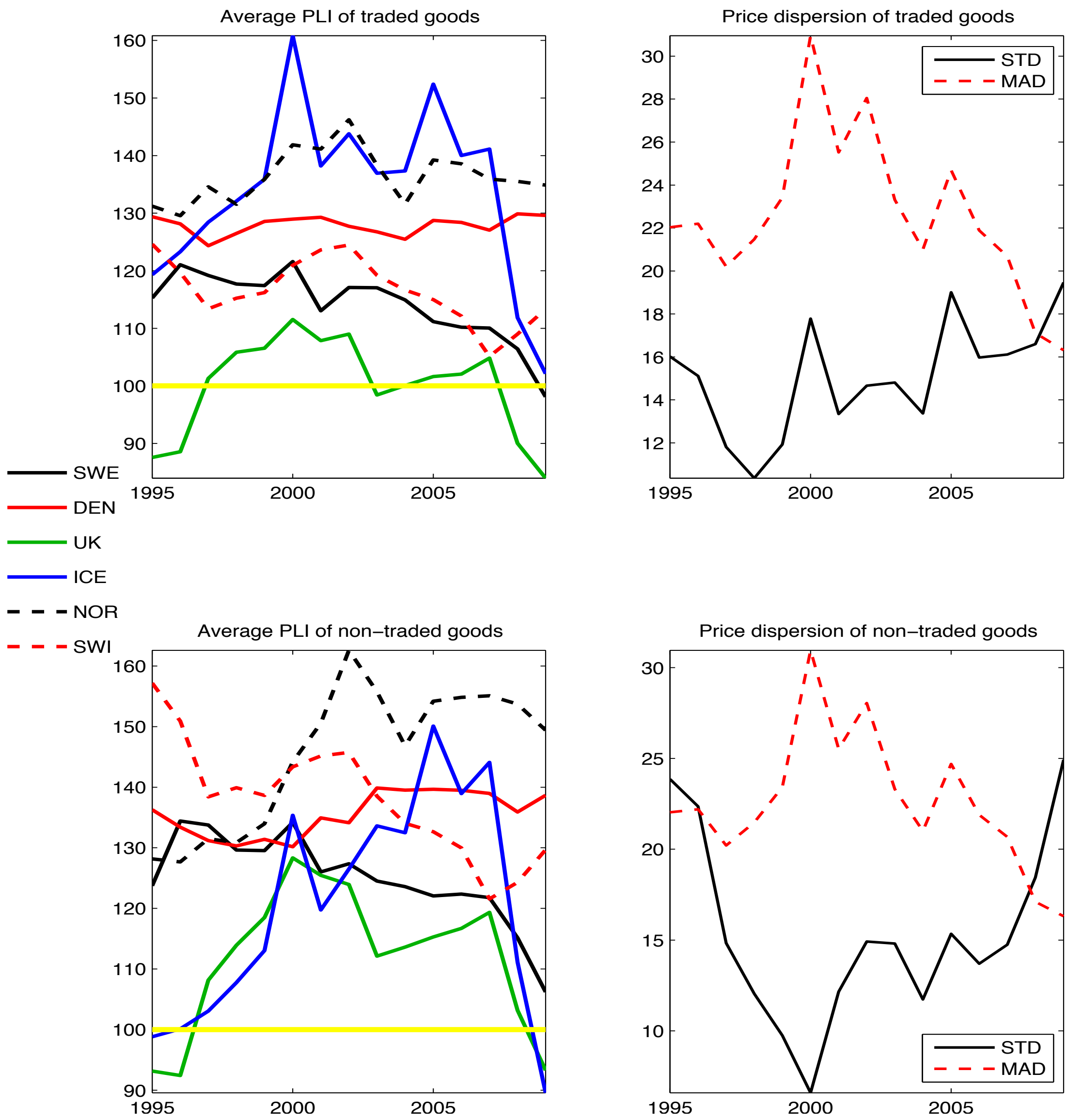

Figure 6: Decomposition into Traded and Non-Traded, Southern and Eastern Europe

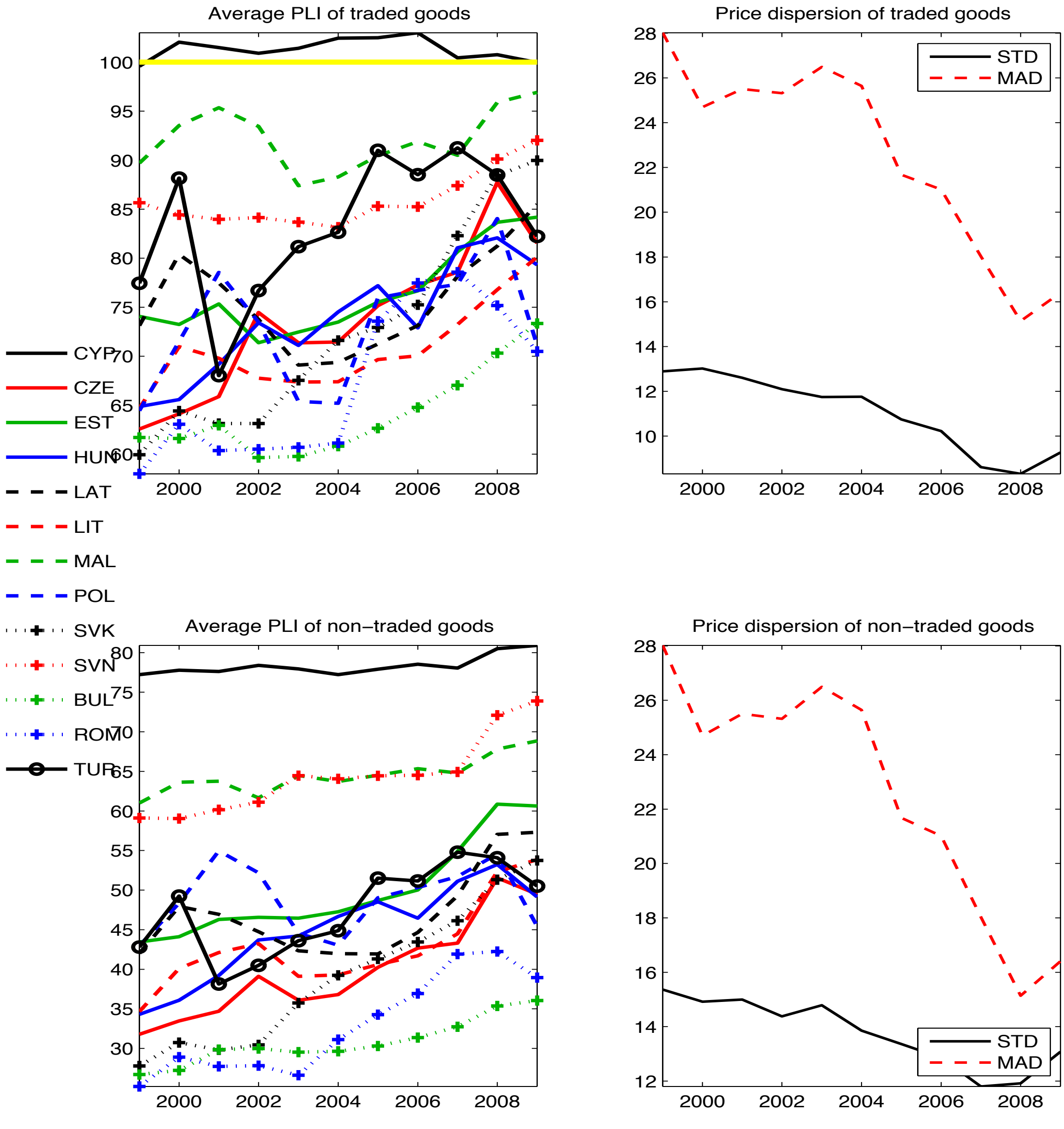

Figure 7: Average levels of Price of Non-traded to Traded goods and Real Exchange Rates

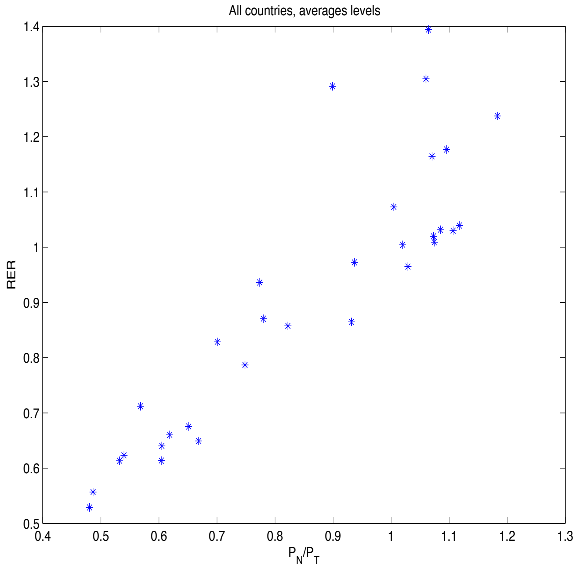


Figure 8: Average growth rates of Price of Non-traded to Traded goods and Real Exchange Rates

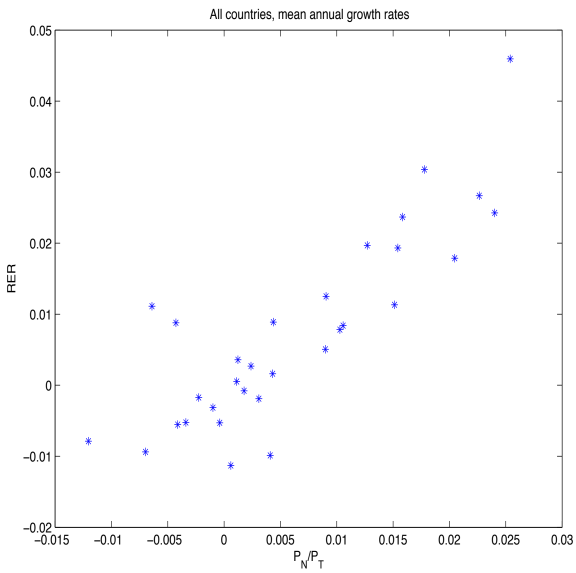

Figure 9: Relative GDP per capita and average PLI's in Western Europe

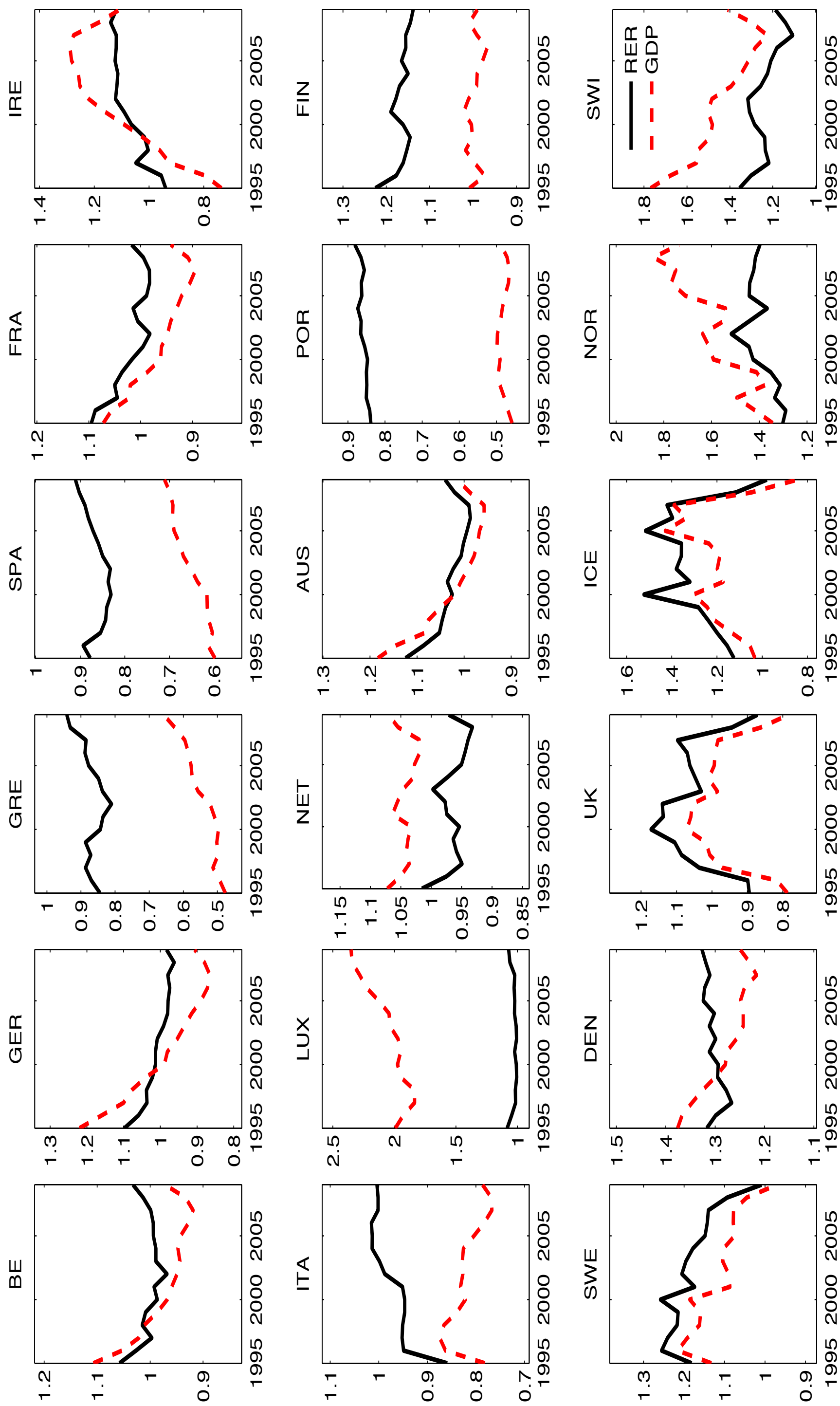

Figure 9 continued: Relative GDP per capita and average PLI's in Southern and Eastern Europe

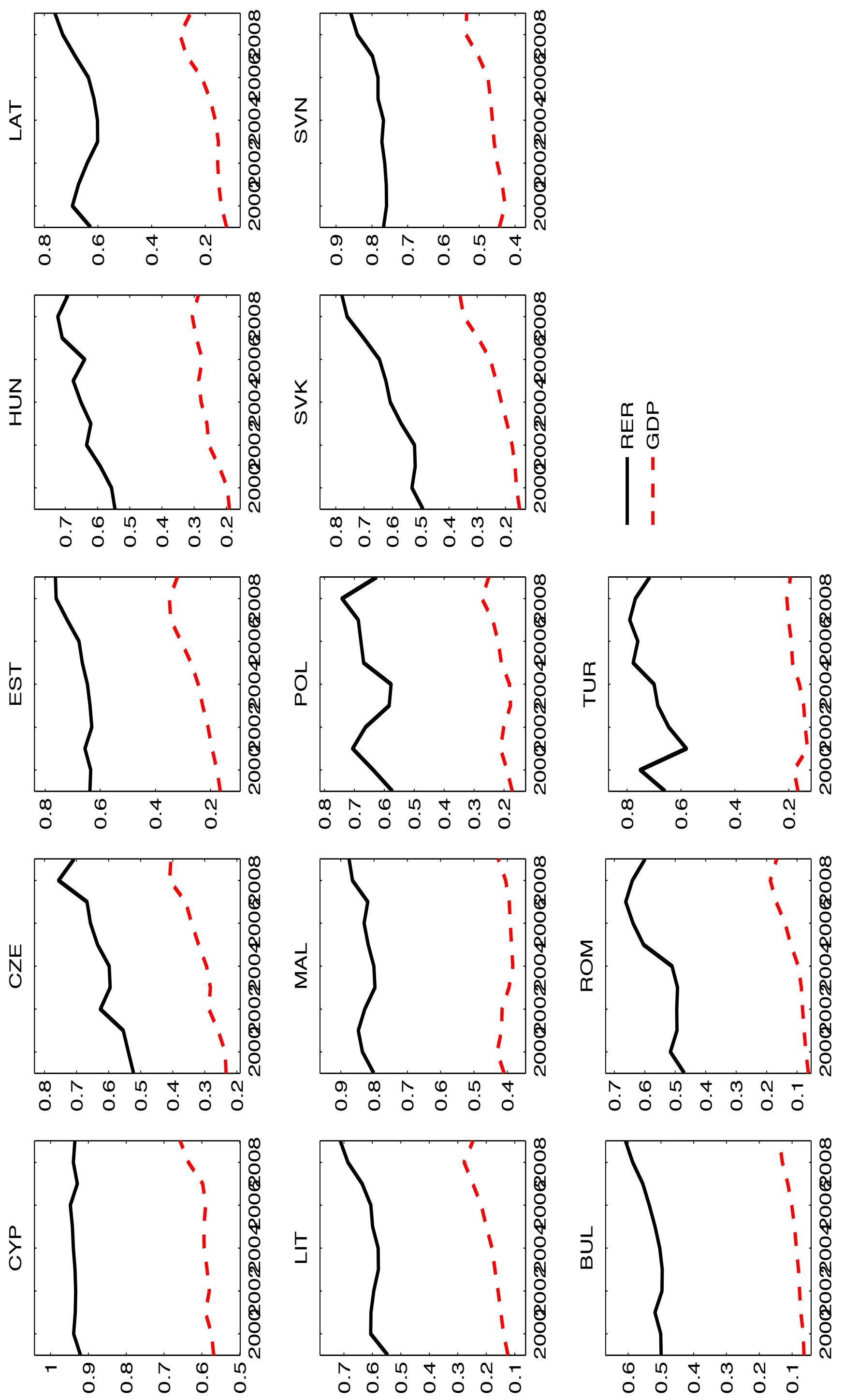

Figure 10: Real exchange rate and GDP: pooled

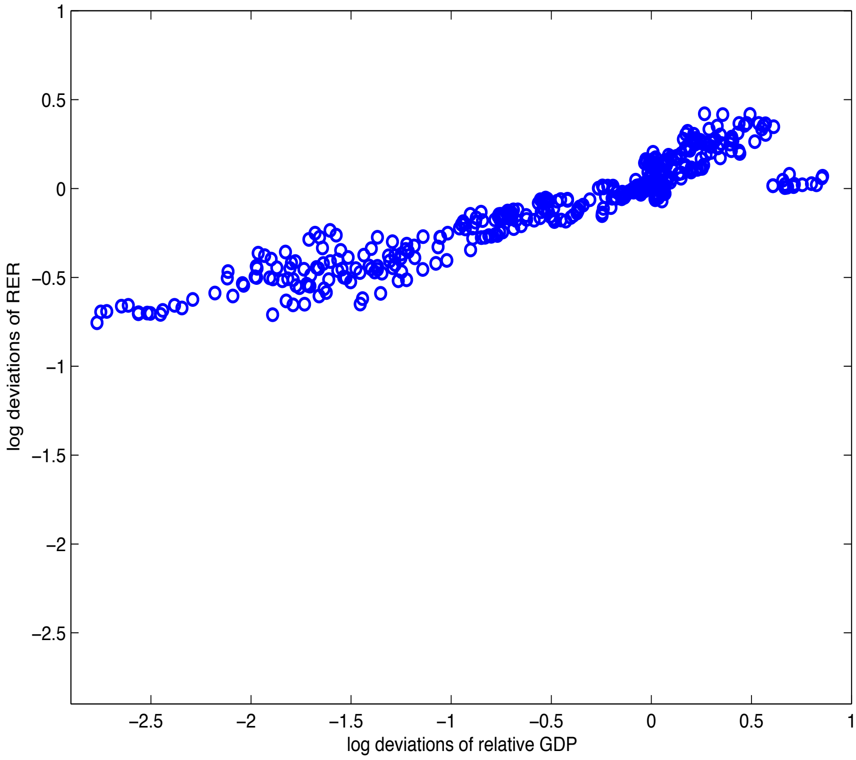

Figure 11: Kernel density estimates of prices for all goods, conditional on relative GDP per capita differences (within a country group by year)

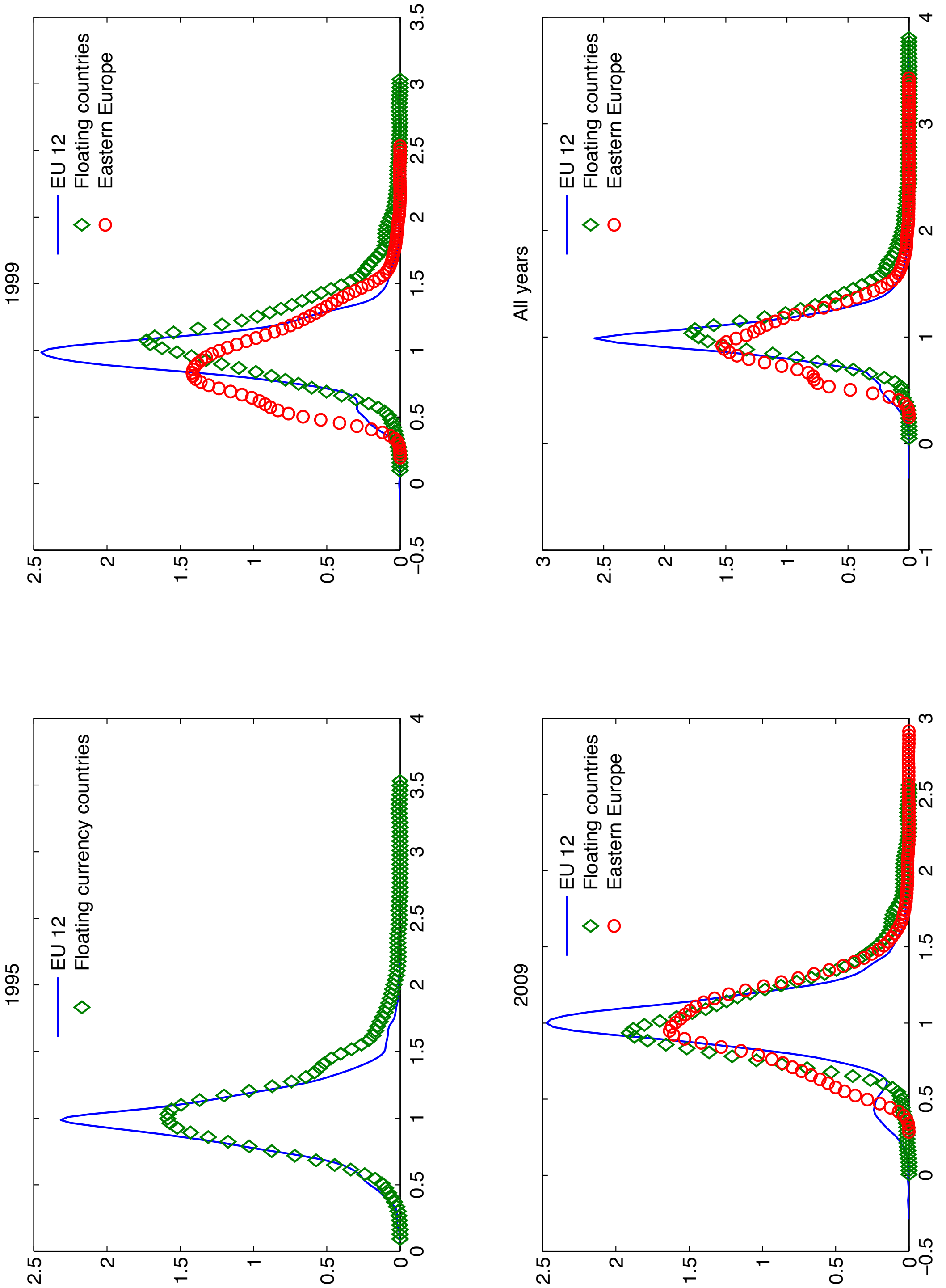

Figure 12: Model elasticity of RER to RGDP

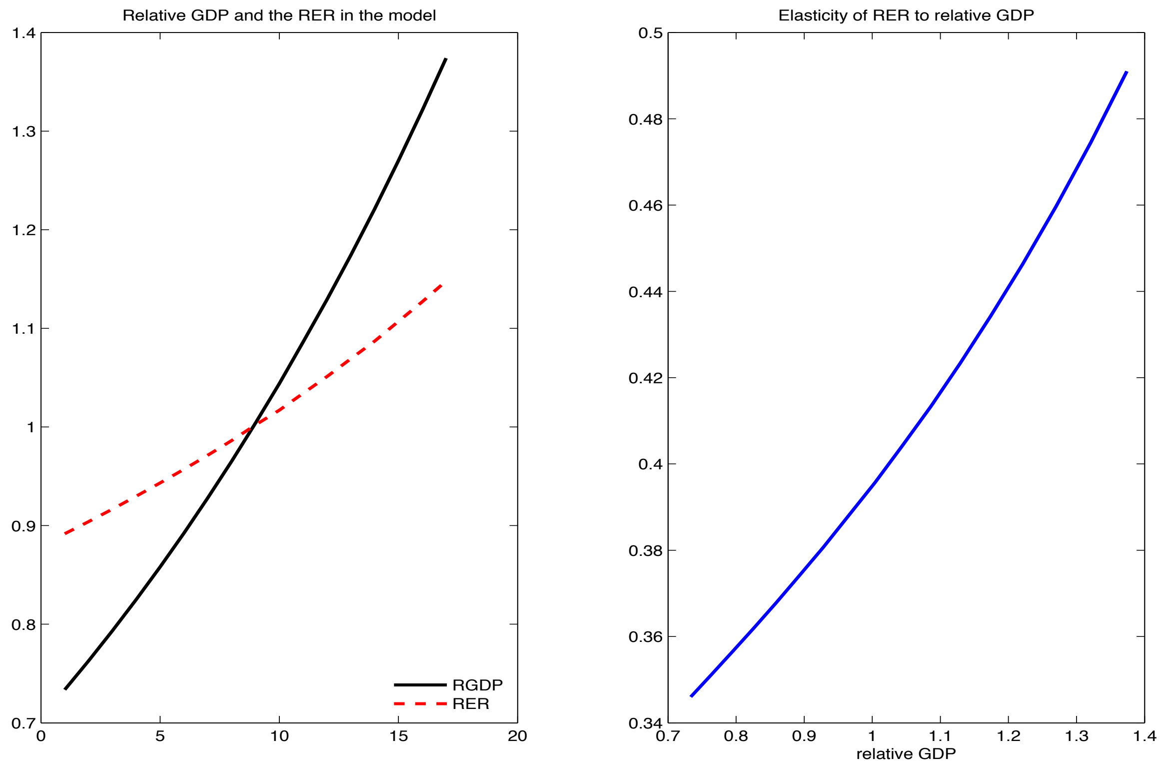

Figure 13: Model prediction and Average PLI's in EU12

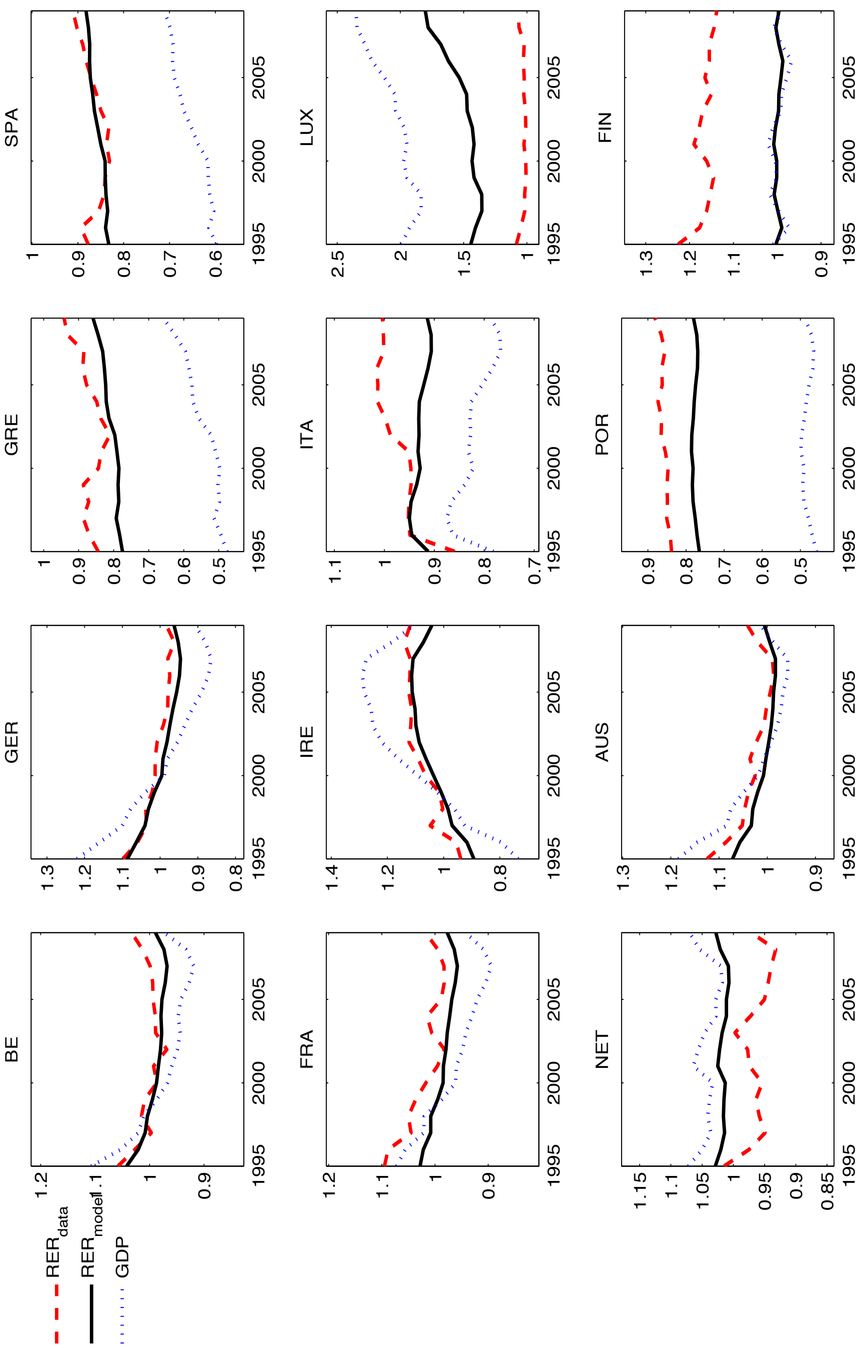

Figure 14: Model prediction and Average PLI's in countries with floating exchange rates

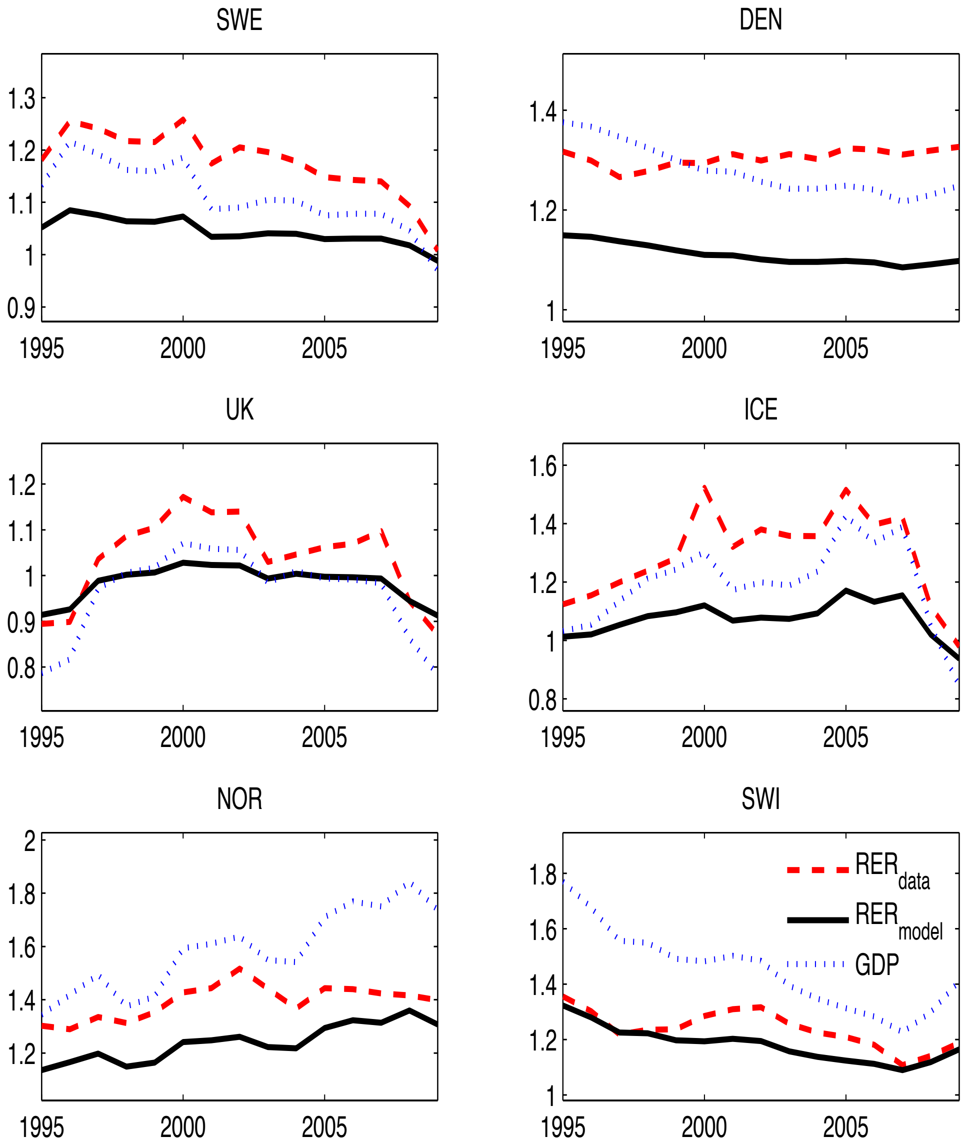

Figure 15: Model prediction and Average PLI's in Southern and Eastern Europe

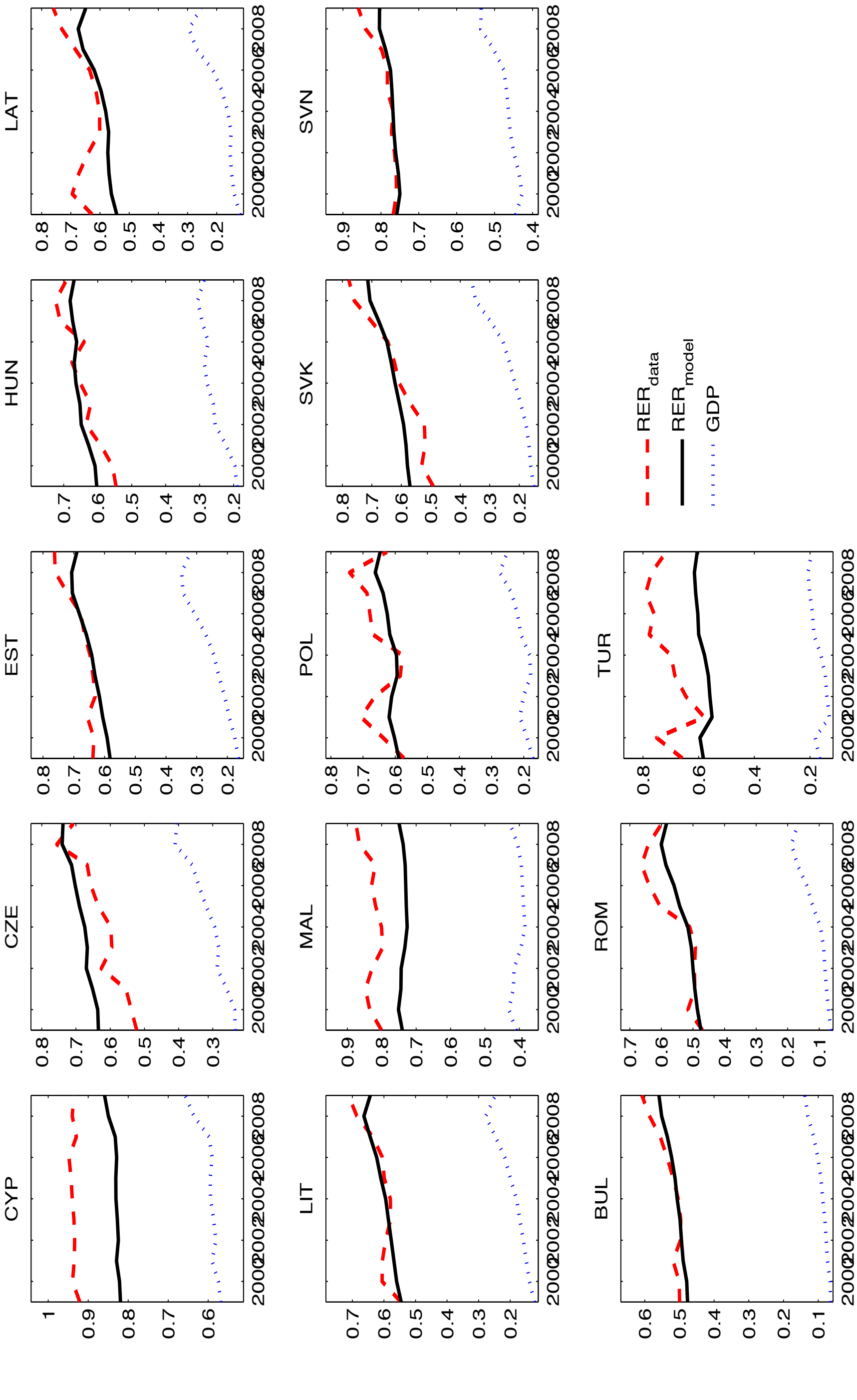

Figure 16: Average relative GDP growth and average relative endowment growth