What determines European real exchange rates?

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First draft: December 2009
This version: February 2011

Abstract

We study a newly constructed 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.

1 Introduction

This paper examines the behavior 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 structural open economy model can explain 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 both for individual goods and at the aggregate level. 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 not 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 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.

We employ a newly constructed data set of European price levels to conduct such a study. The data 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 that there are large and persistent deviations from

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[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.

absolute PPP among all European countries. These deviations hold for all categories of goods, but are much more pronounced for non-tradable than for tradable 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 these 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. This pattern holds at all levels of aggregation. The data show that some countries displayed declining relative GDP per capita, combined with persistent depreciation in their real exchange rate - in particular this applied to the 'Old-Europe' countries; France, Germany, the Netherlands, Belgium, and Austria, while other countries displayed substantial appreciation combined with increasing relative GDP per capita - notably Ireland, UK, some Scandinavian countries, as well as many countries of emerging Eastern Europe. Then, at the end of the sample, we find that this trend was to a considerable extent reversed during the post 2008 economic crisis.

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 goods, 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-tradable and tradable goods separately, the real appreciation coefficient becomes 0.5 percent and 0.2 percent, respectively.

This implies that for all categories of goods, movements in relative GDP per capita are associated with less than proportionate movements in real exchange rates. Faster growing countries tended to experience appreciation from below to above the European average real exchange rates over the sample. In this sense, the relationship between real exchange rates and GDP per capita is robust across countries and over time. Moreover, the pattern of real exchange rate movement following the crisis of 2008 generally preserves the relationship.

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 0.89while 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.[2]

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. This model is consistent with a number of theoretical models of real exchange rate trends, including the classic Balassa-Samuelson theory.

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. Thus, for most European countries, relative per capita GDP can well account for the level and time path of real exchange rates.

There has been a large literature discussing the properties of real exchange rates and relative price comparisons across countries, using both aggregate and disaggregated data. Engel and Rogers (1996) study 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, especially when adjusting for GDP per capita. Our paper differs from theirs in that we have a panel covering up

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[2]The only exception is for the floating exchange rate countries, where the *cross country* correlation of real exchange rates and internal relative prices is negative.

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. We find less compelling evidence for PPP in our study.

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. In a short section below however, we do follow the Faber and Stokman strategy of linking HICP indices to our data on price levels. This allows us a check on our main results by giving us the ability to study relative prices at higher frequencies than those of the main data-set.

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. Furthermore, we explore the extent to which these findings are consistent with a simple general equilibrium model based loosely on a Balassa-Samuelson-Bhagwati type mechanism.

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[3]. PLI's are derived from Basic Heading-level PPP's,

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

and are measured relative to the 15 members of the EU area[4]. 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 are 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 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.

2.2 Monthly HICP price levels

While the PLI's have the advantage of being expressed in terms of price levels, they have the drawback of being published only at annual frequencies. By contrast, the European Harmonized Index of Consumer Prices (HICP) for all countries in Europe is reported at a monthly frequency. The HICP has the converse disadvantage of being an index, rather than a price level, however. But it is possible to use the PLI's and the HICP's in combination, so as to produce a monthly series of price level equivalents[5]. We do this by using Eurostat expenditure weights to aggregate from the Basic Heading PLI level of prices up to the HICP level[6]. Since the BH-PPP PLI's are in terms of levels, relative to the EU average, we can then compute a proxy relative price level for categories in the HICP, and then using the rates of change of the HICP indices for each category, derive a monthly frequency series in relative price levels for all countries in the sample. The difficulty of aggregating up from the annual PLI frequency to the monthy HICP frequency is handled by using a Eurostat provided set of 'temporal adjustment factors' which are used to go from the annual frequency of the PLI's to the implied PLI for any month. A matrix of these temporal adjustment factors is available for years 2003-2006.

In the discussion below, we report some results for comparative prices using the monthly price series. One drawback of this analysis is that missing data in the HICP

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

[5]For a similar methodology, see Faber and Stokman (2009).

[6]This uses the EKS method of aggregation (see Eurostat Manual).

series reduces significantly the number of goods that can be used in a balanced panel of monthly HICP level prices. A second complicating factor is the extreme seasonality in many of the individual HICP series, with seasonal movements for similar products differing considerably across different countries. We resolve this by applying a common seasonal adjustment algorithm for all countries and all prices.

3 Characteristics of PLI's

3.1 Mean Comparisons across Countries

We first focus on the properties of annual mean 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.[7]

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 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

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[7]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.

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.[8] 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 EU12 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 sigificantly higher than those in the EU12. We also see the trends in the distribution over time. For the EU12, 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, as well as the mean coefficient of variation (CV) of prices within countries. The 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. It is also apparent that the dispersion of prices is much 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 real exchange rate departures from PPP are strongly representative of PPP departures at the individual good level, for most countries. Equivalently, 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)

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[8]The distributions in Figure 3 are Kernel density estimates.

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 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.[9]

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 is 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. Spain and Portugal have real exchange rates for traded goods equal to 90 percent of the EU average, and show no indications of convergence. Finland's real exchange rate in traded goods is persistently more than 15 percent above the EU average. Again Ireland and Italy go from being below to being above the average. France, Germany, Belgium, Austria and the Netherlands display gradual downward convergence as before.

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

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

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, Figures 6 show 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 tradable and non-tradable 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-tradable component, the pattern of persistent departures from PPP in both tradable and non-tradable 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. This is perhaps not very surprising, since it is consistent with traditional evidence that the prices of services are higher in more wealthy countries. But 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. Hence, there is clear 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.[10]

4 Real Exchange Rate Determinants

4.1 Real Exchange Rates and Relative GDP per capita

It is well known that richer countries have higher price levels . 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[11]. 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,

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

[11]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.

Switzerland, Norway and the Netherlands; real GDP per capita is proportionally more 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[12] . 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[13]. The Figure also supports the observation made above that, unconditionally, the real exchange rate increases by less than in proportion to relative GDP.

4.2   Real Exchange Rates at Monthly Frequency

How robust are these results to alternative data frequencies? Figures A2-A3 of the Appendix describe the equivalent measures for relative prices and price dispersion at monthly frequencies, for the three groups of countries. Due to lack of complete coverage of HICP data for the full sample of countries and months, and the higher level of aggregation for the HICP series, relative to the BH-PPP data, these data are restricted to 38 good categories of HICP series, in 25 countries. The Figures show that the general features of the real exchange rates in the annual series carry over to the monthly data, but these

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[12]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.

[13]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.

measures of real exchange rates exhibit substantially more volatility. One interesting feature of the monthly data is the more distinct tendency cross country price dispersion to fall in the post 2000 period for the eurozone countries.

5   Structural Determinants of Real Exchange Rates

From the figures above, relative GDP is clearly an important factor in the determination of country-level real exchange rates. The most popular explanation for this is the celebrated Balassa-Samuelson model (Balassa 1964, Samuelson 1964). This model says 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, faster productivity growth in the traded sector implies trend real appreciation over time. Even without differences in productivity sectoral productivity, however, a country may have a higher real exchange rate if it has higher average productivity, relative to the rest of the world, as long as the non-traded goods sector is relatively labor intensive. This point was first emphasized by Bhagwati (1984).

Both these views are 'supply side' explanations for real exchange rate determination. There are alternative 'demand side' models of the relationship between real exchange rates and relative GDP. In particular, 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 a rise in national income will tend to push up the relative price of non-traded goods, and lead to a real exchange rate appreciation. This is explained 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. Thus, ceteris paribus, a higher government spending to GDP ratio should be associated with a higher real exchange rate, relative to the european average. 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 an 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[14]. As a related measure of the importance of trade, we also

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[14]Of course it must be noted that the PLI's we are examining are not pure traded goods, but represent

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.

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 price convergence that do not operate for other countries, even if they maintain stable exchange rates vis a vis the euro. 11 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, as well as the regression results we see momentarily, 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 level real exchange rates on relative GDP per capita, and these other variables, for the full sample[15]. 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 it 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 insignificant, while openness has a negative coefficient, but also small.

Table 3 also provides a breakdown of these regressions separately into tradable and non-tradable goods. For tradables, the coefficient on relative GDP falls to approximately

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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.

[15]The regressions are run in levels. 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. Nevertheless if we ran the estimation in first differences, the elasticity estimate would be even higher and again very highly significant.

0.26, but remains highly significant. Euro and Distance are still significant in the basic specification, but again, Euro loses significance when country fixed effects are allowed. In the non-tradables case, the GDP coefficient is much higher - around 0.57, and again highly significant under all specifications. In this 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 tradable and non-tradable goods separately.

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.

6   A Simple General Equilibrium Model

The key feature of the data is the strong cross-country and time-series relationship between real exchange rates and relative GDP. 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. Moreover, an increase in relative GDP from below to above the EU average leads to a real exchange rate appreciation from below to above the EU average. The opposite mechanism holds for most countries that have had relative GDP falling from above to below the EU average. 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 within a country.

Is this relationship consistent with a theoretical model of real exchange rate determination? We now 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. We also note real exchange rate differentials in Europe tend to be strongly associated with the relative price of non-traded to traded goods. In general, countries with high real exchange rates tend to have higher relative prices of non-traded goods, and countries that experienced appreciation over time also had an increasing relative price of non-traded goods. This gives us some guidance in terms of the appropriate model for understanding real exchange rates.

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-tradeable 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-tradables. 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-tradables 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-tradables, 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. The mechanism is consistent either with a Balassa Samuelson approach, or the Bhagwati factor intensity approach, in that

both approaches tend to imply that trend growth increases the relative supply of traded goods to non-traded goods. We introduce this link in an endowment economy framework, amended to allow for trends in the real exchange rate. What we do is to choose this differential sectoral growth rate to be consistent with the average evidence on the real exchange rate relative GDP per capita relationship over the whole sample (across time and countries), and then to ask how much explanatory power does this mechanism have on a country by country basis. At a mininum, the procedure can help inform us whether there seems to be a unified explanation for the pattern of real exchange rates in Europe. 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 has this property by definition. 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 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.

6.1 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 θ. 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 ω 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 λ is the elasticity of substitution between home and foreign tradables.

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 tradable and non-tradable price levels, and P_X and P_M are retail prices of home exportables and foreign importables. The analogue of the real

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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 may ignore the presence of nominal exchange rates. Given that we are primarily interested in accounting for relative prices, and not quantities, we 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 quite difficult. Instead, we take a simpler approach where the output of non-tradable and tradable goods are assumed to evolve exogenously[16].

While the evidence presented above indicated that real exchange rate movements were associated with movements in the relative price of non-tradables, we also found that relative GDP was positively correlated with tradables goods prices, although less strongly than for non-tradables. 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 intertemporal borrowing or lending across countries. This is a simplifying assumption,

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[16]In the Appendix, we show how the model can be extended to allow for endogenous capital accumulation and intersectoral labour mobility, with similar implications for the real exchange rate real GDP per capita relationship as in this simpler model.

but it unlikely to have first order implications for the evolution of the real exchange rate, at least over the sample period in question for European exchange rates.

Goods market clearing conditions are given as:

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

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 θ 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 endownment 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, the interaction between GDP and the real exchange rate is consistent with the mechanism underlying the Balassa-Samuelson or Bhagwati models.

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. We choose $b = .7$. This value reproduces an elasticity of 0.39 at the symmetric point $Y = RER = 1$.

Figure 11 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). The simulation illustrates the key properties of the real exchange rate seen in the data - the deviations in relative GDP per capita are larger than the deviations in the real exchange rate from PPP, and as relative GDP per capita transits from below

average to above average, the real exchange rate moves from being below PPP to being above PPP, with the relative GDP per capita locus intersecting the real exchange rate locus from below.

We now take this calibration and apply it to to observed GDP data for all countries in the sample. What we are doing then is to use exactly the same calibration for all countries, but solving the model as described above so as to reproduce the observed movements in relative GDP per capita for each country.

Figures 12-14 report the results for the three groups of countries. Figure 12 gives the 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).[17]

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[17]Italy presents a puzzle, from the point of view of the model. Italy experienced considerable real

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Figure 13 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 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, we see that the model offers an improved picture for these countries.

Figure 14 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.[18]

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 behaviour of the Italian real exchange rate.

[18]We have assumed that relative GDP over time and across countries is positively correlated with the

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 12-14, 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.

7   Conclusions

relative supply of traded goods to non-traded goods. How true is this assumption? We do not have accurate data on sectoral level output for all our countries. However, it is shown in the Appendix (Figure A12) that for the subset of 25 countries in our sample, 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.

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

	$\bar{P}_i$	$\bar{P}_{i,T}$	$\bar{P}_{i,NT}$	$CV(P_i)$	$\overline{CV}(p_{ij})$	$\bar{Y}$
Belgium	100	100	102	2	15	109
Germany	101	98	106	4	17	109
Greece	87	94	73	4	25	61
Spain	86	89	82	3	18	73
France	102	100	107	4	17	104
Ireland	107	107	108	6	19	123
Italy	97	99	93	4	20	91
Luxembourg	103	99	110	2	21	230
Netherlands	96	96	98	2	17	116
Austria	103	100	109	4	16	114
Portugal	86	91	75	1	23	54
Finland	116	114	122	2	18	111
Sweden	118	114	125	6	20	124
Denmark	130	128	136	1	20	143
United Kingdom	104	100	112	9	23	107
Iceland	129	134	120	12	27	133
Norway	139	136	145	5	24	178
Switzerland	124	117	138	6	23	161
Cyprus	94	101	78	1	28	68
Czech Republic	62	74	40	12	40	35
Estonia	68	76	50	7	34	29
Hungary	64	74	45	9	36	30
Latvia	66	76	47	8	38	22
Lithuania	61	71	43	8	39	22
Malta	83	92	65	3	38	46
Poland	65	73	49	9	35	24
Slovakia	61	73	39	16	41	27
Slovenia	79	86	64	4	23	54
Bulgaria	53	64	31	7	51	11
Romania	56	67	33	13	53	13
Turkey	71	83	47	9	50	19

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. $CV(P_i)$ is the coefficient of variation of the aggregate real exchange rate, and $\overline{CV}(p_{ij})$ is the average (over time) coefficient of variation of all relative prices in a country i. Y_i is GDP per capita of country i relative to the average of EU15 (=100). 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. 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.

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

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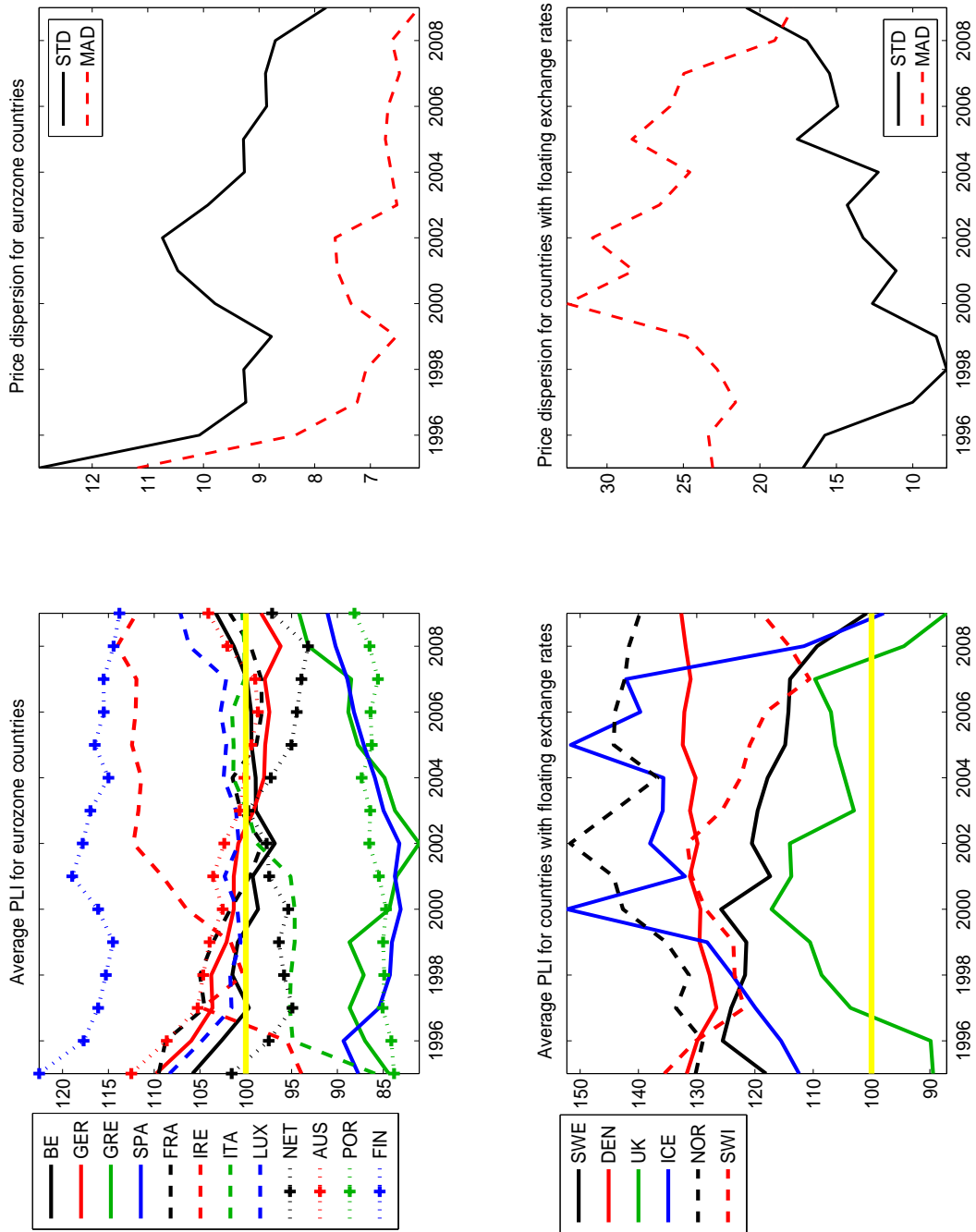
Figure 2: Average PLI's in Southern and Eastern Europe

36
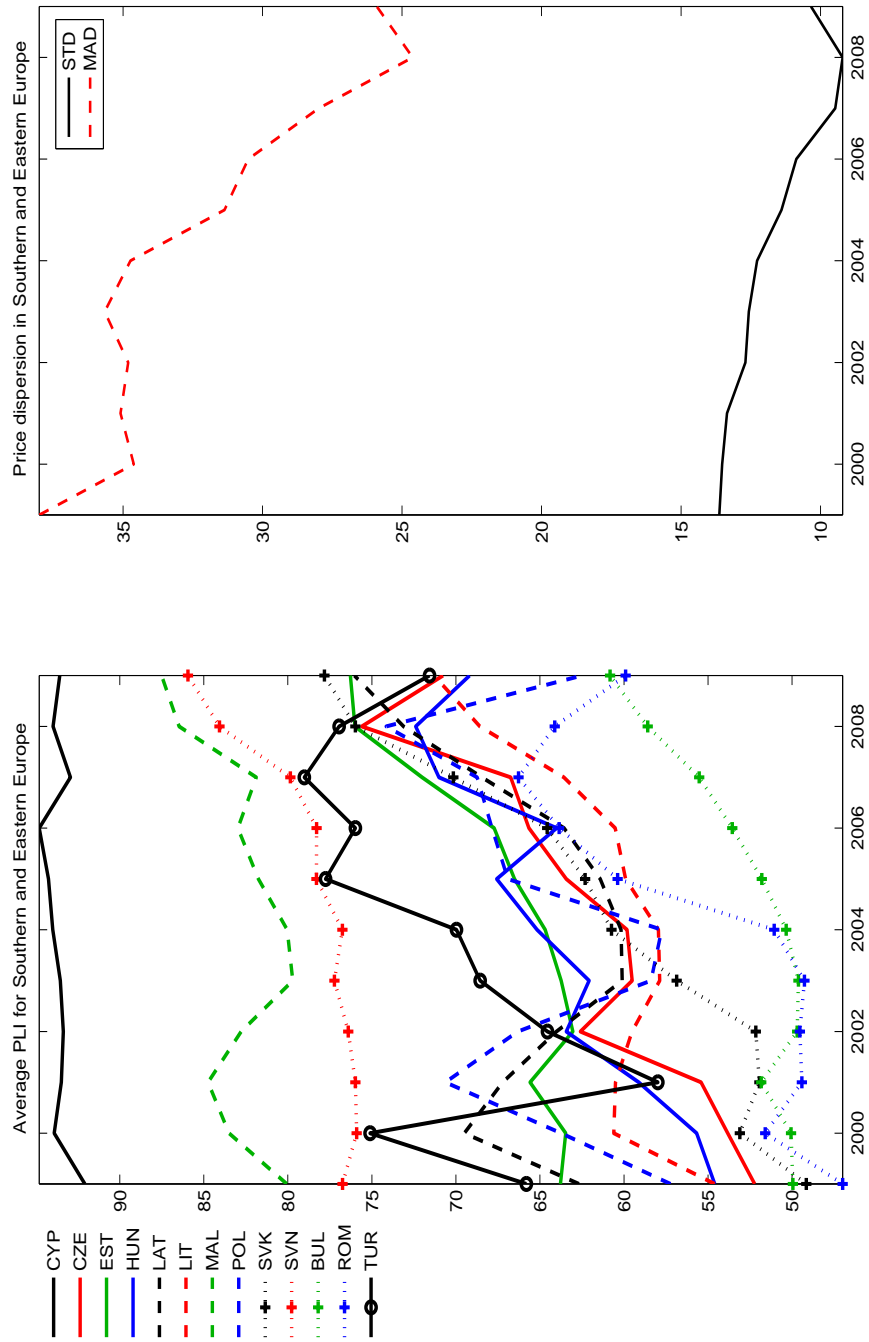
Figure 3: Kernel density estimates of prices for all goods within a country group by year
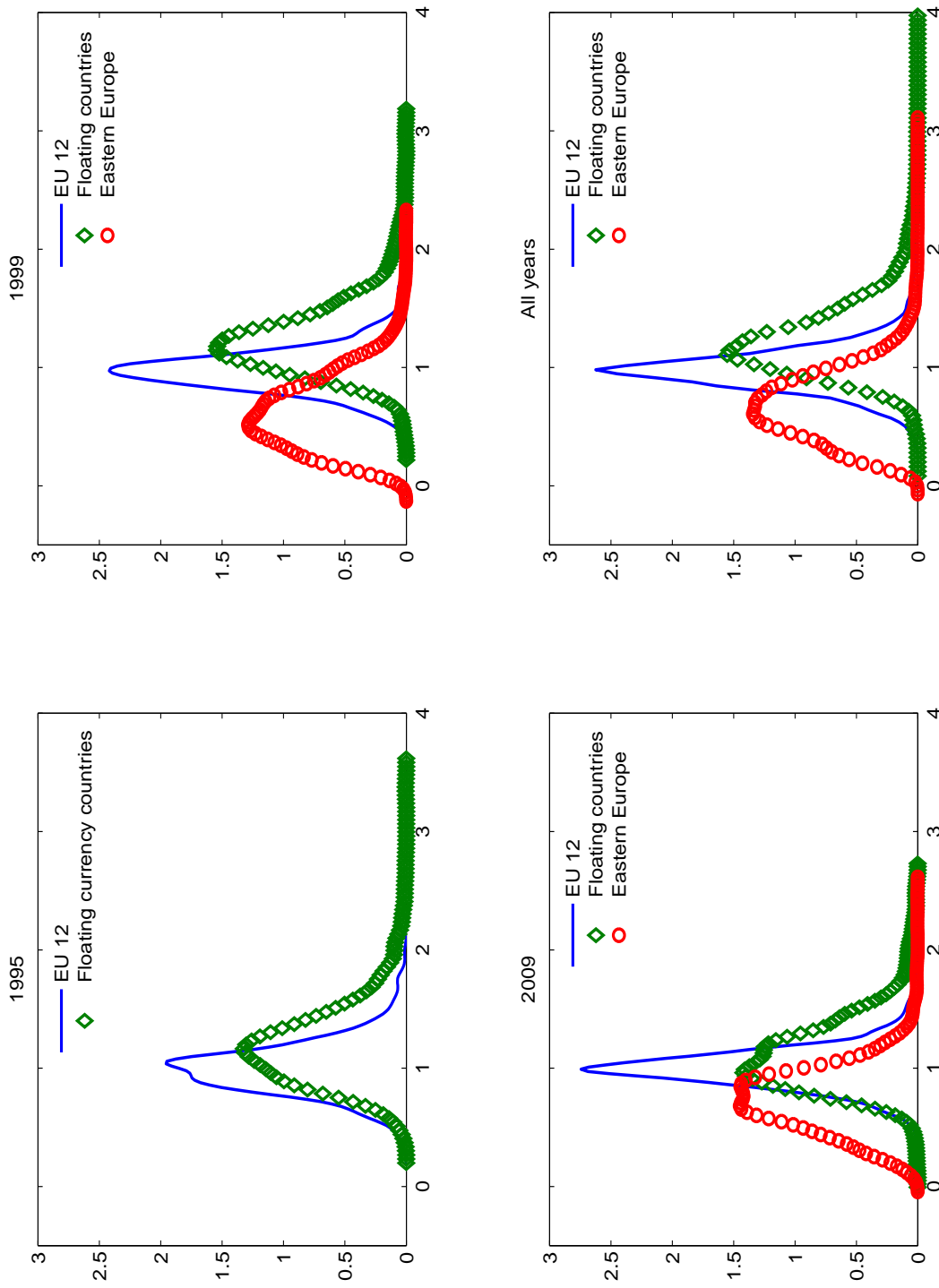
Figure 4: Decomposition into Traded and Non-Traded, Eurozone countries
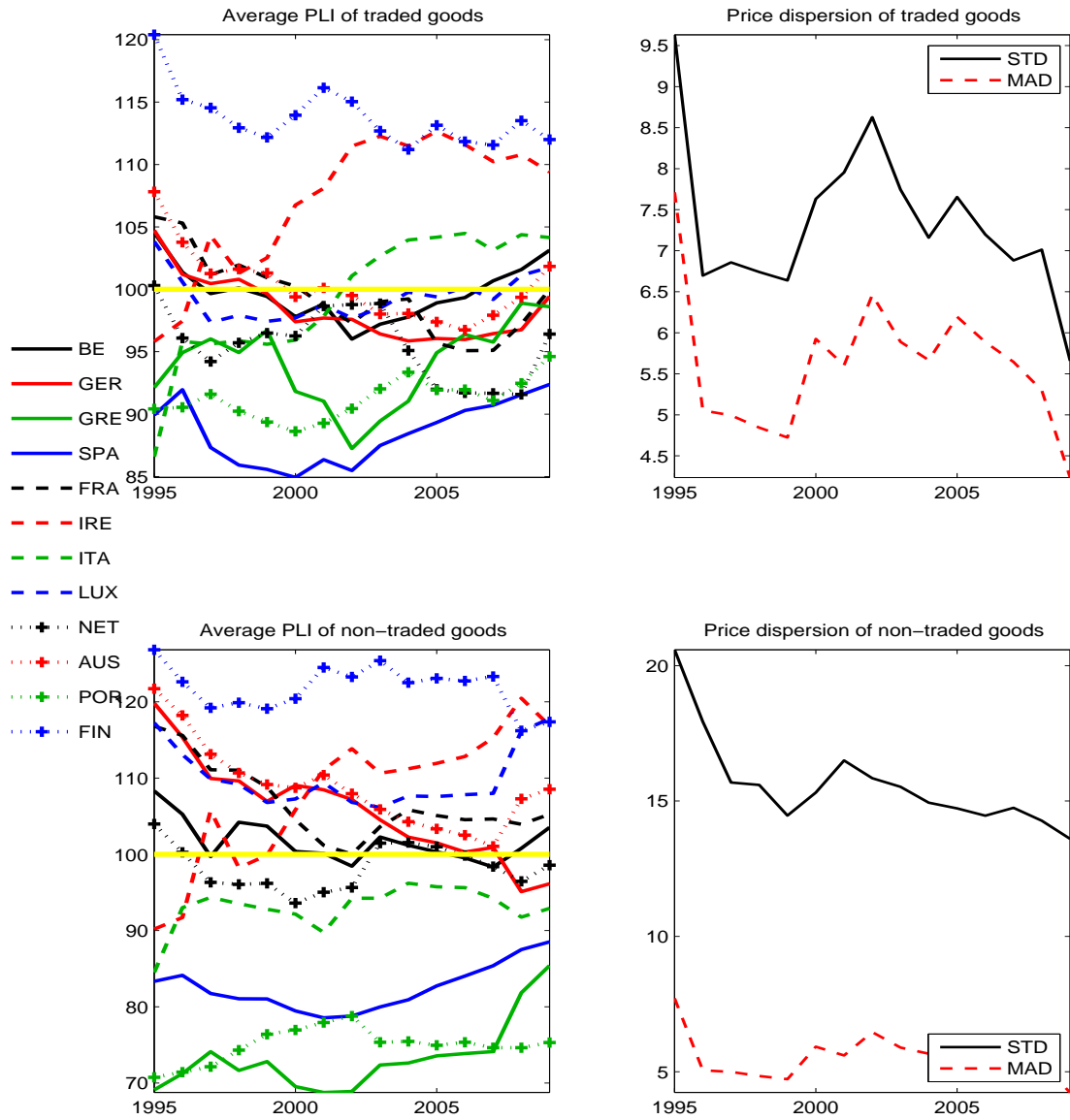
Figure 5: Decomposition into Traded and Non-Traded, countries in Western Europe with floating exchange rates
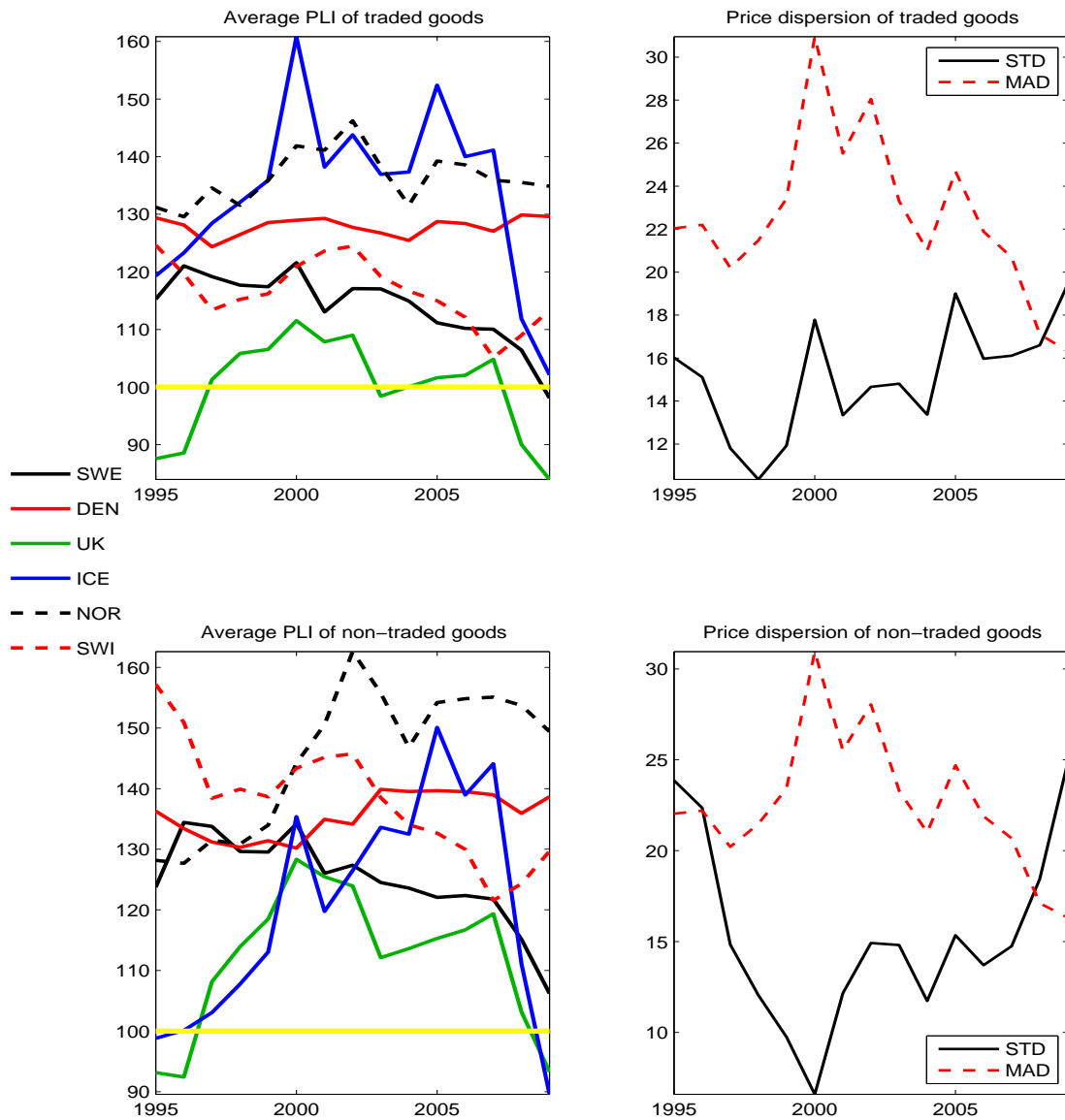
Figure 6: Decomposition into Traded and Non-Traded, Southern and Eastern Europe
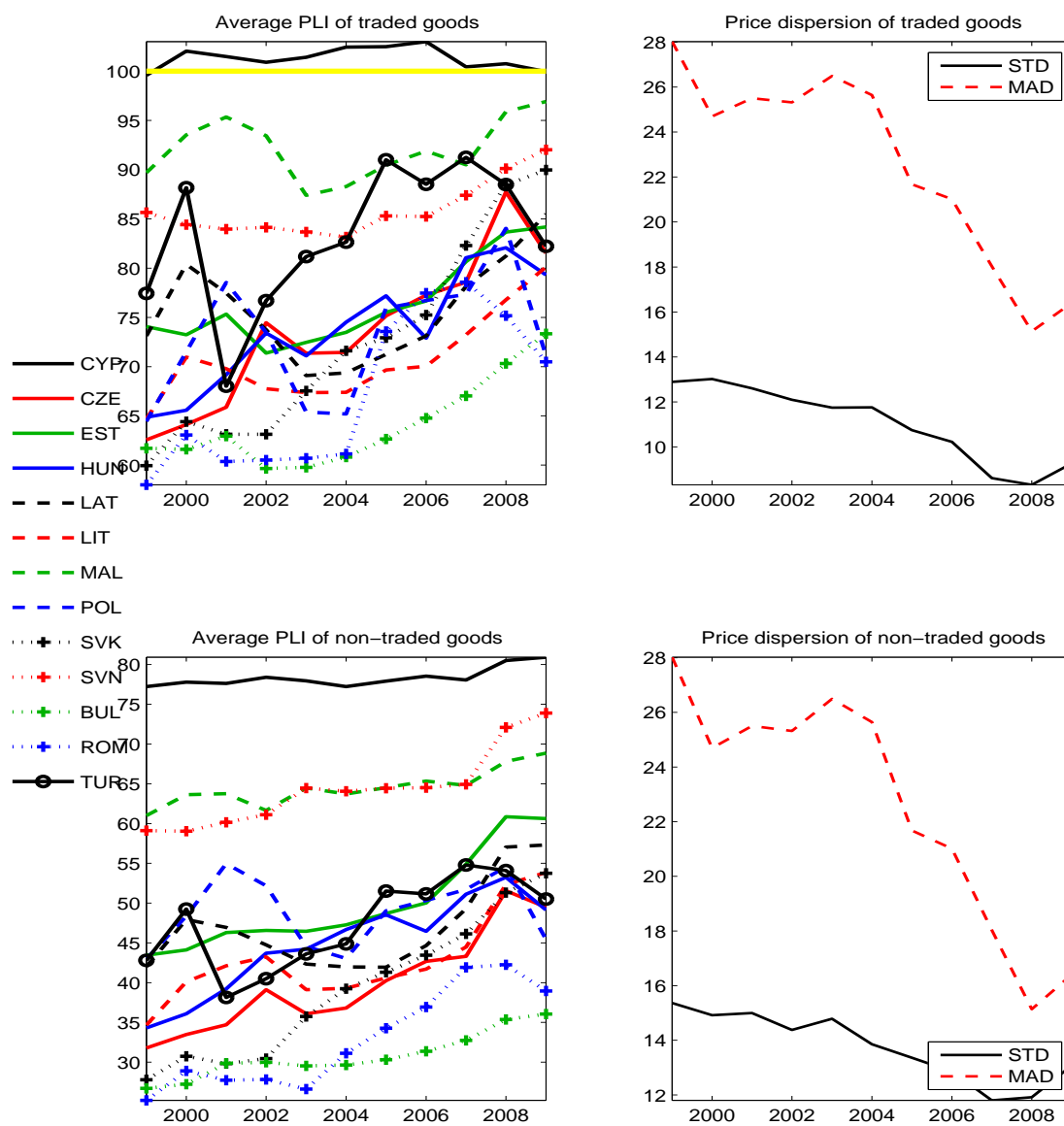
Figure 7: Average levels of Price of Non-traded to Traded goods and Real Exchange Rates

All countries, averages levels

41
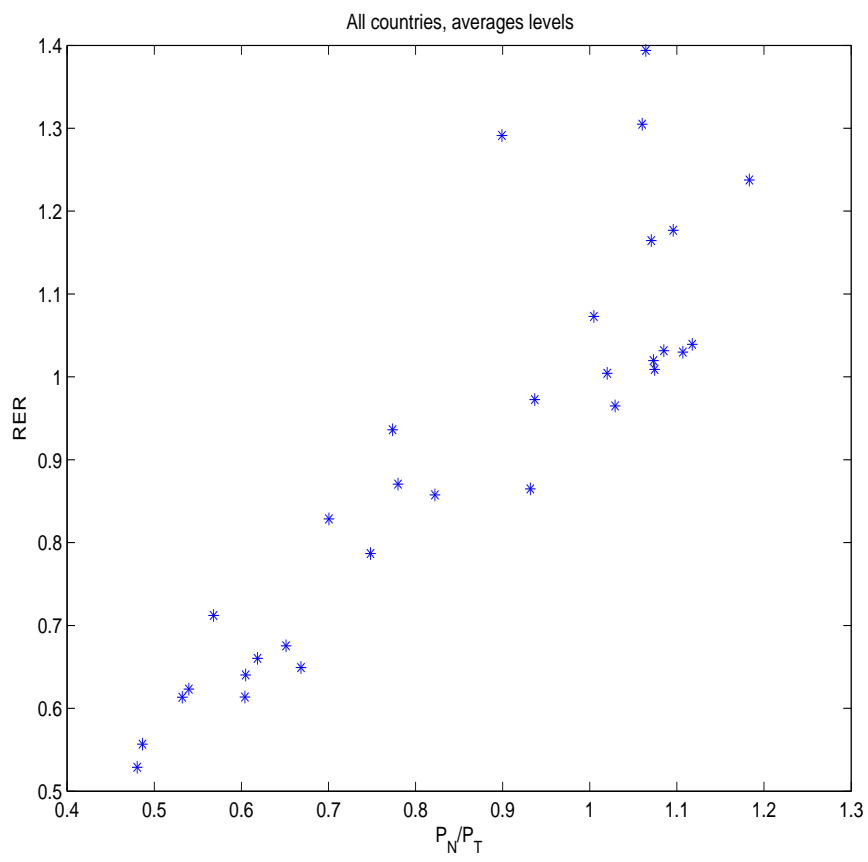
Figure 8: Average growth rates of Price of Non-traded to Traded goods and Real Exchange Rates

All countries, mean annual growth rates
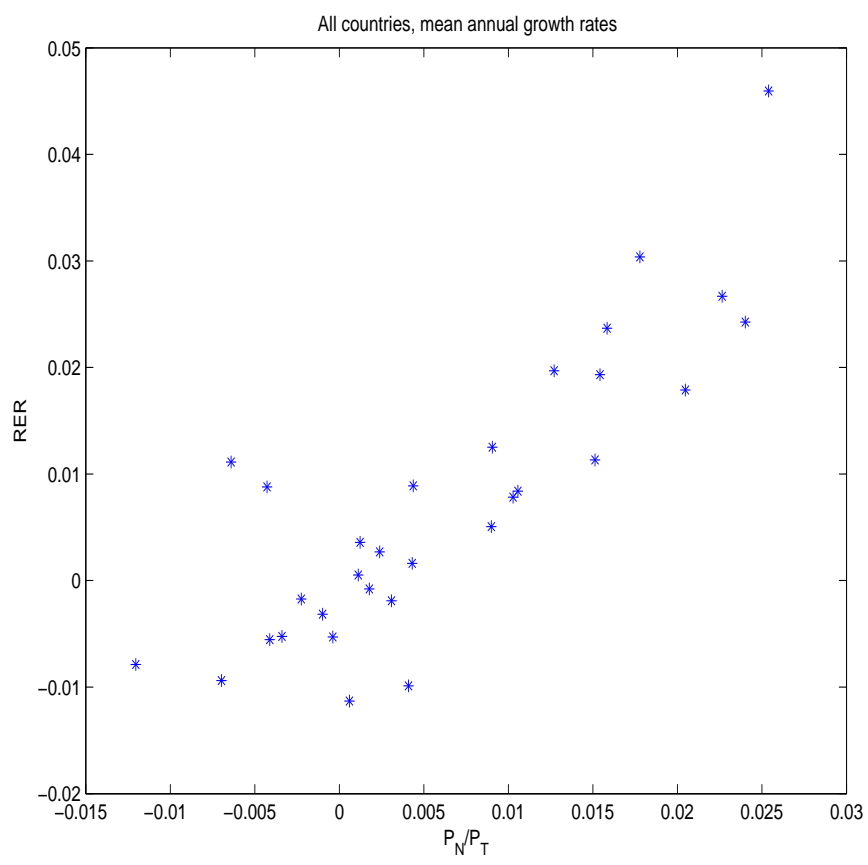
Figure 9: Relative GDP per capita and average PLI's in Western Europe

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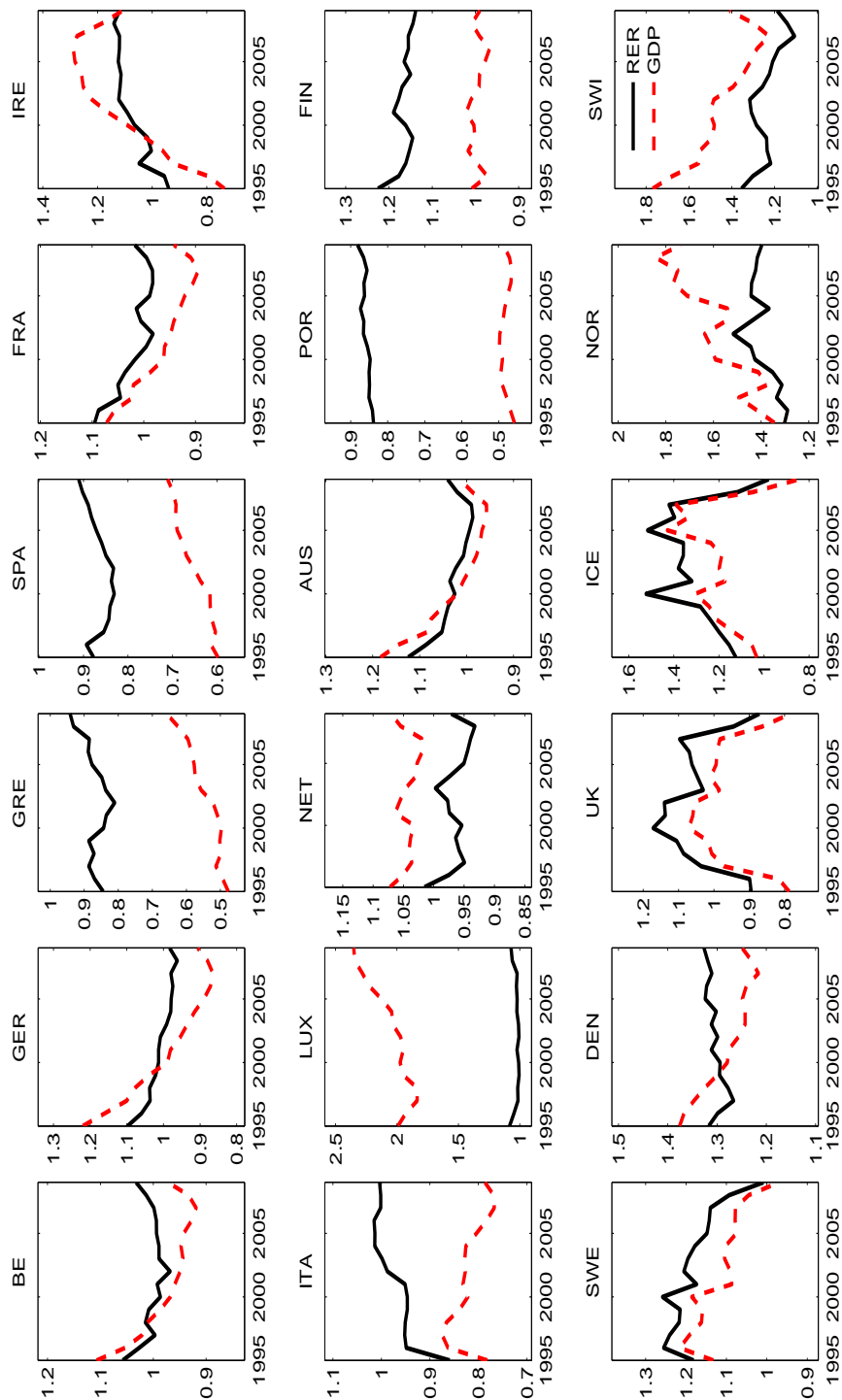
Figure 9 continued: Relative GDP per capita and average PLI's in Southern and Eastern Europe
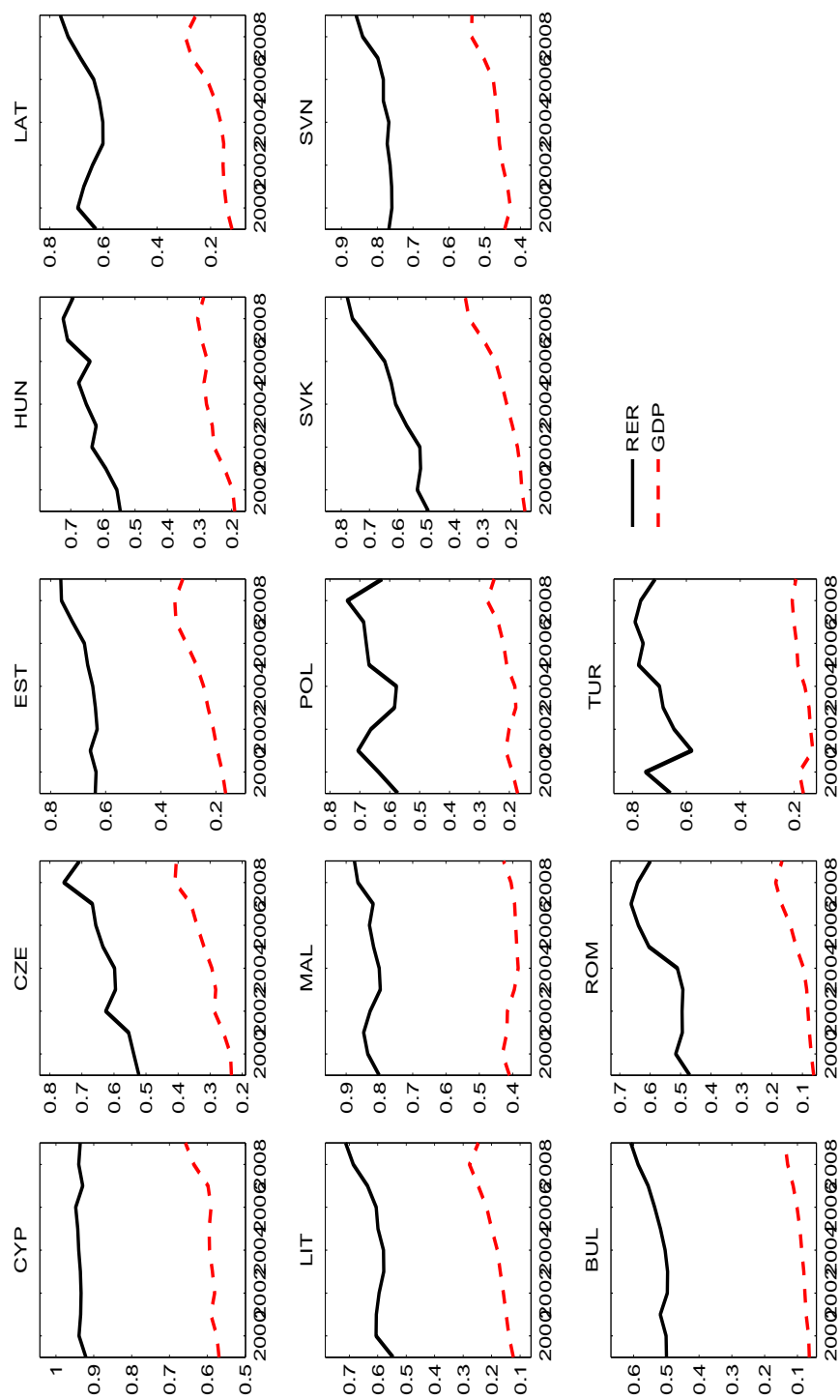
Figure 10: Real exchange rate and GDP: pooled
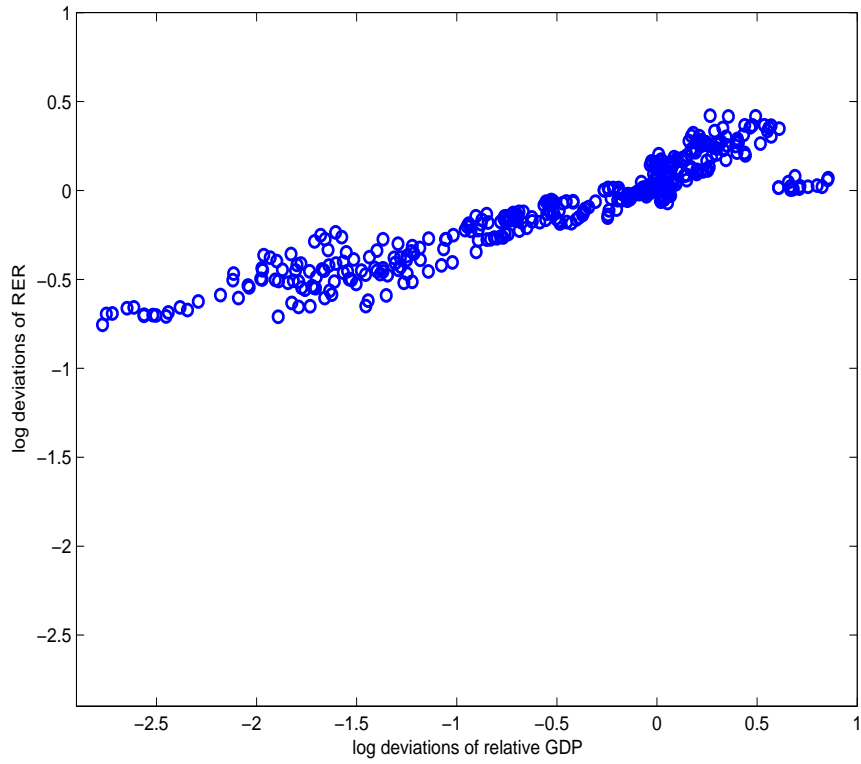
Figure 11: Model elasticity of RER to RGDP
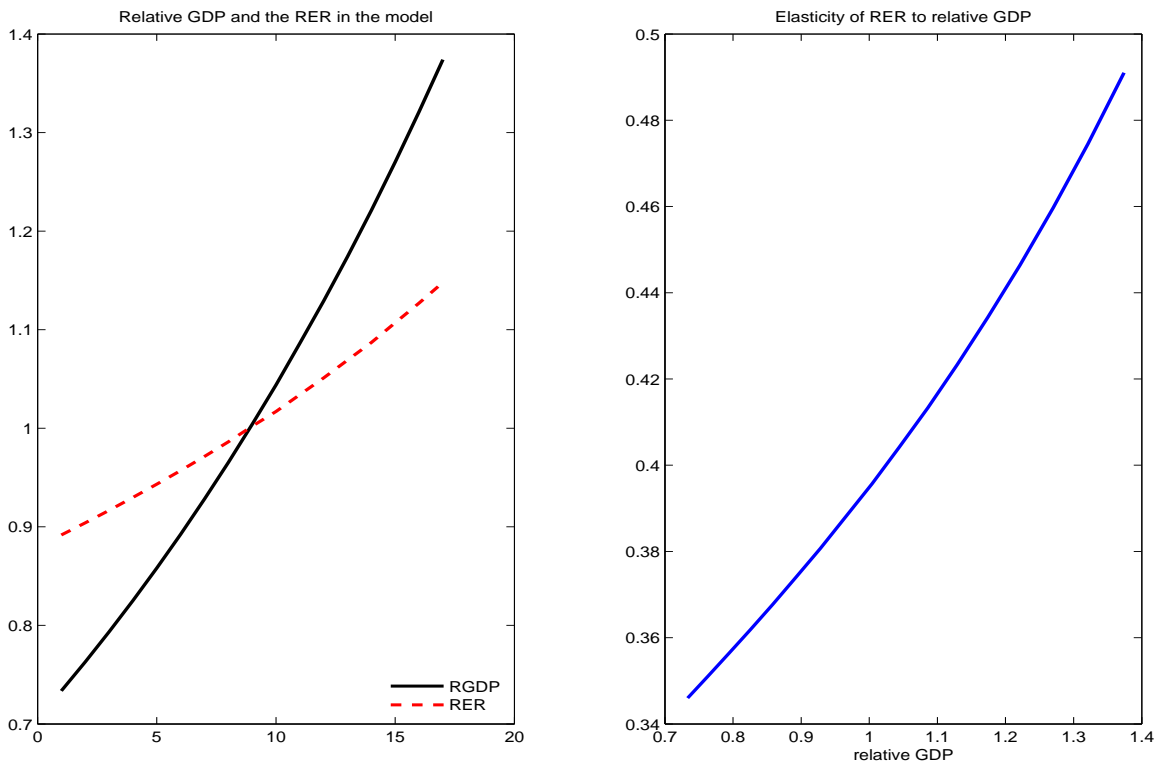
Figure 12: Model prediction and Average PLI's in EU12

RER$_{data}$
RER$_{modell.1}$
GDP

46
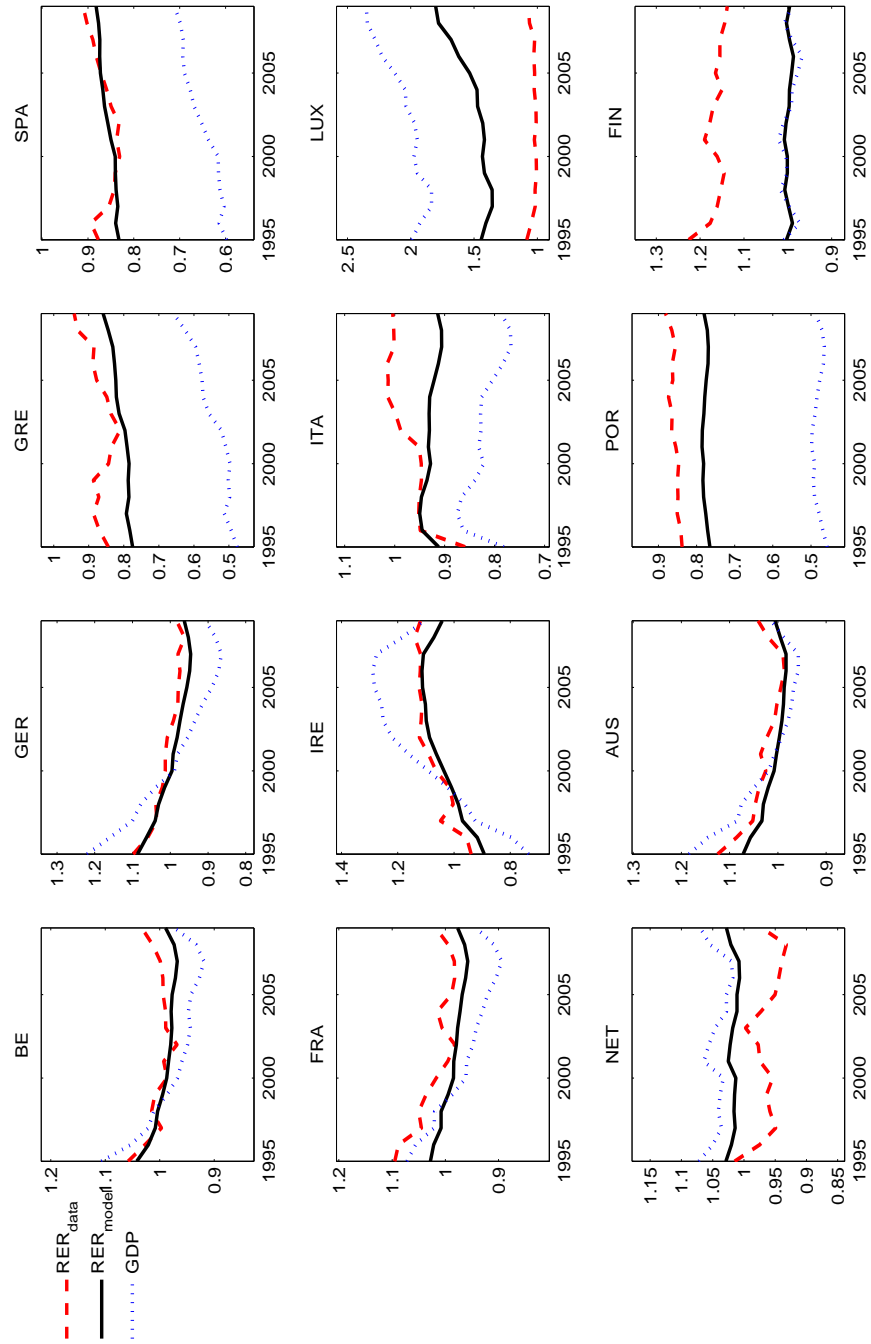
Figure 13: Model prediction and Average PLI's in countries with floating exchange rates
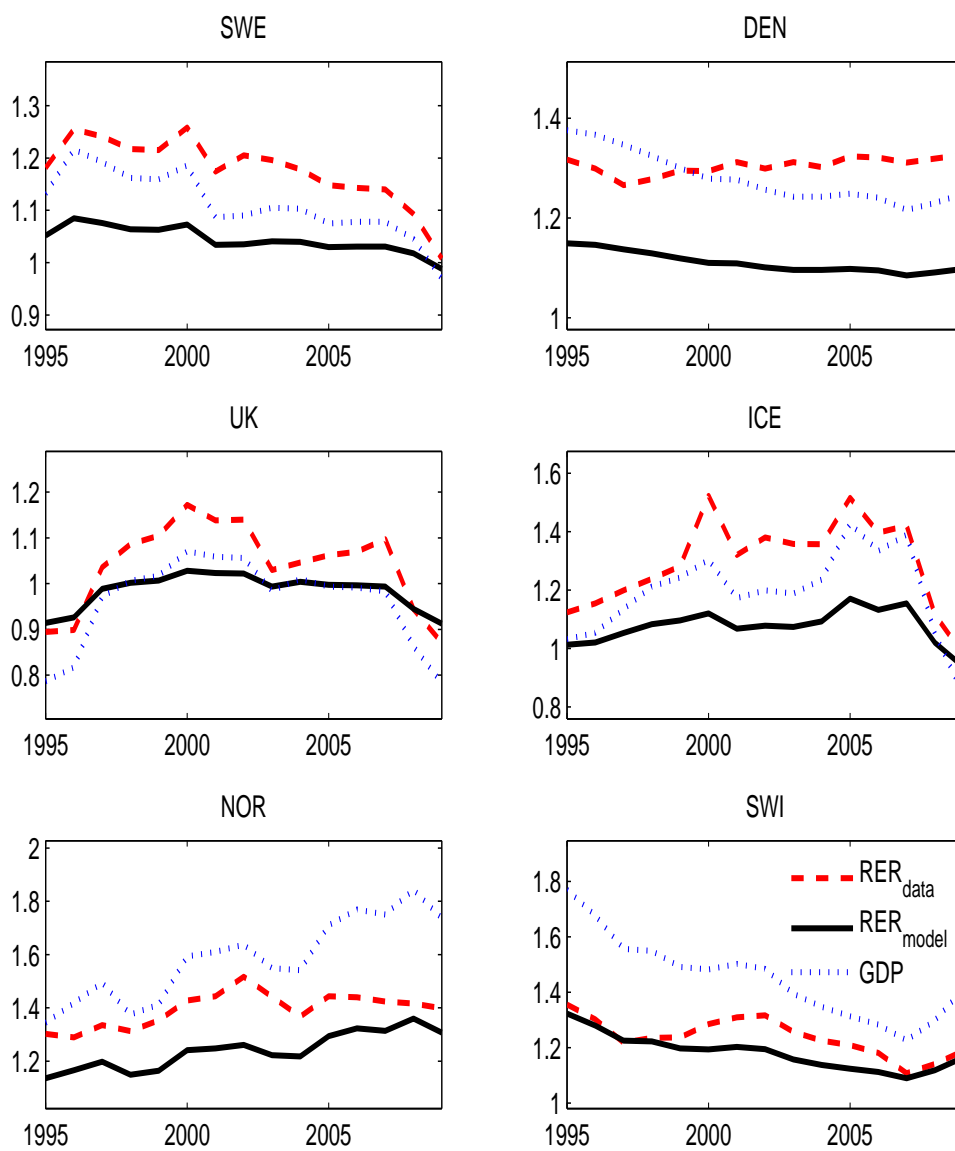
Figure 14: Model prediction and Average PLI's in Southern and Eastern Europe
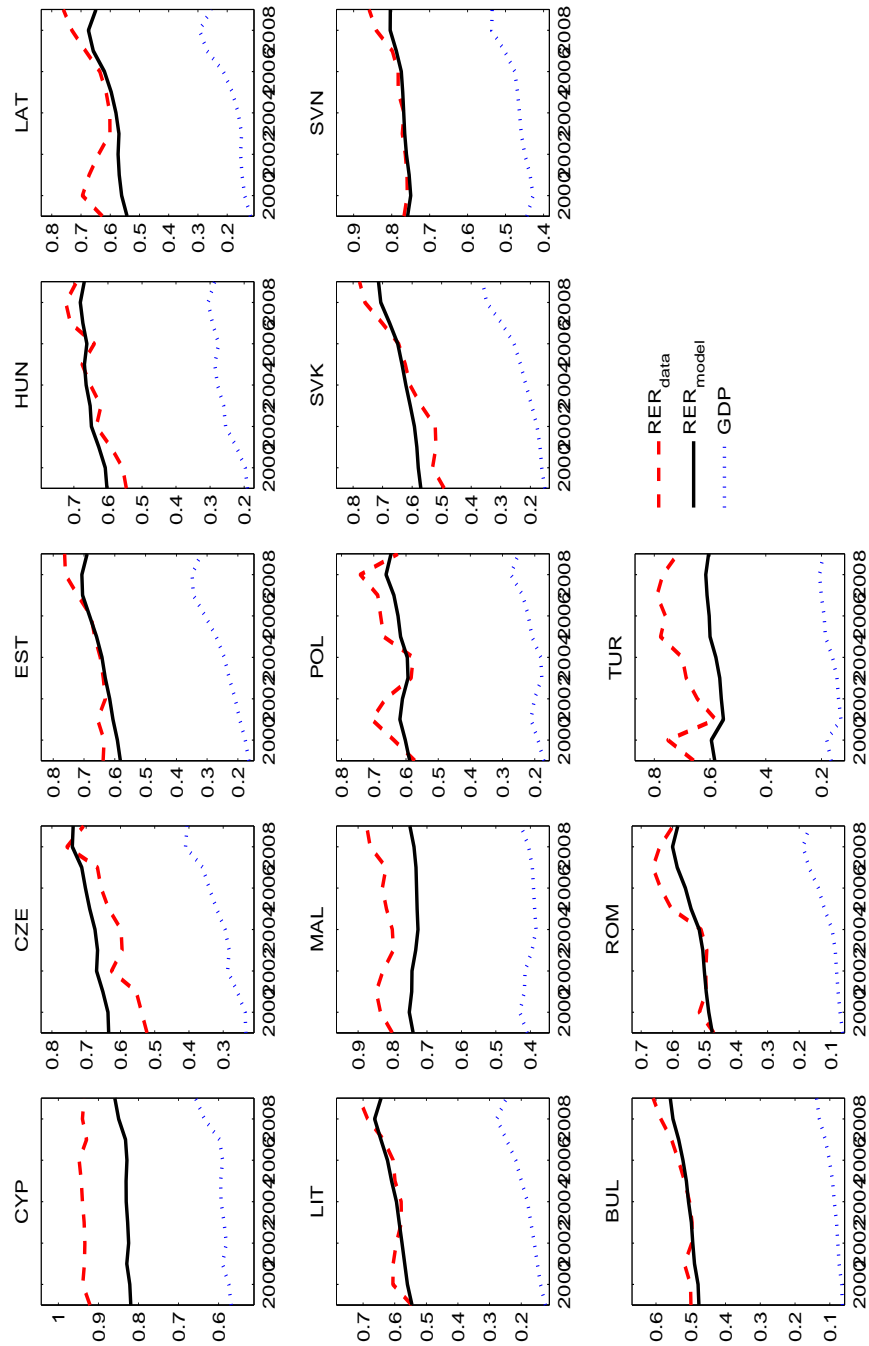
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Appendix to
"What Determines European Real Exchange Rates?"
by Martin Berka and Michael B. Devereux

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A. Expenditure weights

Composition of the consumption baskets differs across goods, countries, and time. At the same time, components of inflation are known to co-move strongly with aggregate inflation, suggesting that non-equal weighting should not affect the behaviour of the RER. To explore the degree to which this may influence our results we construct expenditure weights for each good, country, and year, using the local currency expenditures data provided by Eurostat. Specifically, for good i, country j and year t, we construct a weight $\gamma_{i,j,t} = \frac{exp_{i,j,t}}{\sum_i^M exp_{i,j,t}}$ where exp is the local currency expenditure. We then construct an expenditure-weighted PLI's for all countries using $\gamma_{i,j,t}$, and plot them against the un-weighted PLI's in the figures below.

For each country, Figure A1 plots an un-weighted average real exchange rate as the red dashed line, as well as the expenditure-weighted average as the solid black line. While there are differences between the two, these are small for most countries. Even in situations when there is a level difference between the two, there is a strong co-movement between them. We conclude that our results are not driven by the use of equally-weighted average PLI's.

B. Good description

Table A1 Describes the set of consumer goods in the PLI data set. The Table also illustrates the breakdown of goods between the categories "Traded" and "Non-traded". The criterion of this breakdown follows the categorization of goods into traded and non-traded in Table A2 of Crucini, et al. (2005). All goods with a positive trade share are categorized as "traded", and those with a zero trade share as "non-traded". Our data contains two types of services that are not in Crucini, et al. (2005): education (at different levels), and prostitution. While some some tertiary education engages international trade, the nature of price setting in this sector suggests that the trade has at most a negligible influence on the price of tertiary education. We therefore categorize education as non-traded.

C. Examples

Figure A4 gives some examples of individual goods prices for the three groups of countries used in the text. Note that prices are expressed so that on average across the EU 15 countries, the price of any good is 100.

D. PPP deviations at the good level

Figure A5 illustrates the deviation from PPP of each of the 146 consumer goods for three separate years in the sample for both groups of countries, respectively. It is apparent that the mean PLI's are quite representative. For for the central European group of countries (Belgium, Germany, Netherlands, France and Austria), there is an even distribution above and below PPP across the goods. For the Scandinavian countries, most goods are above PPP, while for the southern European countries, most goods are below PPP. In addition, the time variation seen in the means can be seen across the range of goods, for Ireland, UK, Iceland, and Switzerland, for instance.

Figure A5 also shows that for the Southern and Eastern European countries, almost all goods are substantially below PPP relative to the EU15. For some countries, the comparison is quite dramatic. For instance, in 2007, Bulgaria had only 6 of the total 146 good categories with prices at or above the EU average.

E. Monthly frequency

Figures A2 and A3 describe the equivalent measures for relative prices and price dispersion at monthly frequencies, for the three groups of countries. Due to lack of complete coverage of HICP data for the full sample of countries and months, and the higher level of aggregation for the HICP series, relative to the BH-PPP data, these data are restricted to 38 good categories of HICP series, in 25 countries. The Figures show that the general features of the real exchange rates in the annual series carry over to the monthly data, but these measures of real exchange rates exhibit substantially more volatility. One interesting feature of the monthly data is the more distinct tendency cross country price dispersion to fall in the post 2000 period for the eurozone countries. Comparing with Figure 1 of the text, there is a clear tendency for monthly cross country price dispersion to fall after 2004

F. Incorporating VAT differentials

We noted above that the simple simulation model did not account for differential VAT rates across different European countries. 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 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? 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 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.

Similarly, the results remain broadly unchanged when model results are compared with expenditure-weighted real exchange rate in the data (Figures A9 - A11).

G. Model with endogenous capital accumulation

Here we sketch out a model similar to that of the text, but extended to allow for endogenous production. We assume that there is a fixed supply of labour, but labour is mobile between sectors. In addition, we allow for capital accumulation through investment, with sectors potentially differing in their factor intensities. To make the exposition simple, we abstract from terms of trade changes here, and simply make the price of tradable goods the numeraire, which is consistent either with a very high elasticity between domestic and foreign traded goods, or a situation where the home country is not the sole supplier of its export good, and is small enough that it cannot affect its terms of trade. Also, we assume log utility, with a unit elasticity of substitution between traded and non-traded

goods, as well as Cobb Douglas production in each sector.

Assume that the representative individual in the home country has preferences defined over intertemporal consumption given by

$$U = \sum_{t=0}^{\infty} \beta^t \ln C_t, \quad \beta < 1.$$

where $C_t = \Omega C_{Nt}^{\varepsilon} C_{Tt}^{1-\varepsilon}$.

The home budget constraint is

$$P_t C_t + P_t I_t = P_{Nt} Y_{Nt} + Y_{Tt}$$

where $I_t = K_{t+1} - (1-\delta)K_t$ is investment, which is constructed using traded and non-traded goods in the same manner as consumption, and K_t is the aggregate capital stock. Let the traded good be the numeraire, so that the consumption and investment price index is $P_t = P_{Nt}^{\varepsilon}$.

Let the production functions for traded and non-traded goods be given by

$$Y_{Tt} = A_{Tt} K_{Tt}^{\alpha} L_{Tt}^{1-\alpha} \ , \qquad Y_{Nt} = A_{Nt} K_{Nt}^{\gamma} L_{Nt}^{1-\gamma}.$$

where A_{Tt} and A_{Nt} are exogenous productivity terms that may grow at separate rates.

Again assume that there is no intertemporal capital mobility. Then in a perfect foresight equilibrium, it is straightforward to confirm that the following relationships hold

$$P_{Nt} Y_{Nt} = \frac{\varepsilon}{1-\varepsilon} Y_{Tt} \ , \quad a K_{Nt} = \gamma K_{Tt} \frac{\varepsilon}{1-\varepsilon} \ , \quad (1-a) L_{Nt} = (1-\gamma) L_{Tt} \frac{\varepsilon}{1-\varepsilon}$$

Since labour supply is fixed, and sectoral labour is proportionally allocated, then it must be that labour allocation in each sector is constant. Since capital allocation is proportional across sectors, the growth rate of capital in each sector is constant. Let A_{Tt} and A_{Nt} grow at rates g_T and g_N respectively. Then the growth rate of P_{Nt} is $g_p = \frac{g_T}{1-\alpha} - \frac{g_N}{1-\gamma}$, and the growth rates of traded and non-traded goods outputs are $\frac{g_T}{1-\alpha}$ and $\frac{g_N}{1-\gamma}$ respectively. The real exchange rate will appreciate over time if the traded goods sector grows faster than the non-traded goods sector. If exogenous productivity grows at the same rate in each sector, then a sufficient condition for the traded good sector to grow at a higher rate than the non-traded sector is that $\alpha > \gamma$, i.e. the non-traded sector is relatively labour intensive. This is Bhagwati's (1984) case. But even if factor intensities are the same, the traded sector grows at a faster rate if $g_T > g_N$. This is the Balassa-Samuelson case.

H. GDP growth and relative outputs of traded and non-traded goods

The theoretical model assumes that GDP growth is associated with faster growth in traded goods relative to non-traded goods. Figure A12 shows that this assumption is

true on average in the data. We construct sectoral output levels using the main aggregates tables of the OECD Structural Analysis Database for 25 countries in our sample. Traded goods output is 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 A12 shows that, on average, faster growing countries have higher growth rates of traded goods relative to non-traded goods.

Table A1. PLI basic headings, Household expenditures

T	Rice	T	Major tools and equipment
T	Other cereals, flour and other cereal products	T	Small tools and miscellaneous accessories
T	Bread	T	Non-durable household goods
T	Other bakery products	NT	Domestic services
T	Pasta products	NT	Household services
T	Beef and Veal	T	Pharmaceutical products
T	Pork	T	Other medical products
T	Lamb, mutton and goat	T	Therapeutical appliances and equipment
T	Poultry	NT	Medical Services
T	Other meats and edible offal	NT	Services of dentists
T	Delicatessen and other meat preparations	NT	Paramedical services
T	Fresh, chilled or frozen fish and seafood	NT	Hospital services
T	Preserved or processed fish and seafood	T	Motor cars with diesel engine
T	Fresh milk	T	Motor cars with petrol engine of cubic capacity of less than 1200cc
T	Preserved milk and other milk products	T	Motor cars with petrol engine of cubic capacity of 1200cc to 1699cc
T	Cheese	T	Motor cars with petrol engine of cubic capacity of 1700cc to 2999cc
T	Eggs and egg-based products	T	Motor cars with petrol engine of cubic capacity of 3000cc and over
T	Butter	T	Motor cycles
T	Margarine	T	Bicycles
T	Other edible oils and fats	T	Animal drawn vehicles
T	Fresh or chilled fruit	T	Spare parts and accessories for personal transport equipment
T	Frozen, preserved or processed fruit	T	Fuels and lubricants for personal transport equipment
T	Fresh or chilled vegetables other than potatoes	NT	Maintenance and repair of personal transport equipment
T	Fresh or chilled potatoes	NT	Other services in respect of personal transport equipment
T	Frozen, preserved or processed vegetables	NT	Passenger transport by railway
T	Sugar	NT	Passenger transport by road
T	Jams, marmalades and honey	NT	Passenger transport by air
T	Confectionery, chocolate and other cocoa preps	NT	Passenger transport by sea and inland waterway
T	Edible ice, ice cream and sorbet	NT	Combined passenger transport
T	Coffee, tea and cocoa	NT	Other purchased transport services
T	Mineral waters	NT	Postal services
T	Soft drinks and concentrates	T	Telephone and telefax equipment
T	Fruit and vegetable juices	NT	Telephone and telefax services
T	Spirits	T	Equipment for reception, recording and reproduction of sound and pictures
T	Wine	T	Photographic and cinematographic equipment and optical instruments
T	Beer	T	Information processing equipment
T	Tobacco	T	Pre-recorded recording media
T	Narcotics	T	Unrecorded recording media
T	Other clothing and clothing accessories	NT	Repair of audio-visual, photographic and information processing equipment
T	Clothing materials	T	Major durables for outdoor recreation
T	Men's clothing	T	Musical instruments and major durables for indoor recreation
T	Women's clothing	NT	Maintenance and repair of other major durables for recreation and culture
T	Childrens and infants clothing	T	Games, toys and hobbies
T	Other clothing and clothing accessories	T	Equipment for sport, camping and open-air recreation
NT	Cleaning, repair and hire of clothing	T	Gardens, plants and flowers
T	Men's footwear	T	Pets and related products
T	Women's footwear	T	Veterinary and other services for pets
T	Children's and infant's footwear	NT	Recreational and sporting services
NT	Repair and hire of footwear	NT	Photographic services
NT	Actual rentals for housing	NT	Other cultural services
NT	Imputed rentals for housing	T	Games of chance
T	Materials for maintenance and repair of dwelling	T	Books
NT	Services for maintenance and repair of dwelling	T	Newspapers and periodicals
T	Water supply	T	Miscellaneous printed matter, stationery and drawing materials
NT	Miscellaneous services relating to the dwelling	T	Package holidays
T	Electricity	NT	Pre-primary and primary education
T	Gas	NT	Secondary education
T	Liquid fuels	NT	Post-secondary education
T	Solid fuels	NT	Tertiary education
T	Heat energy	NT	Education not definable by level
T	Kitchen furniture	NT	Restaurant services whatever the type of establishment
T	Bedroom furniture	NT	Pubs, bars, cafs, tea rooms and the like
T	Living-room and dining-room furniture	NT	Canteens
T	Other furniture and furnishings	NT	Accommodation services
T	Carpets and other floor coverings	NT	Hairdressing salons and personal grooming establishments
NT	Repair of furniture, furnishings and floors	T	Electric appliances for personal care
T	Household textiles	T	Other appliances, articles and products for personal care
T	Major household appliances electric or not	NT	Prostitution
T	Small electric household appliances	T	Jewellery, clocks and watches
NT	Repair of household appliances	T	Other personal effects
T	Glassware, tableware and household utensils	NT	Social protection
		NT	Insurance
		T	Net purchases abroad
		NT	Other financial services n.e.c.
		NT	Other services n.e.c.

Table A2. Value Added Tax rates

Country	VAT rate (in %)
Belgium	21.0
Germany	19.0
Greece	19.0
Spain	16.0
France	19.6
Ireland	21.5
Italy	20.0
Luxembourg	15.0
Netherlands	19.0
Austria	20.0
Portugal	20.0
Finland	22.0
Denmark	25.0
Sweden	25.0
UK	15.0
Iceland	24.5
Norway	25.0
Switzerland	7.6
Cyprus	15.0
Czech Republic	19.0
Estonia	20.0
Hungary	25.0
Latvia	21.0
Lithuania	21.0
Malta	18.0
Poland	22.0
Slovakia	19.0
Slovenia	20.0
Bulgaria	20.0
Romania	19.0
Turkey	18.0

Figure A1: Equal- and Expenditure-weighted real exchange rates in western Europe
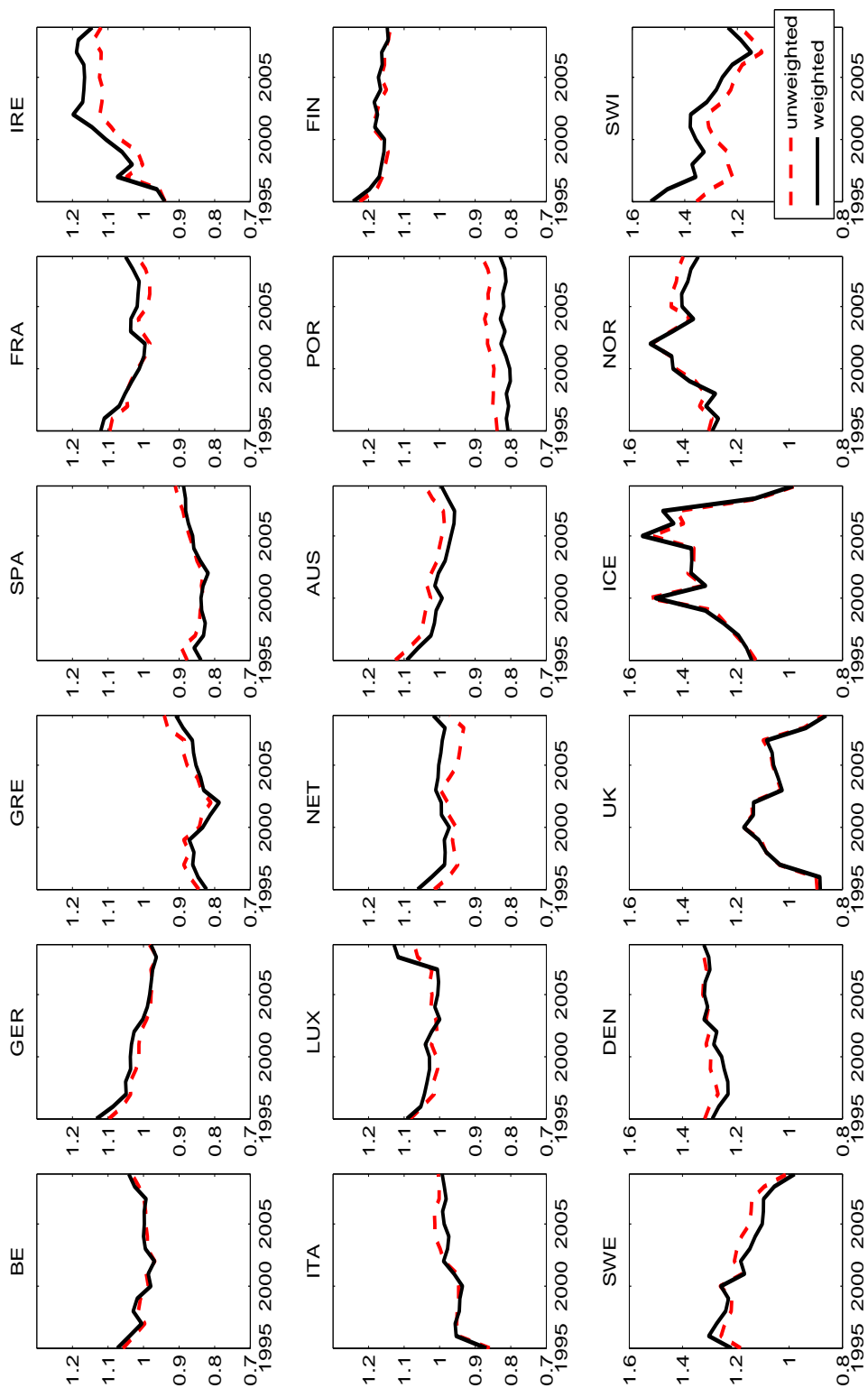
Figure A1 continued: Equal- and Expenditure-weighted real exchange rates in Southern and Eastern Europe
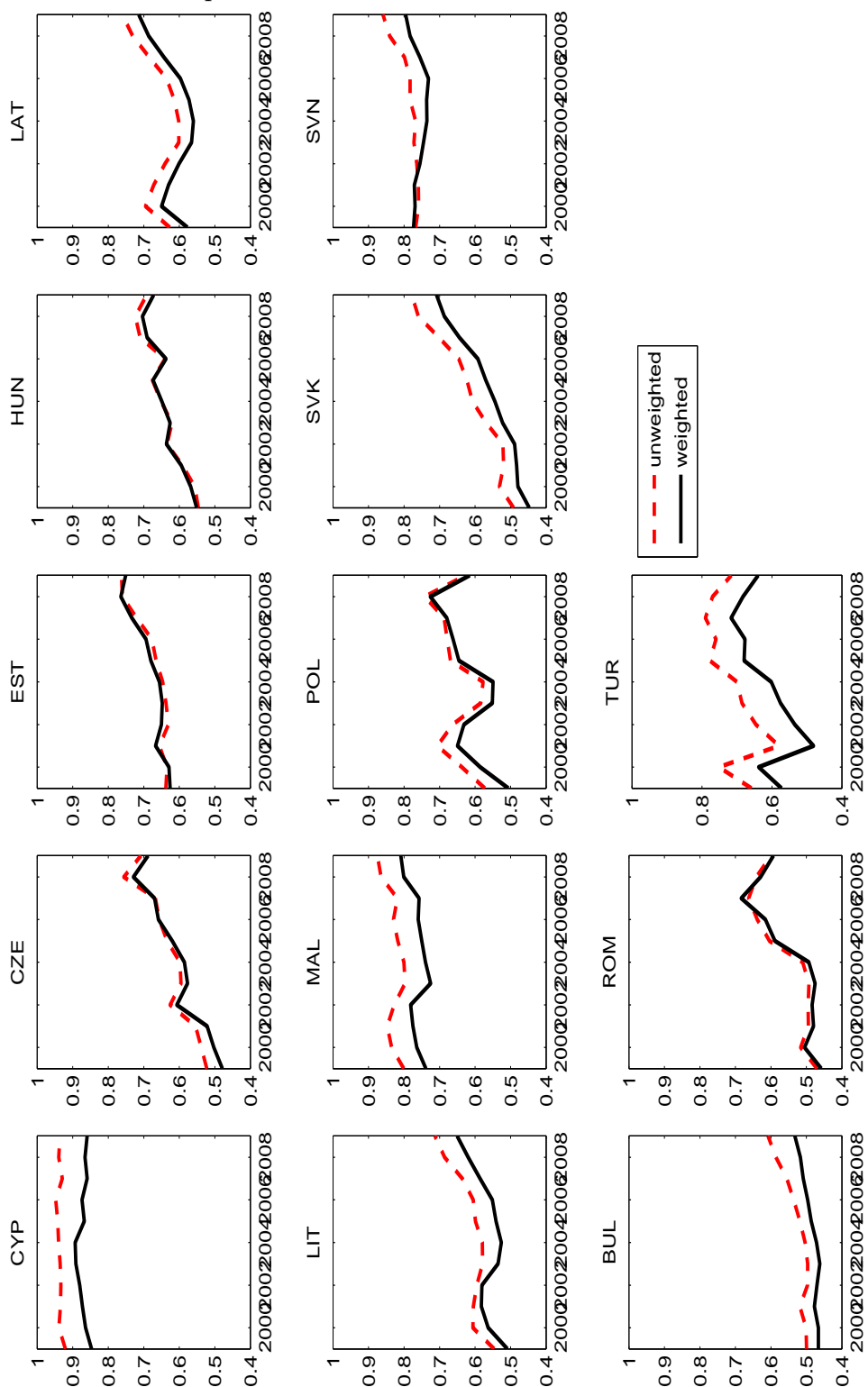
Figure A2: Average monthly prices relative to EU15 mean
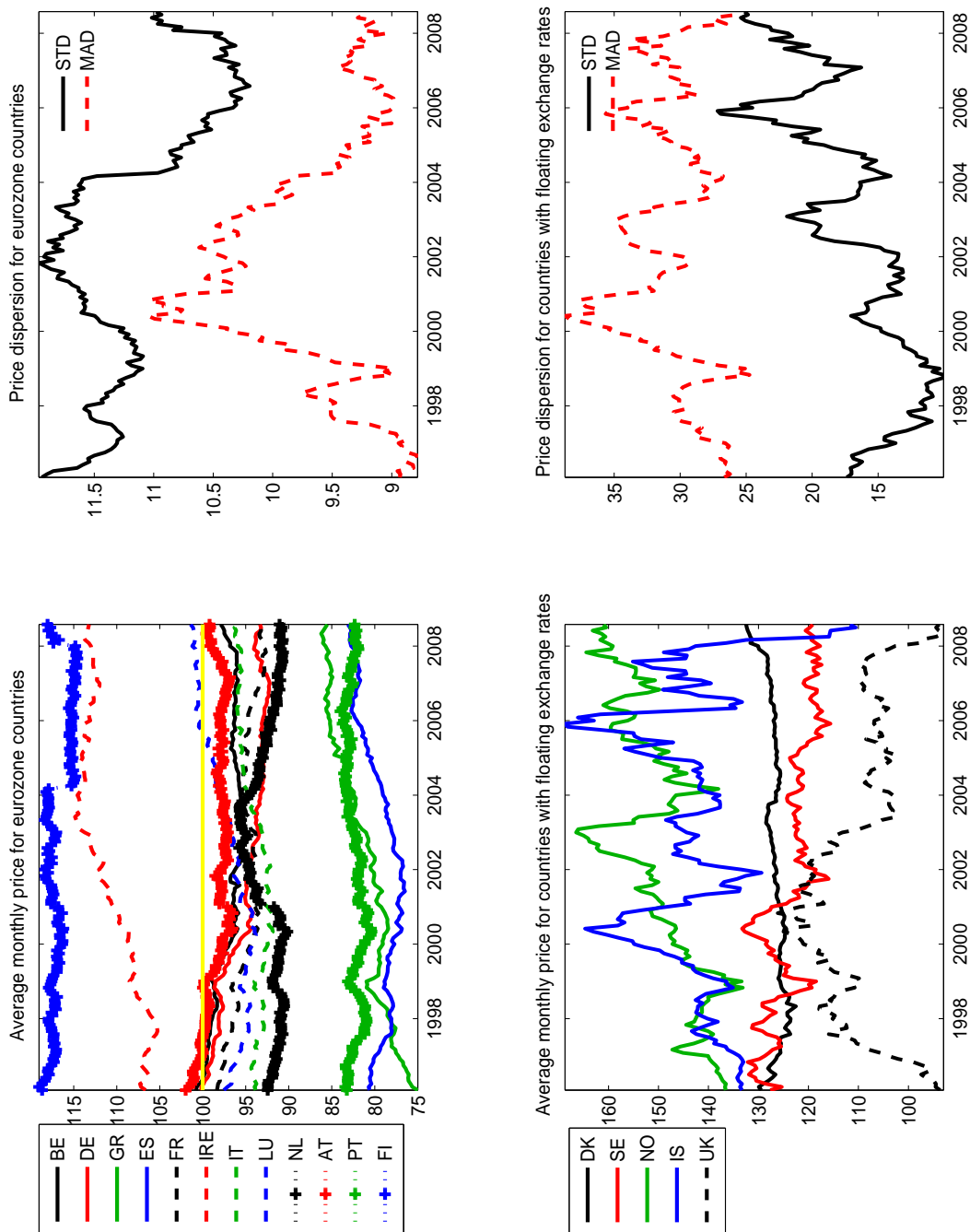
Figure A3: Average monthly prices relative to EU15 mean
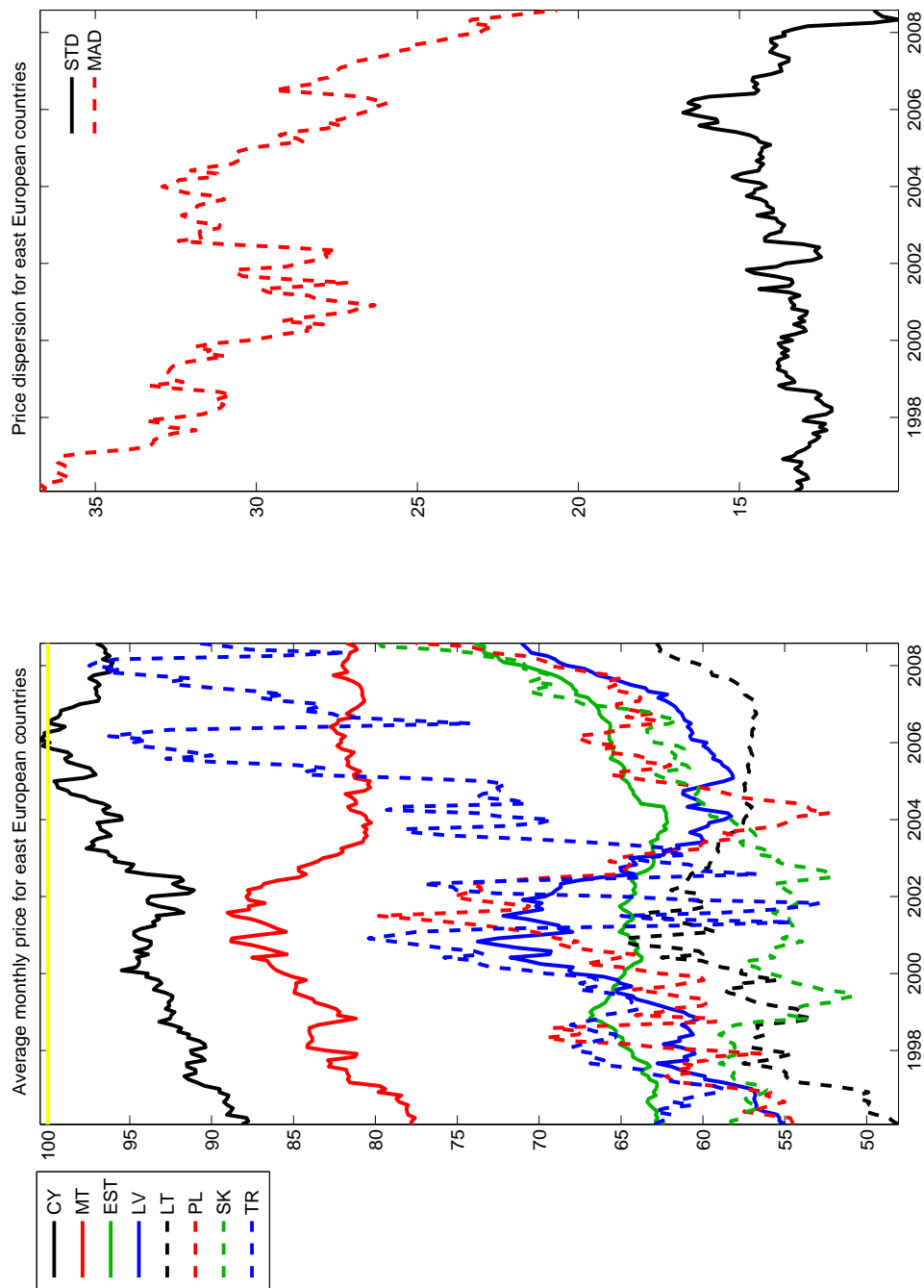
Figure A4: Examples of prices
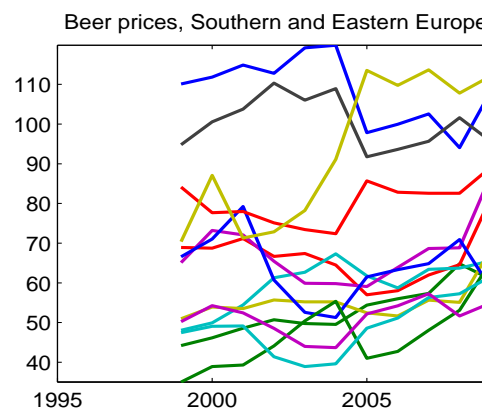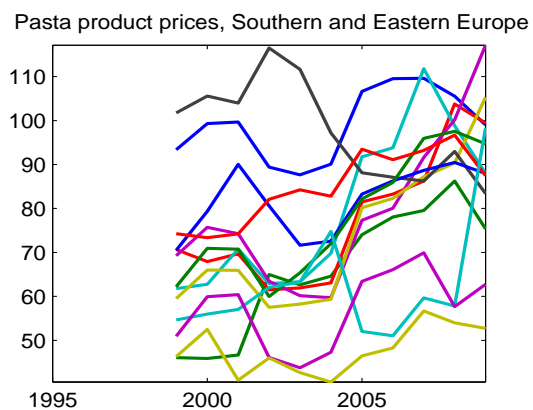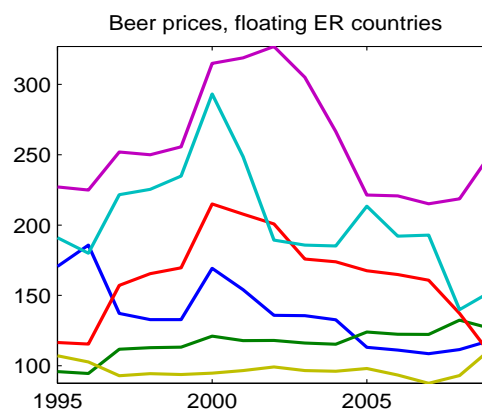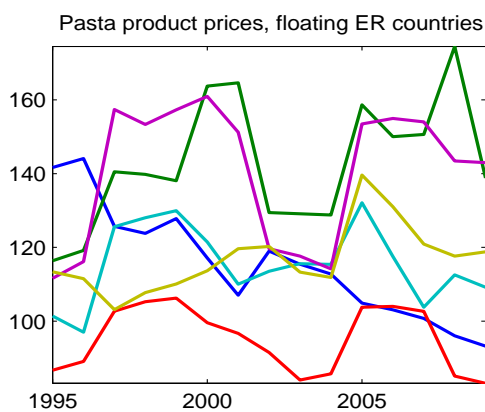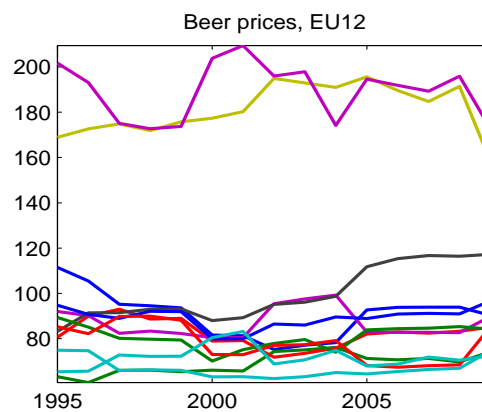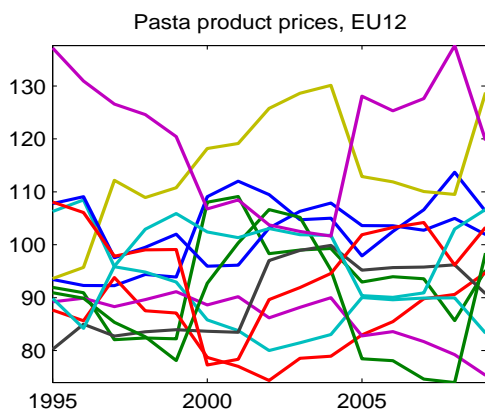
Figure A5: Prices of 146 goods and services vis-a-vis EU15 mean, Western Europe
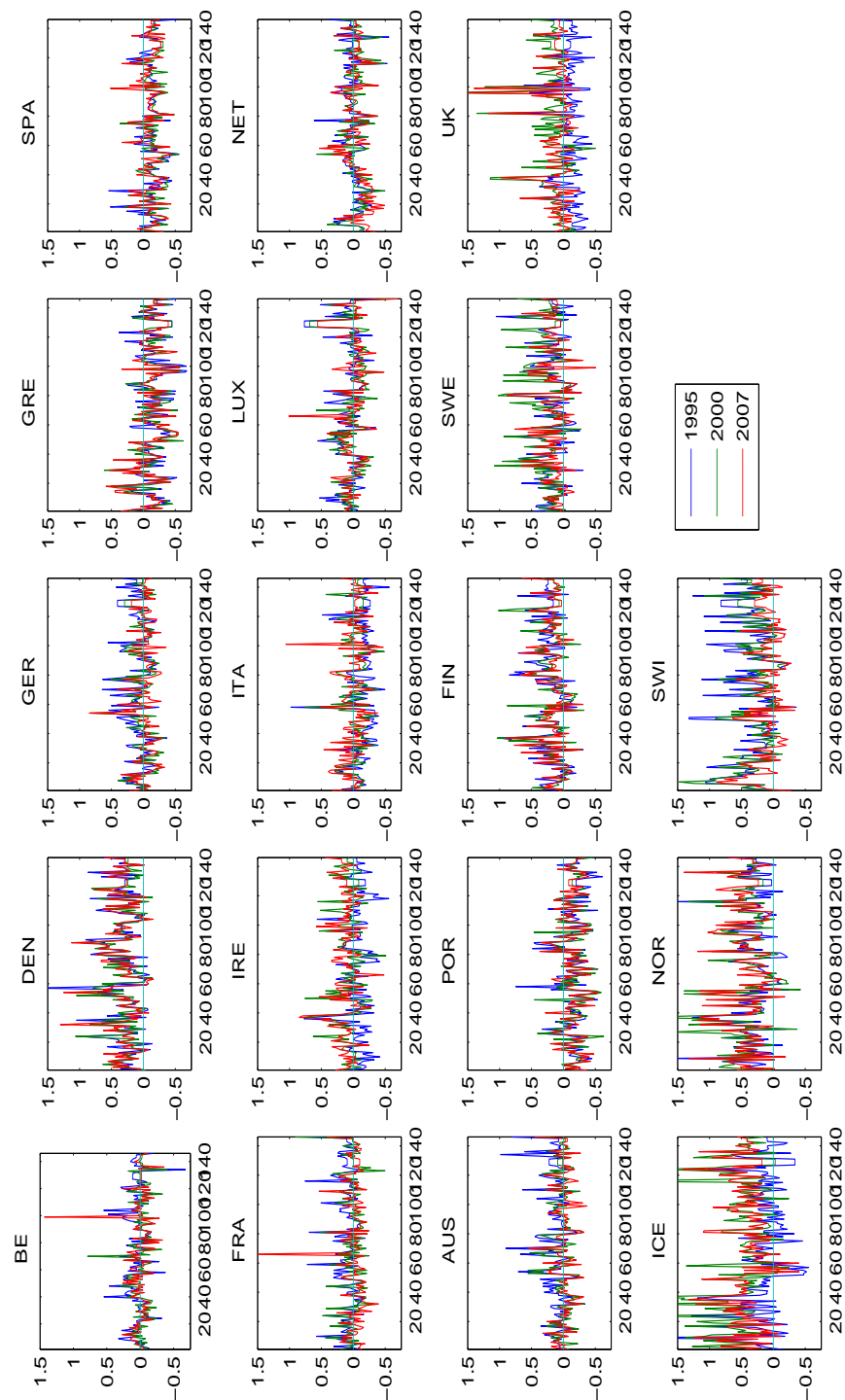
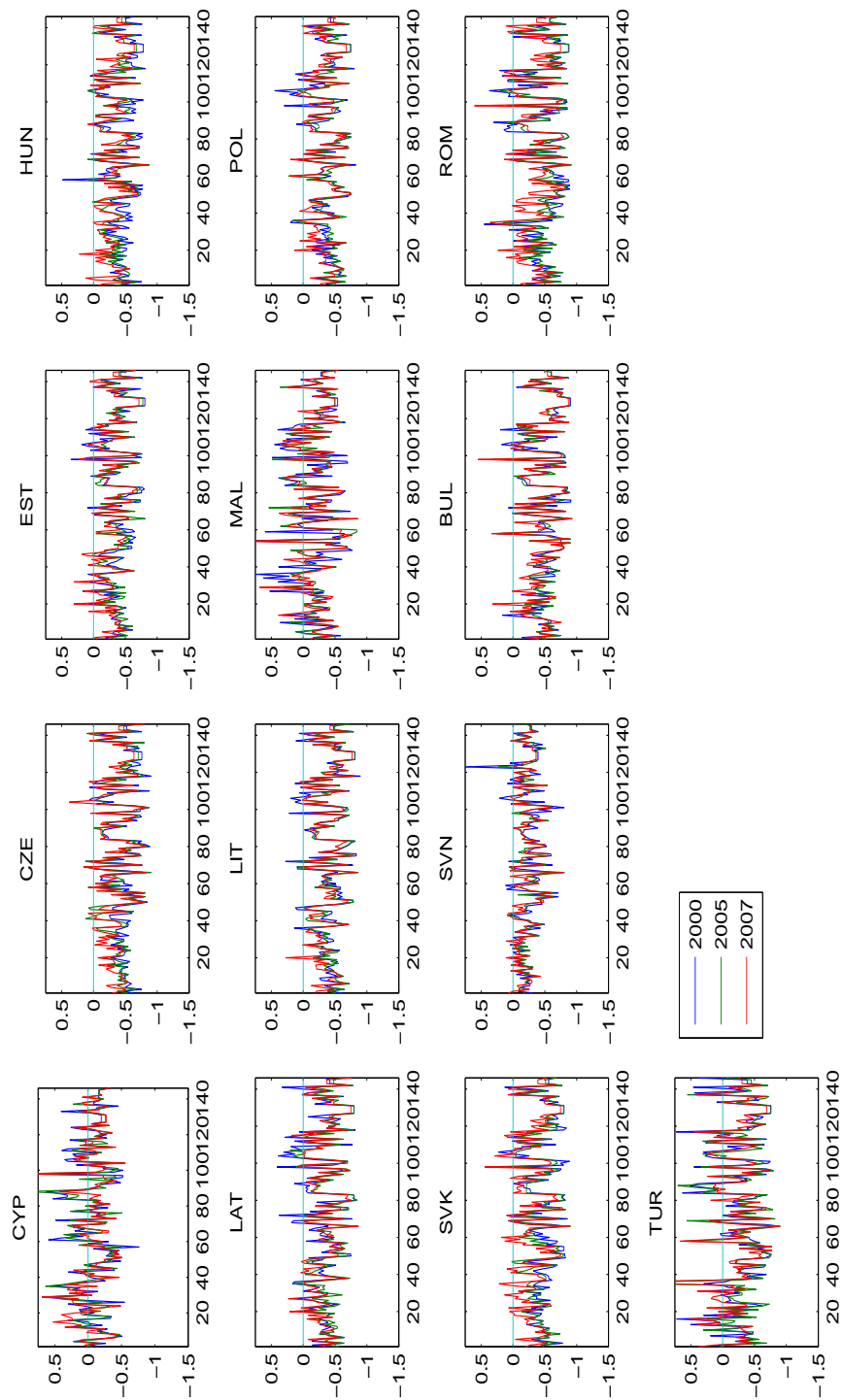Figure A5 continued: Prices of 146 goods and services vis-a-vis EU15 mean, Southern and Eastern Europe

Figure A6: Prediction of model with taxation, and average PLI's in EU12
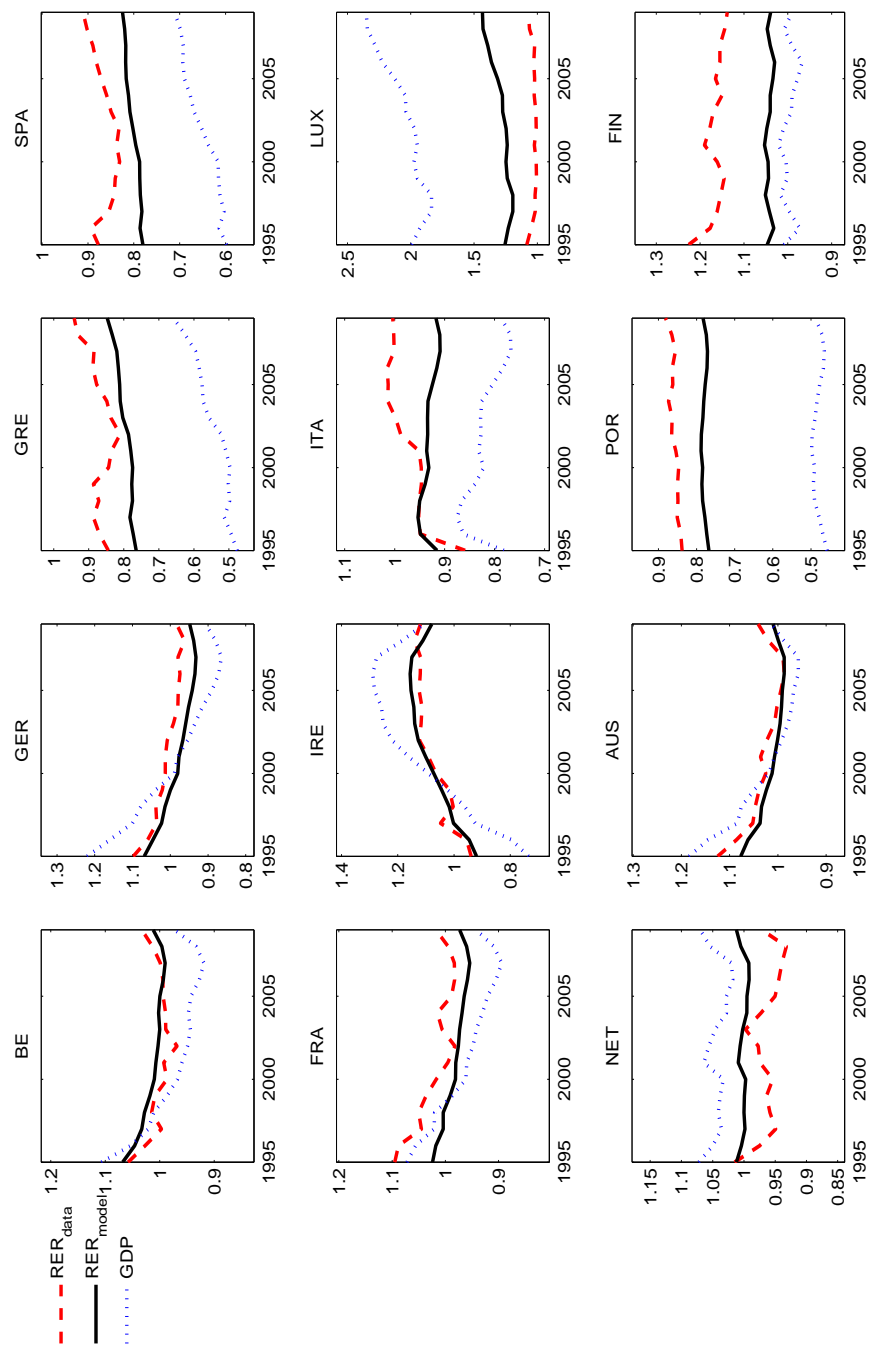
Figure A7: Prediction of model with taxation, and average PLI's in countries with floating exchange rates
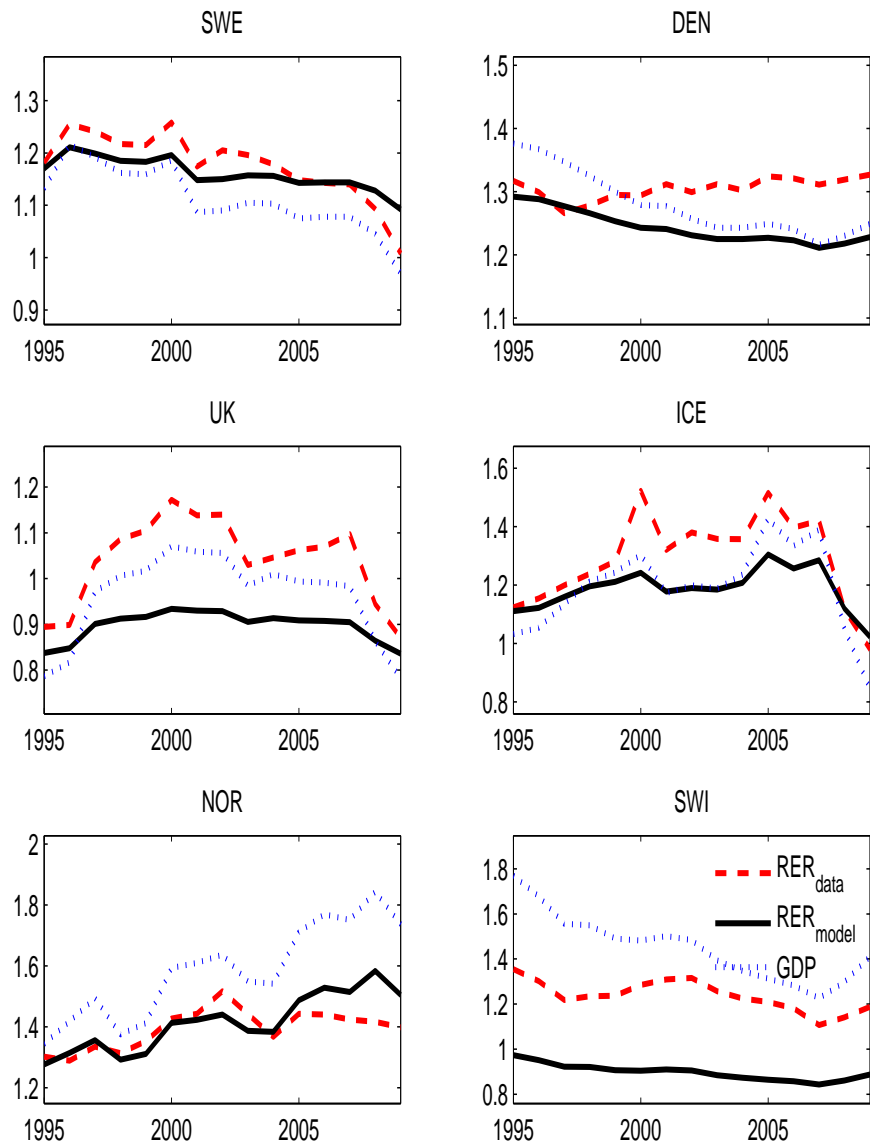
Figure A8: Prediction of model with taxation, and average PLI's in Southern and Eastern Europe
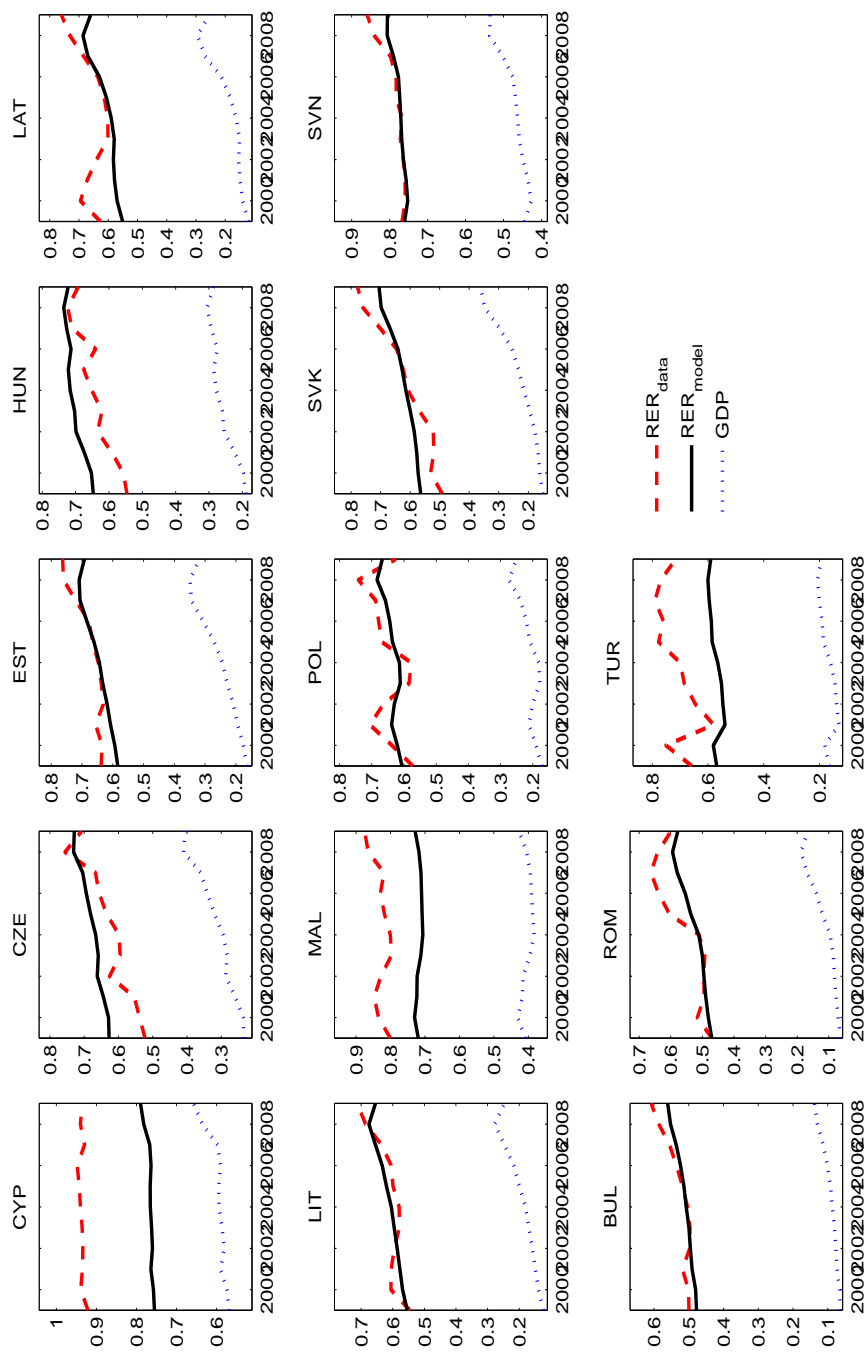
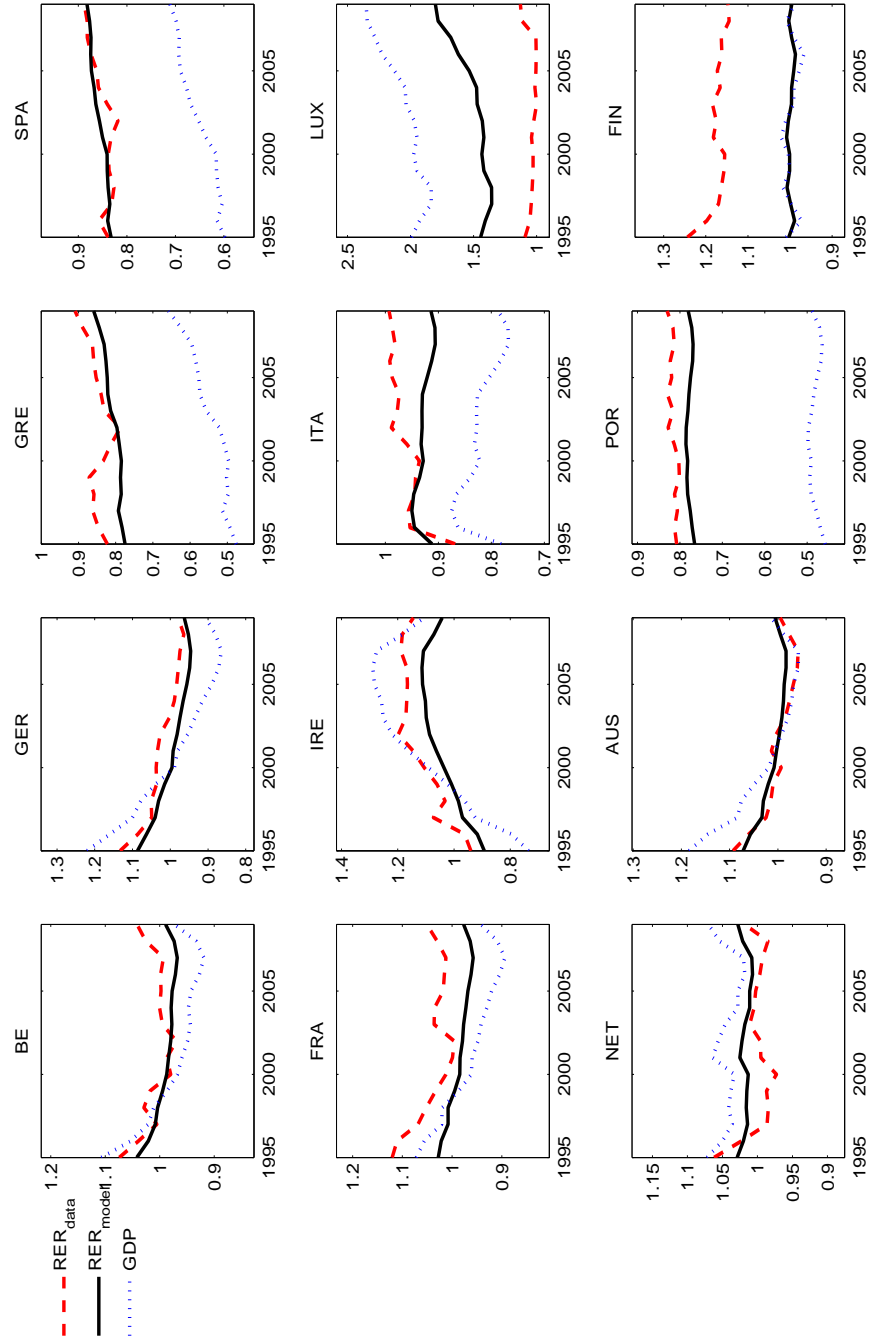Figure A9: Model prediction and Expenditure-weighted PLI's in EU12

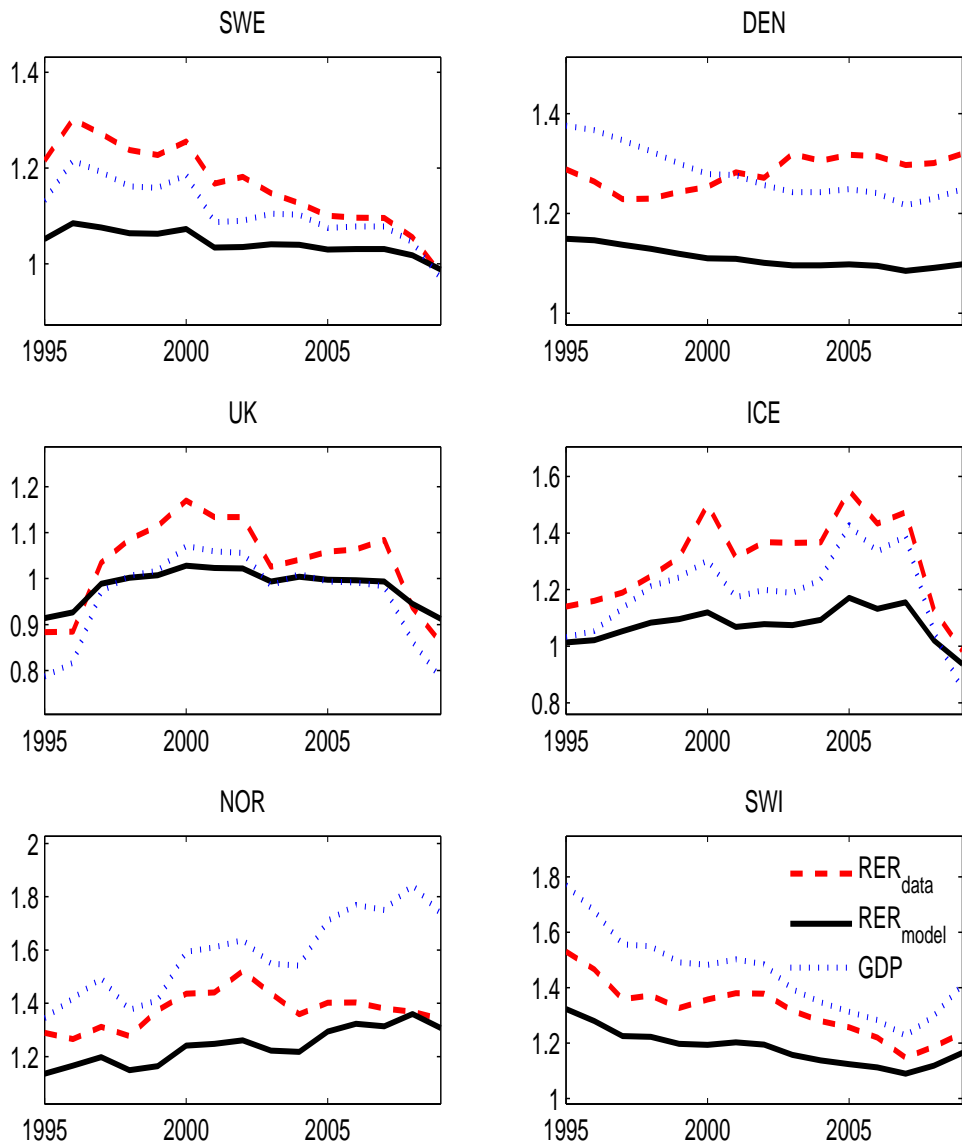Figure A10: Model prediction and Expenditure-weighted PLI's in countries with floating exchange rates

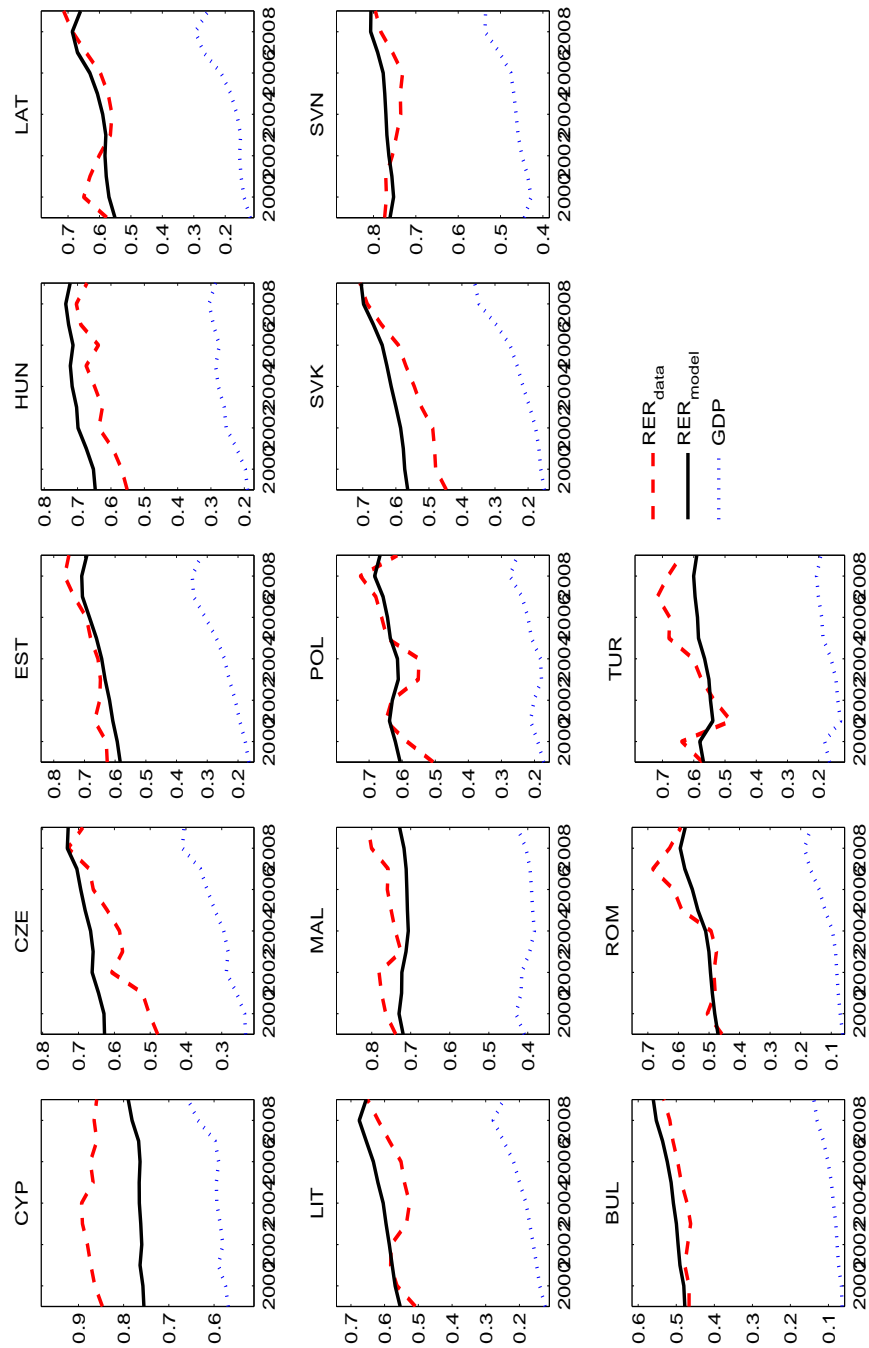Figure A11: Model prediction and Expenditure-weighted PLI's in Southern and Eastern Europe

Figure A12: Average relative GDP growth and average relative endowment growth