The purchasing power parity fallacy: time to reconsider the PPP hypothesis*

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Abstract

Traded good prices affect the real exchange rate first through their effect on the overall price level and second through their effect on the nominal exchange rate. Whereas the price level effect, which is positive in sign, is universally recognized, the nominal exchange rate effect, which is negative in sign, is routinely ignored. We calculate to which extent real exchange rate changes are accounted for by traded good prices and other components of the real exchange rate. We find that the nominal exchange rate effect neutralizes the price level effect entirely, suggesting that, contrary to popular belief, good market arbitrage is not conducive to purchasing power parity (the purchasing power parity fallacy). Rather than traded or non-traded good prices, the main driving force behind the real exchange rate is currency market pressure, a variable that, as we argue, is largely determined by the cumulative trade and capital flows of a country.

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1 Introduction

The real exchange rate is defined as the ratio of two countries' price levels. It is tempting to think that the reversion of the real exchange rate to its long-run mean is mainly a matter of convergence of international traded good prices. However, traded good price movements have two effects of opposite sign on the real exchange rate. A rise in domestic traded good prices, for instance, leads to a real appreciation (as a result of the rise of the domestic price level) as well as a real depreciation (due to the nominal depreciation caused by the fall in the domestic currency's purchasing power). The second effect can potentially offset the first one, especially when the nominal exchange rate is flexible. However, it plays no role in the theory of purchasing power parity (PPP), which is why

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we regard that theory as fallacious. What this paper shows is that what drives the real exchange rate is mostly currency market pressure, not traded or non-traded good prices.

It is all too easy to fall victim to the PPP fallacy. To see why, consider the standard argument that economists put forward to explain why the real exchange rate should revert to a value near one, provided there are no transport costs or differences in non-traded good prices across countries. If traded good prices are lower at home than abroad, an arbitrage opportunity arises which will raise the demand for domestic goods and lower that for foreign goods. The subsequent rise in the prices of traded goods at home and fall in the prices of traded goods abroad will then restore PPP.

This reasoning is put forward in every textbook on international economics, yet it also underlies much of the academic research on PPP. What it does not take into account, however, is that the rise in domestic traded good prices leads to a fall in the purchasing power of the domestic currency, and vice versa abroad, such that there is a force at work that makes the real exchange rate move away from its long-run mean. Whether the price level effect (which favours PPP convergence) or the exchange rate effect (which favours PPP divergence) dominates is the empirical question which this paper seeks to answer.

To challenge the conventional understanding of real exchange rates, we rely on a technical innovation, namely a new method for measuring the contribution of several time series to their sum. In the literature initiated by Engel (1999), sample statistics such as the mean, the variance, the covariance and the mean squared error are used to measure the contribution of (at most) two components of the real exchange rate to changes in that variable. Our approach is much simpler: If the real exchange rate rises, say, by 10 units and one of its summands by 7, then we say that this summand contributes 70% to the movement of the real exchange rate. If the summand rises by 13 units, then we say that it contributes 130% to the movement of the real exchange rate. And if, as a final example, it falls by 3 units, then we actually speak of a deduction of 30% from the movement of the real exchange rate. We like our procedure because it is arguably the most simple, exact and intuitive. What is more, it allows us to measure the contribution of more than two component series to the real exchange rate.

The central conclusion of this paper is that traded good price changes account for practically none of the real exchange rate movements that we observe across countries. Instead, the main driving force behind real exchange rates is what we define as currency market pressure, namely the part of the nominal exchange rate that is not explained by traded good price differences. So the natural question arises of what it is that determines currency market pressure. We address this question in a theoretical section, in which we argue that changes in currency market pressure are largely determined by real interest changes, the current account balance, net capital inflows (that is, net outflows of non-monetary, non-reserve financial assets), net sales of official reserves by the domestic central bank and net purchases of the domestic currency by foreign central banks.

The paper is structured as follows: Section 2 contains a review of the relevant literature. Section 3 introduces and defines two contribution measures proposed by us, namely the unbounded contribution measure (UCM) and the bounded contribution measure (BCM), and explains why we choose to work with the former. Section 4 measures the contributions of traded good inflation and currency market pressure to nominal exchange rate movements. Section 5 uses real exchange rate accounting to show empirically that traded good arbitrage is a not a suitable mechanism to bring about purchasing power parity, thereby demonstrating the purchasing power parity fallacy. Section 6 offers further reflections on the concept of currency market pressure, the variable that is found to account for most of the movements of the real exchange rate. Finally, Section 7 provides conclusions.

2 Literature review

Our study is related to two different research areas in the economic literature on exchange rates. Work in the first research area was spurred by Engel (1999) who showed empirically that the ratio of non-traded to traded good prices accounts for almost none of US real exchange rate changes. Engel's finding stands in stark contrast to theories that explain real exchange rate movements through the relative price of non-traded goods. Contributions to this research area include Betts and Kehoe (2006, 2008), Burstein, Eichenbaum and Rebelo (2006), Chen, Choi and Devereux (2006), Drozd and Nosal (2010) and Bache, Sveen and Torstensen (2013). For a detailed discussion of the methodological approaches and empirical results, the reader is referred to Sections 3 and 5.4 and Appendix A. This literature is of interest to us since it deals with the question of how different components of the real exchange rate contribute to real exchange rate movements. However, our interest is to gauge the capacity of traded good price convergence to restore purchasing power parity. Thus unlike the cited studies, whose focus is on the relative price of non-traded goods, we concentrate on the contribution of traded good prices to real exchange rate movements.

The second research area addresses what has become known as the ”purchasing power parity puzzle”. This puzzle refers to the finding that it is difficult to reconcile the enormous short-run volatility of real exchange rates with their very slow convergence towards purchasing power parity (Rogoff, 1996, Sarno and Taylor, 2002, Taylor and Taylor, 2004). Most authors attribute the slow mean reversion of real exchange rates to the existence of transport costs that give rise to ”commodity points” delineating a region of no central tendency among relative prices (Obstfeld and Taylor, 1997). Hence a large number of papers have tested whether PPP actually holds in the medium or long run (Enders, 1988, Manzur and Ariff, 1995, Alexius and Nilsson, 2000, Vataja, 2000, Choi, Kapetanios and Shin, 2002, Ho and Ariff, 2011, Hall, Hondroyiannis, Kenjegaliev, Swamy and Tavlas, 2013) and whether the PPP hypothesis can be used to forecast real exchange rates (Ca' Zorzi, Muck and Rubaszek, 2016, Cheung, Chinn, García Pascual and Zhang, 2017). Moreover, researchers have applied nonlinear time series models to data on real exchange rates so as to determine the location of the commodity points as well as the adjustment speeds and half-lives of deviations from purchasing power parity inside and outside the bands of no arbitrage (Michael, Nobay and Peel, 1997, Obstfeld and Taylor, 1997, Baum, Barkoulas and Caglayan, 2001, Lo and Zivot, 2001, Taylor, Peel and Sarno, 2001, Imbs, Mumtaz, Ravn and Rey, 2003, 2005, Paya, Venetis and Peel, 2003, Heimonen, 2006, Juvenal and Taylor, 2008, Nakagawa, 2010, Yoon, 2010, Pavlidis, Paya and Peel, 2011, Woo, Lee and Chan, 2014). There have also been several empirical refinements of the PPP hypothesis. Imbs et al. (2005), for instance, show that slow mean reversion of the aggregate real exchange rate is consistent with much faster adjustment of disaggregated relative prices. All of these studies have added to our knowledge of the empirical behaviour of real exchange rates. Nevertheless, it should be stressed that they are all based on the belief that good market arbitrage and the law of one price are conducive to purchasing power parity, a belief that is directly challenged in this paper.

What is overlooked not only in the cited papers, but in the literature on exchange rates in general, is the fact that good market arbitrage does not only induce price adjustments, but also, as a kind of knock-on effect, adjustments of the nominal exchange rate. The only studies we found that are aware of the relevance of nominal exchange rate adjustments for the PPP hypothesis are those by Engel and Morley (2001), Cheung, Lai and Bergman (2004) and Beckmann (2013). These authors provide empirical evidence showing that the convergence of the nominal exchange rate is slower than that of prices and use their findings to explain the slow convergence towards PPP. What we point out, however, is that since nominal exchange rate movements are inversely linked to price level changes through the nominal exchange rate equation (see Section 4), one cannot treat nominal exchange rate convergence and price convergence separately.

To see this last point more clearly, suppose, for instance, that domestic traded good prices are too low for PPP to hold. Then good market arbitrage would induce domestic traded good prices to rise and foreign traded good prices to fall, providing a force to restore PPP. Yet since the price changes affect most traded goods, the domestic traded good price level would rise and the foreign traded good price level fall, inducing a nominal depreciation and therefore a movement of the real exchange rate *away* from its long-run trend. As long as the nominal exchange rate is allowed to float more or less freely, there are thus two countervailing forces, one provoking the convergence towards PPP and the other one the divergence away from PPP. Which of these two forces dominates is an empirical question, which to our knowledge has never been posed, let alone answered.[1]

3 Choice of contribution measure

Let us now define formally the contribution measures proposed by us—namely the unbounded contribution measure (UCM) and the bounded contribution measure (BCM)—and explore their usefulness. A detailed comparison with alternative contribution measures used in the literature is provided in Appendix A.

Suppose you have a variable x_t that is the sum of the variables $x_{1,t}, x_{2,t}, \ldots, x_{k,t}$:

$$x_t = \sum_{i=1}^{k} x_{i,t}. \tag{1}$$

[1] The only exception is the study by Eleftheriou and Müller-Plantenberg (2017), who run nonparametric regressions on various data sets to examine how the real exchange rate, the price differential and the nominal exchange rate react to an overvalued real exchange rate over time. In line with the hypothesis of this paper, their results show that when price adjustment is fast (which it is for traded good real exchange rate data), the nominal exchange rate tends to diverge in response to deviations from purchasing power parity.

Then the unbounded contribution measure quantifies how much the movements of $x_{i,t}$, $i = 1, 2, \ldots, k$, account for those of x_t:

$$\mathrm{UCM}(x_{i,t}, x_t) = \sum_{t=h+1}^{T} \frac{|\Delta_h x_t|}{\sum_{\tau=h+1}^{T} |\Delta_h x_\tau|} \times \frac{\Delta_h x_{i,t}}{\Delta_h x_t}, \tag{2}$$

where $\Delta_h = 1 - L^h$ and L is the lag operator.

Note the following very useful properties of the unbounded contribution measure:

$$\mathrm{UCM}(x_{i,t} + x_{j,t}, x_t) = \mathrm{UCM}(x_{i,t}, x_t) + \mathrm{UCM}(x_{j,t}, x_t), \tag{3}$$

$$\mathrm{UCM}(a x_{i,t}, x_t) = \mathrm{UCM}\left(x_{i,t}, \frac{1}{a} x_t\right) = a\,\mathrm{UCM}(x_{i,t}, x_t), \tag{4}$$

$$\sum_{i=1}^{k} \mathrm{UCM}(x_{i,t}, x_t) = 1. \tag{5}$$

One could also consider the bounded contribution measure:

$$\mathrm{BCM}(x_{i,t}, x_t) = \sum_{t=h+1}^{T} \frac{|\Delta_h x_t|}{\sum_{\tau=h+1}^{T} |\Delta_h x_\tau|} \times \max\left[\min\left(\frac{\Delta_h x_{i,t}}{\Delta_h x_t}, 1\right), 0\right]. \tag{6}$$

When $0 < x_{i,t}/x_t < 1$, the unbounded and bounded contribution measure take the same values. When $x_{i,t}/x_t > 1$, the contribution of the component series $x_{i,t}$ to the composite series x_t is more than a hundred percent, which is why the bounded contribution measure takes the value of one. When $x_{i,t}/x_t < 0$, the component series $x_{i,t}$ takes the sign that is opposite to that of the composite series x_t, implying a deduction of $x_{i,t}$ from x_t rather than a contribution. This is why in this case the bounded contribution measure takes the value of zero.

As long as $k = 2$, the bounded contribution measure has similar properties as the unbounded one:

$$\mathrm{BCM}(x_{1,t} + x_{2,t}, x_t) = \mathrm{BCM}(x_{1,t}, x_t) + \mathrm{BCM}(x_{2,t}, x_t), \tag{7}$$

$$\sum_{i=1}^{2} \mathrm{BCM}(x_{i,t}, x_t) = 1. \tag{8}$$

If, however, $k > 2$, the properties in Equations 7 and 8 do not hold any longer in general.

This paper uses the unbounded contribution measure for the exchange rate decompositions, first because of its homogeneity of degree one (see Equation 4) and because of the very convenient way that composite variables with more than two components can be studied.

4 Nominal exchange rate accounting

In this paper, we decompose the nominal exchange rate into two components. We shall call these two components, respectively, the ”nominal exchange rate anchor” and ”currency market pressure". The purpose of this decomposition is to enable us to measure how much traded good prices impact on the real exchange rate through their effect on the nominal exchange rate (see Section 5).

It should be noted that in this and the following sections, we employ quarterly price data from the OECD's Main Economic Indicators, using prices from the category food (excluding restaurants) as a proxy for traded good prices and prices from the category construction as a proxy for non-traded good prices. We calculate bilateral nominal exchange rates from the US dollar exchange rates of the individual countries. Real exchange rates are constructed on the basis of different hypothetical shares of non-traded goods, α, namely 0.25, 0.50 and 0.75. More information on the country coverage and the length of the time series can be found in Appendix B.1.

To illustrate the unbounded contribution measure (UCM) for the components of nominal and real exchange rates, we use box plots that represent the distributions of the UCM of all available country pairs for horizons ranging from 1 quarter to 30 years. On each box, the central mark is the median, the edges of the box are the 25th and 75th percentiles, the whiskers extend to the most extreme data points not considered outliers, and outliers are plotted individually. Points are drawn as outliers if they are larger than $q_3 + w(q_3 – q_1)$ or smaller than $q_1 – w(q_3 – q_1)$, where q_1 and q_3 are the 25th and 75th percentiles, respectively, and $w = 1.5$ (Matlab's default value corresponding to approximately $+/–2.7\sigma$ and 99.3% coverage if the data are normally distributed).

4.1 The nominal exchange rate anchor

Most economists would agree that the nominal exchange rate should, at least in the long run, revert to a value that ensures that traded goods cost the same everywhere, provided one compares their prices in the same currency. If the comparison is made in the domestic currency, it should hold that

$$p_t^{\mathrm{T,H}} = -s_t + p_t^{\mathrm{T,F}}, \tag{9}$$

where s_t is the nominal exchange rate of the home country vis-à-vis the foreign country (defined as the foreign-currency price of the domestic currency) and $p_t^{\mathrm{T,H}}$ and $p_t^{\mathrm{T,F}}$ are, respectively, the price levels of traded goods at home and abroad. (Note that all exchange rates and prices are expressed as logarithms in this paper.)

For suppose that traded goods are denominated in the domestic currency at home and in the foreign currency abroad. Then a violation of Equation 9 would imply that the currencies' purchasing powers in terms of the same traded goods would differ, a situation that would induce the weaker currency to gain and the stronger currency to lose value.

Since in this paper international price differentials play an important role, we adopt the simplified notation shown in Tables 1 and 2. The nominal exchange rate anchor can thus be written as:

$$s_t^{\mathrm{anchor}} = -p_t^{\mathrm{T}} = -(p_t^{\mathrm{T,H}} - p_t^{\mathrm{T,F}}). \tag{10}$$

Variable	Definition	Description
p_t^{T}	$p_t^{\mathrm{T,H}} - p_t^{\mathrm{T,F}}$	Difference between domestic and foreign traded good prices
p_t^{N}	$p_t^{\mathrm{N,H}} - p_t^{\mathrm{N,F}}$	Difference between domestic and foreign non-traded good prices
p_t	$p_t^{\mathrm{H}} - p_t^{\mathrm{F}}$ $= (1-\alpha)p_t^{\mathrm{T}} + \alpha p_t^{\mathrm{N}}$	Difference between domestic and foreign overall price levels
$p_t^{\mathrm{N}} - p_t^{\mathrm{T}}$	$(p_t^{\mathrm{N,H}} - p_t^{\mathrm{T,H}}) - (p_t^{\mathrm{N,F}} - p_t^{\mathrm{T,F}})$	Difference between domestic and foreign differences between non-traded and traded good prices
$p_t^{\mathrm{T}} - p_t$	$(p_t^{\mathrm{T,H}} - p_t^{\mathrm{H}}) - (p_t^{\mathrm{T,F}} - p_t^{\mathrm{F}})$ $= -\alpha(p_t^{\mathrm{N}} - p_t^{\mathrm{T}})$	Difference between domestic and foreign differences between traded good prices and the overall price level (equal to minus α times the difference between domestic and foreign differences between non-traded and traded good prices)
$p_t^{\mathrm{N}} - p_t$	$(p_t^{\mathrm{N,H}} - p_t^{\mathrm{H}}) - (p_t^{\mathrm{N,F}} - p_t^{\mathrm{F}})$ $= (1-\alpha)(p_t^{\mathrm{N}} - p_t^{\mathrm{T}})$	Difference between domestic and foreign differences between non-traded good prices and the overall price level (equal to one minus α times the difference between domestic and foreign differences between non-traded and traded good prices)

Table 1: **Notation for price differentials.** The parameter α stands for the share of non-traded goods in the overall price level. The superscript T stands for traded goods, the superscript N for non-traded goods, the superscript H for the home country and the superscript F for the foreign country. Note that prices are expressed as logarithms.

The idea that the nominal exchange rate is inversely proportional to the price level differential is an old one and, for instance, forms the basis of the monetary model of exchange rate determination. The reason the traded good price differential, rather than the overall price level differential, is chosen for the calculation of the PPP-consistent value of the nominal exchange rate is that foreign exchange traders will mostly rely on traded goods, which are available everywhere, in order to determine and compare the purchasing powers of different currencies.

4.2 Currency market pressure

Often, especially in the short and medium run, yet possibly even in the long run, the nominal exchange rate will differ from the value indicated by the traded good price differential, p_t^{T}. Or in other words, the traded good real exchange rate—which we define as the real exchange rate based on traded good prices, or as $q_t^{\mathrm{T}} = s_t + p_t^{\mathrm{T}}$—will not be equal to zero. Now we define currency market pressure, or $\tilde{s}_t$, to be the difference between the nominal exchange rate, s_t, and the nominal exchange rate anchor, s_t^{anchor}:

$$\tilde{s}_t = s_t - s_t^{\text{anchor}} = s_t - (-p_t^{\mathrm{T}}) = s_t + p_t^{\mathrm{T}}. \tag{11}$$

Variable	Definition	Description
s_t		Nominal exchange rate (price of the domestic currency in terms of the foreign currency)
s_t^{anchor}	$-p_t^{\text{T}}$	Nominal exchange rate anchor (nominal exchange rate that is consistent with PPP for traded goods)
$\tilde{s}_t$	$s_t - s_t^{\text{anchor}}$	Currency market pressure (difference between actual and PPP-consistent nominal exchange rate)
$\tilde{s}_t^{\text{core}}$	$\tilde{s}_t - \tilde{s}_t^{\text{inflation-offsetting}}$	Core currency market pressure (part of currency market pressure that is unrelated to official intervention used to offset the effect of price level changes on the nominal exchange rate)
$\tilde{s}_t^{\text{infl.-offs.}}$	γp_t^{T}, where γ is chosen so that $\text{UCM}(p_t^{\text{T}}, \tilde{s}_t^{\text{core}}) = 0$	Inflation-offsetting currency market pressure (part of currency market pressure resulting from official intervention used to offset the effect of price level changes on the nominal exchange rate)
q_t	$s_t + p_t$	Real exchange rate (difference between domestic and foreign overall price levels, when both are expressed in the same currency)
q_t^{T}	$s_t + p_t^{\text{T}}$	Traded good real exchange rate (difference between domestic and foreign traded good prices, when both are expressed in the same currency)

Table 2: **Notation for currency market pressure and exchange rates.** The superscript T stands for traded goods. Note that exchange rates and prices are expressed as logarithms.

One may think of currency market pressure, $\tilde{s}_t$, as the excess demand for the domestic currency in the foreign exchange market that arises due to trade and capital flows as well as the official intervention by central banks. Section 6 elaborates in more detail on how currency market pressure could be interpreted in economic terms.

4.3 Nominal exchange rate accounting

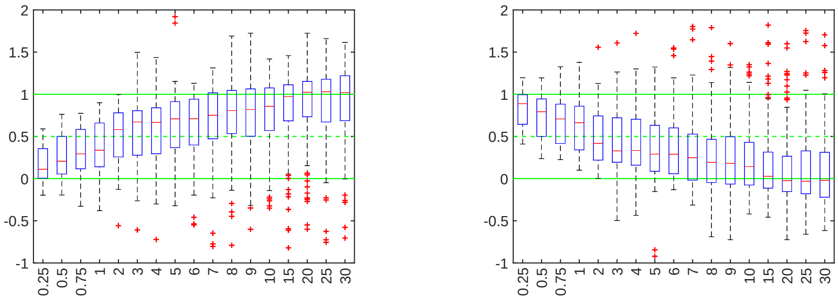
As explained above, the nominal exchange rate can be decomposed as follows (decomposition 1):

$$s_t = x_{1,t} + x_{2,t}, \tag{12}$$

where

$$x_{1,t} = s_t^{\text{anchor}} = -p_t^{\text{T}},$$
$$x_{2,t} = \tilde{s}_t.$$

Figure 1 reveals to what extent the traded good price differential and currency market pressure account for changes in nominal exchange rates. The results are as expected. Here we concentrate on the medians of the distributions shown in Figure 1. At horizons of up to one year, traded good



(a) Part of nominal exchange rate explained by difference between domestic and foreign traded good prices ($-p_t^{\mathrm{T}}$)

(b) Currency market pressure ($\tilde{s}_t$)

Figure 1: **Nominal exchange rate accounting: traded good prices and currency market pressure.** The nominal exchange rate accounting is based on the decomposition 1 in Equation 12, using the food and construction price data set (see Appendix B.1).

prices account for only a tiny fraction of nominal exchange rate movements. The contribution of traded good prices then rises almost monotonically as the horizons considered become longer. At horizons of 15 years or more, traded good prices account for almost exactly 100 percent of nominal exchange rate changes. Since $\mathrm{UCM}(\tilde{s}_t, s_t) = 1 - \mathrm{UCM}(-p_t^{\mathrm{T}}, s_t)$, currency market pressure is an all-important determinant of the nominal exchange rate at short horizons, yet has on average almost no effect on nominal exchange rates in the long run.

5 Real exchange rate accounting

We now turn to real exchange rate accounting. In this paper, the real exchange rate is defined as:

$$q_t = s_t + (1 - \alpha) p_t^{\mathrm{T}} + \alpha p_t^{\mathrm{N}}. \tag{13}$$

Real exchange rates can be calculated for one good (for example, the Big Mac index) or for baskets of goods (for example, the CPI-based real exchange rate). Here we are interested in the relative contribution of traded and non-traded good prices to real exchange rate movements. Engel (1999) used real exchange rates based on baskets of goods for his analysis and tried to divide those baskets into sub-baskets containing either traded or non-traded goods. The problem with this approach is that the sub-baskets contain to a great extent categories that have both large traded and non-traded components. This carries the risk of underestimating the difference between traded and non-traded good prices.

Our approach consists instead in looking at only two categories of goods, food and construction, where the price level of the first category is a proxy for traded good prices and the price level of the second category a proxy for non-traded good prices. Apart from getting cleaner measures of the prices of both types of goods, there is also a practical advantage. Just as other contribution measures, the UCM is not very stable when one compares different country pairs and horizons, h. It is therefore important to consider many country pairs in order to be able to discern patterns for the quartiles of the contribution measures. By looking at only two good categories, we are able to obtain comparable data for 16 countries, giving us a total of 120 country pairs.

5.1 Core versus inflation-offsetting currency market pressure

The aim of this section is to determine how much traded good prices and currency market pressure contribute to real exchange rate movements. It is important to note that traded good prices affect the exchange rate through three channels: first, through their effect on the overall price level, $(1-\alpha)p_t^{\mathrm{T}}+\alpha p_t^{\mathrm{N}}$; second, through their effect on the nominal exchange rate anchor, $s_t^{\text{anchor}} = -p_t^{\mathrm{T}}$; and third, through their effect on currency market pressure, $\tilde{s}_t$. This last effect is empirically important as it is common for countries to offset exchange rate changes brought about by changes in the traded good price differential, p_t^{T}, through official intervention.

Suppose, for instance, that a country wants to fix the exchange rate by raising currency market pressure in response to a rise in the traded good price differential, p_t^{T}. Since this change in currency market pressure is directly related to changes in p_t^{T}, we will refer to it as "inflation-offsetting" currency market pressure and denote it as $\tilde{s}^{\,\text{inflation-offsetting}}$. Inflation-offsetting currency market pressure must be distinguished from "core" currency market pressure, $\tilde{s}_t^{\text{core}}$, which on average is not influenced by the movements of the traded good price differential.

Formally, core and inflation-offsetting currency market pressure are defined by the following two equations:

$$\tilde{s}_t^{\text{core}} = \tilde{s} - \tilde{s}_t^{\text{inflation-offsetting}}, \tag{14}$$

$$\tilde{s}_t^{\text{inflation-offsetting}} = \gamma p_t^{\mathrm{T}}, \tag{15}$$

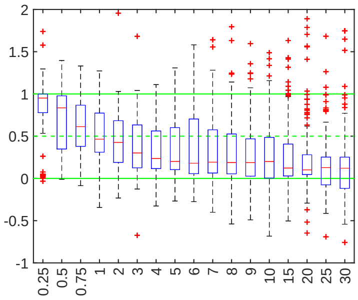
where γ is a parameter that is chosen in such a way that $\mathrm{UCM}(p_t^{\mathrm{T}}, \tilde{s}^{\,\text{core}}) = 0$. Appendix C shows how γ, which is normally positive, can be estimated through a grid search to any desired degree of accuracy.

Note that γ, which measures the proportion of traded good price changes offset by official intervention, will normally differ depending on the country pair and the horizon considered. The more a country is committed to stabilizing its exchange rate in the face of traded good price fluctuations, the higher will be γ. However, if a country tries to neutralize traded good price movements, say, in the short term but not in the long term, this will be reflected by higher values of γ at short horizons and lower values of γ at long horizons.

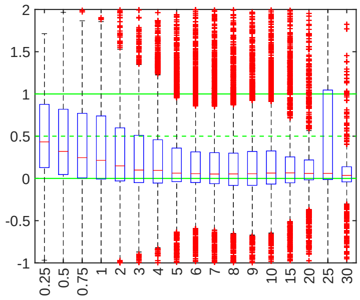
Figure 2 plots the distribution of γ for all our country pairs at different horizons. Panel a of Figure 2 uses the OECD's food price index to proxy for traded good prices. It shows that most countries act in a way that implies a value of γ near one at short horizons and a value of γ near zero at very long horizons. (Note that Panel b of Figure 2 is based on an alternative data set, which will be discussed in Section 5.3.)

The total contribution of traded good prices to the real exchange rate with its three components can thus be measured by:

$$\mathrm{UCM}([(1-\alpha)p_t^{\mathrm{T}}] + [-p_t^{\mathrm{T}}] + [\gamma p_t^{\mathrm{T}}], q_t^{\mathrm{T}})$$



(a) Proportion of traded good price changes offset by official intervention (γ), based on the food and construction price data set



(b) Proportion of traded good price changes offset by official intervention (γ), based on the PPI and CPI data set

Figure 2: **Inflation-offsetting currency market pressure.** The figures show box plots of the proportion of traded good price changes offset by official intervention, γ, at different horizons. A value of one implies that the central bank uses official intervention so as to suppress the effect of traded good prices on the nominal exchange rate, whereas a value of zero indicates that the central bank stays passive. The box plot in Panel a is based on the food and construction price data set (see Appendix B.1) and the box plot in Panel b on the PPI and CPI data set (see Appendix B.2).

$$\begin{aligned} &= \mathrm{UCM}([(1-\alpha)-(1-\gamma)]p_t^{\mathrm{T}}, q_t^{\mathrm{T}}) \qquad (16) \\ &= \mathrm{UCM}((\gamma-\alpha)p_t^{\mathrm{T}}, q_t^{\mathrm{T}}). \end{aligned}$$

In this paper, we refer to $(1-\alpha)$ as the "price level effect" of traded good prices on the real exchange rate and to $-(1-\gamma)$ as the "nominal exchange rate effect". Note that the latter effect measures the combined effects of traded good prices on the nominal exchange rate anchor, s_t^{anchor}, which is negative, and on the inflation-offsetting currency market pressure, $\tilde{s}_t^{\text{inflation-offsetting}}$, which in general is positive, but smaller.

5.2 The purchasing power parity fallacy

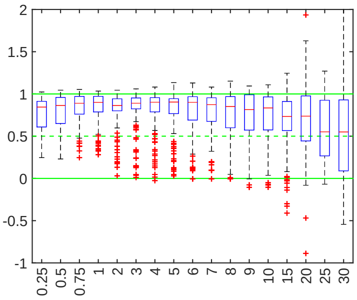
5.2.1 Contribution of traded good prices to real exchange rate changes

We are now in a position to decompose the real exchange rate as follows (decomposition 2):

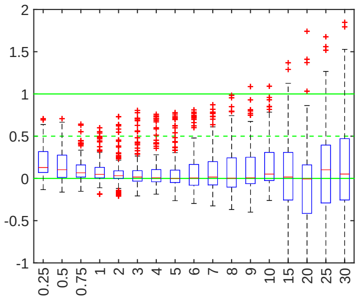
$$q_t = x_{1,t} + x_{2,t} + x_{3,t}, \qquad (17)$$

where

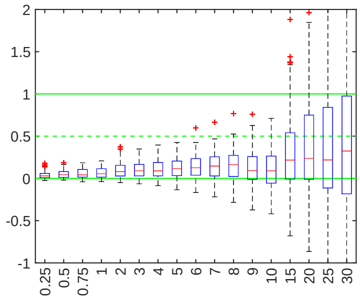
$$\begin{aligned} x_{1,t} &= \tilde{s}_t^{\text{core}}, \\ x_{2,t} &= (\gamma-\alpha)p_t^{\mathrm{T}}, \\ x_{3,t} &= \alpha p_t^{\mathrm{N}}. \end{aligned}$$



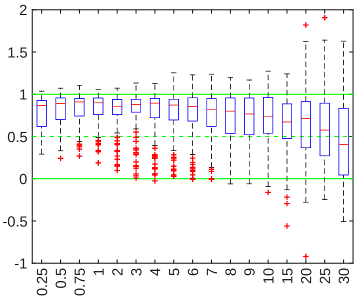
(a) Core currency market pressure ($\tilde{s}_t^{\text{core}}$), $\alpha = 0.25$



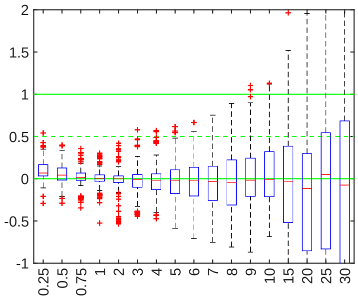
(b) Weighted difference between domestic and foreign traded good prices ($(\gamma - \alpha)p_t^{\text{T}}$), $\alpha = 0.25$



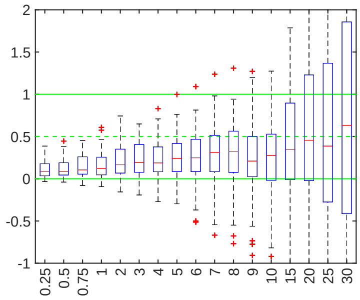
(c) Weighted difference between domestic and foreign non-traded good prices (αp_t^{N}), $\alpha = 0.25$



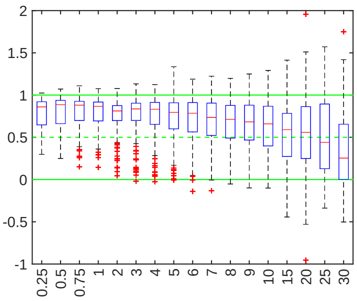
(d) Core currency market pressure ($\tilde{s}_t^{\text{core}}$), $\alpha = 0.50$



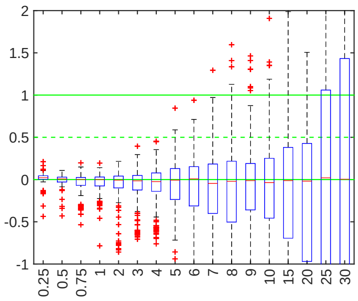
(e) Weighted difference between domestic and foreign traded good prices ($(\gamma - \alpha)p_t^{\text{T}}$), $\alpha = 0.50$



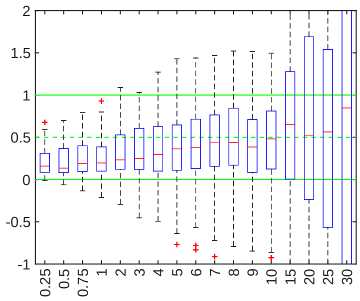
(f) Weighted difference between domestic and foreign non-traded good prices (αp_t^{N}), $\alpha = 0.50$



(g) Core currency market pressure ($\tilde{s}_t^{\text{core}}$), $\alpha = 0.75$



(h) Weighted difference between domestic and foreign traded good prices ($(\gamma - \alpha)p_t^{\text{T}}$), $\alpha = 0.75$



(i) Weighted difference between domestic and foreign non-traded good prices (αp_t^{N}), $\alpha = 0.75$

Figure 3: **Real exchange rate accounting: core currency market pressure, traded good prices and nontraded good prices.** The real exchange rate accounting is based on the decomposition 2 in Equation 17, using the food and construction price data set (see Appendix B.1). Note that the low values of $\text{UCM}((\gamma - \alpha)p_t^{\text{T}}, q_t)$ show that, contrary to common belief, traded good price adjustments account for almost none of the movements of the real exchange rate (the PPP fallacy).

The results, which are shown in Figure 3 and Table 3, are striking for two reasons. The first is that core currency market pressure, $\tilde{s}_t^{\text{core}}$, is responsible for most of the real exchange rate changes. This is true for all horizons, from 1 quarter to 30 years. Besides, the variability of the UCM is rather small, adding confidence to this finding. For most of the horizons, the median UCM of core

Horizon	$\tilde{s}_t^{\text{core}}$			$(\gamma - \alpha)p_t^{\text{T}}$			αp_t^{N}		
	α = 0.25	α = 0.50	α = 0.75	α = 0.25	α = 0.50	α = 0.75	α = 0.25	α = 0.50	α = 0.75
0.25	84.4%	86.7%	86.0%	12.9%	6.8%	2.1%	3.0%	8.3%	15.9%
0.50	86.4%	89.2%	88.6%	10.3%	4.3%	0.7%	4.4%	8.4%	13.5%
0.75	89.0%	90.9%	88.1%	6.7%	1.7%	-0.0%	4.2%	10.5%	19.1%
1	90.1%	89.9%	86.7%	4.9%	0.2%	-0.2%	5.5%	12.3%	19.7%
2	86.3%	85.2%	81.2%	3.2%	-0.1%	-0.6%	8.0%	16.6%	23.3%
3	89.0%	88.0%	83.6%	1.6%	-0.7%	-1.5%	9.1%	19.1%	24.8%
4	90.2%	89.5%	83.2%	0.7%	-1.8%	-2.5%	8.9%	18.8%	29.6%
5	90.4%	87.2%	79.6%	0.0%	-1.7%	-0.7%	11.5%	24.1%	36.4%
6	90.2%	85.6%	78.5%	0.5%	-1.8%	0.7%	12.6%	24.8%	37.7%
7	87.3%	82.3%	73.6%	1.6%	-3.5%	-4.5%	14.7%	31.2%	44.2%
8	85.1%	80.0%	71.3%	0.3%	-4.7%	-2.1%	16.2%	32.0%	43.8%
9	81.4%	76.7%	68.3%	0.7%	-1.7%	-1.4%	9.1%	20.9%	38.5%
10	83.5%	74.0%	66.0%	5.1%	-0.7%	-3.6%	9.0%	27.5%	48.1%
15	73.4%	67.2%	59.0%	1.6%	-3.0%	-1.3%	21.7%	34.4%	65.0%
20	73.7%	71.5%	55.9%	-0.6%	-11.5%	-1.9%	23.9%	45.6%	51.8%
25	55.2%	57.6%	44.1%	10.2%	5.1%	2.0%	21.9%	38.7%	56.4%
30	55.0%	40.4%	25.4%	5.2%	-7.5%	0.4%	32.4%	63.2%	84.7%

Table 3: **Real exchange rate accounting: core currency market pressure, traded good prices and nontraded good prices.** The real exchange rate accounting is based on the decomposition 2 in Equation 17, using the food and construction price data set (see Appendix B.1). Note that the low values of $\mathrm{UCM}((\gamma-\alpha)p_t^{\text{T}}, q_t)$ show that, contrary to common belief, traded good price adjustments account for almost none of the movements of the real exchange rate (the PPP fallacy).

currency market pressure is above 70 to 80%, and it is only at horizons of about 10 years or more that the UCM falls to about one half.

The second reason is that the contribution of traded good prices to real exchange rate movements is negligible. This indicates that the exchange rate effect more or less offsets the price level effect. So rising domestic traded good prices, for instance, raise the overall price level at home yet lead to a nominal depreciation of the domestic currency of about the same magnitude.

At horizons of less than a year, there seems to be at least a very low positive contribution of traded good prices to real exchange rate changes, particularly if the share of traded goods, $1-\alpha$, is high (that is, if α is low). This is probably due to the fact that γ is close to one at very short horizons as central banks strive to keep the nominal exchange stable, with the result that the exchange rate effect of traded good prices is close to zero.

In general, though, the plots in Figure 3 suggest that traded good prices practically do not contribute to the movements of the real exchange rate, no matter the horizon considered. As a consequence, it appears that good market arbitrage cannot be regarded as an effective mechanism to restore purchasing power parity.

In Sections 5.2.2 and 5.2.3, we present two more arguments against the PPP hypothesis.

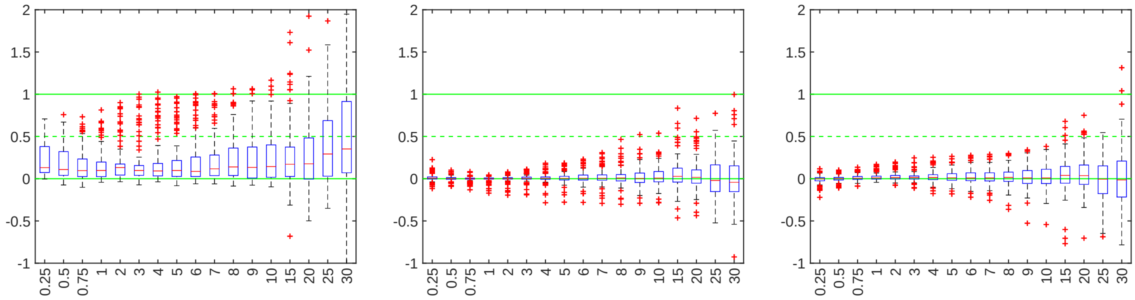
5.2.2 The deviation of traded good prices from the overall price level

Especially over the longer term, traded and non-traded good prices are mostly driven by overall inflation, rather than by good market arbitrage. Overall inflation in turn is mainly linked to monetary variables such as the money supply and aggregate income. One could therefore argue that it is the difference between traded good prices and the overall price level, rather than traded good prices themselves, that is driven by good market arbitrage. This is why we have also carried out the real exchange rate accounting based on the following decomposition (decomposition 3):

$$q_t = x_{1,t} + x_{2,t} + x_{3,t} + x_{4,t}, \tag{18}$$

where

$$\begin{aligned}
x_{1,t} &= \tilde{s}_t^{\text{core}}, \\
x_{2,t} &= \gamma p_t, \\
x_{3,t} &= (\gamma - \alpha)(p_t^{\text{T}} - p_t), \\
x_{4,t} &= \alpha(p_t^{\text{N}} - p_t).
\end{aligned}$$



(a) Weighted difference between domestic and foreign overall price levels (γp_t), $\alpha = 0.50$

(b) Weighted difference between domestic and foreign differences between traded good prices and the overall price level ($(\gamma - \alpha)(p_t^{\text{T}} - p_t)$), $\alpha = 0.50$

(c) Weighted difference of the domestic and foreign differences between the non-traded good prices and the overall price level ($\alpha(p_t^{\text{N}} - p_t)$), $\alpha = 0.50$

Figure 4: **Real exchange rate accounting: overall price level and traded and non-traded good price differentials vis-à-vis the overall price level.** The real exchange rate accounting is based on the decomposition 3 in Equation 18, using the food and construction price data set (see Appendix B.1). Note that the low values of $\text{UCM}((\gamma - \alpha)(p_t^{\text{T}} - p_t), q_t)$ show that, contrary to common belief, traded good price adjustments account for almost none of the movements of the real exchange rate (the PPP fallacy).

The results are shown in Figure 4 and Table 4. Again, most of the changes of the real exchange rate are accounted for by core currency market pressure, $\tilde{s}_t^{\text{core}}$. Note that the distribution of $\text{UCM}(\tilde{s}_t^{\text{core}}, q_t)$ is identical to that of decomposition 2 and is plotted in Panels a, d and g of Figure 3.

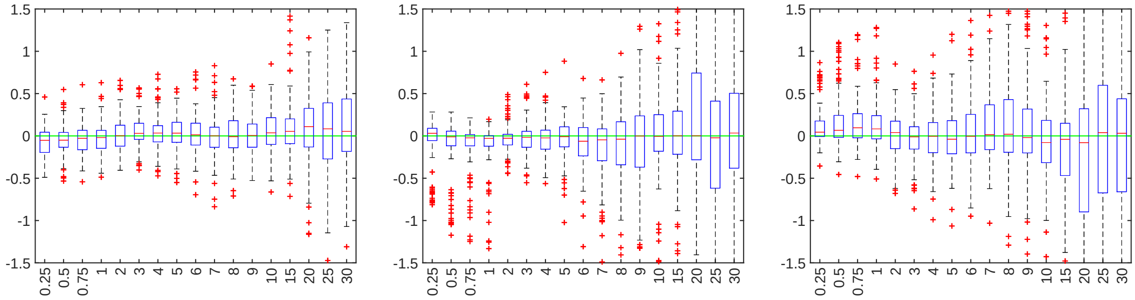
Horizon	γp_t			$(\gamma-\alpha)(p_t^{\mathrm{T}}-p_t)$			$\alpha(p_t^{\mathrm{N}}-p_t)$		
	α = 0.25	α = 0.50	α = 0.75	α = 0.25	α = 0.50	α = 0.75	α = 0.25	α = 0.50	α = 0.75
0.25	15.6%	13.0%	13.8%	1.7%	0.7%	-0.1%	-1.9%	-0.1%	1.1%
0.50	14.0%	10.8%	11.2%	1.1%	0.2%	-0.1%	-1.6%	0.1%	1.4%
0.75	11.3%	9.5%	9.7%	0.4%	0.0%	0.4%	-1.0%	0.6%	1.9%
1	10.6%	9.7%	10.1%	0.2%	-0.0%	1.0%	-0.7%	1.0%	2.2%
2	13.4%	13.1%	12.8%	0.1%	0.1%	2.6%	-0.5%	1.3%	2.4%
3	10.3%	9.7%	8.8%	0.0%	0.4%	3.1%	-0.2%	1.4%	2.2%
4	10.5%	9.2%	9.4%	-0.0%	0.5%	3.3%	-0.4%	1.5%	2.7%
5	10.2%	9.7%	10.0%	-0.0%	0.5%	3.8%	-0.9%	1.1%	2.6%
6	10.2%	8.7%	8.0%	-0.1%	0.6%	5.0%	-1.3%	0.8%	2.6%
7	12.8%	11.8%	9.5%	-0.0%	0.6%	4.6%	-1.5%	0.9%	3.0%
8	15.4%	14.0%	11.1%	-0.1%	0.8%	6.1%	-1.4%	1.6%	3.7%
9	15.7%	13.5%	11.4%	-0.2%	0.4%	6.2%	-2.6%	0.9%	3.5%
10	17.7%	14.3%	14.3%	-0.1%	0.7%	6.1%	-2.3%	0.8%	2.8%
15	21.4%	17.1%	16.2%	0.2%	2.9%	10.9%	-1.0%	4.0%	5.9%
20	22.3%	17.7%	14.7%	-0.0%	1.7%	9.0%	-2.1%	3.6%	6.0%
25	34.9%	29.3%	24.2%	-1.1%	-2.0%	3.4%	-6.5%	-0.6%	2.8%
30	53.7%	35.2%	36.2%	-1.0%	-4.2%	9.5%	-6.2%	-1.4%	4.2%

Table 4: **Real exchange rate accounting: overall price level and traded and non-traded good price differentials vis-à-vis the overall price level.** The real exchange rate accounting is based on the decomposition 3 in Equation 18, using the food and construction price data set (see Appendix B.1). Note that the low values of $\mathrm{UCM}((\gamma-\alpha)(p_t^{\mathrm{T}}-p_t), q_t)$ show that, contrary to common belief, traded good price adjustments account for almost none of the movements of the real exchange rate (the PPP fallacy).

As regards prices, overall inflation, p_t, contributes between 9 and 18% to the movements of the real exchange rate (for horizons of up to twenty years and assuming $\alpha = 0.50$). Yet the traded and non-traded good price differentials vis-à-vis the overall price level, $p_t^{\mathrm{T}} - p_t$ and $p_t^{\mathrm{N}} - p_t$, account for almost none of the fluctuations of the real exchange rate. Moreover, the distributions of $\mathrm{UCM}(p_t^{\mathrm{T}} - p_t, q_t)$ and $\mathrm{UCM}(p_t^{\mathrm{N}} - p_t, q_t)$ show very little variation across country pairs, giving even more credibility to our finding that the traded good and non-traded good excess inflations are practically irrelevant when it comes to explaining real exchange rate changes.

5.2.3 As much contribution to PPP convergence as to PPP divergence

In theory, it could be the case that traded good price movements contribute to real exchange rate changes more when the real exchange rate moves towards PPP than when it moves away from PPP. If this happened to be true, it would indicate that good market arbitrage helps to bring about real exchange rate convergence. However, as Figure 5 shows, the difference of the unbounded contribution measures, or UCMs, for mean-reverting and mean-diverting real exchange rate changes is very close to zero, indicating that traded good prices account as much for movements of the real exchange rate towards PPP as for movements away from PPP.



(a) Core currency market pressure ($\tilde{s}_t^{\text{core}}$), $\alpha = 0.50$

(b) Weighted difference between domestic and foreign traded good prices ($(\gamma - \alpha)p_t^{\text{T}}$), $\alpha = 0.50$

(c) Weighted difference between domestic and foreign non-traded good prices (αp_t^{N}), $\alpha = 0.50$

Figure 5: **Directional real exchange rate accounting: core currency market pressure, traded good prices and nontraded good prices.** The real exchange rate accounting is based on the decomposition 2 in Equation 17, using the food and construction price data set (see Appendix B.1). Shown is the difference between the contributions of a given variable to the mean-reverting real exchange rate and its contribution to the mean-diverting real exchange.

5.3 Robustness of the purchasing power parity fallacy

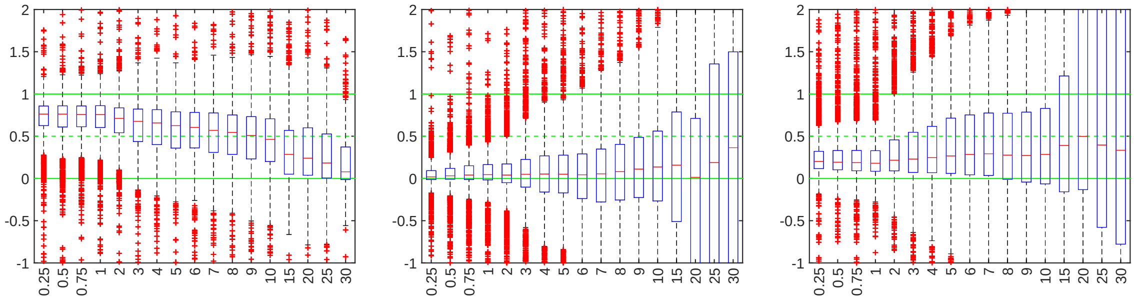
To check whether our result that good market arbitrage does not contribute to PPP is robust, we have repeated our calculations with an alternative data set of traded and non-traded good prices. As before, we find that traded good price changes account for hardly any of the movements of the real exchange rate. Interestingly, however, we are able to demonstrate that the nominal exchange rate effect may outweigh the price level effect for certain data sets. The convergence of traded good prices may therefore even push the real exchange rate away from PPP.

Since it is notoriously difficult to construct accurate indices of traded and non-traded good prices, the literature has used a variety of proxies. Betts and Kehoe (2006), for instance, recommend using the gross output deflators by sector to construct traded good price measures. However, as they point out, ”data on [gross output] by sector are only available for a small subset of countries, and only at the annual frequency”. For our purposes, this is problematic since we need a relatively large set of countries in order to be able to construct a meaningful distribution of traded good price contributions to real exchange rate fluctuations. Betts and Kehoe's ”next conceptually preferred, and most broadly available, measure of an aggregate traded goods price for a country is, therefore, its [producer price index (PPI)] for all goods”. Since PPI data is available for a large number of countries, we decided to check the robustness of the PPP fallacy using the PPI as a proxy for traded good prices.

Specifically, what we did was to take PPI and CPI as well as nominal exchange rate data from the International Financial Statistics of the IMF. Since data for all three variables are available for 77 countries, we were able to construct time series of the PPI differential, the CPI differential and the bilateral real exchange rate for a total of 2,926 country pairs. Denoting the PPI differential as p_t^{T} and the CPI differential as p_t, we then computed the non-traded good price differential, p_t^{N}, as follows:

$$p_t = (1-\alpha)p_t^{\mathrm{T}} + \alpha p_t^{\mathrm{N}} \quad \Leftrightarrow \quad p_t^{\mathrm{N}} = \frac{1}{\alpha}\left[p_t - (1-\alpha)p_t^{\mathrm{T}}\right] \underset{\alpha=0.50}{\Leftrightarrow} \quad p_t^{\mathrm{N}} = 2p_t - p_t^{\mathrm{T}}. \quad (19)$$

Our first task was to re-estimate the parameter γ, which measures the proportion of traded good price changes offset by official intervention. The resulting box plots, which are shown in Figure 2b, are similar to those of Figure 2a, which plots γ for the food price index. As in the case of the γ based on food prices, the PPI-based γ falls as the horizon increases, which indicates that central banks try to offset short-term price-induced exchange rate fluctuations, but not long-term ones. Nevertheless, the values of γ calculated from the PPI are somewhat lower than those computed from the food price index; indeed, no matter the horizon considered, the median values never exceed 0.5. This is as expected, too, since the proportion of traded good price changes offset by official intervention must be greater for the relatively volatile food price index than for the more persistent PPI.



(a) Core currency market pressure ($\tilde{s}_t^{\text{core}}$), $\alpha = 0.50$

(b) Weighted difference between domestic and foreign traded good prices ($(\gamma-\alpha)p_t^{\mathrm{T}}$), $\alpha = 0.50$

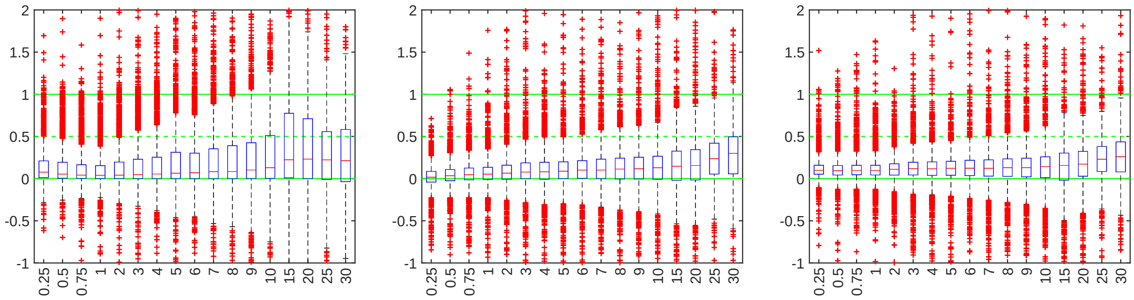
(c) Weighted difference between domestic and foreign non-traded good prices (αp_t^{N}), $\alpha = 0.50$

Figure 6: **Real exchange rate accounting: core currency market pressure, traded good prices and nontraded good prices.** The real exchange rate accounting is based on the decomposition 2 in Equation 17, using the PPI and CPI data set (see Appendix B.2). Note that the low values of $\mathrm{UCM}((\gamma-\alpha)p_t^{\mathrm{T}}, q_t)$ show that, contrary to common belief, traded good price adjustments account for almost none of the movements of the real exchange rate (the PPP fallacy). Notice also that since $\gamma - \alpha < 0$ in general, positive values of $\mathrm{UCM}((\gamma-\alpha)p_t^{\mathrm{T}}, q_t)$ imply that traded good price convergence contributes to PPP divergence.

The results of the real exchange rate accounting based on this PPI-based data set are shown in Figures 6 and 7. For brevity, we only consider a non-traded good share, α, of 0.50 here.

Three things are worth noting. First, both in the case of decomposition 2 in Equation 17 and of decomposition 3 in Equation 18, real exchange rate fluctuations are mostly accounted for by changes in core currency market pressure, $\tilde{s}_t^{\text{core}}$. Second, the PPI and CPI data show that traded and non-traded good prices contribute little to real exchange rate movements over time, providing additional evidence for the PPP fallacy.

Third and most importantly, however, given that, as we have just seen, $\gamma < \alpha$ in general, the contribution of traded good prices to real exchange rate changes is of opposite sign of what any



(a) Weighted difference between domestic and foreign overall price levels (γp_t), $\alpha = 0.50$

(b) Weighted difference between domestic and foreign differences between traded good prices and the overall price level ($(\gamma - \alpha)(p_t^{\mathrm{T}} - p_t)$), $\alpha = 0.50$

(c) Weighted difference of the domestic and foreign differences between the non-traded good prices and the overall price level ($\alpha(p_t^{\mathrm{N}} - p_t)$), $\alpha = 0.50$

Figure 7: **Real exchange rate accounting: overall price level and traded and non-traded good price differentials vis-à-vis the overall price level.** The real exchange rate accounting is based on the decomposition 3 in Equation 18, using the PPI and CPI data set (see Appendix B.2). Note that the low values of $\mathrm{UCM}((\gamma - \alpha)(p_t^{\mathrm{T}} - p_t), q_t)$ show that, contrary to common belief, traded good price adjustments account for almost none of the movements of the real exchange rate (the PPP fallacy). Notice also that since $\gamma - \alpha < 0$ in general, positive values of $\mathrm{UCM}((\gamma - \alpha)p_t^{\mathrm{T}}, q_t)$ imply that traded good price convergence contributes to PPP divergence.

well-trained economist would expect:

$$\mathrm{UCM}(p_t^{\mathrm{T}}, q_t) = \underbrace{\frac{1}{\gamma - \alpha}}_{<0} \times \underbrace{\mathrm{UCM}((\gamma - \alpha)p_t^{\mathrm{T}}, q_t)}_{>0} < 0 \tag{20}$$

This means that the *convergence* of traded good prices, when it occurs, leads to a *divergence* of the real exchange rate away from PPP, and vice versa. After all, recall from Section 5.1 that $(1 - \alpha)$ measures the "price level effect" of traded good prices on the real exchange rate and $-(1 - \gamma)$ the "nominal exchange rate effect". Therefore, if $\gamma < \alpha$, this means that the (negative) nominal exchange rate effect dominates the (positive) price level effect, implying that good market arbitrage is actually detrimental to PPP.

5.4 Engel's (1999) decomposition revisited

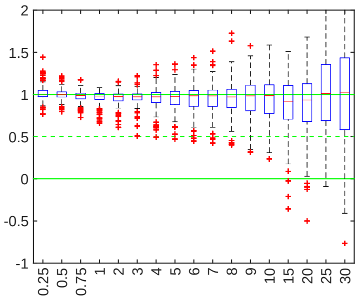
Although it is not precisely the topic of this paper, it may be of interest to know what kind of results the methodology used here (see Section 3) yields when it is applied to the decomposition of the real exchange rate that Engel (1999) considered in his influential paper (decomposition 4):

$$q_t = x_{1,t} + x_{2,t}, \tag{21}$$

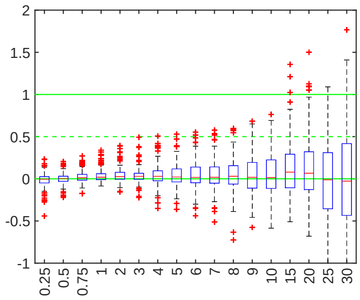
where

$$x_{1,t} = q_t^{\mathrm{T}},$$

$$x_{2,t} = \alpha(p_t^{\mathrm{N}} - p_t^{\mathrm{T}}).$$



(a) Real exchange rate based on traded good prices (q_t^{T}), $\alpha = 0.50$



(b) Weighted difference of the domestic and foreign differences between the prices of non-traded and traded goods ($\alpha(p_t^{\mathrm{N}} - p_t^{\mathrm{T}})$), $\alpha = 0.50$

Figure 8: **Real exchange rate accounting: traded good real exchange rate and relative price of non-traded goods.** The real exchange rate accounting is based on the decomposition 4 in Equation 21, using the food and construction price data set (see Appendix B.1).

The results are shown in Figure 8. What is striking is that even though we use only two categories of goods we arrive at the same conclusions as Engel. The traded good real exchange rate, q_t^{T}, accounts for practically all of the changes in the real exchange rate, q_t, whereas the ratio of the domestic and foreign relative prices of non-traded goods accounts for practically none of the changes. Moreover, the dispersion of the box plots is small, meaning that the finding is robust across all the country pairs.

Several authors have replicated Engel's (1999) analysis using different contribution measures (see Appendix A.1) or data sets. Betts and Kehoe (2006, 2008) confirm by and large the finding whereby the relative price of non-traded to traded goods accounts for almost none of the movements of the real exchange rate. They point out, however, that the empirical results depend on the price series used and on the choice of trade partners. Bache et al. (2013) suggest that the violation of the law of one price for traded goods may be less due to movements in the relative price of traded goods at the dock, but rather to movements in the relative distribution wedge. In a similar spirit, Burstein et al. (2006) claim that the relative price of non-traded goods accounts for roughly half of the cyclical movements in the real exchange rate (however, as is explained in Section A.1.2, their accounting methodology differs from that of Engel, 1999). Finally, Chen et al. (2006) look at real exchange rates between regions of the United States (where the nominal exchange rate is fixed) and find that the relative price of non-traded goods can explain up to 80% of real exchange rate changes over medium and long horizons (assuming a share of non-traded goods of 0.51). Their work was inspired by Mendoza (2000) who had reported comparable results for the real exchange rate between Mexico and the United States during periods of fixed or managed exchange rates.

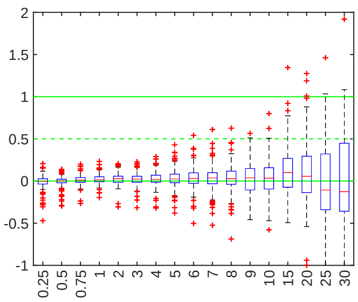
As we show in Appendix A.1.1, the contribution measures used by Engel (1999), $\text{CM}^{\text{MSE}(1)}$ and $\text{CM}^{\text{MSE}(2)}$, can only be used to decompose the real exchange rate into two components, not more. However, a question that Engel's research raises is for how much of the changes of the real exchange rate the domestic and foreign relative prices of non-traded goods by themselves, rather than their ratio, account. For it could be the case that the relative prices of non-traded goods at home and abroad are actually quite variable and that it is only their ratio that turns out to hardly matter at all. However, this question is easily answered using the unbounded contribution measure, UCM, since this measure can be applied to any number of components of a composite variable.

The decomposition we are interested in is thus the following (decomposition 5):

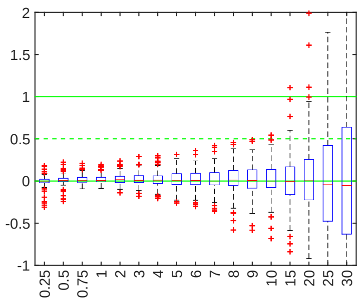
$$q_t = x_{1,t} + x_{2,t} + x_{3,t}, \tag{22}$$

where

$$\begin{aligned}
x_{1,t} &= q_t^{\text{T}}, \\
x_{2,t} &= \alpha(p_t^{\text{N,H}} - p_t^{\text{T,H}}), \\
x_{3,t} &= -\alpha(p_t^{\text{N,F}} - p_t^{\text{T,F}}).
\end{aligned}$$



(a) Weighted domestic difference between the prices of non-traded and traded goods ($\alpha(p_t^{\text{NH}} - p_t^{\text{TH}})$), $\alpha = 0.50$



(b) Minus the weighted foreign difference between the prices of non-traded and traded goods ($-\alpha(p_t^{\text{NF}} - p_t^{\text{TF}})$), $\alpha = 0.50$

Figure 9: **Real exchange rate accounting: domestic and foreign relative prices of non-traded goods.** The real exchange rate accounting is based on the decomposition 5 in Equation 22, using the food and construction price data set (see Appendix B.1).

The results are of decomposition 5 are shown in Figure 9. What we find is that it is not just the ratio of the relative prices of non-traded goods at home and abroad that accounts for practically none of the real exchange changes, but the relative prices themselves. Indeed, the variation of $\text{UCM}(\alpha(p_t^{\text{N,H}} - p_t^{\text{T,H}}), q_t)$ and $\text{UCM}(-\alpha(p_t^{\text{N,F}} - p_t^{\text{T,F}}), q_t)$ across country pairs is even smaller than the already small variation of $\text{UCM}(\alpha(p_t^{\text{N}} - p_t^{\text{T}}), q_t)$ in Panel b of Figure 8.

5.5 The law of one price for traded goods

5.5.1 Contribution of traded good prices to traded good real exchange rate changes

Engel's (1999) work suggests that real exchange rate changes are primarily accounted for by deviations of the law of one price for traded goods or, what is the same, to deviations of the traded good real exchange rate, q_t^{T}, from zero. In this section, we turn to the traded good real exchange rate and ask to what extent it itself is driven by traded good prices. Our interest is to find out whether good market arbitrage is conducive to restoring if not purchasing power parity ($q_t = 0$), then at least the law of one price for traded goods ($q_t^{\mathrm{T}} = 0$).

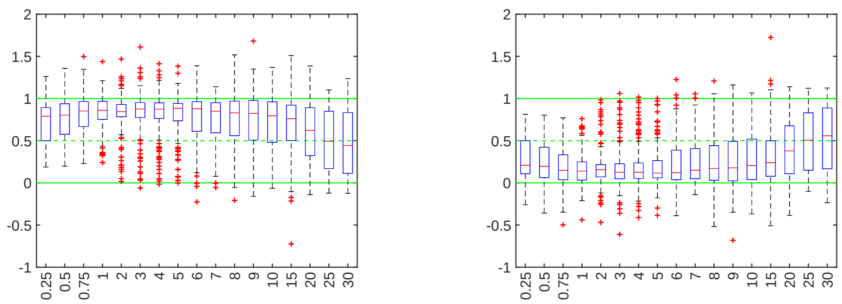
Since the traded good real exchange rate, which is defined as $q_t^{\mathrm{T}} = s_t + p_t^{\mathrm{T}}$, is equal to currency market pressure, $\tilde{s}_t$, we decompose it as follows (decomposition 6):

$$q_t^{\mathrm{T}} = x_{1,t} + x_{2,t}, \tag{23}$$

where

$$x_{1,t} = \tilde{s}_t^{\text{core}},$$
$$x_{2,t} = \tilde{s}_t^{\text{inflation-offsetting}} = \gamma p_t^{\mathrm{T}}.$$

Note that traded good prices affect the traded good real exchange rate only through inflation-offsetting currency market pressure.



(a) Core currency market pressure ($\tilde{s}_t^{\text{core}}$), $\alpha = 0.50$

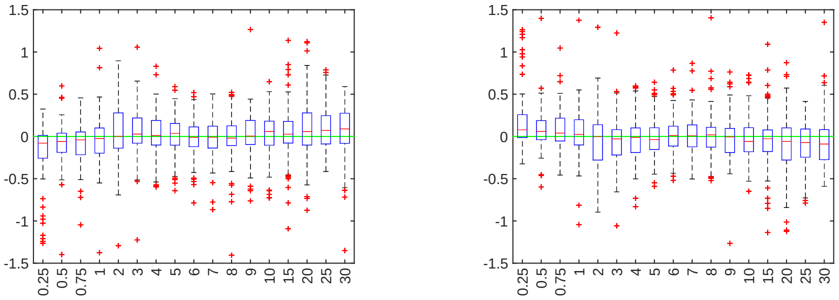
(b) Inflation-offsetting currency market pressure ($\tilde{s}_t^{\text{inflation-offsetting}} = \gamma p_t^{\mathrm{T}}$), $\alpha = 0.50$

Figure 10: **Traded good real exchange rate accounting: core currency market pressure and inflation-offsetting currency market pressure.** The traded good real exchange rate accounting is based on the decomposition 6 in Equation 23, using the food and construction price data set (see Appendix B.1).

The box plots for the contributions of core currency market pressure and inflation-offsetting currency market pressure to changes in the traded good real exchange rate are shown in Figure 10. We see that at horizons of up to ten years, core currency market pressure accounts for as much as 79 to 88% of the movements of the traded good real exchange rate, whereas traded good prices account for as little as 12 to 21%. This finding offers a very straightforward explanation of why deviations of the traded good real exchange rate from the law of one price do not damp out more quickly. For although traded good price movements affect the traded good real exchange rate, this effect is dwarfed by the much stronger impact of core currency market pressure. As we will show in Section 6, core currency market pressure is heavily driven by balance of payments flows, whose movements are known to be large and highly persistent.

5.5.2 More contribution to PPP convergence than to PPP divergence

To gauge the extent to which traded good arbitrage helps to equalize traded good prices across countries, we ask a question similar to that posed in Section 5.2.3, namely: Do traded good price movements contribute more to mean-reverting changes in q_t^{T} than to mean-diverting ones? We take an affirmative answer to this question as evidence of the effectiveness of the law of one price for traded goods.



(a) Core currency market pressure ($\tilde{s}_t^{\text{core}}$), $\alpha = 0.50$

(b) Inflation-offsetting currency market pressure ($\tilde{s}_t^{\text{inflation-offsetting}} = \gamma p_t^{\mathrm{T}}$), $\alpha = 0.50$

Figure 11: **Directional traded good real exchange rate accounting: core currency market pressure and inflation-offsetting currency market pressure.** The traded good real exchange rate accounting is based on the decomposition 6 in Equation 23, using the food and construction price data set (see Appendix B.1). Shown is the difference between the contributions of a given variable to the mean-reverting traded good real exchange rate and its contribution to the mean-diverting traded good real exchange.

The results are shown in Panel b of Figure 11. We find that the difference between $\mathrm{UCM}(\gamma p_t^{\mathrm{T}}, q_t^{\mathrm{T}})$ when q_t^{T} is mean-reverting and $\mathrm{UCM}(\gamma p_t^{\mathrm{T}}, q_t^{\mathrm{T}})$ when q_t^{T} is mean-diverting is zero on average for most horizons, yet that it is markedly positive for short horizons. For example, the median difference is 8%, 6%, 4% and 3% at horizons of one, two, three and four quarters, respectively, and it is close to zero only at horizons of more than a year. We interpret this as evidence that traded good prices are partly driven by arbitrage in traded goods and that exchange rates are kept sufficiently stable at short horizons for good market arbitrage to have an effect on the traded good real exchange rate. On the other hand, Panel a of Figure 11 indicates that short-term movements away from traded good purchasing power parity are caused primarily by the fluctuations of the core currency market pressure variable.

6 Economic interpretation of currency market pressure

Currency market pressure is defined in this paper as the deviation of the nominal exchange rate from its PPP-consistent value (based on the traded good real exchange rate, see Equation 11). The economic determinants of currency market pressure depend on the model one uses to explain the nominal exchange rate. Here we use an extended version of the model developed in the Supplementary Appendix of Müller-Plantenberg (2017b) to derive what we consider to be the main driving forces of currency market pressure (see also Brooks, Edison, Kumar and Sløk, 2001, Müller-Plantenberg, 2006, 2010, 2017a, Combes, Kinda and Plane, 2012, Gabaix and Maggiori, 2015).

Suppose there are two economic agents, a domestic one and a foreign one. Assume the domestic agent sells goods or financial assets to the foreign agent. In the first case there would be a current account surplus, in the second case a ”capital inflow”. In both cases, the foreign agent would have to pay money to the domestic agent. To understand how this payment affects currency market pressure, $\tilde{s}_t$, and the exchange rate, s_t, we now consider the optimization problems faced by both agents.

To start with, let us introduce the necessary notation. The domestic agent's holdings of the foreign currency are denoted as $m_t^{\text{H:FC}}$ and the foreign agent's holdings of domestic currency as $m_t^{\text{F:HC}}$. The values of both currency holdings may be measured in terms of a world currency, so as to make them comparable. Furthermore, the difference between both currency holdings shall be represented by the variable $\tilde{m}_t^{\text{HF}}$; that is, $\tilde{m}_t^{\text{HF}} = m_t^{\text{H:FC}} - m_t^{\text{F:HC}}$. Finally, let Δm_t denote the amount of foreign currency the domestic agent exchanges for domestic currency with the foreign agent.

Furthermore, we let $R_{l,t}^{\text{H}}$ and $R_{l,t}^{\text{F}}$ denote the cumulative nominal interest rates on, respectively, domestic and foreign monetary assets between t and $t+l$ and $r_{l,t}^{\text{H}}$ and $r_{l,t}^{\text{F}}$ the corresponding real interest rates (based on traded good inflation). To abbreviate the notation for the international interest differentials, we let $R_{l,t} = R_{l,t}^{\text{H}} - R_{l,t}^{\text{F}}$ and $r_{l,t} = r_{l,t}^{\text{H}} - r_{l,t}^{\text{F}}$ (just as $p_t^{\text{T}} = p_t^{\text{T,H}} - p_t^{\text{T,F}}$).

Now let us return to our economic example. If the balance of payments transaction mentioned above is denominated in the foreign currency, the domestic agent would have to go long in the foreign currency; in other words, $m_t^{\text{H:FC}}$ would rise. It is reasonable to assume that, to start with, the domestic agent would want to avoid any open position in the foreign currency, be it long or short, since she or he will not be able to know whether the foreign currency will appreciate or depreciate in the future. However, the domestic agent will be willing to go long in the foreign currency if she or he expects that the foreign currency will buy more goods in the future than an equivalent amount of the domestic currency.

Let $t+l$ denote the period in which the domestic agent expects to use her or his foreign currency holdings to buy traded goods. Then the domestic agent faces the following optimization problem:

$$\min_{s_t} \frac{1}{2} \left\{ \left[\left(R_{l,t}^{\text{F}} - p_{t+l}^{\text{T,F}} \right) - \left(-s_t + R_{l,t}^{\text{H}} - p_{t+l}^{\text{T,H}} \right) \right] - 2\xi \left(m_t^{\text{H:FC}} - \Delta m_t \right) \right\}^2, \tag{24}$$

where ξ is a positive parameter. Note that $R^{\text{F}}_{l,t} - p^{\text{T,F}}_{t+l}$ is the purchasing power of one unit of the foreign currency that is saved for l periods and then spent on foreign traded goods and that $-s_t + R^{\text{H}}_{l,t} - p^{\text{T,H}}_{t+l}$ is the purchasing power of an equivalent amount of the domestic currency that is saved for l periods and then spent on domestic traded goods.

If, on the other hand, the balance of payments transaction is denominated in the domestic currency, the foreign agent would have to go short in the domestic currency; in other words, $m^{\text{F:HC}}_t$ would fall. Similar reasoning to that above leads to the following optimization problem for the foreign agent:

$$\min_{s_t} \frac{1}{2} \left\{ \left[\left(R^{\text{H}}_{l,t} - p^{\text{T,H}}_{t+l} \right) - \left(s_t + R^{\text{F}}_{l,t} - p^{\text{T,F}}_{t+l} \right) \right] - 2\xi \left(m^{\text{F:HC}}_t - \Delta m_t \right) \right\}^2 . \tag{25}$$

The first-order conditions for the optimization problems in equations 24 and 25 yield a system of two linear equations with two unknowns, s_t and Δm_t. The solution is as follows:

$$\Delta m_t = \frac{1}{2} \left(m^{\text{H:FC}}_t + m^{\text{F:HC}}_t \right), \tag{26}$$

$$\begin{aligned} s_t &= R_{l,t} - p^{\text{T}}_{t+l} + \xi \tilde{m}^{\text{HF}}_t \\ &= -p^{\text{T}}_t + R_{l,t} - \left(p^{\text{T}}_{t+l} - p^{\text{T}}_t \right) + \xi \tilde{m}^{\text{HF}}_t \\ &= s^{\text{anchor}}_t + r_{l,t} + \xi \tilde{m}^{\text{HF}}_t , \end{aligned} \tag{27}$$

Note that at the optimum the domestic and foreign agents exchange their currencies in the amount required to ensure that the same nominal exchange rate is optimal for both of them.

A comparison of Equation 11 with Equation 27 shows us that currency market pressure, $\tilde{s}_t$, is determined by the real interest differential, $r_{l,t}$, and the gap between the foreign currency holdings of the domestic agent and the domestic currency holdings of the foreign agent, $\tilde{m}^{\text{HF}}_t$:

$$\tilde{s}_t = r_{l,t} + \xi \tilde{m}^{\text{HF}}_t . \tag{28}$$

Note that the variable $\tilde{m}^{\text{HF}}_t$ is a stock that, as we have suggested in our example, is linked to the past and present balance of payments flows between the home country and the foreign country. To be more specific, let z^{HF}_t be the cumulative current account, or international investment position, e^{HF}_t be the difference between the domestic agent's holdings of foreign equity and the foreign agent's holdings of domestic equity, b^{HF}_t be the difference between the domestic agent's holdings of foreign bonds and the foreign agent's holdings of domestic bonds and $b^{\bar{\text{H}}\bar{\text{F}}}_t$ be the difference between the domestic central bank's holdings of foreign bonds and the foreign central bank's holdings of domestic bonds. Then the stock version of the balance of payments identity implies the following relationship between those variables:

$$\tilde{m}^{\text{HF}}_t = z^{\text{HF}}_t - e^{\text{HF}}_t - b^{\text{HF}}_t - b^{\bar{\text{H}}\bar{\text{F}}}_t . \tag{29}$$

Equations 27 and 29 capture most of the nominal exchange rate determinants that are generally considered to be empirically relevant. The flow versions of both equations tell us that the net appreciation of the domestic currency against the foreign currency is the stronger: the lower domestic inflation is and the higher foreign inflation is, the more the real interest differential rises, the higher the current account balance is, the higher net FDI and equity investment inflows into the home country are, the higher net lending inflows (bonds, loans, trade credits etc.) into the home country are and the more official reserves the domestic central bank is selling and the foreign central bank is buying. The inflation differential itself depends, of course, on other variables such as money supply growth and output growth at home and abroad.

7 Conclusions

In the minds of many international economists, certain beliefs regarding the real exchange rate seem to be unshakable. First, deviations from purchasing power parity must be temporary. Second, traded good prices can only differ across countries inasmuch as transport costs hinder arbitrage. Third, movements of the real exchange rate outside the no-arbitrage bands or indeed persistent deviations from absolute PPP ($q_t = 0$) must be due to international differences in the relative prices of non-traded goods. And fourth, the slow mean reversion of the real exchange rate is probably due either to the fact that we mix up movements outside the no-arbitrage bands (where mean reversion is fast) and inside the no-arbitrage bands (where there is no reason to expect any mean reversion) or to the fact that it is difficult to distinguish well traded goods (for which arbitrage is possible) and non-traded goods (for which arbitrage is not possible).

This paper challenges all of the aforementioned beliefs. First, the idea that the law of one price implies that the real exchange rate, defined as $q_t = s_t + p_t^{\mathrm{H}} - p_t^{\mathrm{F}}$, is always brought back to zero through traded good arbitrage is questionable. For the nominal exchange rate, s_t, depends itself negatively on domestic traded good prices and positively on foreign traded good prices, with the consequence that the real exchange rate is pretty much unaffected by the movements of traded good prices at home and abroad (what is more, depending on the data set used, good market arbitrage may even be detrimental to PPP). This is what we call the purchasing power parity fallacy. Instead, this paper shows that the main driving force behind the real exchange rate is core currency market pressure, a variable that is linked to economic variables such as real interest rates and balance of payments flows.

Second, the fact that traded good prices differ across countries, or that the traded good real exchange rate is different from zero, is hardly surprising. After all, we find that core currency market pressure, which is unrelated to traded good prices, accounts for as much as 79 to 88% of traded good real exchange rate movements (for horizons of up to ten years) and inflation-offsetting currency market pressure, which is linked to traded good inflation, for the rest. If traded good prices affect the traded good real exchange rate so little, it should seem that differences in international traded good prices can persist independently of whether they exceed transport costs or not. The comforting news is that at short horizons traded good prices appear to contribute somewhat more to traded good real exchange rate movements towards the mean than away from it, suggesting that the law of one price may work at least partially for traded goods.

Now consider the third point. Our paper confirms the finding of several recent studies that the relative price of non-traded goods hardly contributes to real exchange rate movements. However, here we calculate the contribution of non-traded good prices to real exchange rate movements using exact contribution measures. In Appendix A, these measures are shown to potentially deviate from the contribution measures used in the literature. Another advantage of the present work is that it considers far more country pairs. Last but not least, by using price data of single categories of traded and non-traded goods, the calculations carried out here avoid as much as possible the use of price data for categories that include both traded and non-traded goods.

Finally, by suggesting that real exchange rate movements are primarily accounted for by changes in core currency market pressure, this paper calls for a very different approach to what has become known as the purchasing power parity puzzle. Rogoff (1996) summarizes the PPP puzzle as follows:

> ”How can one reconcile the enormous short-term volatility of real exchange rates with the extremely slow rate at which shocks appear to damp out? [...] Consensus estimates for the rate at which PPP deviations damp [...] suggest a half-life of three to five years, seemingly far too long to be explained by nominal rigidities.”

As is shown here, currency market pressure is heavily driven by currency flows that arise when differences between current account balances and net capital outflows produce balance of payments imbalances. There is every reason to believe that these currency flows are very volatile. Indeed, there is strong empirical evidence that short-term capital flows, which tend to vary strongly over time, have significant effects on exchange rates. At the same time, it is no secret that cumulative balance of payments imbalances, particularly as a result of lasting current account surpluses or deficits, can be very persistent in the medium and long term. This suggests that movements in currency market pressure must be persistent, too, and thus provides a very simple and intuitive explanation of the slow decay of real exchange rate deviations from PPP. Put differently, the question of whether traded or non-traded good prices are sticky or not does not pose itself.

Appendix A The unbounded and bounded contribution measures versus alternative contribution measures

In this appendix, the performance of the UCM and the BCM is compared to that of various contribution measures proposed in the literature. We start by introducing those alternative contribution measures in Appendix A.1. The comparison is then carried out in Appendix A.2 using a Monte Carlo approach.

A.1 Alternative contribution measures

A.1.1 Engel's (1999) contribution measures

Engel (1999) uses contribution measures that build on the mean squared error criterion (MSE). Although the mean squared error is a concept used in statistics to quantify the difference between values implied by an estimator and the true values of the quantity being estimated, we follow Engel and adopt this concept analogously in the context of exchange rate accounting. Suppose that x_t is the sum of only two components, $x_{1,t}$ and $x_{2,t}$, so that $x_t = x_{1,t} + x_{2,t}$. From the definition of the mean squared error, we can deduce the following:

$$\begin{aligned}\mathrm{MSE}(\Delta_h x_t) &= \mathrm{MSE}(\Delta_h x_{1,t} + \Delta_h x_{2,t}) \\ &= \mathrm{Var}(\Delta_h x_{1,t} + \Delta_h x_{2,t}) + [\mathrm{Bias}(\Delta_h x_{1,t} + \Delta_h x_{2,t})]^2 \\ &= \mathrm{Var}(\Delta_h x_{1,t}) + \mathrm{Var}(\Delta_h x_{2,t}) + 2\,\mathrm{Cov}(\Delta_h x_{1,t}, \Delta_h x_{2,t}) \\ &\quad + [\mathrm{Bias}(\Delta_h x_{1,t})]^2 + [\mathrm{Bias}(\Delta_h x_{2,t})]^2 + 2\,\mathrm{Bias}(\Delta_h x_{1,t})\,\mathrm{Bias}(\Delta_h x_{2,t}) \\ &= \mathrm{MSE}(\Delta_h x_{1,t}) + \mathrm{MSE}(\Delta_h x_{2,t}) + 2\,\mathrm{Bias}(\Delta_h x_{1,t})\,\mathrm{Bias}(\Delta_h x_{2,t}) \\ &\quad + 2\,\mathrm{Cov}(\Delta_h x_{1,t}, \Delta_h x_{2,t}).\end{aligned} \tag{30}$$

The mean squared error of the composite series $\Delta_h x_t$ is thus equal to the sum of the mean squared errors of its two components, $\Delta_h x_{1,t}$ and $\Delta_h x_{2,t}$, plus an additional term involving the product of the "biases" and the covariance of both components.

It is natural to use the mean squared errors of both components to measure their respective contribution to the mean squared error of the composite series. However, it is less clear what should be done with the additional term. Two possibilities that suggest themselves are to either ignore this term or to attribute it equally to both component series. Engel applies both alternatives and finds that they lead to similar results in his context. Specifically, the two contribution measures he considers are the following:

$$\mathrm{CM}^{\mathrm{MSE}(1)}(x_{i,t}, x_t) = \frac{\mathrm{MSE}(\Delta_h x_{1,t})}{\mathrm{MSE}(\Delta_h x_{1,t}) + \mathrm{MSE}(\Delta_h x_{2,t})}, \tag{31}$$

$$\begin{aligned}&\mathrm{CM}^{\mathrm{MSE}(2)}(x_{i,t}, x_t) \\ &\quad = \frac{\mathrm{MSE}(\Delta_h x_{1,t}) + \mathrm{Bias}(\Delta_h x_{1,t})\,\mathrm{Bias}(\Delta_h x_{2,t}) + \mathrm{Cov}(\Delta_h x_{1,t}, \Delta_h x_{2,t})}{\mathrm{MSE}(\Delta_h x_t)}.\end{aligned} \tag{32}$$

Note that the "bias" is measured around zero and is thus equal to the arithmetic mean of the variable in question. For the variance, Engel uses a small-sample correction:

$$\mathrm{Bias}(\Delta_h x_{\cdot,t}) = \frac{h}{T-1}(x_{\cdot,T} - x_{\cdot,1}), \tag{33}$$

$$\mathrm{Var}(\Delta_h x_{\cdot,t}) = \frac{T}{(T-h-1)(T-h)} \sum_{t=h+1}^{T} [\Delta_h x_{\cdot,t} - \mathrm{Bias}(\Delta_h x_{\cdot,t})]^2. \tag{34}$$

A.1.2 Other contribution measures

One contribution measure used in the literature is based on sample variances:

$$\mathrm{CM}^{\mathrm{Var}(1)}(x_{1,t}, x_t) = \frac{\mathrm{Var}(\Delta_h x_{1,t})}{\mathrm{Var}(\Delta_h x_{1,t}) + \mathrm{Var}(\Delta_h x_{2,t})}. \tag{35}$$

Similar to the contribution measure $\mathrm{CM}^{\mathrm{MSE}(1)}$, the measure $\mathrm{CM}^{\mathrm{Var}(1)}$ can only take values between zero and one.

An alternative measure is also based on variances, but takes the correlation between $\Delta_h x_{1,t}$ and $\Delta_h x_{2,t}$ into account:

$$\begin{aligned}\mathrm{CM}^{\mathrm{Var}(2)}(x_{1,t}, x_t) &= \frac{\mathrm{Var}(\Delta_h x_{1,t}) + \mathrm{Cov}(\Delta_h x_{1,t}, \Delta_h x_{2,t})}{\mathrm{Var}(\Delta_h x_t)} \\ &= \frac{\mathrm{Var}(\Delta_h x_{1,t}) + \mathrm{Cov}(\Delta_h x_{1,t}, \Delta_h x_{2,t})}{\mathrm{Var}(\Delta_h x_{1,t}) + \mathrm{Var}(\Delta_h x_{2,t}) + 2\,\mathrm{Cov}(\Delta_h x_{1,t}, \Delta_h x_{2,t})}.\end{aligned} \tag{36}$$

Yet another contribution measure proposed in the literature is based on the sample standard deviations:

$$\mathrm{CM}^{\mathrm{Std}}(x_{1,t}, x_t) = \frac{\mathrm{Std}(\Delta_h x_{1,t})}{\mathrm{Std}(\Delta_h x_t)}. \tag{37}$$

Finally, authors have looked at the sample correlation between the component series and the composite series:

$$\mathrm{CM}^{\mathrm{Corr}}(x_{1,t}, x_t) = \frac{\mathrm{Cov}(\Delta_h x_{1,t}, \Delta_h x_t)}{\mathrm{Std}(\Delta_h x_{1,t})\,\mathrm{Std}(\Delta_h x_t)}. \tag{38}$$

Note that $-1 < \mathrm{CM}^{\mathrm{Corr}} < 1$. There is no obvious relationship with the UCM.

The contribution measures $\mathrm{CM}^{\mathrm{Var}(1)}$, $\mathrm{CM}^{\mathrm{Var}(2)}$, $\mathrm{CM}^{\mathrm{Std}}$ and $\mathrm{CM}^{\mathrm{Corr}}$ have been proposed by Betts and Kehoe (2006, 2008). These authors apply those measures to the levels of the real exchange rate and its components and to the linearly detrended levels. They further use the measures $\mathrm{CM}^{\mathrm{MSE}(1)}$, $\mathrm{CM}^{\mathrm{Std}}$ and $\mathrm{CM}^{\mathrm{Corr}}$ for the one-year and four-year differences of the real exchange rate and its components. Burstein et al. (2006) adopt $\mathrm{CM}^{\mathrm{Var}(2)}$ with a slight modification: by attributing the covariance term of the variance of the composite series, $2\,\mathrm{Cov}(x_1, x_2)$, either fully to one component series or to the other one, they obtain lower and upper bounds for the contribution of the component series to the composite series. Moreover, Burstein et al. actually do not apply $\mathrm{CM}^{\mathrm{Var}(2)}$ to the differences of the series but to their levels, where the levels have previously been detrended using a Hodrick-Prescott filter with a smoothing parameter of 1600. Drozd and Nosal (2010) use the measures $\mathrm{CM}^{\mathrm{Std}}$ and $\mathrm{CM}^{\mathrm{Corr}}$, Bache et al. (2013) the measure $\mathrm{CM}^{\mathrm{Var}(1)}$. However, Chen et al. (2006) use Engel's (1999) original measures, $\mathrm{CM}^{\mathrm{MSE}(1)}$ and $\mathrm{CM}^{\mathrm{MSE}(2)}$.

A.2 Comparison of contribution measures

In order to compare the properties of the UCM and the BCM with those of the contribution measures used in the literature, we rely on Monte Carlo simulations. We look at three different models, in all of which $x_{1,t}$ and $x_{2,t}$ are modelled as random walks:

$$x_{i,t} = x_{i,t-1} + \Delta x_{i,t}, \qquad \text{for } i = 1, 2, \tag{39}$$

where $t = 2, 3, \ldots, T$, $T = 100$ and $x_{i,1} = 0$. The stochastic processes in models 1 to 3 differ only with respect to their innovations, $\Delta_h x_{1,t}$ and $\Delta_h x_{2,t}$, as will be shown below. We also experimented with stochastic processes with some kind of mean reversion or error correction mechanism, but the results we obtained were similar; this is why we only report the results for the random walk processes which are easier to interpret. The sample size of the Monte Carlo runs is 1000 in each case. The results are shown in Table 5. Differences refer to first-order differences ($h = 1$).

	Model 1			Model 2			Model 3		
	Median	Mean	SD	Median	Mean	SD	Median	Mean	SD
Differences									
UCM	-0.994	-1.004	0.143	0.510	0.511	0.119	0.278	0.281	0.065
BCM	0.000	0.000	0.000	0.396	0.396	0.043	0.311	0.314	0.059
$\text{CM}^{\text{MSE}(1)}$	0.248	0.248	0.028	0.385	0.384	0.033	0.075	0.084	0.045
$\text{CM}^{\text{MSE}(2)}$	-0.504	-0.513	0.099	0.203	0.207	0.074	0.074	0.082	0.050
$\text{CM}^{\text{Var}(1)}$	0.248	0.248	0.028	0.240	0.240	0.000	0.074	0.084	0.045
$\text{CM}^{\text{Var}(2)}$	-0.505	-0.513	0.100	-1.282	-1.282	0.000	0.074	0.082	0.050
CM^{Std}	0.996	1.008	0.151	1.282	1.282	0.000	0.274	0.280	0.075
CM^{Corr}	-0.509	-0.509	0.058	-1.000	-1.000	0.000	0.275	0.276	0.117
Levels									
$\text{CM}^{\text{MSE}(1)}$	0.239	0.270	0.153	0.951	0.915	0.094	0.068	0.137	0.165
$\text{CM}^{\text{MSE}(2)}$	-0.478	-0.487	0.762	0.832	0.842	0.151	0.059	0.071	0.276
$\text{CM}^{\text{Var}(1)}$	0.245	0.259	0.111	0.937	0.902	0.095	0.070	0.115	0.121
$\text{CM}^{\text{Var}(2)}$	-0.494	-0.482	0.518	0.824	0.835	0.148	0.063	0.080	0.175
CM^{Std}	0.977	1.076	0.521	0.835	0.844	0.150	0.267	0.319	0.202
CM^{Corr}	-0.555	-0.452	0.408	0.991	0.989	0.006	0.286	0.230	0.475

Table 5: **Comparison of contribution measures.** Comparison of the UCM and BCM with the contribution measures used in the literature. In the case of differences, the contribution of $\Delta x_{1,t}$ to Δx_t is measured. In the case of levels, the contribution of $x_{1,t}$ to x_t is measured.

A.2.1 Model 1

Model 1 takes the following form:

$$\Delta x_{1,t} = -u_t \times \varepsilon_t, \tag{40}$$

$$\Delta x_{2,t} = \varepsilon_t, \tag{41}$$

where $u_t \sim \text{U}(0, 1)$ and $\varepsilon_t \sim \text{N}(0, 1)$. Note that in this model, it will always be the case that $\Delta x_{1,t}/\Delta x_t < 0$, so that necessarily UCM < 0 and BCM $= 0$. In fact, since $\Delta x_{1,t} = -u_t \times \varepsilon_t$, $\Delta x_t = (1 - u_t) \times \varepsilon_t$ and $\text{E}(u_t) = \text{E}(1 - u_t) = \frac{1}{2}$, the UCM should take on a value near minus one in the simulated sample:

$$\lim_{T\to\infty} \text{UCM}(x_{1,t}, x_t) = \lim_{T\to\infty} \sum_{t=1}^{T} \frac{|(1 - u_t)\varepsilon_t|}{\sum_{\tau=1}^{T} |(1 - u_\tau)\varepsilon_\tau|} \times \frac{-u_t\varepsilon_t}{(1 - u_t)\varepsilon_t}$$

$$= \lim_{T \to \infty} \sum_{t=1}^{T} \frac{-u_t |\varepsilon_t|}{\sum_{\tau=1}^{T} (1 - u_\tau) |\varepsilon_\tau|} = \lim_{T \to \infty} \frac{-\frac{1}{2} \sum_{t=1}^{T} |\varepsilon_t|}{\frac{1}{2} \sum_{t=1}^{T} |\varepsilon_t|} = -1. \quad (42)$$

Turning now to the contribution measures used in the literature, it is easy to see that the standard deviation of the component series $\Delta x_{1,t}$ is equal in expectation to that of the composite series Δx_t. This implies that $\mathrm{CM}^{\mathrm{Std}}$ should be positive and near one in the simulated sample, no matter whether we look at the series in differences or in levels, even though $x_{1,t}$ clearly does not contribute at all to the movements of x_t. Therefore, $\mathrm{CM}^{\mathrm{Std}}$ is not useful as a measure of co-movement between the component and composite series.

Another insight to take away from model 1 is that the contribution measures $\mathrm{CM}^{\mathrm{MSE}(1)}$ and $\mathrm{CM}^{\mathrm{Var}(1)}$ ignore the negative correlation between $\Delta x_{1,t}$ and Δx_t and between $x_{1,t}$ and x_t and thus take on positive values, whereas the UCM and the BCM suggest that they should be negative or zero. Both $\mathrm{CM}^{\mathrm{MSE}(1)}$ and $\mathrm{CM}^{\mathrm{Var}(1)}$ thus appear inadequate as contribution measures, too. While the measures $\mathrm{CM}^{\mathrm{MSE}(2)}$ and $\mathrm{CM}^{\mathrm{Var}(2)}$ do take on negative values in this model, the values lie somewhere between the UCM and the BCM and are arguably more difficult to interpret than the latter.

A.2.2 Model 2

Model 2 takes the following form:

$$\Delta x_{1,t} = \mu_1 + \varepsilon_t, \quad (43)$$

$$\Delta x_{2,t} = \mu_2 - \theta \varepsilon_t, \quad (44)$$

where $\mu_1 = 1$, $\mu_2 = 0.2$, $\theta = 1.78$ and $\varepsilon_t \sim \mathrm{N}(0, 1)$. The parameter θ is chosen so that the UCM is about one half (with the BCM near 0.4). However, note that the correlation between the differences of the component series and the composite series is perfectly negative, whereas the correlation between the corresponding levels is almost perfectly positive. This demonstrates that $\mathrm{CM}^{\mathrm{Corr}}$, whether measured for differences or levels, is a misleading measure of the contribution of $x_{1,t}$ and $x_{2,t}$ to the movements of x_t.

As mentioned, the contribution of $x_{1,t}$ to the movements of x_t is roughly one half on average. The contribution measure that comes closest to this value is $\mathrm{CM}^{\mathrm{MSE}(1)}$ when applied to differences; it takes a value 0.382, or about 76% of the UCM. However, this measure did badly in model 1, where it took a positive sign, rather than a negative one as the UCM. The values of the measures $\mathrm{CM}^{\mathrm{MSE}(2)}$ and $\mathrm{CM}^{\mathrm{Var}(1)}$ for differences are unreasonably low (around 0.2), whereas those of the measures $\mathrm{CM}^{\mathrm{MSE}(1)}$, $\mathrm{CM}^{\mathrm{MSE}(2)}$, $\mathrm{CM}^{\mathrm{Var}(1)}$ and $\mathrm{CM}^{\mathrm{Var}(2)}$ for levels are all too high (around 0.8–0.9). Due to the negative correlation between $\Delta x_{1,t}$ and $\Delta x_{2,t}$, the measure $\mathrm{CM}^{\mathrm{Var}(2)}$ takes on a negative value when applied to the differences:

$$\mathrm{CM}^{\mathrm{Var}(2)}(x_{1,t}, x_t) = (1 - 1.78)/(1 + 1.78^2 - 2 \times 1.78) = -1.282. \quad (45)$$

This example shows why it is problematic to use a contribution measure that ignores the drifts of $x_{1,t}$ and $x_{2,t}$ if they exist.

A.2.3 Model 3

Model 3 takes the following form:

$$\Delta x_{1,t} = \varepsilon_{1,t}, \tag{46}$$

$$\Delta x_{2,t} = \varepsilon_{2,t}^3, \tag{47}$$

where $\varepsilon_{1,t} \sim \mathrm{N}(0,1)$, $\varepsilon_{2,t} \sim \mathrm{N}(0,1)$ and $\varepsilon_{1,t}$ and $\varepsilon_{2,t}$ are drawn independently. This example demonstrates that if $x_{1,t}$ and $x_{2,t}$ are driven by shocks from different distributions, $\mathrm{CM}^{\mathrm{MSE(1)}}$, $\mathrm{CM}^{\mathrm{MSE(2)}}$, $\mathrm{CM}^{\mathrm{Var(1)}}$ and $\mathrm{CM}^{\mathrm{Var(2)}}$ can all be significantly biased compared to the UCM and the BCM. The only measures that come close to the UCM and the BCM in this particular example are $\mathrm{CM}^{\mathrm{Std}}$ and $\mathrm{CM}^{\mathrm{Corr}}$. However, those latter measures proved clearly inadequate in the other two experiments.

A.2.4 Conclusions from the comparison of contribution measures

When a variable is the exact sum of other variables, the contribution of the latter variables to the composite series can be calculated precisely using the UCM and the BCM. These two contribution measures are simple and intuitive. As the Monte Carlo simulations have shown, all the measures proposed in the literature deviate from the UCM and the BCM for even quite simple stochastic processes. In many cases, they have the wrong sign or are significantly biased. Even if those measures do well in one model, they do badly in others. Our impression is that for very simple models, the measure $\mathrm{CM}^{\mathrm{MSE(2)}}$ based on differences is the one that comes closest to the UCM. However, as the models 1 to 3 show, $\mathrm{CM}^{\mathrm{MSE(2)}}$ can also be quite off the target.

Appendix B Data

B.1 Food and construction price data set

The food and construction price data set used in this paper has already been described at the beginning of Section 4. Here we add information on the country coverage and length of the time series data that we took from the Main Economic Indicators of the OECD. The data set covers the following countries:

> Austria, Brazil, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Mexico, Norway, Portugal, Spain and Sweden.

The available series vary in length, with the longest price and nominal exchange rate series spanning the period from 1960Q1 to 2017Q2. Note that with 16 countries, we can compute nominal and real exchange rates as well as price differentials for a total of 120 country pairs (= (16 $\times$ 15) / 2).

We thought that the fact that some country pairs had fixed bilateral exchange rates during parts of the sample could be of relevance, yet found that taking out those pairs hardly affected our results and hence left them in. It should be noted that using data on countries that temporarily fix their exchange rates vis-à-vis other countries will overstate the effect of traded good prices on the real exchange rate as the nominal exchange rate effect is reduced. This adds, of course, confidence to our finding that traded good prices account for almost none of the movements of real exchange rates. However, as already said, our results were practically identical for the full sample and the sub-sample.

B.2 PPI and CPI data set

The PPI and CPI data set that we use for our robustness analysis in section 5.3 was taken from the International Financial Statistics of the IMF. In this database, nominal exchange rate as well as PPI and CPI data are available for the following set of countries:

> Albania, Algeria, Argentina, Armenia, Austria, Belgium, Brazil, Bulgaria, Canada, Central African Republic, Chile, China, Colombia, Costa Rica, Croatia, Czech Republic, Denmark, Ecuador, Egypt, El Salvador, Estonia, Ethiopia, Finland, France, Georgia, Germany, Greece, Hong Kong, Hungary, India, Indonesia, Iran, Israel, Italy, Japan, Kazakhstan, Kuwait, Kyrgyzstan, Latvia, Lithuania, Macedonia, Malaysia, Mexico, Morocco, Netherlands, Norway, Pakistan, Panama, Paraguay, Peru, Philippines, Poland, Portugal, Republic of the Congo, Romania, Saudi Arabia, Senegal, Singapore, Slovakia, Slovenia, South Africa, South Korea, Spain, Sri Lanka, Sweden, Switzerland, Syria, Thailand, Trinidad and Tobago, Tunisia, Turkey, Ukraine, United Kingdom, United States, Uruguay, Venezuela and Zambia.

The available series vary in length, with the longest price and nominal exchange rate series spanning the period from 1957Q1 to 2016Q2. Note that with 77 countries, we can compute nominal and real exchange rates as well as price differentials for a total of 2,926 country pairs (= (77 $\times$ 76) / 2).

Appendix C Determining inflation-offsetting currency market pressure

In this paper, inflation-offsetting currency market pressure, $\tilde{s}_t^{\text{inflation-offsetting}}$, is defined as γp_t^{T}, where γ is chosen such that $\mathrm{UCM}(p_t^{\mathrm{T}}, \tilde{s}_t^{\text{core}}) = 0$. Denoting $\mathrm{UCM}(p_t^{\mathrm{T}}, \tilde{s}_t^{\text{core}})$ as $\Phi(\gamma)$, we see that:

$$\begin{aligned}
\Phi(\gamma) &= \mathrm{UCM}(p_t^{\mathrm{T}}, \tilde{s}_t^{\text{core}}) \\
&= \mathrm{UCM}(p_t^{\mathrm{T}}, \tilde{s}_t - \gamma p_t^{\mathrm{T}}) \\
&= \sum_{t=h+1}^{T} \frac{|\Delta_h \tilde{s}_t - \gamma \Delta_h p_t^{\mathrm{T}}|}{\sum_{\tau=h+1}^{T} |\Delta_h \tilde{s}_\tau - \gamma \Delta_h p_\tau^{\mathrm{T}}|} \times \frac{\Delta_h p_t^{\mathrm{T}}}{\Delta_h \tilde{s}_t - \gamma \Delta_h p_t^{\mathrm{T}}} \qquad (48) \\
&= \Phi_1(\gamma) \times \Phi_2(\gamma),
\end{aligned}$$

where

$$\Phi_1(\gamma) = \frac{1}{\sum_{\tau=h+1}^{T} |\Delta_h \tilde{s}_\tau - \gamma \Delta_h p_\tau^{\mathrm{T}}|},$$
$$\Phi_2(\gamma) = \sum_{t=h+1}^{T} \operatorname{sgn}(\Delta_h \tilde{s}_t - \gamma \Delta_h p_t^{\mathrm{T}}) \times \Delta_h p_t^{\mathrm{T}}. \tag{49}$$

It is easily verified that $\Phi_2(\gamma)$ is weakly decreasing in γ, that $\Phi_2(\gamma) \to \bar{\Phi}_2 > 0$ as $\gamma \to -\infty$ and that $\Phi_2(\gamma) \to \underline{\Phi}_2 < 0$ as $\gamma \to +\infty$. Hence there exists exactly one interval of values of γ for which $\Phi_2(\gamma) = 0$. Since $\Phi_1(\gamma) > 0$ always (unless $\Delta_h \tilde{s}_t = \gamma \Delta_h p_t^{\mathrm{T}}$ for all t), it follows that $\Phi(\gamma) = 0$ for the same interval of values of γ for which $\Phi_2(\gamma) = 0$. Computationally, this interval can be estimated using a grid search with an arbitrarily fine, possibly adaptive grid. As for the value of γ, we used the midpoint of the estimated interval. It should be noted, however, that the estimated interval is of zero length most of the time so that a point estimate can be used for γ.

References

Alexius, Annika and Jonny Nilsson. Real exchange rates and fundamentals: Evidence from 15 oecd countries. *Open Economies Review*, vol. 11, 2000, 383–397.

Bache, Ida Wolden, Tommy Sveen and Kjersti Naess Torstensen. Revisiting the importance of non-tradable goods' prices in cyclical real exchange rate fluctuations. *European Economic Review*, vol. 57, Jan. 2013, 98–107.

Baum, Christopher F., John T. Barkoulas and Mustafa Caglayan. Nonlinear adjustment to purchasing power parity in the post-Bretton Woods era. *Journal of International Money and Finance*, vol. 20, no. 3, Jun. 2001, 379–399.

Beckmann, Joscha. Nonlinear adjustment, purchasing power parity and the role of nominal exchange rates and prices. *North American Journal of Economics and Finance*, vol. 24, 2013, 176–190.

Betts, Caroline M. and Timothy J. Kehoe. U.S. real exchange rate fluctuations and relative price fluctuations. *Journal of Monetary Economics*, vol. 53, no. 7, Oct. 2006, 1297–1326.

Betts, Caroline M. and Timothy J. Kehoe. Real exchange rate movements and the relative price of non-traded goods. *Federal Reserve Bank of Minneapolis Research Department Staff Reports*, , no. 415, Oct. 2008.

Brooks, Robin, Hali J. Edison, Manmohan Kumar and Torsten Sløk. Exchange rates and capital flows. *International Monetary Fund Working Paper Series*, , no. 190, Nov. 2001.

Burstein, Ariel, Martin Eichenbaum and Sergio Rebelo. The importance of nontradable goods' prices in cyclical real exchange rate fuctuations. *Japan and the World Economy*, vol. 18, no. 3, 2006, 247–253.

Ca' Zorzi, Michele, Jakub Muck and Michal Rubaszek. Real exchange rate forecasting and PPP: This time the random walk looses. *Open Economies Review*, vol. 27, no. 3, Jul. 2016, 585–609.

Chen, Lein-Lein, Seungmook Choi and John Devereux. Accounting for US regional real exchange rates. *Journal of Money, Credit, and Banking*, vol. 38, no. 1, Feb. 2006, 229–244.

Cheung, Yin-Wong, Menzie David Chinn, Antonio García Pascual and Yi Zhang. Exchange rate prediction redux: New models, new data, new currencies. *National Bureau of Economic Research Working Paper Series*, , no. 23267, Mar. 2017.

Cheung, Yin-Wong, Kon S. Lai and Michael Bergman. Dissecting the PPP puzzle: the unconventional roles of nominal exchange rate and price adjustments. *Journal of International Economics*, vol. 64, no. 1, Oct. 2004, 135–150.

Choi, Kwan, George Kapetanios and Yongcheol Shin. Nonlinear mean reversion in real exchange rates. *Economics Letters*, vol. 77, no. 3, Nov. 2002, 411–417.

Combes, Jean-Luis, Tidiane Kinda and Patrick Plane. Capital flows, exchange rate flexibility, and the real exchange rate. *Journal of Macroeconomics*, vol. 34, no. 4, Dec. 2012, 1034–1043.

Drozd, Lukasz A. and Jaromir B. Nosal. The nontradable goods' real exchange rate puzzle. In Lucrezia Reichlin and Kenneth D. West (eds.), *National Bureau of Economic Research International Seminar on Macroeconomics 2009*, vol. 6. 2010, pp. 227–249.

Eleftheriou, Maria and Nikolas Müller-Plantenberg. Price level convergence and purchasing power divergence. *International Finance*, 2017. Forthcoming.

Enders, Walter. ARIMA and cointegration tests of purchasing power parity. *Review of Economics and Statistics*, vol. 70, no. 3, Aug. 1988, 504–508.

Engel, Charles. Accounting for US real exchange rate changes. *Journal of Political Economy*, vol. 107, no. 3, Jun. 1999, 507–538.

Engel, Charles and James C. Morley. The adjustment of prices and the adjustment of the exchange rate. *National Bureau of Economic Research Working Paper Series*, , no. 8550, Oct. 2001.

Gabaix, Xavier and Matteo Maggiori. International liquidity and exchange rate adjustment. *Quarterly Journal of Economics*, vol. 130, no. 3, Aug. 2015, 1369–1420.

Hall, Stephen G., George Hondroyiannis, Amangeldi Kenjegaliev, P. A. V. B. Swamy and George S. Tavlas. Is the relationship between prices and exchange rates homogeneous? *Journal of International Money and Finance*, vol. 37, Oct. 2013, 411–438.

Heimonen, Kari. Nonlinear adjustment in PPP: Evidence from threshold cointegration. *Empirical Economics*, vol. 31, no. 2, Jun. 2006, 479–495.

Ho, Catherine S. F. and M. Ariff. Sticky prices and time to equilibrium: Evidence from Asia-Pacific trade-related economies. *Applied Economics*, vol. 43, no. 21, 2011, 2851–2861. Mimeo.

Imbs, Jean, Haroon Mumtaz, Morten O. Ravn and Hélène Rey. Non-linearities and real exchange rate dynamics. *Journal of the European Economic Association*, vol. 1, no. 2, 2003, 639–649.

Imbs, Jean, Haroon Mumtaz, Morten O. Ravn and Hélène Rey. PPP strikes back: Aggregation and the real exchange rate. *Quarterly Journal of Economics*, vol. 120, no. 1, Feb. 2005, 1–43.

Juvenal, Luciana and Mark P. Taylor. Threshold adjustment of deviations from the law of one price. *Studies in Nonlinear Dynamics and Econometrics*, vol. 12, no. 3, 2008, 1–44.

Lo, Ming Chien and Eric Zivot. Threshold cointegration and nonlinear adjustment to the law of one price. *Macroeconomic Dynamics*, vol. 5, no. 4, Sep. 2001, 533–576.

Manzur, Meher and M. Ariff. Purchasing power parity: New methods and extensions. *Applied Financial Economics*, vol. 5, no. 1, 1995, 19–26.

Mendoza, Enrique Gabriel. On the instability of variance decompositions of the real exchange rate across exchange-rate-regimes: Evidence from Mexico and the United States. *National Bureau of Economic Research Working Paper Series*, , no. 7768, 2000.

Michael, Panos, A. Robert Nobay and David A. Peel. Transaction costs and nonlinear adjustment in real exchange rates: an empirical investigation. *Journal of Political Economy*, vol. 105, no. 4, Aug. 1997, 862–879.

Müller-Plantenberg, Nikolas. Japan's imbalance of payments. In Michael M. Hutchison and Frank Westermann (eds.), *Japan's Great Stagnation: Financial and Monetary Policy Lessons for Advanced Economies*. MIT Press, Cambridge, Massachusetts, and London, 2006, pp. 239–266.

Müller-Plantenberg, Nikolas. Balance of payments accounting and exchange rate dynamics. *International Review of Economics and Finance*, vol. 19, no. 1, Jan. 2010, 46–63.

Müller-Plantenberg, Nikolas. Boom-and-bust cycles, external imbalances and the real exchange rate. *The World Economy*, vol. 40, no. 1, Jan. 2017a, 56–87.

Müller-Plantenberg, Nikolas. Currency flows and currency crises. *CESifo Economic Studies*, vol. 63, no. 2, Jun. 2017b, 182–209.

Nakagawa, Hironobu. Investigating nonlinearities in real exchange rate adjustment: Threshold cointegration and the dynamics of exchange rates and relative prices. *Journal of International Money and Finance*, vol. 29, no. 5, Sep. 2010, 770–790.

Obstfeld, Maurice and Alan M. Taylor. Nonlinear aspects of goods-market arbitrage and adjustment: Heckscher's commodity points revisited. *Journal of the Japanese and International Economies*, vol. 11, 1997, 441–479.

Pavlidis, Efthymios G., Ivan Paya and David A. Peel. Real exchange rates and time-varying trade costs. *Journal of International Money and Finance*, vol. 30, no. 6, Oct. 2011, 1157–1179.

Paya, Ivan, Ioannis A. Venetis and David A. Peel. Further evidence on PPP adjustment speeds: The case of effective real exchange rates and the EMS. *Oxford Bulletin of Economics and Statistics*, vol. 65, no. 4, Sep. 2003, 421–437.

Rogoff, Kenneth S. The purchasing power parity puzzle. *Journal of Economic Literature*, vol. 34, no. 2, Jun. 1996, 647–668.

Sarno, Lucio and Mark P. Taylor. Purchasing power parity and the real exchange rate. *International Monetary Fund Staff Papers*, vol. 49, no. 1, 2002, 65–105.

Taylor, Alan M. and Mark P. Taylor. The purchasing power parity debate. *Journal of Economic Perspectives*, vol. 18, no. 4, 2004, 135–158.

Taylor, Mark P., David A. Peel and Lucio Sarno. Nonlinear mean-reversion in real exchange rates: Toward a solution to the purchasing power parity puzzles. *International Economic Review*, vol. 42, no. 4, Nov. 2001, 1015–1042.

Vataja, Juuso. Should the law of one price be pushed away? evidence from international commodity markets. *Open Economies Review*, vol. 11, no. 4, Oct. 2000, 399–415.

Woo, Kai-Yin, Shu-Kam Lee and Alan Chan. Non-linear adjustments to intranational PPP. *Journal of Macroeconomics*, vol. 40, Jun. 2014, 360–371.

Yoon, Gawon. Nonlinear mean-reversion to purchasing power parity: Exponential smooth transition autoregressive models and stochastic unit root processes. *Applied Economics*, vol. 42, no. 4, 2010, 489–496.