Real Exchange Rates And Firms' Mark-Ups



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Abstract

This thesis investigates the drivers of real exchange rates, their theoretical modelling implications, and their forecasting power for nominal exchange rates. The first chapter provides a brief introduction to this thesis. Chapter 2 goes on to present empirical evidence that the debate around drivers of real exchange rates should not exclusively focus on tradable and non-tradable goods' prices but also take into account two additional terms: the relative distribution cost, and the relative profit margins in the two economies. The results yield two conclusions: first, these factors account for a large proportion of real exchange rate variations. Second, the margin estimates from the top-down approach considered here compare well with micro data estimates from the literature. Chapter 3 takes these results to the theoretical literature to test under which assumptions current macroeconomic models can replicate this empirical finding. The results show that broadly similar dynamics to those observed in the data can be obtained from a two-country open economy model with local currency pricing, tradable and non-tradable goods, and a distribution sector. Chapter 4 then tests whether the distribution real exchange rate can be a helpful predictor for nominal exchange rates at a number of different horizons. The results show that forecast performance can be improved by using the distribution margin real exchange rate, especially at longer horizons. The distribution real exchange rate, however, only improves forecast performance at the one-quarter ahead horizon a little, a conclusion in line with the existing literature.

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1 Introduction

This thesis consists of three essays on the link between distribution margins and real and nominal exchange rates. The exact connection between the drivers of real exchange rates, their impact on nominal exchange rates, and the implications for policy remains elusive. This thesis builds on the existing literature in this field to show that one subcomponent of the real exchange rate - the distribution real exchange rate - accounts for a large amount of variation in the overall real exchange rate. It then goes on to show that this empirical fact can be micro-founded in an open-economy macro model with local currency pricing, non-tradable goods, and a distribution sector. The last chapter then shows that the distribution real exchange rate also holds valuable information for forecasting the nominal exchange rate. In doing so, this paper makes a number of important contributions towards deepening the understanding of the drivers of real exchanges rates, the modelling choices in the open-economy macro literature, and towards the exchange rate forecasting literature.

The first essay (chapter 2) explores the drivers of real exchange rates. In particular, it expands on earlier work that has focused on the distinction between traded goods' prices and those of non-traded goods (see for example Engel (1999) and Betts and Kehoe (2006)) to include an additional factor, the distribution real exchange rate, which can be decomposed further into relative profit margins and relative transport costs. Building on the work of Bache et al. (2013), the second

chapter shows that the distribution real exchange rate accounts for about half of real exchange rates variations. Within this, about 50% of the variation of the relative distribution margin can be accounted for by changes in relative profit margins. It then goes on to show that the resulting top-down estimates of profit margins are comparable to those obtained in De Loecker and Warzynski (2012) using micro data.

These results have two important implications: first, following the argument by Engel (2014), changes in the real exchange rate due to relative mark-up changes are inefficient and cause a welfare loss. Second, a model that attempts to capture real exchange rate movements to, for example, analyse monetary policy and pass-through in such a setting needs to account for this relationship between varying relative mark-ups and the exchange rate. Including non-tradable goods alone is not sufficient to capture this mechanism: in addition, the price setting structure needs to be such that mark-ups correlate with the real exchange rate.

Chapter 2 therefore makes three contributions: first, it extends existing analysis and shows robustly that a breakdown in the law of one price cannot fully account for real exchange rate movements. It therefore adds to the literature advocating the introduction of non-tradable goods in open economy models. Second, this paper provides empirical evidence for the assumptions underlying the pricing decisions of firms in open economy models. Finally, the paper shows that mark-up estimates from macro and micro data yield comparable results.

The second essay (chapter 3) takes these empirical results to the theoretical open-economy macro literature to explore whether current modelling techniques produce results in line with the empirical evidence presented in Chapter 2. To do so, the chapter develops a two-economy model featuring tradable and non-tradable goods, local currency pricing, and a distribution sector. While recent research on this type of model has paid much attention to optimal monetary policy under different firm pricing strategies, such as producer currency pricing (PCP) and local currency pricing (LCP) (see, Engel (2011) and Corsetti et al. (2011)), relatively little attention has been paid to the relationship between mark-ups themselves and the real exchange rate. The chapter goes on to demonstrate that this modified

version of the standard local currency pricing model can better match the empirical evidence. The distribution sector, that takes domestic non-tradable goods as an input to deliver imports from the dock to final consumers, ensures that time-varying profit margins on imported goods play a role, but this effect is dampened through the reliance on domestic goods in the distribution sector.

The contribution to the literature of this chapter is that it shows that both tradable and non-tradable goods as well as a distribution sector are needed to replicate the empirical dynamics of real exchange rates. This is crucial because of its implications for exchange rate pass-through, monetary policy and welfare (see for example Corsetti et al. (2011) andEngel (2011)).

Having highlighted the importance of the distribution real exchange rate for overall real exchange rates and the implications of this for theoretical models, the third essay (chapter 4) explores whether the distribution real exchange rate holds information for forecasting nominal exchange rate changes. The rationale for utilising the distribution real exchange rate in this context is as follows: a shock to a country's profit margins affects the distribution real exchange rate but should also affect that country's monetary policy (Corsetti and Pesenti (2005)). Since a large body of literature has shown that interest rate differentials, proxied for by so-called "Taylor-Rule" fundamentals, can aid nominal exchange rate forecast performance, any factor that gives a steer on future monetary policy ought to therefore also help predict nominal exchange rate changes. Given that the distribution real exchange rate is a subcomponent of the overall real exchange rate, it might be that using the distribution real exchange rate directly can provide a cleaner measure of open-economy monetary policy considerations than the overall real exchange rate. Nominal exchange rate forecast performance could therefore be improved.

Chapter 4 goes on to make two key contributions to the literature: first, the results show that focusing on the distribution real exchange rate, rather than the overall real exchange rate as an economic fundamental, can improve forecast performance. Second, this improvement in forecast performance is across all

horizons considered, from two quarters to sixteen quarter ahead, though most of the improvement is at long horizons.

This thesis therefore highlights the importance of the distribution real exchange rate both for empirical questions relating to both real and nominal exchange rates, but also to modelling choices in the open-economy literature. Potential avenues for future work are proposed in the conclusion.

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2

Mark-ups and real exchange rate fluctuations

Abstract

Much of the debate about the drivers of real exchange rates has focused on the relative importance of tradable and non-tradable goods' prices. This paper instead decomposes the real exchange rate into four subcomponents, yielding two additional terms: the first one is the relative distribution cost in the two countries, the second one is the relative profit margin in the two countries. The contributions of this paper are threefold: first, this paper extends previous analysis to show that the distribution wedge accounts for a large proportion of real exchange rate variations using a larger sample. Second, this analysis shows that within this distribution wedge, relative mark-ups between countries play a significant role. This result provides empirical evidence for the pricing choice - local or producer currency pricing - of macroeconomic models, with implications, for example, for optimal monetary policy. The final contribution of this paper is that tentative evidence is presented to show that the margin estimates of the top-down approach here compare well with micro data estimates from the literature.

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2.1 Introduction

The question of what drives real exchange rates has been much debated in the literature. Earlier work has focused on the distinction between traded goods' prices and those of non-traded goods, and which one of them is key to driving real exchange rates. The implications of this, at first, empirical question are tremendous as they directly impact how open economies should be modelled in the macro literature. For example, is it necessary to model non-traded goods separately or is a one good economy a satisfactory simplification. Policy recommendations as well as our understanding of the transmission of shocks between economies depends crucially on this modelling choice. While the consensus has agreed that non-tradable goods are in fact important, more recently the focus has shifted on the distinction between prices of traded goods at the dock, and the prices consumers eventually pay for them. The policy and modelling conclusions of this question are no less important than that of tradable and non-tradable goods alone. This paper therefore attempts to shine more light on this distinction and the relevance for real exchange rates.

In the literature Engel (1999) shows in a seminal paper that the relative prices of non-traded goods account for almost none of the variation of real exchange rates (RER). He shows that most of the variation in the RER can be accounted for by changes in the relative prices of tradable goods. This is at odds with the prediction of the theory of the law of one price (LOOP): according to LOOP, variations in the real exchange rate should be fully accounted for by changes in the relative prices of non-tradable goods and services, as originally proposed by Cassel (1918) and Pigou (1923).

In a follow up paper, Betts and Kehoe (2006) find that, using different prices indices, relative prices of non-tradable goods account for a larger share of RER variations. Relative prices of non-tradable goods account for a larger fraction of RER movements when producer price indices (PPI) are used instead of consumer prices indices (CPI). They also find that this effect is stronger, the more important the country's trade relationship with the US is.

Bache et al. (2013) extend this analysis by decomposing the real exchange rate further and find that the relative distribution wedge, the wedge between at-the-dock-prices and final consumer prices, account for a large fraction of RER variation. Their analysis also suggests that variations in the relative distribution wedge between countries are driven by mark-up fluctuations rather than distribution cost changes, although they do not obtain margin estimates explicitly.

This paper takes Bache, Sveen and Torstensen's decomposition as a starting point and extends their analysis. First, the set of countries as well as the time dimension of the analysis is expanded to add to the robustness of their results. Second, this paper investigates the tentative evidence that the relative distribution wedge is driven by relative profit margins, rather than distribution cost variations, by explicitly constructing a new index for profit margins as well as distribution costs for each country. Third, this result is tested through various robustness checks. This extended analysis confirms Bache, Sveen and Torstensen's initial result that the relative distribution wedge is driven by relative mark-up changes rather than distribution cost variations. The analysis shows that the distribution wedge accounts for about half of real exchange rates variations. Within this, about 50% of the variation of the relative distribution margin can be accounted for by changes in relative profit margins. As a final step, this paper compares the resulting top-down estimates of profit margins to those obtained from a micro-data study, and shows that the results are broadly the same.

These results have two important implications: first, following the argument by Engel (2014), changes in the real exchange rate due to relative mark-up changes are inefficient and cause a welfare loss. Second, a model that attempts to capture real exchange rate movements and analyse monetary policy and pass-through in such a setting needs to account for this relationship between varying relative mark-ups and the exchange rate. Including non-tradable goods alone is not sufficient to capture this mechanism: in addition, the price setting structure needs to be such that mark-ups correlate with the real exchange rate.

This paper makes three contributions: first, it extends existing analysis and shows robustly that a breakdown in the law of one price cannot fully account for real exchange rate movements. It therefore adds to the literature advocating the essential introduction of non-tradable goods in open economy models. Second, this paper provides empirical evidence for the assumptions underlying the pricing decisions of firms in open economy models. In particular, it highlights the importance of profit margins, in addition to existing models that feature a distribution sector, as is for example the case in Corsetti et al. (2008). Finally, the paper shows that mark-up estimates from macro and micro data yield comparable results.

These contributions directly address the argument Engel makes in his conclusion: "It is tempting to attribute the movements in the traded-goods price indexes to failures of the law of one price. However, there are many issues to be resolved in that area: What determines export prices to different regions from the same country? How important is pricing to market in determining real exchange rate movements? What systematic relationship is there between the price of a good at the port and at the consumer outlet? To what extent do the degree of product differentiation and the competitiveness of the industry determine differences in prices between locations? [...] The key to understanding real exchange rate movements may be found in the answers to these questions."

The remainder of this paper is structured as follows: section 2.2 discusses the related literature and goes into more detail on the specific differences of this paper and its contributions. Section 4.3 introduces the empirical methodology. Section 2.4 discusses the data sources, including the novel data employed in this paper. Section 2.5 presents the results while section 2.6 concludes.

2.2 Related literature

This paper is related to two main strands of the literature: first, the strand explaining movements in the real exchange rate. Second, the theoretical foundations for risk sharing across countries, real exchange rate determination, and exchange rate pass-through.

The seminal paper decomposing real exchange rate movements is Engel (1999). Engel argues that most of the real exchange rate movements can be accounted by movements in relative prices of tradable goods, a conclusion that is starkly at odds with the prediction of the theory of the law of one price (LOOP). Betts and Kehoe (2006) use different price indices and find that non-tradable goods prices matter. They use this to argue for the inclusion of non-tradable goods in theoretical papers exploring real exchange rate behaviour, optimal policy, and pass-through, as first explored in Betts and Kehoe (2001). Burstein et al. (2006) construct price indices for at-the-dock prices of tradable goods and come to a similar conclusion to that of Betts and Kehoe (2006): relative prices of tradable to non-tradable goods matter.

More recently, Bache et al. (2013) explore the wedge between at-the-dock prices and final consumer goods prices and find that this wedge accounts for a large proportion of real exchange rate movements. For consistency and comparability, this paper continues with the analytical strategy of the previous papers by using similar summary statistics. It also employs a slightly modified version of Burstein et al. (2006) at-the-dock price indices, and uses as a baseline the decomposition of Bache et al. (2013).

The main result of this paper, that relative mark-ups play an important role in determining real exchange rate movements, adds empirical support to papers exploring pricing decisions of exporting firms in open-economy models, specifically those that include non-tradable goods. An early example of this is Betts and Kehoe (2001), who develop a multicountry, multisector intertemporal general equilibrium model with different degrees of tradability across sectors. More recently, a debate about local currency pricing (LCP), in which firms set mark-ups individually in each market, versus producer currency pricing (PCP), in which mark-ups are determined by firms only in their home market, has yielded various implications for welfare analysis, the analysis of optimal monetary policy, and exchange rate pass-through. Examples of this strand of the literature are Corsetti et al. (2008), Drozd and Nosal (2009), Gopinath et al. (2010), Corsetti et al. (2011), and Engel (2011),

among others. This paper supports the theory of LCP, as mark-ups appear to be time-varying and economy-specific, a feature that can only by explained by LCP.

The policy relevance of this paper is summarised in Engel (2014). He argues that policymakers might have to target the exchange rate in addition to domestic inflation as a result of currency misalignments to mitigate the effects of exchange rates on domestic variables such as inflation and output gaps. As such, understanding the drivers of real exchange rates are important both for the accuracy of open-economy macroeconomics models as well as for policymakers.

2.3 Methodology

2.3.1 Decomposition

The real exchange rate between two countries can be expressed as:

$$RER_{i,j,t} = S_{i,j,t}\frac{P_{j,t}}{P_{i,t}} \tag{2.1}$$

where $RER_{i,j,t}$ is the real exchange rate between countries i and j at time t, $S_{i,j,t}$ is the nominal exchange rate between those countries and $P_{i,t}$ and $P_{j,t}$ are price indices in countries i and j, respectively.

As most price indices (for example the consumer price index) includes both traded and non-traded goods and services, Engel and others have decomposed the real exchange rate further as a next step:

$$RER_{i,j,t} = S_{i,j,t}\frac{P_{j,t}}{P_{i,t}} = \underbrace{(S_{i,j,t}\frac{P^T_{j,t}}{P^T_{i,t}})}_{RER^T_{i,j,t}}\underbrace{(\frac{P^T_{i,t}}{P_{i,t}}/\frac{P^T_{j,t}}{P_{j,t}})}_{RER^N_{i,j,t}} \tag{2.2}$$

where $P^T_{i,t}$ and $P^T_{j,t}$ are indices for tradable goods and services in countries i and j, respectively.

$RER^T_{i,j,t}$ is the real exchange rate based on tradable goods prices only. If the law of one price holds for tradable goods, $S_{i,j,t}\frac{P^T_{j,t}}{P^T_{i,t}}$ is equal to one at all times, which implies that real exchange rate based on tradable goods should have a constant value of one. Therefore, all variation in the real exchange rate based on a full

consumption basket should be due to variations in the relative price of tradable and non-tradable goods in the two economies. In this decomposition, this component of the real exchange rate is captured by $RER^N_{i,j,t}$.

Engel (1999) finds that the variation in the real exchange rate is nearly completely due to variations in the real exchange based on tradable goods prices only, while Betts and Kehoe (2006) find that using the same decomposition but different price indices and country pairs, the relative price of tradable and non-tradable goods matters and cannot be ignored. The next section will go into more detail about the selection of the data and the sample.

This difference in results highlights the importance of both the choice of sample, as well as the choice of prices indices used in the analysis. This motivates the first part of the analysis, which is to extend the methodology of Bache et al. (2013) to span a larger time range as well as include more countries to check the robustness of their results.

Bache et al. (2013) expand the decomposition of the real exchange rate to include a third term based on relative prices of final consumer goods and at-the-dock prices of those tradable goods. This wedge captures two effects: first, the transport wedge, that is the cost to deliver tradable goods to final consumers from the dock. This includes shipment costs, rental costs of sales premises, and salaries of sales staff, to name a few. Second, the distribution wedge captures the profit made by the importing firm: any price difference between final goods prices and at-the-dock prices that is not used to pay distributors or is required in the sales process is retained as profit. Therefore, the distribution wedge provides a clear link between the real exchange rate and firms' profit margins.

Bache et al. (2013) decompose the real exchange rate as follows:

$$RER_{i,j,t} = S_{i,j,t}\frac{P_{j,t}}{P_{i,t}} = \underbrace{(S_{i,j,t}\frac{\bar{P^T_{j,t}}}{\bar{P^T_{i,t}}})}_{RER^T_{i,j,t}}\underbrace{(\frac{P^T_{i,t}}{P_{i,t}}/\frac{P^T_{j,t}}{P_{j,t}})}_{RER^N_{i,j,t}}\underbrace{(\frac{P^T_{j,t}}{\bar{P^T_{j,t}}}/\frac{P^T_{i,t}}{\bar{P^T_{i,t}}})}_{RER^D_{i,j,t}} \tag{2.3}$$

where $\bar{P}^T_{i,t}$ and $\bar{P}^T_{j,t}$ are indices of at-the-dock prices of tradable goods in country i and j respectively. $P^T_{i,t}$ and $P^T_{j,t}$ are price indices of final prices that consumers face when purchasing tradable goods.

$RER^T_{i,j,t}$ is the real exchange rate based on at-the-dock prices. $RER^N_{i,j,t}$ is the ratio of tradable good consumer prices to overall consumer prices, while $RER^D_{i,j,t}$ captures the distribution wedge.

The distribution wedge is defined as the relative ratio of tradable good consumer prices to tradable good at-the-dock prices in the two countries. Bache et al. (2013) use this decomposition to show that $RER^D_{i,j,t}$ accounts for about half of overall RER variations.

Bache et al. (2013) postulate that marginal costs of traded goods in the retail sector are $MC^T_t = {P^T_t}^{1-\alpha} {P^N_t}^{\alpha}$. It therefore follows that price of tradable goods is given by:

$$P^T_{i,t} = \exp^{\mu_{i,t}} {P^N_{i,t}}^{\alpha_{i,t}} \bar{P}^{T\,(1-\alpha_{i,t})}_{i,t} \tag{2.4}$$

$\mu_{i,t}$ is the mark-up included in the price charged by retailers to consumers over the at-the-dock price, after taking into account the use of non-tradable resources for domestic logistics needed to bring goods from the dock to consumers. The mark-up is time-varying and country specific, and *alpha*, the share of resources used for logistics, is also country-specific and time varying. The authors use equation 2.4 this to motivate their correlation analysis of the relative distribution wedge to investigate whether changes are caused by cross-country differences in logistic costs or time-varying mark-ups They find some evidence that changes in relative mark-ups are likely to play a larger role in changes in the relative distribution wedge.

This paper expands on their methodology by explicitly decomposing the real exchange rate further, assuming the same functional form for $P^T_{i,t}$ as Bache et al. (2013). With this, the distribution wedge of the real exchange rate can be written as:

$$RER^D_{i,j,t} = \frac{P^T_{j,t}/\bar{P}^T_{j,t}}{P^T_{i,t}/\bar{P}^T_{i,t}} = \underbrace{\frac{\exp^{\mu_{j,t}}}{\exp^{\mu_{i,t}}}}_{Mark-up} \underbrace{\frac{(P^D_{j,t}/\bar{P}^T_{j,t})^{\alpha_{j,t}}}{(P^D_{i,t}/\bar{P}^T_{i,t})^{\alpha_{i,t}}}}_{Transport/Logistics} \tag{2.5}$$

With new data on $\alpha_{i,t}$ and $P^D_{i,t}$, it is possible to back out $\exp^{\mu_{j,t}}$, assuming the underlying functional form is correct.

Using this, it is then possible to decompose movements in the distribution wedge into its two components: the variation arising due to changes in the relative logistics wedge in the two countries and the variation in the real exchange rate as a result of changes in the relative mark-up in the two countries. In log-form, this can be written as:

$$RER^D_{i,j,t} = RER^M_{i,j,t} + RER^L_{i,j,t}$$

where $RER^M_{i,j,t}$ is the real exchange rate based on relative mark-ups, and $RER^L_{i,j,t}$ is the real exchange rate based on relative logistics costs.

This decomposition provides empirical evidence for two debates in the literature: first, the argument put forward by Engel (2011) that if real exchange rates are driven by profit margins rather than marginal costs, central banks should take into account exchange rate movements as well as domestic inflation. In such a world, exchange rate movements introduce inefficiencies in prices as relative prices of tradables to non-tradable goods change, without this being driven by changes in marginal costs. This implies inefficient allocations similar to the welfare losses arising due to inflation under staggered price setting. From a central bank's point of view therefore, reducing exchange rate volatility improves welfare, in addition to the welfare gain from inflation stability.

Second, while Bache et al. (2013) already provide some evidence in support of Engel's argument, to the best of my knowledge this is the first paper that quantifies the proportion of real exchange rate volatility that is accounted for by relative mark-ups. This has important implications for the theoretical models aimed at understanding risk sharing between countries or explaining real exchange rate movements: if relative mark-ups are an important driver of real exchange rate volatility, then this feature needs to be incorporated in theories of the exchange rate.

2.3.2 Summary statistics

The importance of the distribution wedge

The first part of the analysis reconfirms the results of Bache et al. (2013) on the basis of a larger dataset.

In line with the analysis of Bache et al. (2013) I compute the variance decomposition. In addition to this, I add two summary statistics in line with the work of Betts and Kehoe (2006). Therefore the three summary statistics considered to quantify the importance of the distribution wedge for movements in the real exchange rate are:

- Sample correlation,

$$corr(RER_{i,j}, RER^D_{i,j}) = \frac{cov(RER_{i,j}, RER^D_{i,j)}}{\sqrt{var(RER_{i,j}) \times var(RER^D_{i,j})}}$$

- Ratio of sample standard deviations,

$$\frac{std(RER^D_{i,j})}{std(RER_{i,j})} = \sqrt{\frac{var(RER^D_{i,j})}{var(RER_{i,j})}}$$

- Variance decomposition,

$$vardec(RER^D_{i,j}, RER_{i,j}) = \frac{var(RER^D_{i,j})}{var(RER^D_{i,j} + var(RER^T_{i,j}) + +var(RER^N_{i,j}))}$$

The sample correlation enables an overview of co-movements of the distribution wedge and the real exchange rate. The ratio of sample standard deviations gives in insights into the relative volatility of the two series, while the variance decomposition shows the proportion of the overall variance accounted for by the measure considered.

Betts and Kehoe (2006) based on the work of Rogers and Jenkins (1995) and Engel (1999) also discuss a fourth summary statistic, a mean squared error (MSE) decomposition. If there is a common trend in the series, then the variance decomposition may assign too large a proportion to the factor considered. However, Betts and Kehoe (2006) find that in their sample, the common trend is vastly outweighed by other fluctuations and their results are not influenced by their choice of decomposition statistic. Given the similarity of the data used in their analysis and the one presented here, I will assume that their result holds true in this setting, and not consider a MSE based decomposition.

The importance of relative mark-ups

The second part of the analysis explores the importance of relative mark-ups for explaining movements in the distribution wedge. The sample moments remain the same, and for ease of exposition and comparability, the methodology remains the same, too, as for the first part of the analysis. The summary statistics computed therefore are:

- Sample correlation,

$$corr(RER^D_{i,j}, RER^M_{i,j}) = \frac{cov(RER^D_{i,j}, RER^M_{i,j)}}{\sqrt{var(RER^D_{i,j}) \times var(RER^M_{i,j})}}$$

- Ratio of sample standard deviations,

$$\frac{std(RER^M_{i,j})}{std(RER^D_{i,j})} = \sqrt{\frac{var(RER^M_{i,j})}{var(RER^D_{i,j})}}$$

- Variance decomposition,

$$vardec(RER^D_{i,j}, RER^M_{i,j}) = \frac{var(RER^M_{i,j})}{var(RER^M_{i,j} + var(RER^L_{i,j}))}$$

The interpretations of the summary statistics also remain the same as in the first part of the analysis.

2.3.3 Trends in the real exchange rate

The variance decomposition is biased if the underlying data is non-stationary. To account for this, the various real exchange rate measures are detrended to isolate cyclical frequencies. Previous papers have used either the Hodrick-Prescott filter with a smoothing parameter of 1600 (for quarterly data), or a linear trend (e.g. Betts and Kehoe (2006), Burstein et al. (2006), and Bache et al. (2013)). Detrending also has the advantage that there is no need to explain these trends or permanent components in the data, which is outside the scope of this analysis. Instead, it makes the statistical properties directly comparably across transformations and data series.

As Betts and Kehoe (2006) point out, the method used for detrending matters for the results: while the main part of this paper's analysis uses HP filtering as

the preferred method, results for linear trends are also presented either in the main body of the analysis or in the appendix.

2.4 Data

This section discusses the various data sources and the construction of the relevant price indices.

2.4.1 Real exchange rate decomposition

The first step is to replicate the decomposition of Bache et al. (2013), as in equation 2.3. This requires data on final consumer prices, tradable goods consumer prices, and at-the-dock prices of tradable goods , $P_{i,t}$, $P^T_{i,t}$, and $\bar{P^T_{i,t}}$ respectively.

The sample covers thirteen countries: Australia, Austria, Canada, Denmark, Spain, France, Ireland, Italy, Japan, Germany, New Zealand, the United Kingdom, and the US. The data in the first part of the analysis is quarterly and covers the period 1980Q1 until 2016Q4 and the analysis is done for each bilateral exchange rate pair to maximise sample size.

The sample is chosen by data availability: the two main constraint in this analysis are first, the consumer price indices for tradable goods, as these need to be collected individually from each country's statistical agency, as to the best of my knowledge no summary database exists. Further, not all countries publish tradable goods price indices.

Second, the index of transport costs used in the latter part of the analysis, is only available for seven countries at an annual frequency. While this is the preferred measure for the analysis, the frequency and cross-sectional sample limits puts a limit to the scope of the analysis. As a robustness check, this paper also considers a decomposition based on unit labour costs, which is available at a higher frequency and for more countries.

Table 2.1 summarises the data availability. The rest of this section discusses the choice and construction of the price indices used in the analysis.

	Measure						
	CPI	**Goods CPI**	**Import Price Index**	**Export Price Index**	**Import weights**	**Distribution Share**	**Unit Labour Cost**
Australia (AUS)	1989Q1-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	2012-2015	1989Q1-2016Q4
Austria (AUT)	1989Q1-2016Q4	1999Q4-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	1999Q1-2016Q4	2010-2012	1989Q1-2016Q4
Canada (CAN)	1989Q1-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	2010-2013	1989Q1-2016Q4
Denmark (DNK)	1989Q1-2016Q4	2001Q1-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	2005-2014	1989Q1-2016Q4
Spain (ESP)	1989Q1-2016Q4	2002Q1-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	1999Q1-2016Q4	N/A	1989Q1-2016Q4
France (FRA)	1989Q1-2016Q4	1990Q1-2016Q4	1999Q1-2016Q4	1999Q1-2016Q4	1999Q1-2016Q4	2010-2015	1989Q1-2016Q4
Ireland (IRL)	1989Q1-2016Q4	1996Q4-2016Q4	2000Q1-2016Q4	2000Q1-2016Q4	1999Q1-2016Q4	N/A	2000Q1-2016Q4
Italy (ITA)	1989Q1-2016Q4	1999Q4-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	1999Q1-2016Q4	2010-2014	1989Q1-2016Q4
Japan (JPN)	1989Q1-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	N/A	1990Q1-2016Q4
Germany (DEU)	1989Q1-2016Q4	1991Q1-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	1999Q1-2016Q4	N/A	1989Q1-2016Q4
New Zealand (NZL)	1989Q1-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	N/A	1989Q1-2016Q4
United Kingdom (GBR)	1989Q1-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	N/A	1989Q1-2016Q4
United States (USA)	1989Q1-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	1989Q1-2016Q4	1997-2016	1989Q1-2016Q4

Table 2.1: Summary of sample data availability

Consumer prices ($P_{i,t}$)

For final consumer prices, the analysis uses two alternative measures: consumer price indices (CPI) and GDP deflators, both taken from the OECD's database.

The CPI is a measure of all goods and services consumed in an economy, so includes both traded and non-traded goods and services. It is a non-geometric base-year quantity weighted average of the prices of a basket of goods and services - a Laspeyres price index. CPIs are readily available throughout the sample at all frequencies required.

GDP deflators (also sometimes called the implicit price deflator for GDP by the OECD) are calculated as GDP at current prices divided by GDP at "constant prices". "Constant prices" are either chained volume estimates or fixed-base volume estimates, depending on countries. GDP deflators are also readily available throughout the sample at all frequencies required.

Due to the high degree of correlation between measures of consumer prices and GDP deflators, the qualitative results of the analysis do not change. However, for a quantitative assessment the chosen price index matters, as has been found in previous studies. On conceptual grounds, real exchange rates based on CPIs are preferable as they reflect imported goods, too. They also make the distinction between at-the-dock prices and final consumer prices clearer. Using CPI series for the overall price level also makes the data used for traded goods final consumer prices and overall consumer prices consistent.

For robustness purposes, Betts and Kehoe employ another measures of consumer prices: the personal consumption deflator (PCD). While they find that the price series used does matter, they point out that data availability and the frequency at which data is available act as constraints on their analysis. As data availability is also a constraint on the latter part of the analysis, this analysis focuses on CPIs and output deflators.

	Source	Notes
Australia (AUS)	Australian Bureau of Statistics	Series covering goods
Austria (AUT)	Eurostat	Series covering goods
Canada (CAN)	Statistics Canada	Series covering goods
Denmark (DNK)	Statistics Denmark	Series covering goods
Spain (ESP)	Instituto Nacional de Estadística	Series covering industrial goods
France (FRA)	Insee France	Series covering manufactured products
Ireland (IRL)	Central Statistics Office Ireland	Series covering goods
Italy (ITA)	Eurostat	Series covering goods
Japan (JPN)	Statistics Bureau Japan (E-stat)	Series covering goods
Germany (DEU)	DESTATIS, Statistisches Bundestamt	Series covering goods
New Zealand (NZL)	Statistics New Zealand Infoshare	Series covering goods
United Kingdom (GBR)	Office for National Statistics	Series covering goods
United States (USA)	Bureau of Labor Statistics	Series covering goods

Table 2.2: Goods CPI data sources

Consumer tradable goods prices($P_{i,t}^T$)

Data on final consumer goods prices is collected from national statistical agencies. Detailed statistical tables are used to gather the series: goods are treated as tradable, and services as non-tradable for the purpose of this analysis, when no more specific measure if available.

This has two advantages: first, it is in line with Engel (1999) analysis and therefore the results are comparable to the results in his seminal paper as well as papers building on his work. Second, few countries publish data on prices of tradable goods and services. Restricting the choice of countries to be included in the analysis to those that publish data on tradable goods and services prices therefore reduces the sample significantly. There is clearly a trade-off here between the breadth of the analysis and the accuracy, and, in keeping with Engel (1999), and Betts and Kehoe (2006), this paper prioritises breadth.

Table 2 summarises the sources, and the series used from national statistical agencies. All series are price indices of goods, except for Spain and France for which this data is not available. For Spain a series covering industrial goods is used instead, while for France the series covers manufactured products.

At-the-dock prices of tradable goods ($\bar{P}^T_{i,t}$)

Following Burstein et al. (2006), the price index for at-the-dock prices of tradable goods are constructed in a similar manner. The indices are a geometric mean of aggregate import price indices (IPI), and aggregate export price indices (EPI), both taken from the IMF's IFS. Unlike BER, this paper does not equally weight import and export prices, but instead uses import weights as the weight in the geometric mean. This ensures that for countries that heavily rely on imports, their at-the-dock price index reflects this fact and does not underweight imports.

Therefore the indices are constructed for each country as:

$$\bar{P}^T_{i,t} = (P^I_{i,t})^{\gamma} \times (P^X_{i,t})^{1-\gamma} \tag{2.6}$$

where γ is the import share, $P^I_{i,t}$ is the IPI, and $P^E_{i,t}$ is the EPI.

These indices are preferable to retail prices and producer price indices in that they only include prices of goods that are actually traded. While it is not possible to fully exclude mark-ups and transport costs from the indicies, the one used here is, to the best of my knowledge, the index least contaminated. This should ensure a high degree of confidence in the final results.

As pointed out by Burstein et al. (2006), there are two caveats to import and export prices: first, some traded goods' price can reflect transfer prices within multinational companies rather than actually traded goods. Second, the indices include consumption goods, as well as investment and intermediate goods, and raw materials. A measure that only comprises consumption goods would be ideal to avoid this contamination, however, to the best of my knowledge such data does not exist.

Nominal Exchange Rates

Data on nominal effective exchange rates (NEER) is sourced from the IMF's International Financial Statistics (IFS). NEERs are "a measure of the value of a currency against a weighted average of several foreign currencies".

NEERs are used instead of bilateral exchange rates, because the index of at-the-dock prices of tradable goods cannot be calculated for each individual

country pairing. It is not possible to construct import and export price indices for each bilateral country pair due to data limitations. Therefore, the exchange rate measure is kept in line with the index of at-the-dock prices to ensure consistency in the measure of $RER^{T}_{i,j,t}$.

Distribution real exchange rate decomposition

To be able to back out mark-ups, data is required on the proportion of final expenditure on tradable goods spent on transport and trade margins. The OECD's Supply and Use Tables provide data on "Trade and transport margins in percentage of final consumption expenditure by households." This, paired with data on nominal and real expenditure, gives the two data series required to approximate equation 2.4. In keeping with the convention, trade and transport margins in the manufactured goods sector are used.

Whatever is not accounted for by trade or transport margins must be mark-ups either charged by importers or domestic retailers. Therefore, we can decompose the distribution margin into logistics costs, as well as mark-ups charged.

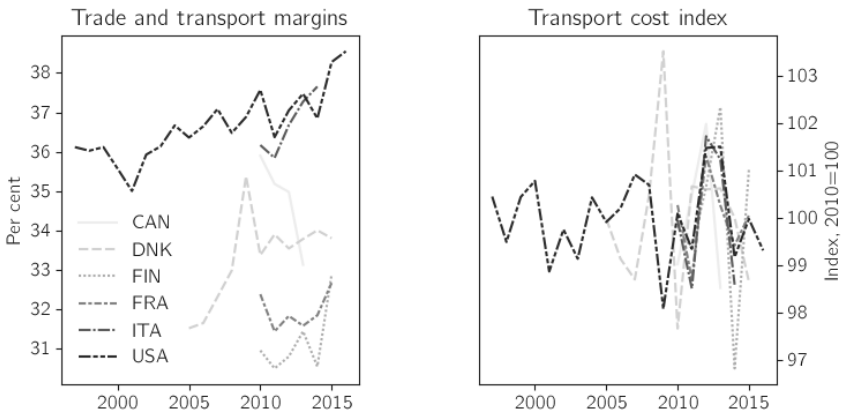


Figure 2.1: Plot of the trade and transport margin and the backed-out transport cost index for selected countries. The transport cost index has been detrended using the HP-filter.

Figure 2.1 plots the raw data on trade and transport margins and the backed-out transport price index. The transport price index has been de-trended using the HP-filter.

As discussed previously, the OECD data has limited availability. Therefore, an alternative measure is to use unit labour costs (ULC), as suggested by Bache et al. (2013). This is more of an approximation to the true cost than the preferred OECD data, but has the advantage of being more widely available. Therefore, as a robustness check, ULC data from the OECD is used to construct an alternative index of domestic logistics costs.

2.5 Results

This section is split into two parts: the first part considers the role of the distribution wedge as put forward by Bache et al. (2013), and the second part then analyses in more depth the role of relative profit margins in determining real exchange rate fluctuations.

2.5.1 The importance of the distribution wedge

The first contribution of this paper is to reconfirm the importance of the distribution wedge in explaining movements in the real exchange rate. To do this, the analysis of Bache et al. (2013) is expanded to cover a larger dataset and more summary statistics are considered. Summaries of the results are presented in figures 2.2 and 2.4. Detailed results are presented in tables 2.3 to 2.8 in the appendix.

The results of the variance decomposition are broadly in line with the results of Bache et al. (2013). It is worth noting that using GDP deflators rather than consumer prices as the measure for final consumer prices slightly reduces the importance of the distribution wedge. One explanation for this could be that the GDP deflator does not account for imported consumer goods, a category of goods for which the distribution wedge is likely to be most important.

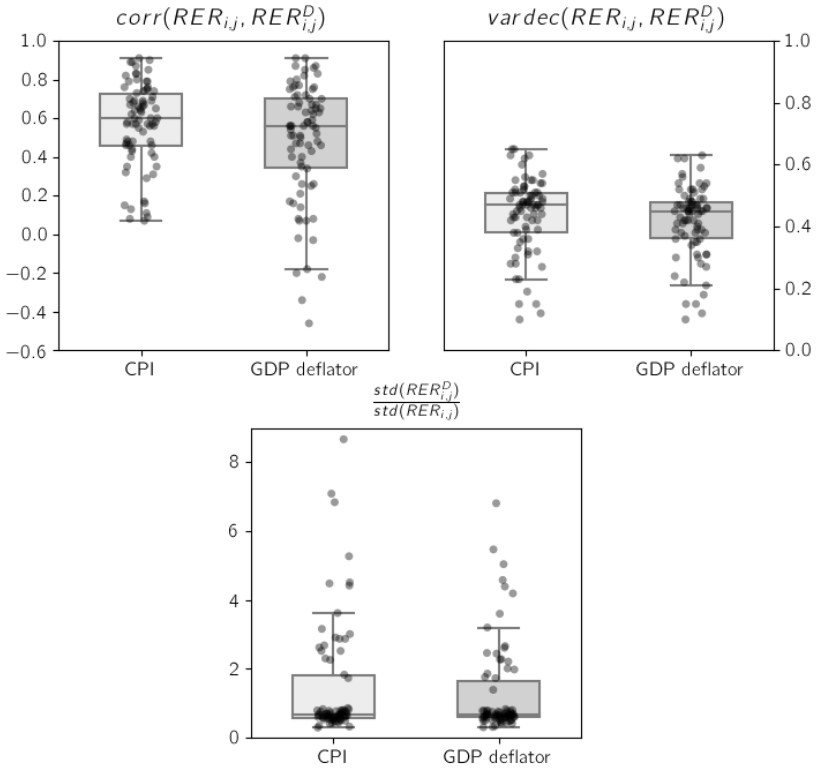


Figure 2.2: Decomposition based on HP filtering

The correlation between the real exchange rate and the distribution wedge is positive (figure 2.2). This suggests that an depreciation of the real exchange rate is associated with an increase in the relative distribution costs.

However, the distribution wedge is more stable than the overall real exchange rate: on average, the relative standard deviation of the two is a little less than one.

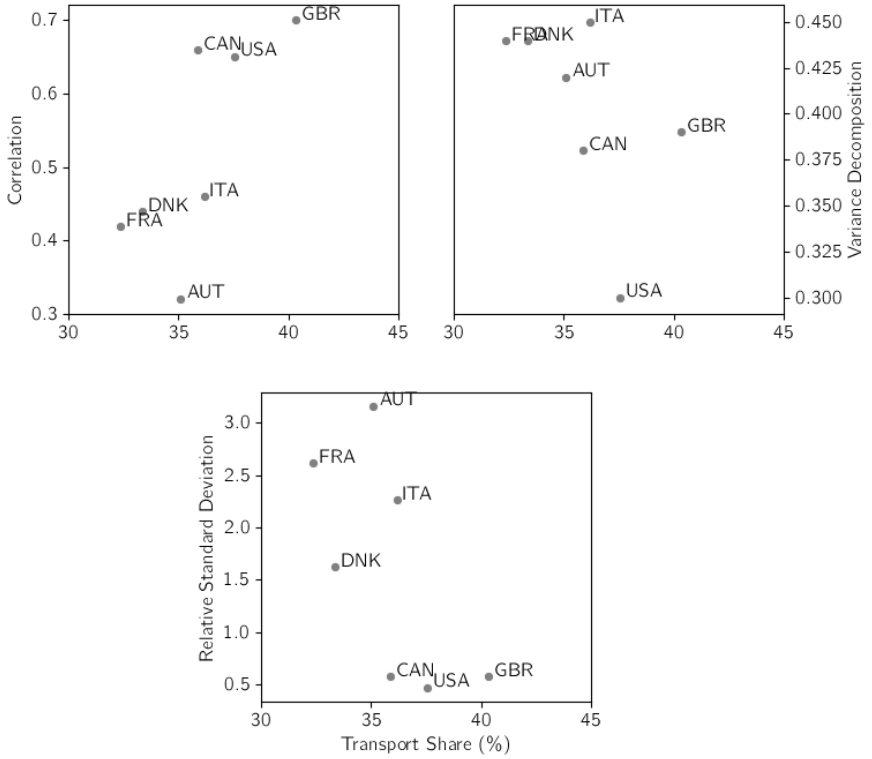


Figure 2.3: Plot of the summary statistics on the y-axis and the transport share in 2010 on the x-axis.

Figure 2.3 plots the summary statistics on the y-axis and each country's transport share in 2010 on the x-axis.The correlation between the distribution wedge and the real exchange rate is stronger, the higher the transport share, but on average a higher transport share means that the variance decomposition assigns less weight to the distribution component of the real exchange rate.

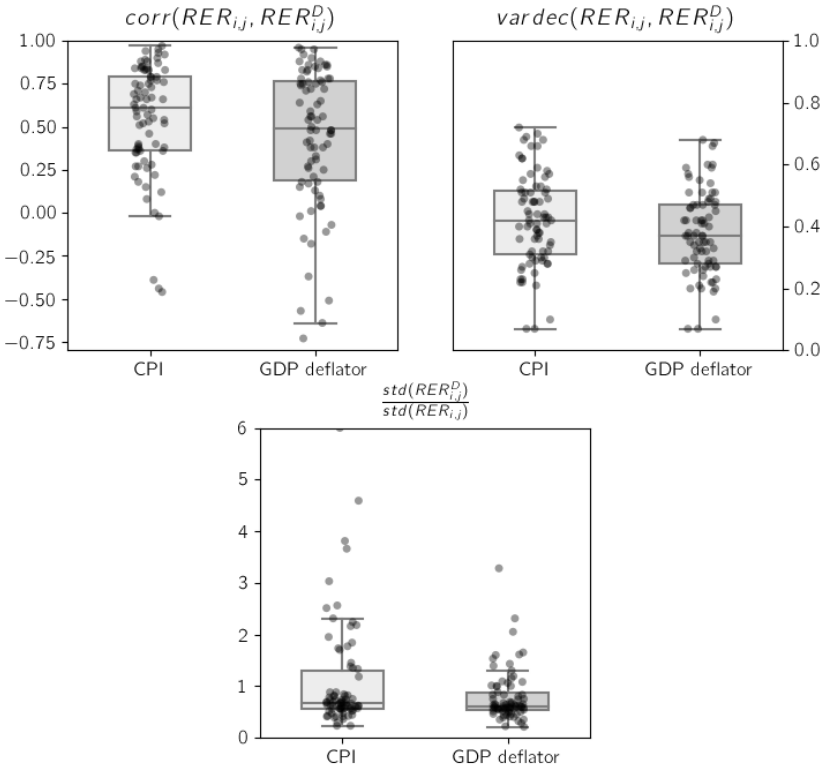


Figure 2.4: Decomposition based on a linear trend

All results are robust to using either the GDP deflator or consumer price indices as a measure for final consumer prices. While the results also broadly hold regardless of which detrending method is used, it is worth noting that detrending using the HP filter leads to an increased variance decomposition and relative standard deviation, but a lower correlation (figure 2.4). However, given that these changes are somewhat small in nature, and it is not clear which trend is the more appropriate one, this analysis will not further consider which one of the two the 'correct' results are.

Given the significant variation of the distribution wedge and the positive correlation with the real exchange rate, this result confirms more firmly the hypothesis of Bache et al. (2013) that the distribution wedge is an important driver of real exchange rate movements. As shown here, their result also holds in a larger sample over a longer time horizon, and is consistent with other summary statistics not previously considered.

2.5.2 The role of mark-ups

The second contribution of this analysis is to consider the role of the distribution wedge in more detail. In particular, this section aims to answer the question what role relative profit margins play in determining real exchange rate fluctuations.

This section is split in two parts: the first section considers a decomposition of the distribution wedge based on trade and transport margins as the measure for transport costs. The second section considers a decomposition based on unit labour costs (ULCs), thereby assuming that costs in the logistics industry evolve in line with aggregate ULCs. Both sections use CPIs and GDP deflators as final consumer price indices for robustness purposes.

Trade and transport margins

Figures 2.5 and 2.6 summarise the results of the analysis. Tables 2.15 to 2.26 in the appendix provide detailed results.

The three measures shown are first, the correlation between the real exchange rate based on relative profit margins and the overall real exchange rate, second, the share of the distribution wedge's variance accounted for by relative profit margins, and third, the relative standard deviation of the real exchange rate based on relative profit margins and the overall real exchange rate.

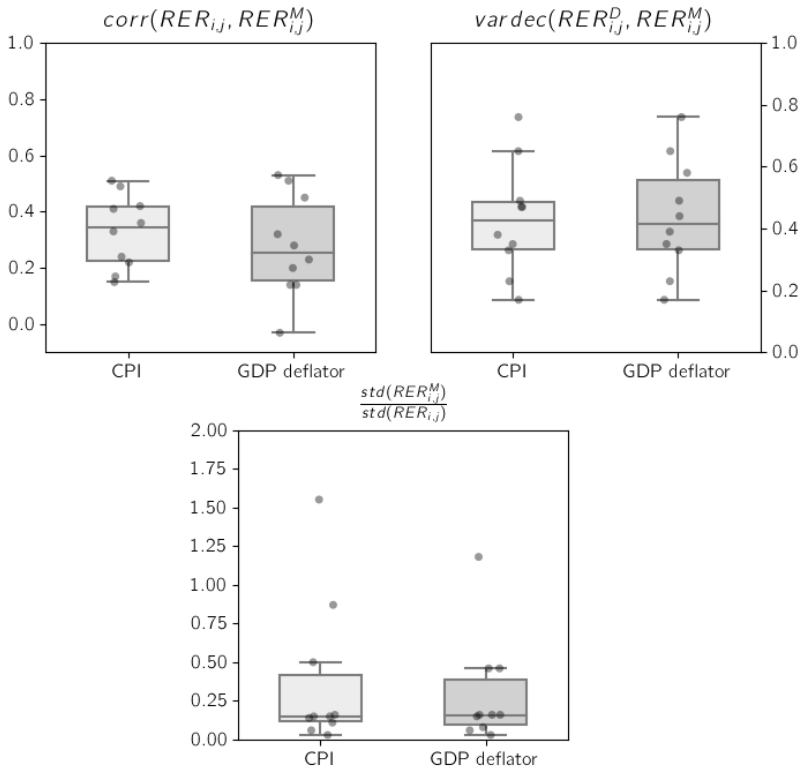


Figure 2.5: Decomposition based on HP filtering

Relative profit margins account for about half of the variation in the distribution wedge. Given that the distribution wedge accounts for about half of total real exchange rate variation, this implies that relative profit margins account for about a quarter of total real exchange rate variation. This makes relative mark-ups an important factor in real exchange rate variations.

Relative profit margins, like the distribution wedge itself, are positively correlated with the overall real exchange rate. Relative profit margins are, however, significantly less volatile than the overall real exchange rate, meaning they cannot fully account for RER fluctuations.

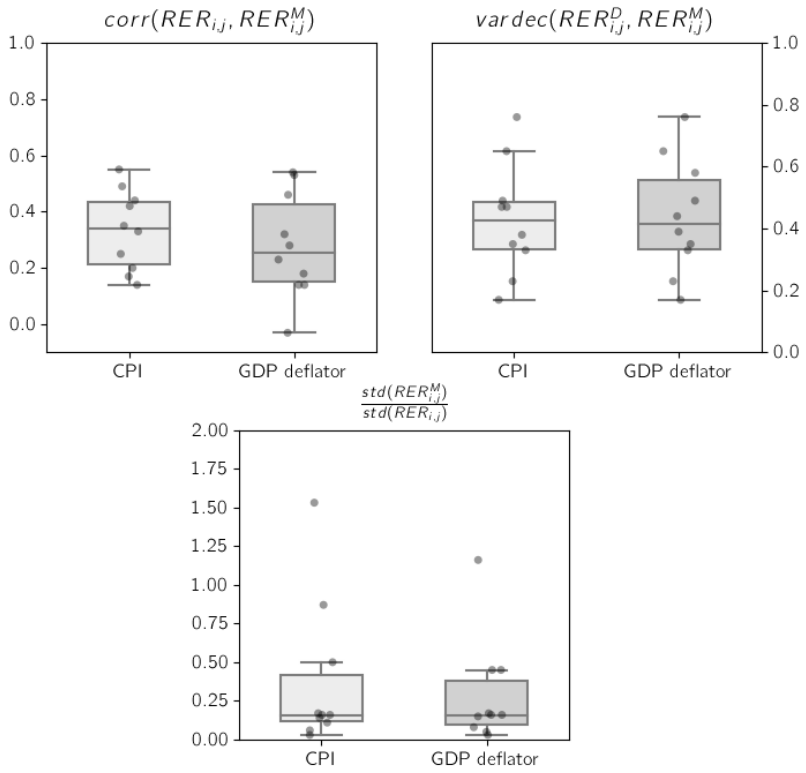


Figure 2.6: Decomposition based on a linear trend

These results are robust to using a different overall price index and/or a different de-trending method: using GDP deflators rather than CPIs slightly lowers the mean of all summary statistics but qualitatively the results still hold. There is virtually no difference between using the HP filter or a linear trend.

As a final step, one can compare the resulting profit margin index from this exercise to those from the literature. One good comparison study is De Loecker and Warzynski (2012), which uses factory-level production data to estimate mark-ups firms charge. To do so, the authors estimate production functions at the plant level - a completely different approach to the one used in this paper. If the results from the top-down framework in this paper can replicate the results from a bottom-up methodology, this should provide some confidence that the methodology is correct, and that the conclusions drawn are valid.

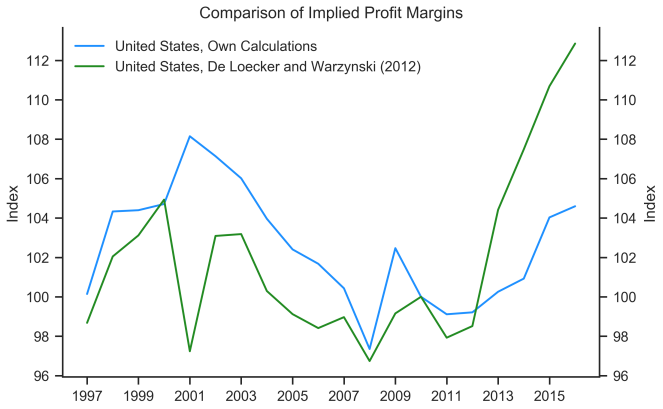


Figure 2.7: US profit margin estimates versus literature estimates

Figure 2.7 plots the margins calculated using trade and transport margins against the profit margin index from De Loecker and Warzynski (2012).[1] Given limited data availability, I focus the comparison on the United States. The methodology presented here is able to reproduce the trends in the data well. As in De Loecker and Warzynski (2012), our results suggest that profit margins rose prior to the dotcom bubble, then declined until the financial crisis and subsequently rose again. Both approaches also suggest that profit margins fell sharply in the financial crisis in 2008 before rebounding quickly. The prediction for the dotcom bubble, however, differs, where the top-down approach suggests that profit margins actually rose sharply in 2001, in contrast to the estimates by De Loecker and Warzynski (2012). One reason for that could be that the approach presented here concludes that unprofitable technology firms exiting the market raises aggregate profit margins, though more work is needed to confirm this hypothesis. More generally, while the evidence is tentative at this point, the two approaches appear to produce consistent results, thereby raising confidence in the estimation methodology suggested here.

[1]The author's provide updated estimates online, so their work has not been reproduced for this study.

Unit labour costs

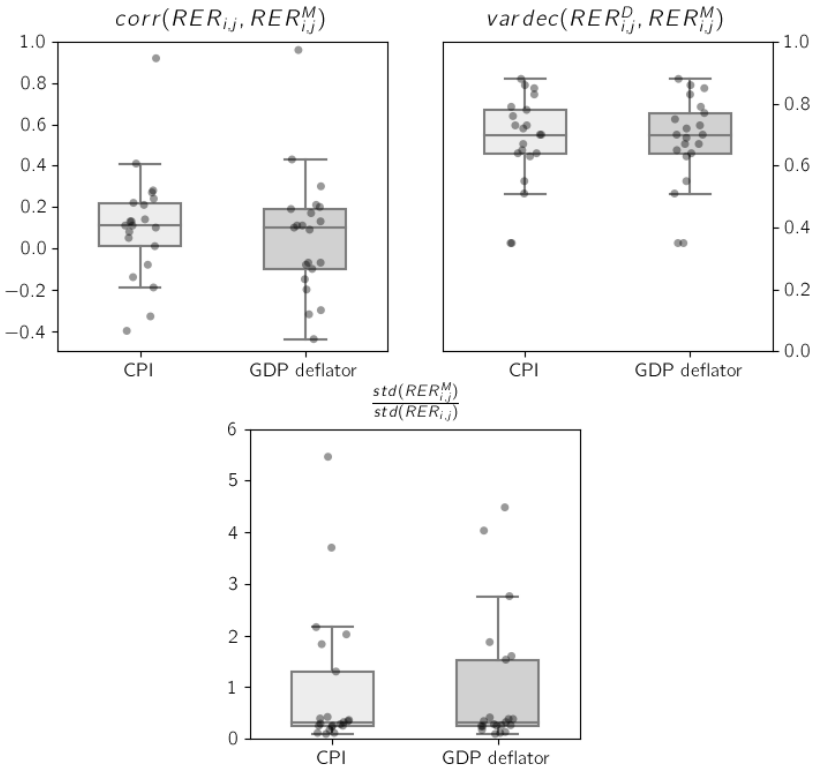


Figure 2.8: Decomposition based on HP filtering

Figures 2.8 and 2.9 summarise the results of the analysis using unit labour costs. Tables 2.27 to 2.38 in the appendix provide detailed results.

Using a decomposition based on ULCs rather than trade and transport margins assigns less importance to relative profit margins: the estimated correlation is somewhat lower, turning negative in some cases. However, the variance decomposition assigns a larger share to relative profit margins in explaining the distribution margin's variance. Based on this analysis, about 35% of the overall real exchange rate's variation can be attributed to the relative mark-ups.

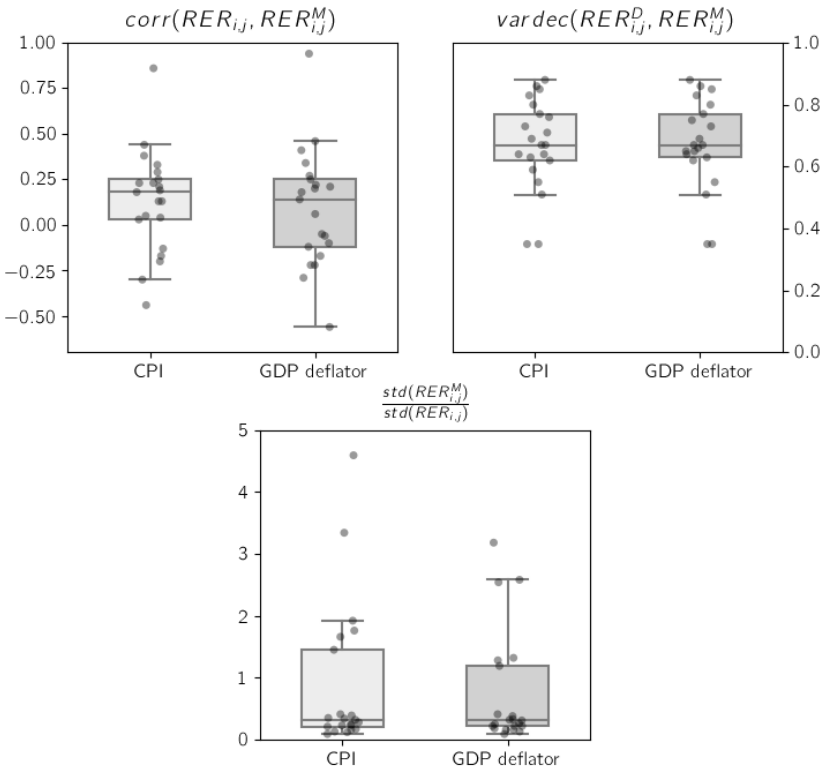


Figure 2.9: Decomposition based on a linear trend

The relative standard deviation remains broadly unchanged when ULCs are used relative to the case of trade and transport margins. As was the case in the previous section, the detrending method makes little difference, adding confidence to the quantitative results.

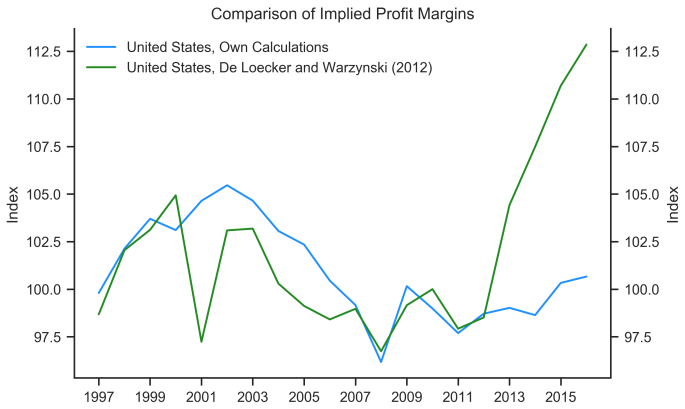


Figure 2.10: US profit margin estimates versus literature estimates

Figure 2.10 repeats the previous exercise and plots US profit margins based on the ULC decomposition versus those in De Loecker and Warzynski (2012). Here again the trends broadly match but the ULC based decomposition suggests that the rise in profit margins post financial crisis has been more limited.

Overall, the results therefore show that relative mark-ups or profit margins are an important driver of the distribution wedge, which in turn is an important driver of the real exchange rate. This adds empirical evidence to the argument of Engel (2014), that relative profit margins, specifically adapted for each economy, lead to misalignments in the real exchange rate. This leads to welfare losses from misallocations similar to the case of inflation as a result of staggered price setting.

2.6 Conclusion

This paper decomposes the real exchange rate (RER) into its components, extending the approach by Engel (1999) and Betts and Kehoe (2006), among others. It shows that the distribution margin, first proposed by Bache et al. (2013), is an important determinant of real exchange rate movements. To do this, their analysis is extended to include a larger sample, more summary statistics and further robustness checks.

Next this paper demonstrates that within the distribution margin, relative mark-ups or profits play an important role and shows that the estimates from this paper are comparable with estimates gained through the use of firm-level data. It provides empirical support for the local currency pricing literature and adds evidence that the hypothesis proposed by Engel (2014), that relative profit margins can lead to misalignments of the real exchange rate. This has important implications for policymakers and the analysis of exchange rate pass through.

Future research should therefore address the question whether models proposed to implement local currency pricing or producer currency pricing are consistent with the real exchange rate behaviour observed in the data. Based on this, future work could establish whether the relative mark-up wedge is an important factor in exchange rate pass through. Another line of research could explore whether the welfare loss due to misallocations as a result of staggered pricing and variable mark

ups warrants a change in policymakers' priorities: should policymakers focus on the exchange rates as well as domestic inflation to minimise this welfare loss?

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2.A $RER_{i,j}$ decomposition

The tables in this section show the detailed decompositions of the real exchange rate. The tables show the various summary statistics for when CPIs and GDP deflators are used as well as for linear detrending and HP filtering.

2.A.1 CPI based $RER_{i,j}$

HP filter

	AUS	AUT	CAN	DNK	ESP	FRA	IRL	ITA	JPN	DEU	NZL	GBR	USA	Average
AUS		0.57	0.66	0.59	0.53	0.57	0.60	0.64	0.85	0.58	0.48	0.69	0.80	0.63
AUT	0.57		0.40	0.12	0.11	0.13	0.16	0.07	0.69	0.08	0.67	0.48	0.35	0.32
CAN	0.66	0.40		0.64	0.57	0.57	0.62	0.67	0.90	0.56	0.75	0.68	0.89	0.66
DNK	0.59	0.12	0.64		0.35	-0.11	0.41	0.12	0.79	0.46	0.66	0.76	0.48	0.44
ESP	0.53	0.11	0.57	0.35		0.40	0.46	0.46	0.79	0.31	0.60	0.57	0.49	0.47
FRA	0.57	0.13	0.57	-0.11	0.40		0.43	0.09	0.79	0.17	0.68	0.75	0.58	0.42
IRL	0.60	0.16	0.62	0.41	0.46	0.43		0.35	0.79	0.29	0.59	0.56	0.55	0.48
ITA	0.64	0.07	0.67	0.12	0.46	0.09	0.35		0.83	0.15	0.73	0.74	0.65	0.46
JPN	0.85	0.69	0.90	0.79	0.79	0.79	0.79	0.83		0.76	0.89	0.91	0.87	0.82
DEU	0.58	0.08	0.56	0.46	0.31	0.17	0.29	0.15	0.76		0.64	0.71	0.60	0.44
NZL	0.48	0.67	0.75	0.66	0.60	0.68	0.59	0.73	0.89	0.64		0.76	0.83	0.69
GBR	0.69	0.48	0.68	0.76	0.57	0.75	0.56	0.74	0.91	0.71	0.76		0.74	0.70
USA	0.80	0.35	0.89	0.48	0.49	0.58	0.55	0.65	0.87	0.60	0.83	0.74		0.65

Table 2.3: $corr(RER^D_{i,j}, RER_{i,j})$ for all bilateral country pairs

	AUS	AUT	CAN	DNK	ESP	FRA	IRL	ITA	JPN	DEU	NZL	GBR	USA	Average
AUS		0.82	0.68	0.79	0.72	0.79	0.86	0.73	0.71	0.79	0.83	0.68	0.64	0.75
AUT	0.82		0.53	4.05	4.48	8.67	3.01	6.84	0.70	7.09	0.78	0.60	0.41	3.16
CAN	0.68	0.53		0.52	0.50	0.53	0.69	0.55	0.66	0.46	0.59	0.54	0.66	0.58
DNK	0.79	4.05	0.52		2.08	3.18	2.19	2.70	0.67	1.90	0.64	0.48	0.31	1.63
ESP	0.72	4.48	0.50	2.08		3.62	2.87	2.52	0.66	2.87	0.60	0.59	0.42	1.83
FRA	0.79	8.67	0.53	3.18	3.62		2.91	4.42	0.52	5.27	0.73	0.57	0.29	2.62
IRL	0.86	3.01	0.69	2.19	2.87	2.91		2.68	0.80	2.52	0.80	0.77	0.64	1.73
ITA	0.73	6.84	0.55	2.70	2.52	4.42	2.68		0.61	4.51	0.65	0.53	0.35	2.26
JPN	0.71	0.70	0.66	0.67	0.66	0.52	0.80	0.61		0.62	0.63	0.60	0.61	0.65
DEU	0.79	7.09	0.46	1.90	2.87	5.27	2.52	4.51	0.62		0.76	0.49	0.32	2.30
NZL	0.83	0.78	0.59	0.64	0.60	0.73	0.80	0.65	0.63	0.76		0.65	0.56	0.68
GBR	0.68	0.60	0.54	0.48	0.59	0.57	0.77	0.53	0.60	0.49	0.65		0.44	0.58
USA	0.64	0.41	0.66	0.31	0.42	0.29	0.64	0.35	0.61	0.32	0.56	0.44		0.47

Table 2.4: $\frac{std(RER^D_{i,j})}{std(RER_{i,j})}$ for all bilateral country pairs

	AUS	AUT	CAN	DNK	ESP	FRA	IRL	ITA	JPN	DEU	NZL	GBR	USA	Average
AUS		0.46	0.44	0.48	0.42	0.46	0.51	0.47	0.63	0.47	0.43	0.47	0.54	0.48
AUT	0.46		0.23	0.47	0.47	0.53	0.49	0.51	0.47	0.48	0.51	0.31	0.15	0.42
CAN	0.44	0.23		0.29	0.27	0.28	0.42	0.32	0.63	0.23	0.43	0.33	0.65	0.38
DNK	0.48	0.47	0.29		0.45	0.53	0.53	0.53	0.54	0.56	0.43	0.31	0.11	0.44
ESP	0.42	0.47	0.27	0.45		0.52	0.49	0.54	0.53	0.46	0.40	0.36	0.19	0.43
FRA	0.46	0.53	0.28	0.53	0.52		0.56	0.46	0.38	0.62	0.50	0.39	0.10	0.44
IRL	0.51	0.49	0.42	0.53	0.49	0.56		0.52	0.65	0.51	0.49	0.45	0.35	0.50
ITA	0.47	0.51	0.32	0.53	0.54	0.46	0.52		0.51	0.55	0.48	0.36	0.15	0.45
JPN	0.63	0.47	0.63	0.54	0.53	0.38	0.65	0.51		0.48	0.60	0.57	0.55	0.55
DEU	0.47	0.48	0.23	0.56	0.46	0.62	0.51	0.55	0.48		0.50	0.32	0.12	0.44
NZL	0.43	0.51	0.43	0.43	0.40	0.50	0.49	0.48	0.60	0.50		0.48	0.47	0.48
GBR	0.47	0.31	0.33	0.31	0.36	0.39	0.45	0.36	0.57	0.32	0.48		0.28	0.39
USA	0.54	0.15	0.65	0.11	0.19	0.10	0.35	0.15	0.55	0.12	0.47	0.28		0.30

Table 2.5: $vardec(RER^D_{i,j}, RER_{i,j})$ for all bilateral country pairs

Linear trend

	AUS	AUT	CAN	DNK	ESP	FRA	IRL	ITA	JPN	DEU	NZL	GBR	USA	Average
AUS		0.18	0.26	0.22	0.15	0.27	0.35	0.40	0.84	0.12	0.08	0.61	0.70	0.35
AUT	0.18		0.22	0.27	0.21	-0.02	0.73	0.00	0.74	0.52	0.53	0.67	0.61	0.39
CAN	0.26	0.22		0.42	0.36	0.30	0.67	0.37	0.94	0.36	0.84	0.88	0.97	0.55
DNK	0.22	0.27	0.42		0.17	0.10	0.63	0.04	0.79	-0.04	0.60	0.85	0.82	0.41
ESP	0.15	0.21	0.36	0.17		0.51	0.38	0.46	0.75	-0.44	0.52	0.75	0.76	0.38
FRA	0.27	-0.02	0.30	0.10	0.51		0.69	0.27	0.85	-0.46	0.54	0.77	0.66	0.37
IRL	0.35	0.73	0.67	0.63	0.38	0.69		0.60	0.84	0.71	0.59	0.83	0.88	0.66
ITA	0.40	0.00	0.37	0.04	0.46	0.27	0.60		0.89	-0.39	0.56	0.83	0.83	0.40
JPN	0.84	0.74	0.94	0.79	0.75	0.85	0.84	0.89		0.77	0.95	0.93	0.87	0.85
DEU	0.12	0.52	0.36	-0.04	-0.44	-0.46	0.71	-0.39	0.77		0.57	0.83	0.79	0.28
NZL	0.08	0.53	0.84	0.60	0.52	0.54	0.59	0.56	0.95	0.57		0.90	0.92	0.63
GBR	0.61	0.67	0.88	0.85	0.75	0.77	0.83	0.83	0.93	0.83	0.90		0.66	0.79
USA	0.70	0.61	0.97	0.82	0.76	0.66	0.88	0.83	0.87	0.79	0.92	0.66		0.79

Table 2.6: $corr(RER^D_{i,j}, RER_{i,j})$ for all bilateral country pairs

	AUS	AUT	CAN	DNK	ESP	FRA	IRL	ITA	JPN	DEU	NZL	GBR	USA	Average
AUS		0.73	0.88	0.79	0.75	0.67	0.88	0.60	0.52	0.81	0.73	0.41	0.39	0.68
AUT	0.73		0.70	2.47	1.35	3.03	1.77	2.56	0.51	6.00	0.84	0.55	0.29	1.73
CAN	0.88	0.70		0.65	0.62	0.81	0.58	0.74	0.68	0.53	0.63	0.66	0.64	0.68
DNK	0.79	2.47	0.65		1.00	2.75	1.47	2.86	0.56	2.48	0.75	0.53	0.29	1.38
ESP	0.75	1.35	0.62	1.00		2.24	2.51	2.16	0.57	1.38	0.61	0.57	0.36	1.18
FRA	0.67	3.03	0.81	2.75	2.24		2.31	3.81	0.42	4.59	0.73	0.47	0.23	1.84
IRL	0.88	1.77	0.58	1.47	2.51	2.31		2.18	0.69	1.45	0.78	0.81	0.56	1.33
ITA	0.60	2.56	0.74	2.86	2.16	3.81	2.18		0.48	3.66	0.64	0.42	0.23	1.70
JPN	0.52	0.51	0.68	0.56	0.57	0.42	0.69	0.48		0.57	0.62	0.62	0.57	0.57
DEU	0.81	6.00	0.53	2.48	1.38	4.59	1.45	3.66	0.57		0.82	0.67	0.41	1.95
NZL	0.73	0.84	0.63	0.75	0.61	0.73	0.78	0.64	0.62	0.82		0.60	0.55	0.69
GBR	0.41	0.55	0.66	0.53	0.57	0.47	0.81	0.42	0.62	0.67	0.60		0.44	0.56
USA	0.39	0.29	0.64	0.29	0.36	0.23	0.56	0.23	0.57	0.41	0.55	0.44		0.41

Table 2.7: $\frac{std(RER^D_{i,j})}{std(RER_{i,j})}$ for all bilateral country pairs

	AUS	AUT	CAN	DNK	ESP	FRA	IRL	ITA	JPN	DEU	NZL	GBR	USA	Average
AUS		0.32	0.36	0.34	0.30	0.28	0.42	0.30	0.45	0.32	0.29	0.22	0.23	0.32
AUT	0.32		0.29	0.48	0.42	0.49	0.66	0.51	0.35	0.51	0.48	0.28	0.10	0.41
CAN	0.36	0.29		0.31	0.31	0.37	0.40	0.34	0.70	0.25	0.52	0.58	0.72	0.43
DNK	0.34	0.48	0.31		0.34	0.57	0.63	0.51	0.44	0.50	0.47	0.36	0.13	0.42
ESP	0.30	0.42	0.31	0.34		0.59	0.52	0.53	0.44	0.36	0.38	0.43	0.21	0.40
FRA	0.28	0.49	0.37	0.57	0.59		0.68	0.36	0.28	0.57	0.44	0.27	0.07	0.41
IRL	0.42	0.66	0.40	0.63	0.52	0.68		0.62	0.63	0.68	0.51	0.66	0.48	0.57
ITA	0.30	0.51	0.34	0.51	0.53	0.36	0.62		0.38	0.48	0.39	0.22	0.07	0.39
JPN	0.45	0.35	0.70	0.44	0.44	0.28	0.63	0.38		0.43	0.69	0.62	0.53	0.49
DEU	0.32	0.51	0.25	0.50	0.36	0.57	0.68	0.48	0.43		0.51	0.48	0.23	0.44
NZL	0.29	0.48	0.52	0.47	0.38	0.44	0.51	0.39	0.69	0.51		0.56	0.55	0.48
GBR	0.22	0.28	0.58	0.36	0.43	0.27	0.66	0.22	0.62	0.48	0.56		0.26	0.41
USA	0.23	0.10	0.72	0.13	0.21	0.07	0.48	0.07	0.53	0.23	0.55	0.26		0.30

Table 2.8: $vardec(RER^D_{i,j}, RER_{i,j})$ for all bilateral country pairs

2.A.2 GDP deflator based $RER_{i,j}$

HP filter

	AUS	AUT	CAN	ESP	FRA	IRL	ITA	JPN	DEU	NZL	GBR	USA	Average
AUS		0.47	0.56	0.40	0.51	0.47	0.58	0.85	0.46	0.35	0.63	0.77	0.55
AUT	0.47		0.40	-0.18	-0.22	0.08	0.21	0.68	-0.03	0.59	0.46	0.37	0.26
CAN	0.56	0.40		0.56	0.62	0.56	0.70	0.91	0.51	0.72	0.66	0.86	0.64
ESP	0.40	-0.18	0.56		-0.20	0.14	0.16	0.77	-0.34	0.51	0.56	0.43	0.26
FRA	0.51	-0.22	0.62	-0.20		0.07	0.17	0.80	-0.46	0.65	0.75	0.56	0.30
IRL	0.47	0.08	0.56	0.14	0.07		0.08	0.76	0.07	0.48	0.52	0.50	0.34
ITA	0.58	0.21	0.70	0.16	0.17	0.08		0.83	-0.02	0.67	0.76	0.66	0.44
JPN	0.85	0.68	0.91	0.77	0.80	0.76	0.83		0.75	0.87	0.91	0.87	0.82
DEU	0.46	-0.03	0.51	-0.34	-0.46	0.07	-0.02	0.75		0.54	0.70	0.58	0.25
NZL	0.35	0.59	0.72	0.51	0.65	0.48	0.67	0.87	0.54		0.71	0.79	0.63
GBR	0.63	0.46	0.66	0.56	0.75	0.52	0.76	0.91	0.70	0.71		0.72	0.67
USA	0.77	0.37	0.86	0.43	0.56	0.50	0.66	0.87	0.58	0.79	0.72		0.65

Table 2.9: $corr(RER^D_{i,j}, RER_{i,j})$ for all bilateral country pairs

	AUS	AUT	CAN	ESP	FRA	IRL	ITA	JPN	DEU	NZL	GBR	USA	Average
AUS		0.78	0.69	0.68	0.75	0.80	0.68	0.71	0.76	0.77	0.67	0.63	0.72
AUT	0.78		0.51	5.04	6.81	2.28	4.58	0.69	4.39	0.78	0.61	0.41	2.44
CAN	0.69	0.51		0.49	0.51	0.67	0.51	0.65	0.43	0.60	0.54	0.60	0.56
ESP	0.68	5.04	0.49		5.47	2.27	2.66	0.65	3.20	0.60	0.60	0.43	2.01
FRA	0.75	6.81	0.51	5.47		2.46	2.61	0.50	3.60	0.73	0.58	0.30	2.21
IRL	0.80	2.28	0.67	2.27	2.46		1.98	0.78	1.73	0.79	0.83	0.68	1.39
ITA	0.68	4.58	0.51	2.66	2.61	1.98		0.60	4.19	0.65	0.52	0.34	1.76
JPN	0.71	0.69	0.65	0.65	0.50	0.78	0.60		0.61	0.64	0.59	0.61	0.64
DEU	0.76	4.39	0.43	3.20	3.60	1.73	4.19	0.61		0.78	0.49	0.31	1.86
NZL	0.77	0.78	0.60	0.60	0.73	0.79	0.65	0.64	0.78		0.65	0.56	0.69
GBR	0.67	0.61	0.54	0.60	0.58	0.83	0.52	0.59	0.49	0.65		0.44	0.59
USA	0.63	0.41	0.60	0.43	0.30	0.68	0.34	0.61	0.31	0.56	0.44		0.48

Table 2.10: $\frac{std(RER^D_{i,j})}{std(RER_{i,j})}$ for all bilateral country pairs

	AUS	AUT	CAN	ESP	FRA	IRL	ITA	JPN	DEU	NZL	GBR	USA	Average
AUS		0.45	0.42	0.39	0.45	0.48	0.45	0.62	0.45	0.41	0.45	0.52	0.46
AUT	0.45		0.22	0.44	0.52	0.47	0.50	0.47	0.46	0.49	0.31	0.15	0.41
CAN	0.42	0.22		0.24	0.28	0.38	0.30	0.62	0.21	0.42	0.31	0.56	0.36
ESP	0.39	0.44	0.24		0.44	0.45	0.46	0.52	0.39	0.36	0.35	0.18	0.38
FRA	0.45	0.52	0.28	0.44		0.52	0.42	0.37	0.54	0.49	0.39	0.10	0.41
IRL	0.48	0.47	0.38	0.45	0.52		0.49	0.63	0.47	0.46	0.43	0.34	0.47
ITA	0.45	0.50	0.30	0.46	0.42	0.49		0.51	0.53	0.46	0.35	0.15	0.42
JPN	0.62	0.47	0.62	0.52	0.37	0.63	0.51		0.48	0.59	0.57	0.54	0.54
DEU	0.45	0.46	0.21	0.39	0.54	0.47	0.53	0.48		0.48	0.30	0.12	0.40
NZL	0.41	0.49	0.42	0.36	0.49	0.46	0.46	0.59	0.48		0.47	0.46	0.46
GBR	0.45	0.31	0.31	0.35	0.39	0.43	0.35	0.57	0.30	0.47		0.27	0.38
USA	0.52	0.15	0.56	0.18	0.10	0.34	0.15	0.54	0.12	0.46	0.27		0.31

Table 2.11: $vardec(RER^D_{i,j}, RER_{i,j})$ for all bilateral country pairs

Linear trend

	AUS	AUT	CAN	ESP	FRA	IRL	ITA	JPN	DEU	NZL	GBR	USA	Average
AUS		0.01	0.04	-0.07	0.15	-0.02	0.25	0.78	-0.18	-0.11	0.54	0.64	0.18
AUT	0.01		0.33	0.08	-0.15	0.50	0.17	0.74	-0.57	0.48	0.71	0.63	0.27
CAN	0.04	0.33		0.31	0.40	0.54	0.46	0.96	0.41	0.85	0.86	0.95	0.56
ESP	-0.07	0.08	0.31		0.13	-0.37	0.26	0.72	-0.64	0.42	0.75	0.72	0.21
FRA	0.15	-0.15	0.40	0.13		0.18	0.48	0.85	-0.73	0.48	0.82	0.65	0.30
IRL	-0.02	0.50	0.54	-0.37	0.18		0.04	0.78	0.59	0.38	0.75	0.83	0.38
ITA	0.25	0.17	0.46	0.26	0.48	0.04		0.88	-0.51	0.46	0.86	0.83	0.38
JPN	0.78	0.74	0.96	0.72	0.85	0.78	0.88		0.75	0.95	0.92	0.88	0.84
DEU	-0.18	-0.57	0.41	-0.64	-0.73	0.59	-0.51	0.75		0.48	0.78	0.77	0.10
NZL	-0.11	0.48	0.85	0.42	0.48	0.38	0.46	0.95	0.48		0.86	0.90	0.56
GBR	0.54	0.71	0.86	0.75	0.82	0.75	0.86	0.92	0.78	0.86		0.56	0.76
USA	0.64	0.63	0.95	0.72	0.65	0.83	0.83	0.88	0.77	0.90	0.56		0.76

Table 2.12: $corr(RER^D_{i,j}, RER_{i,j})$ for all bilateral country pairs

	AUS	AUT	CAN	ESP	FRA	IRL	ITA	JPN	DEU	NZL	GBR	USA	Average
AUS		0.61	0.83	0.63	0.58	0.68	0.50	0.46	0.67	0.56	0.35	0.35	0.57
AUT	0.61		0.65	0.83	2.05	1.39	1.60	0.51	3.28	0.83	0.61	0.28	1.15
CAN	0.83	0.65		0.56	0.75	0.49	0.65	0.63	0.46	0.63	0.60	0.60	0.62
ESP	0.63	0.83	0.56		1.30	1.08	1.19	0.51	0.59	0.54	0.56	0.32	0.74
FRA	0.58	2.05	0.75	1.30		1.65	2.31	0.40	1.53	0.69	0.51	0.22	1.09
IRL	0.68	1.39	0.49	1.08	1.65		1.61	0.64	1.00	0.75	1.01	0.56	0.99
ITA	0.50	1.60	0.65	1.19	2.31	1.61		0.45	1.43	0.60	0.44	0.21	1.00
JPN	0.46	0.51	0.63	0.51	0.40	0.64	0.45		0.58	0.60	0.58	0.56	0.54
DEU	0.67	3.28	0.46	0.59	1.53	1.00	1.43	0.58		0.88	0.80	0.43	1.06
NZL	0.56	0.83	0.63	0.54	0.69	0.75	0.60	0.60	0.88		0.56	0.56	0.65
GBR	0.35	0.61	0.60	0.56	0.51	1.01	0.44	0.58	0.80	0.56		0.39	0.58
USA	0.35	0.28	0.60	0.32	0.22	0.56	0.21	0.56	0.43	0.56	0.39		0.41

Table 2.13: $\frac{std(RER^D_{i,j})}{std(RER_{i,j})}$ for all bilateral country pairs

	AUS	AUT	CAN	ESP	FRA	IRL	ITA	JPN	DEU	NZL	GBR	USA	Average
AUS		0.29	0.35	0.28	0.27	0.35	0.27	0.41	0.29	0.26	0.20	0.22	0.29
AUT	0.29		0.27	0.32	0.46	0.60	0.49	0.35	0.47	0.47	0.25	0.10	0.37
CAN	0.35	0.27		0.26	0.37	0.28	0.32	0.67	0.20	0.51	0.51	0.68	0.40
ESP	0.28	0.32	0.26		0.47	0.34	0.42	0.41	0.20	0.33	0.42	0.19	0.33
FRA	0.27	0.46	0.37	0.47		0.56	0.32	0.27	0.43	0.42	0.24	0.07	0.35
IRL	0.35	0.60	0.28	0.34	0.56		0.54	0.60	0.57	0.45	0.59	0.47	0.49
ITA	0.27	0.49	0.32	0.42	0.32	0.54		0.38	0.42	0.37	0.21	0.07	0.35
JPN	0.41	0.35	0.67	0.41	0.27	0.60	0.38		0.42	0.66	0.59	0.51	0.48
DEU	0.29	0.47	0.20	0.20	0.43	0.57	0.42	0.42		0.48	0.38	0.23	0.37
NZL	0.26	0.47	0.51	0.33	0.42	0.45	0.37	0.66	0.48		0.51	0.55	0.46
GBR	0.20	0.25	0.51	0.42	0.24	0.59	0.21	0.59	0.38	0.51		0.22	0.37
USA	0.22	0.10	0.68	0.19	0.07	0.47	0.07	0.51	0.23	0.55	0.22		0.30

Table 2.14: $vardec(RER^D_{i,j}, RER_{i,j})$ for all bilateral country pairs

2.B $RER^D_{i,j}$ decomposition

The tables in this section show the detailed decompositions of the distribution real exchange rate. The tables show the various summary statistics for when CPIs and GDP deflators are used as well as for linear detrending and HP filtering. They also show the cases of using transport margins and ULCs as proxies for domestic transport/logistics costs.

2.B.1 CPI and transport margins based $RER^D_{i,j}$ decomposition

HP Filter

	CAN	DNK	FRA	ITA	USA	Average
CAN		0.45	0.49	0.24	0.51	0.42
DNK	0.45		0.30	-0.13	0.44	0.26
FRA	0.49	0.30		0.41	0.22	0.36
ITA	0.24	-0.13	0.41		0.15	0.17
USA	0.51	0.44	0.22	0.15		0.33

Table 2.15: $corr(RER_{i,j}, RER^M_{i,j})$ for all bilateral country pairs

	CAN	DNK	FRA	ITA	USA	Average
CAN		0.15	0.15	0.14	0.16	0.15
DNK	0.15		5.13	0.91	0.19	1.60
FRA	0.15	5.13		0.87	0.03	1.55
ITA	0.14	0.91	0.87		0.06	0.50
USA	0.16	0.19	0.03	0.06		0.11

Table 2.16: $\frac{std(RER^M_{i,j})}{std(RER_{i,j})}$ for all bilateral country pairs

	CAN	DNK	FRA	ITA	USA	Average
CAN		0.34	0.49	0.33	0.23	0.35
DNK	0.34		0.57	0.15	0.37	0.36
FRA	0.49	0.57		0.65	0.17	0.47
ITA	0.33	0.15	0.65		0.76	0.47
USA	0.23	0.37	0.17	0.76		0.38

Table 2.17: $vardec(RER^D_{i,j}, RER^M_{i,j}))$ for all bilateral country pairs

Linear trend

	CAN	DNK	FRA	ITA	USA	Average
CAN		0.45	0.49	0.25	0.55	0.44
DNK	0.45		0.30	-0.13	0.44	0.26
FRA	0.49	0.30		0.42	0.20	0.35
ITA	0.25	-0.13	0.42		0.14	0.17
USA	0.55	0.44	0.20	0.14		0.33

Table 2.18: $corr(RER_{i,j}, RER^M_{i,j})$ for all bilateral country pairs

	CAN	DNK	FRA	ITA	USA	Average
CAN		0.15	0.16	0.14	0.17	0.16
DNK	0.15		5.06	0.91	0.18	1.58
FRA	0.16	5.06		0.87	0.03	1.53
ITA	0.14	0.91	0.87		0.06	0.50
USA	0.17	0.18	0.03	0.06		0.11

Table 2.19: $\frac{std(RER^M_{i,j})}{std(RER_{i,j})}$ for all bilateral country pairs

	CAN	DNK	FRA	ITA	USA	Average
CAN		0.34	0.49	0.33	0.23	0.35
DNK	0.34		0.57	0.15	0.36	0.36
FRA	0.49	0.57		0.65	0.17	0.47
ITA	0.33	0.15	0.65		0.76	0.47
USA	0.23	0.36	0.17	0.76		0.38

Table 2.20: $vardec(RER^D_{i,j}, RER^M_{i,j}))$ for all bilateral country pairs

2.B.2 GDP deflator and transport margins based $RER^D_{i,j}$ decomposition

HP Filter

	CAN	FRA	ITA	USA	Average
CAN		0.53	0.32	0.51	0.45
FRA	0.53		-0.03	0.20	0.23
ITA	0.32	-0.03		0.14	0.14
USA	0.51	0.20	0.14		0.28

Table 2.21: $corr(RER_{i,j}, RER^M_{i,j})$ for all bilateral country pairs

	CAN	FRA	ITA	USA	Average
CAN		0.16	0.15	0.16	0.16
FRA	0.16		1.18	0.03	0.46
ITA	0.15	1.18		0.06	0.46
USA	0.16	0.03	0.06		0.08

Table 2.22: $\frac{std(RER^M_{i,j})}{std(RER_{i,j})}$ for all bilateral country pairs

	CAN	FRA	ITA	USA	Average
CAN		0.49	0.33	0.23	0.35
FRA	0.49		0.65	0.17	0.44
ITA	0.33	0.65		0.76	0.58
USA	0.23	0.17	0.76		0.39

Table 2.23: $vardec(RER^D_{i,j}, RER^M_{i,j}))$ for all bilateral country pairs

Linear trend

	CAN	FRA	ITA	USA	Average
CAN		0.54	0.32	0.53	0.46
FRA	0.54		-0.03	0.18	0.23
ITA	0.32	-0.03		0.14	0.14
USA	0.53	0.18	0.14		0.28

Table 2.24: $corr(RER_{i,j}, RER^M_{i,j})$ for all bilateral country pairs

	CAN	FRA	ITA	USA	Average
CAN		0.17	0.15	0.16	0.16
FRA	0.17		1.16	0.03	0.45
ITA	0.15	1.16		0.05	0.45
USA	0.16	0.03	0.05		0.08

Table 2.25: $\frac{std(RER^M_{i,j})}{std(RER_{i,j})}$ for all bilateral country pairs

	CAN	FRA	ITA	USA	Average
CAN		0.49	0.33	0.23	0.35
FRA	0.49		0.65	0.17	0.44
ITA	0.33	0.65		0.76	0.58
USA	0.23	0.17	0.76		0.39

Table 2.26: $vardec(RER^D_{i,j}, RER^M_{i,j}))$ for all bilateral country pairs

2.B.3 CPI and unit labour cost based $RER^D_{i,j}$ decomposition

HP Filter

	AUT	CAN	DNK	FRA	ITA	GBR	USA	Average
AUT		0.11	-0.01	0.27	0.08	-0.33	0.21	0.05
CAN	0.11		0.33	0.28	0.11	-0.19	0.13	0.13
DNK	-0.01	0.33		0.02	0.25	0.88	0.35	0.30
FRA	0.27	0.28	0.02		0.10	0.92	-0.14	0.24
ITA	0.08	0.11	0.25	0.10		0.41	-0.08	0.14
GBR	-0.33	-0.19	0.88	0.92	0.41		-0.40	0.22
USA	0.21	0.13	0.35	-0.14	-0.08	-0.40		0.01

Table 2.27: $corr(RER_{i,j}, RER^M_{i,j})$ for all bilateral country pairs

	AUT	CAN	DNK	FRA	ITA	GBR	USA	Average
AUT		0.34	2.94	5.46	3.70	0.29	0.25	2.16
CAN	0.34		0.27	0.39	0.36	0.11	0.42	0.32
DNK	2.94	0.27		4.04	1.44	0.18	0.22	1.52
FRA	5.46	0.39	4.04		1.83	0.09	0.28	2.02
ITA	3.70	0.36	1.44	1.83		0.25	0.23	1.30
GBR	0.29	0.11	0.18	0.09	0.25		0.11	0.17
USA	0.25	0.42	0.22	0.28	0.23	0.11		0.25

Table 2.28: $\frac{std(RER^M_{i,j})}{std(RER_{i,j})}$ for all bilateral country pairs

	AUT	CAN	DNK	FRA	ITA	GBR	USA	Average
AUT		0.64	0.71	0.83	0.86	0.88	0.63	0.76
CAN	0.64		0.60	0.85	0.73	0.35	0.70	0.64
DNK	0.71	0.60		0.92	0.91	0.54	0.57	0.71
FRA	0.83	0.85	0.92		0.72	0.35	0.70	0.73
ITA	0.86	0.73	0.91	0.72		0.67	0.79	0.78
GBR	0.88	0.35	0.54	0.35	0.67		0.51	0.55
USA	0.63	0.70	0.57	0.70	0.79	0.51		0.65

Table 2.29: $vardec(RER^D_{i,j}, RER^M_{i,j}))$ for all bilateral country pairs

Linear trend

	AUT	CAN	DNK	FRA	ITA	GBR	USA	Average
AUT		0.13	-0.02	0.13	0.05	-0.30	0.21	0.03
CAN	0.13		0.44	0.44	0.25	-0.20	0.33	0.23
DNK	-0.02	0.44		0.24	0.28	0.84	0.44	0.37
FRA	0.13	0.44	0.24		0.23	0.86	-0.17	0.29
ITA	0.05	0.25	0.28	0.23		0.38	-0.13	0.18
GBR	-0.30	-0.20	0.84	0.86	0.38		-0.44	0.19
USA	0.21	0.33	0.44	-0.17	-0.13	-0.44		0.04

Table 2.30: $corr(RER_{i,j}, RER^M_{i,j})$ for all bilateral country pairs

	AUT	CAN	DNK	FRA	ITA	GBR	USA	Average
AUT		0.34	2.72	3.34	4.59	0.28	0.23	1.92
CAN	0.34		0.28	0.41	0.39	0.13	0.35	0.32
DNK	2.72	0.28		4.87	1.59	0.18	0.14	1.63
FRA	3.34	0.41	4.87		1.66	0.09	0.16	1.76
ITA	4.59	0.39	1.59	1.66		0.24	0.24	1.45
GBR	0.28	0.13	0.18	0.09	0.24		0.12	0.17
USA	0.23	0.35	0.14	0.16	0.24	0.12		0.21

Table 2.31: $\frac{std(RER^M_{i,j})}{std(RER_{i,j})}$ for all bilateral country pairs

	AUT	CAN	DNK	FRA	ITA	GBR	USA	Average
AUT		0.64	0.71	0.83	0.86	0.88	0.63	0.76
CAN	0.64		0.60	0.85	0.73	0.35	0.69	0.64
DNK	0.71	0.60		0.94	0.91	0.54	0.30	0.67
FRA	0.83	0.85	0.94		0.67	0.35	0.62	0.71
ITA	0.86	0.73	0.91	0.67		0.67	0.80	0.77
GBR	0.88	0.35	0.54	0.35	0.67		0.51	0.55
USA	0.63	0.69	0.30	0.62	0.80	0.51		0.59

Table 2.32: $vardec(RER^D_{i,j}, RER^M_{i,j}))$ for all bilateral country pairs

2.B.4 GDP deflator and unit labour cost based $RER^D_{i,j}$ decomposition

HP Filter

	AUT	CAN	FRA	ITA	GBR	USA	Average
AUT		0.17	-0.32	-0.10	-0.30	0.21	-0.07
CAN	0.17		0.30	0.11	-0.20	0.13	0.10
FRA	-0.32	0.30		0.19	0.96	-0.15	0.20
ITA	-0.10	0.11	0.19		0.43	-0.08	0.11
GBR	-0.30	-0.20	0.96	0.43		-0.44	0.09
USA	0.21	0.13	-0.15	-0.08	-0.44		-0.07

Table 2.33: $corr(RER_{i,j}, RER^M_{i,j})$ for all bilateral country pairs

	AUT	CAN	FRA	ITA	GBR	USA	Average
AUT		0.34	4.48	4.03	0.26	0.24	1.87
CAN	0.34		0.41	0.38	0.11	0.38	0.32
FRA	4.48	0.41		2.76	0.09	0.28	1.60
ITA	4.03	0.38	2.76		0.26	0.24	1.53
GBR	0.26	0.11	0.09	0.26		0.13	0.17
USA	0.24	0.38	0.28	0.24	0.13		0.25

Table 2.34: $\frac{std(RER^M_{i,j})}{std(RER_{i,j})}$ for all bilateral country pairs

	AUT	CAN	FRA	ITA	GBR	USA	Average
AUT		0.64	0.83	0.86	0.88	0.63	0.77
CAN	0.64		0.85	0.73	0.35	0.70	0.65
FRA	0.83	0.85		0.72	0.35	0.70	0.69
ITA	0.86	0.73	0.72		0.67	0.79	0.75
GBR	0.88	0.35	0.35	0.67		0.51	0.55
USA	0.63	0.70	0.70	0.79	0.51		0.67

Table 2.35: $vardec(RER^D_{i,j}, RER^M_{i,j}))$ for all bilateral country pairs

Linear trend

	AUT	CAN	FRA	ITA	GBR	USA	Average
AUT		0.18	-0.22	-0.10	-0.29	0.20	-0.05
CAN	0.18		0.46	0.27	-0.22	0.34	0.21
FRA	-0.22	0.46		0.22	0.94	-0.17	0.25
ITA	-0.10	0.27	0.22		0.41	-0.12	0.14
GBR	-0.29	-0.22	0.94	0.41		-0.56	0.06
USA	0.20	0.34	-0.17	-0.12	-0.56		-0.06

Table 2.36: $corr(RER_{i,j}, RER^M_{i,j})$ for all bilateral country pairs

	AUT	CAN	FRA	ITA	GBR	USA	Average
AUT		0.33	2.54	2.58	0.26	0.22	1.19
CAN	0.33		0.41	0.38	0.13	0.32	0.31
FRA	2.54	0.41		3.18	0.09	0.16	1.28
ITA	2.58	0.38	3.18		0.25	0.22	1.32
GBR	0.26	0.13	0.09	0.25		0.16	0.18
USA	0.22	0.32	0.16	0.22	0.16		0.22

Table 2.37: $\frac{std(RER^M_{i,j})}{std(RER_{i,j})}$ for all bilateral country pairs

	AUT	CAN	FRA	ITA	GBR	USA	Average
AUT		0.64	0.83	0.86	0.88	0.63	0.77
CAN	0.64		0.85	0.73	0.35	0.69	0.65
FRA	0.83	0.85		0.67	0.35	0.62	0.66
ITA	0.86	0.73	0.67		0.67	0.80	0.75
GBR	0.88	0.35	0.35	0.67		0.51	0.55
USA	0.63	0.69	0.62	0.80	0.51		0.65

Table 2.38: $vardec(RER^D_{i,j}, RER^M_{i,j}))$ for all bilateral country pairs

3

Modelling The Distribution Real Exchange Rate In A Two-Country Open Economy Framework

Abstract

This paper investigates the relationship between mark-ups and the real exchange rate in a two country model. In the baseline model it is shown that local currency pricing can generate moments that are consistent with those found in the data. Producer currency pricing, however, cannot account for variations in the real exchange rate, as nominal exchange rate changes are passed through to import prices fully and immediately. An extended model is proposed that features a distribution sector to enable the model to match the empirical evidence more closely.

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3.1 Introduction

This paper studies the relationship between mark-ups and the real exchange rate in open economy macroeconomic models. As I have argued in the previous chapter of this thesis, the distinction between non-tradable and tradable goods needs to be further broken down to account for the difference between prices of goods "at-the-dock" and the prices of goods the final consumer faces. As the empirical evidence suggests that this distinction is important to understanding the dynamics of real exchange rates, this chapter therefore analyses whether a two-country open-economy macroeconomic model is able to replicate the relationship between mark-ups and the real exchange rate observed in the earlier chapter.

While recent research has paid much attention to optimal monetary policy under different firm pricing strategies, such as producer currency pricing (PCP) and local currency pricing (LCP) (see, Engel (2011) and Corsetti et al. (2011)). While the effects of these mechanisms on exchange rate pass through have also been studied, little attention has been paid to the relationship between mark-ups themselves and the real exchange rate. Empirical evidence shows that mark-ups account for a large proportion of real exchange rate variation, therefore any open economy model that has the real exchange rate at its core should be able to match this empirical fact to ensure accuracy of our understanding of shock transmission and policy recommendations.

However, this matters not just for the accuracy of the models - another important implication is for example the argument put forward by Engel (2014): under LCP, changes in the exchange rate lead to changes in relative prices, namely the relative price of imports to domestically produced goods. This distorts the price signal and leads to welfare losses through a similar mechanism as that in the case of a welfare loss due to staggered price setting. If these deviations are large, policy makers should pay more attention to the exchange rate, stabilising it in addition to domestic inflation, to minimise these price distortions.

The importance of pricing mechanisms and its implications for pass-through, welfare, and exchange rates are summarised by Engel (2011): in models featuring

PCP, any change in the nominal exchange rate will be passed through immediately to imported goods' prices. As a result, relative prices of imports to domestically produced goods change, but they do so efficiently. Engel argues that if prices of domestic goods produced in the importing country are sticky, then a change in the exchange rate leads to inefficient movements in the price of the same good sold in different countries. However, if prices are only sticky for domestically produced goods, then targeting price inflation of those goods should erase any welfare loss because of sticky prices. In the PCP case, Engel argues, policy makers should target producer-price inflation.

Engel's argument continues for the pricing to market, or LCP, case: with staggered price targeting domestic inflation is inefficient as it implies distorted relative prices between imported goods and domestically produced goods. The distorted price signal leads to an inefficient allocation of resources used for the production of goods and services and thereby causes a welfare loss. Under LCP, imported goods' prices will, to some extent, reflect exchange rate movements, which can be efficient as it signals correctly the relative price of imported goods to domestically produced goods. However, imported goods' prices are also subject to staggered price setting in the pricing to market case, leading to distortions in relative prices: to resolve this, consumer prices of both domestic and imported goods need to be targeted, so it is optimal for policy makers to target overall consumer price inflation.

While Engel (and, for example Corsetti et al. (2011)) focuses on the implications of PCP and LCP for optimal monetary policy, this paper focuses on the appropriateness of using LCP to model firms' pricing behaviour in open-economy models. The key question is whether the co-movement of the real exchange rate and firms' pricing decisions is adequately captured. LCP and PCP clearly have important implications for mark-ups charged on imported goods. The definition of mark-ups that most closely matches the empirical evidence is the price that incorporates full pass-through of an exchange rate change, relative to the price that consumers in the importing country currently face. Using this definition, it is clear that the

correlation of the exchange rate and mark-ups under PCP should be zero, as any exchange rate change is always fully passed through to final consumers. This is not the case, however, under LCP: exporters take into account exchange rate movements and vary the mark-up (the mark-up arising under profit maximisation, not the definition presented here) so that there will be a non-zero correlation between the exchange rate and mark-ups on imported goods.

This paper therefore demonstrates that a modified version of the standard local currency pricing model can better match the empirical evidence. A distribution sector, that takes domestic non-tradable goods as an input to deliver imports from the dock to final consumers, ensures that time-varying profit margins on imported goods play a role, but this effect is dampened through the reliance on domestic goods in the distribution sector. This paper therefore argues that any model that is designed to study the effects of optimal monetary policy, exchange rate pass-through, or cross-country risk sharing needs to feature such a distribution sector to match the empirical co-movements of the real exchange rate and relative profit margins.

This paper is structured as follows: section 3.2 discusses the related literature and places this paper in relation to it. Section 3.3 introduces the baseline model and discusses the basic mechanism underlying the relationship between mark-ups and the exchange rate. Section 3.4 introduces the necessary extensions to enable the model to fit the empirical evidence better, and section 3.5 concludes.

3.2 Related literature

To place this paper in relation to the literature, it is important to understand the existing stock of modelling. The baseline model of this paper is taken from Engel (2011), which expands on the workhorse model developed by Clarida et al. (2002). The latter model is a two-country framework that assumes identical preferences across countries and producer currency pricing.

Engel relaxes the producer currency pricing assumption of Clarida et al. (2002) and introduces local currency pricing. Further, he adds home bias into consumers' preferences. This implies that purchasing power parity breaks down, and as a result

the consumption real exchange rate is no longer constant. Engel then goes on to develop optimal policy rules in this setting, with a particular focus on currency misalignment. He poses the question whether "the optimal exchange-rate behaviour [can] be achieved through a policy that considers inflation and the output gap?".

With this work Engel builds on the work by Devereux and Engel (2003) and Corsetti and Pesenti (2005), which both consider optimal policy under local currency pricing. The former paper concludes that in the presence of LCP, optimal monetary policy implies a fixed exchange rate regime. The latter paper concludes that an inward-looking monetary policy regime is not optimal when firms' mark-ups are subject to exchange rate fluctuations.

The last point is where this paper picks up: how do the model implied impacts of the exchange rate on mark-ups compare with the empirical evidence? As a result, how do the model implied co-movements between the real exchange rate and mark-ups compare to empirical findings?

To answer this question, this paper first examines the moments implied by Engel's model before then expanding the model to achieve a more realistic behaviour of mark-ups and the real exchange rate.

In addition to the previous chapter, a lot of attention has recently been paid to the co-movements of mark-ups and the exchange rates, but to the best of my knowledge none have done so explicitly linking empirical findings to an underlying theoretical model.

Burstein and Gopinath (2014) provide an overview of the existing empirical and theoretical literature covering exchange rates and mark-ups, and propose a model that can provide a link between the two. This paper goes further though by directly linking the LCP/PCP literature to the real exchange rate decomposition literature (e.g. Engel (1999)), a link that has been started by Betts and Kehoe (2001). Betts and Kehoe match the real exchange rate behaviour between the US and Mexico, but do not focus on relative mark-ups, but rather the degree of tradability of different goods. Earlier work by Chari et al. (2002) focuses on the consumption-real exchange rate anomaly: typically open-economy models generate

a high correlation between the real exchange rate and the ratio of consumption across countries, while this does not hold true in the data. This paper follows in that same spirit by testing whether the relationship between real exchanges and profit margins in open-economy models match the empirically observed behaviour.

Additional empirical support for the results of this paper is provided by Berman et al. (2012), who empirically study the reaction of exporters to exchange rate changes using a French dataset. They find that exporting firms increase their mark-ups significantly following a depreciation of the currency, pricing behaviour that is consistent with pricing-to-market, or LCP. This paper studies to what extent this is also true in an LCP modelling framework, and finds that the model's impulse responses are consistent with Berman et al's empirical findings.

3.3 Model Set-Up

The baseline model is a simplified version of the two-country model of Engel (2011), which itself is a modification of Clarida et al. (2002). While the latter model assumes PCP, Engel introduces pricing to market into their framework and allows home and foreign consumers to have different preferences. To maintain focus and to keep the model as simple as possible, the baseline model assumes that relative to Engel's general model, the elasticity of labour supply is zero and there are no cost-push shocks.

The model features two countries of equal size with differing preferences for home and foreign goods in the two countries. Home households put a weight of $\frac{v}{2}$ on domestically produced goods, and a weight of $1 - \frac{v}{2}$ on goods produced abroad. It is commonly argued in the open-economy literature that v is a proxy for openness of the economy.

Like the seminal model of Clarida et al. (2002), each country is inhabited with a continuum of households, which derive positive utility from consumption and disutility from providing labour. Labour is supplied to firms, which take the households' labour as their only input. Each country's economy produces a continuum of goods, with each good being produced by a monopolist. The

monopolist's production function is the same across goods, subject to technology shocks (which are the only shocks considered in this model for simplicity).

Financial markets are complete: as in Corsetti et al. (2008) there is a complete set of state-contingent claims which can be traded. While this particular assumption is unrealistic, the modelling choices are kept simple because in this analysis I want to depart as little as possible from the seminal literature. In the same vein, the remaining modelling choices and calibrations are similar to that in the literature and are a combination of different approaches. The key analytical contribution is to show how, with as few changes as necessary, it is possible to show that the distribution real exchange rate implied by the model's predictions has qualitatively similar properties to those observed in empirical studies.

3.3.1 Households

Households in the home country [1] maximise utility

$$U_t(h) = E_t \left[\sum_{j=0}^{\infty} \beta^j \left(\frac{1}{1-\sigma} C_{t+j}(h)^{1-\sigma} - N_{t+j}(h) \right) \right] \tag{3.1}$$

where $\sigma > 0$ and $C_t(h)$ is aggregate consumption, which is given by:

$$C_t(h) = (C_{H,t}(h))^{\frac{v}{2}} (C_{F,t}(h))^{1-\frac{v}{2}} \tag{3.2}$$

where $0 < v < 2$. $C_{H,t}(h)$ and $C_{F,t}(h)$ are CES aggregates. Each household consumes part of the goods produced by the continuum of firms in each country. That is consumption of home goods in the home country is given by:

$$C_{H,t}(h) = \left(\int_0^1 C_{H,t}(h,f)^{\frac{\xi-1}{\xi}} df \right)^{\frac{\xi}{\xi-1}} \tag{3.3}$$

while consumption of foreign goods in the home country is:

$$C_{F,t}(h) = \left(\int_0^1 C_{F,t}(h,f)^{\frac{\xi-1}{\xi}} df \right)^{\frac{\xi}{\xi-1}} \tag{3.4}$$

Price indices are analogous, and given by:

[1] As the model is symmetric, the same applies to the foreign household.

$$P_t(h) = \frac{1}{(1-\frac{v}{2})^{1-\frac{v}{2}}\frac{v}{2}^{\frac{v}{2}}} P_{H,t}^{\frac{v}{2}} P_{F,t}^{1-\frac{v}{2}} \tag{3.5}$$

$$P_{H,t}(h) = \left(\int_0^1 P_{H,t}(h,f)^{1-\xi} df\right)^{\frac{1}{1-\xi}} \tag{3.6}$$

$$P_{F,t}(h) = \left(\int_0^1 P_{F,t}(h,f)^{1-\xi} df\right)^{\frac{1}{1-\xi}} \tag{3.7}$$

Each household in the home country provides labour to home firms, where $N_t(h)$ is aggregate labour supply in the home country:

$$N_t(h) = \int_0^1 N_t(h,f) df \tag{3.8}$$

The household budget constraint is:

$$P_t C_t(h) + \sum_{\nabla^{t+1} \in \Omega_{t+1}} Z(\nabla^{t+1}|\nabla^t) D(h, \nabla^{t+1}) = W_t(h) N_t(h) + \Gamma_t + D(h, \nabla^t) \tag{3.9}$$

Households receive labour income $W_t(h)N_t(h)$, aggregate profits from the firms they own Γ_t, and payoffs from state-contingent claims they hold, $D(h, \nabla^t)$. They spend the nominal amount of $P_t C_t(h)$ on consumption, and spend $\sum_{\nabla^{t+1} \in \Omega_{t+1}} Z(\nabla^{t+1}|\nabla^t) D(h, \nabla^{t+1})$ purchasing state-contingent claims for the next period. $D(h, \nabla^{t+1})$ is a state contingent claim that pays one unit of currency next period, conditional on state ∇^{t+1} occurring at time $t+1$, and $Z(\nabla^{t+1}|\nabla^t)$ is the price of that claim.

The first-order conditions are standard, and are given by equations 3.10 to 3.14:

$$P_{H,t} C_{H,t} = \frac{v}{2} P_t C_t \tag{3.10}$$

$$P_{F,t} C_{F,t} = (1-\frac{v}{2}) P_t C_t \tag{3.11}$$

$$C_{H,t}(f) = \left(\frac{P_{H,t}(f)}{P_{H,t}}\right)^{-\xi} C_{H,t} \tag{3.12}$$

$$C_{F,t}(f) = \left(\frac{P_{F,t}(f)}{P_{F,t}}\right)^{-\xi} C_{F,t} \tag{3.13}$$

and

$$\beta R_t E_t \left(\frac{C(\nabla^{t+1})^{-\sigma}}{C(\nabla^t)} \frac{P_t}{P_{t+1}}\right) = 1 \tag{3.14}$$

since the sum of $Z(\nabla^{t+1}|\nabla^t)$ over all states must equal $\frac{1}{R_t}$, where R_t is the yield on a non-state contingent bond. This yields the Euler equation (3.14).

Foreign households have analogous preferences and face the same budget constraint.

3.3.2 Firms

Each firm produces their good $Y(f)$ using labour as the only input using production technology:

$$Y_t(f) = A_t N_t(f) \tag{3.15}$$

Productivity A_t is common to all firms in that country, and so productivity shocks are common to all firms in that country.

Firms are profit maximising, with each firm's profits given by the difference between their total revenue and their labour cost:

$$\Gamma_t(f) = P_{H,t}(f)C_{H,t}(f) + E_t P^*_{H,t}(f)C^*_{H,t}(f) - W_t N_t(f) \tag{3.16}$$

where E_t is the exchange rate and $*$ denotes foreign variables, so for example $P^*_{H,t}(f)$ is the price charged to consumers abroad when they purchase good f, which is produced at home. $C^*_{H,t}(f)$ is then the consumption of that variety abroad.

Market clearing implies that the sum of consumption of each good at home and abroad must equal the production of that good. It must therefore be true that $Y_t(f) = C_{H,t}(f) + C^*_{H,t}(f)$.

The model of firms abroad is the same, but production technology shocks differ abroad, so foreign productivity is given by A^*_t.

Producer Currency Pricing

The first pricing technology to be considered in this paper is producer currency pricing (PCP). Under PCP firms set the price in their home currency and the foreign price is the home price adjusted for the exchange rate. Pass-through therefore is full and immediate following an exchange rate change.

PCP is implemented in the same way as in Clarida et al. (2002). The pricing technology is standard Calvo (Calvo (1983)); each firm may reset its prices with a probability of $1-\theta$ each period. Resetting prices allows the firm to reset its prices in both countries simultaneously. Firms set the price in their own currency, and the foreign price is the own currency price adjusted for the exchange rate. As a result, PPP holds under PCP.

As is standard in models with Calvo pricing, each firm maximises the value of expected future discounted dividends. Therefore the firm chooses its reset price $P^0_{H,t}(f)$ at time t to maximise:

$$E_t \sum_{j=0}^{\infty} \theta^j Q_{t,t+j}[P^0_{H,t}(f)(C_{H,t+j}(f) + C^*_{H,t+j}(f)) - W_{t+j}N_{t+j}(f)] \tag{3.17}$$

subject to home and foreign demand. $Q_{t,t+j} \equiv \beta^j(\frac{C_{t+j}}{C_t})^{-\sigma}(\frac{P_t}{P_{t+j}})$ is the stochastic discount factor.

The solution to this maximisation problem is the optimal reset price:

$$P^0_{H,t}(z) = \frac{\xi}{\xi - 1}\frac{E_t \sum_{j=0}^{\infty} \theta^j Q_{t,t+j} W_{t+j} P^{\xi}_{H,t+j}(C_{H,t+j} + C^*_{H,t+j})/A_{t+j}}{E_t \sum_{j=0}^{\infty} \theta^j Q_{t,t+j} P^{\xi}_{H,t+j}(C_{H,t+j} + C^*_{H,t+j})} \tag{3.18}$$

Given that a proportion θ of firms cannot reset its prices, the price of home goods at any time t is therefore given by:

$$P_{H,t} = [\theta(P_{H,t-1})^{1-\xi} + (1-\theta)(P^0_{H,t})^{1-\xi}]^{\frac{1}{1-\xi}} \tag{3.19}$$

A log-linearisation of this result leads to the standard New Keynesian Philips curve.

Local Currency Pricing

As an alternative to PCP, this paper also investigates the relationship between mark-ups and exchange rates under local currency pricing (LCP). Under LCP, firms set the price of their good in each market separately, which implies that there is staggered price setting both in domestic as well as imported goods. This implies welfare losses not just from distorted domestic prices but also due to the distortion of the relative price of domestically produced and imported goods.

LCP is implemented in much the same way as PCP. The only difference is that firms set the foreign price separately from the home prices, that is, $P^0_{H,t}(f)$ is set in the foreign currency directly, not in the home currency. In other words, exports are priced in the importers currency. Again, a fraction of θ firms cannot reset its prices each period. It follows therefore that each firm's maximisation problem is given by:

$$E_t \sum_{j=0}^{\infty} \theta^j Q_{t,t+j}[P^0_{H,t}(f)C_{H,t+j}(f) + E_t P^{0*}_{H,t}(f)C^*_{H,t+j}(f) - W_{t+j}N_{t+j}(f)] \tag{3.20}$$

again, subject to the home and foreign demand curves.

The solution to this problem gives the optimal reset price at home

$$P^0_{H,t}(z) = \frac{\xi}{\xi - 1} \frac{E_t \sum_{j=0}^{\infty} \theta^j Q_{t,t+j} W_{t+j} P^{\xi}_{H,t+j} C_{H,t+j}/A_{t+j}}{E_t \sum_{j=0}^{\infty} \theta^j Q_{t,t+j} P^{\xi}_{H,t+j} C_{H,t+j}} \tag{3.21}$$

and in the foreign currency

$$P^{0*}_{H,t}(z) = \frac{\xi}{\xi - 1} \frac{E_t \sum_{j=0}^{\infty} \theta^j Q_{t,t+j} W_{t+j} (P^*_{H,t+j})^{\xi} C^*_{H,t+j}/A_{t+j}}{E_t \sum_{j=0}^{\infty} \theta^j Q_{t,t+j} (P^*_{H,t+j})^{\xi} C^*_{H,t+j}} \tag{3.22}$$

Equation 3.19 holds in the LCP case as well. But the law of one price breaks down under LCP, and therefore export prices are given by:

$$P^*_{H,t} = [\theta (P^*_{H,t-1})^{1-\xi} + (1-\theta)(P^{0*}_{H,t})^{1-\xi}]^{\frac{1}{1-\xi}} \tag{3.23}$$

This wedge between export prices and domestic prices drives the result of this paper, that mark-ups can only account for variations in the real exchange rate under LCP.

3.3.3 Equilibrium

For the model to be in equilibrium we need the home and foreign goods markets and the home and foreign labour market to be cleared.

Goods market clearing in the home and foreign country imply that:

$$Y_t = C_{H,t} + C^*_{H,t} = \frac{v}{2}\frac{P_t C_t}{P_{H,t}} + (1 - \frac{v}{2})\frac{P^*_t C^*_t}{P^*_{H,t}} \tag{3.24}$$

and

$$Y^*_t = C_{F,t} + C^*_{F,t} = (1 - \frac{v}{2})\frac{P_t C_t}{P_{F,t}} + \frac{v}{2}\frac{P^*_t C^*_t}{P^*_{F,t}} \tag{3.25}$$

As in Engel (2011) and Corsetti et al. (2008), PPP does not hold and because of complete financial markets, the exchange rate adjusts such that the marginal utilities of consumption are equalised in home and foreign. Sticking to Engel's notation and defining S_t as the relative price of imports to domestically produced goods, we can use equation 3.5 and its foreign counterpart to express the market clearing condition as:

$$(\frac{C_t}{C^*_t})^\sigma = \frac{E_t P^*_t}{P_t} = \frac{E_t P^*_{H,t}}{P_{H,t}}(S^*_t)^{-\frac{v}{2}} S_t^{\frac{v}{2}-1} \tag{3.26}$$

where $S_t = \frac{P_{F,t}}{P_{H,t}}$ and $S^*_t = \frac{P^*_{H,t}}{P^*_{F,t}}$.

The sum of outputs of all firms in a country determine that country's total employment. Using the goods market clearing condition for each firm, and equations 3.15 and 3.12 and its foreign counterpart, we can define the market clearing condition for the labour market as:

$$\begin{aligned} N_t &= \int_0^1 N_t(f)df = A_t^{-1}\int_0^1 Y_t(f)df \\ &= A_t^{-1}(C_{H,t}\int_0^1 \left(\frac{P_{H,t}(f)}{P_{H,t}}\right)^{-\xi} df + C^*_{H,t}\int_0^1 \left(\frac{P^*_{H,t}(f)}{P^*_{H,t}}\right)^{-\xi} df) \end{aligned}$$

The foreign labour market clearing condition is analogous to the home ones.

3.3.4 Simulation results

The model is closed with a rule for monetary policy. As the exact form of monetary policy is not the focus of this paper, the model is closed using a Taylor rule for monetary policy.

$$\tilde{y_t} + \xi\pi_{H,t} = 0, \text{ and } \tilde{y_t^*} + \xi\pi^*_{F,t} = 0 \tag{3.27}$$

in the PCP case, and

$$\tilde{y_t^W} + \xi\pi_t^W = 0 \tag{3.28}$$

in the LCP case. For derivations and an in-depth analysis of these results, see Engel (2011).

Empirical evidence suggests that in a decomposition of the real exchange rate the distribution component plays a significant role. That is, when the real exchange rate is decomposed as

$$RER_{H,F,t} = S_{H,F,t}\frac{P_{F,t}}{P_{H,t}} = \underbrace{(S_{H,F,t}\frac{\bar{P^T_{F,t}}}{\bar{P^T_{H,t}}})}_{RER^T_{H,F,t}}\underbrace{(\frac{P^T_{H,t}}{P_{H,t}}/\frac{P^T_{F,t}}{P_{F,t}})}_{RER^N_{H,F,t}}\underbrace{(\frac{P^T_{F,t}}{\bar{P^T_{F,t}}}/\frac{P^T_{H,t}}{\bar{P^T_{H,t}}})}_{RER^D_{H,F,t}} \tag{3.29}$$

$RER^D_{H,F,t}$ accounts for about half of the variation of the real exchange rate.

Assuming that the law of one price holds for at-the-dock prices, the model equivalent of the empirical distribution margin is:

$$\text{Relative mark-up}_{t,H,F} = \frac{\frac{E_t P^*_{H,t}}{P_{H,t}}}{\frac{1/E_t P_{F,t}}{P^*_{F,t}}} = \frac{P^*_{H,t}}{P_{H,t}}\frac{P^*_{F,t}}{P_{F,t}} \tag{3.30}$$

that is, the firm's mark-up charged on exported goods over domestically sold goods is the ratio of the exported good's price abroad in home currency, divided by the price of the domestically sold good. This is the definition this paper will use going forward in the analysis of the relationship between the real exchange rate and relative profit margins.

Producer currency pricing

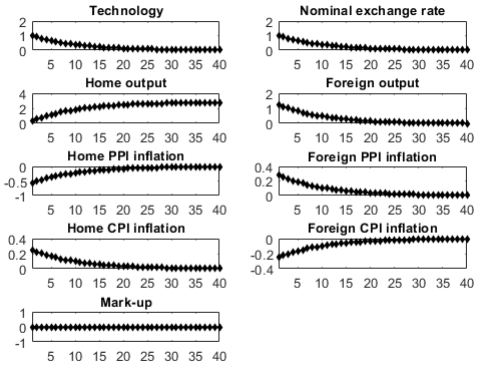


Figure 3.1: Impulse responses to a one per cent point temporary home technology shock in the model with producer currency pricing. Inflation rates are quarterly.

Figure 3.1 plots the impulse response functions of a one percent shock to home technology.

In the PCP case, output rises in both home and foreign, while home inflation falls due to increased supply. Foreign domestically generated inflation rises due to the higher demand for foreign produced goods. Consumer price inflation, however, increases in the home country and decreases in the foreign country as a result of the home country's deterioration in the terms of trade, which comes about due to the depreciation of the nominal exchange rate (depreciation as seen from the home country's perspective).

As a result the relative price of import's to domestic goods in the home country increases, leading to an increase in consumer price inflation. The opposite is true for the foreign country. This relative increase in the price level of home consumers leads to a depreciation of the consumer price based real exchange rate.

As the exchange rate change is fully passed through to prices of goods exported to the foreign country, the mark-up over the price of the same good sold at home does not change. The same is true for exports originating in the foreign country. As a result, the relative mark-up does not change. The correlation between the real exchange rate and relative mark-ups is therefore zero under producer currency pricing.

Local currency pricing

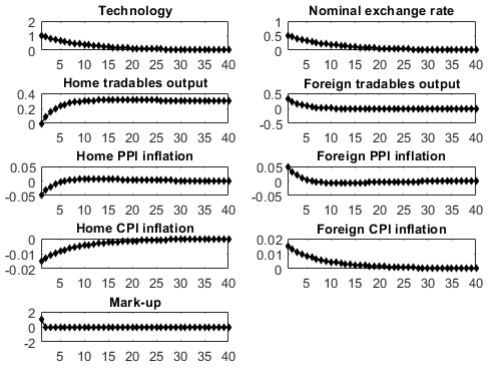


Figure 3.2: Impulse responses to a one per cent point temporary home technology shock in the model with local currency pricing. Inflation rates are quarterly.

The responses to a home technology shock are different under pricing-to-market, and are shown in figure 3.2. Under LCP, prices of tradable home goods fall due to the higher supply, and therefore more is demanded by both foreign and home households. The depreciation leads to an offset of lower domestic inflation pressures in the home country via relatively more expensive foreign goods, remaining the CPI inflation falls by less than PPI inflation.

While actual output rises as a result of the technology shock in both the home and foreign country, the output gap turns negative in the home country, and positive in the foreign country. The reason for that is the slow and incomplete pass-through under LCP. The exchange rate adjusts insufficiently to close the output gaps at home and abroad.

Relative mark-ups change in the LCP case: the depreciation of the exchange rate implies that the consumer price of imported goods increases relative to the (now cheaper) at-the-dock prices of imported goods. As a result, the mark-up for home firms rises, and the opposite is true for foreign firms. This leads to a positive correlation between the exchange rate and relative profit margins of the two countries. Over time, as producers can adjust their prices, firms take into account the depreciated exchange rate and home firms cut their prices in the foreign market (see above, foreign CPI inflation remains constant), reversing the increase in the relative profit margin.

The model correlation between the real exchange rate and relative profit margins is 0.51. This is qualitatively consistent with the empirical evidence presented in the previous chapter, but quantitatively somewhat too large. Qualitatively the results are also consistent with the evidence provided by Berman et al. (2012). Therefore, only pricing-to-market implies a positive correlation between the real exchange rate and relative profit margins. PCP cannot account for this feature in the data.

Given this limited set-up of the model, it is not possible to fully decompose the real exchange rate into a at-the-dock tradable component, a relative non-tradable to tradable price component, and a relative mark-up component. To analyse this, the next section enriches the model to be able to fully reproduce the decomposition. The next section's extensions also aim to make the model quantitatively more consistent with the data, by lowering the model implied correlation between relative mark-ups and the real exchange rate.

3.4 Adding Non-Tradable Goods and the Distribution Sector

To fully test the model's predictions relative to the empirical evidence two additions need to be made: first, to achieve a decomposition of the real exchange rate similar to that frequently used in the literature (for example, in the previous paper or in Engel (1999) and Betts and Kehoe (2001)), non-tradable goods have to be added. Second, to investigate the relative importance of the transport sector and importers' profit margins via a decomposition of the real exchange rate in line with the empirical evidence, a distribution sector needs to be added. Both of these form part of the model of Corsetti et al. (2008). This section adds these features to Engel's model.

3.4.1 Households

Adding non-tradable goods leaves households' utility functions unchanged but changes the price levels and consumption aggregators. Households' new consumption aggregator is now given by:

$$C_t(h) = (C_{T,t}(h))^{\frac{u}{2}}(C_{N,t}(h))^{1-\frac{u}{2}} \tag{3.31}$$

where $C_{T,t}(h)$ is an aggregator of tradable goods, given by

$$C_{T,t}(h) = (C_{H,t}(h))^{\frac{v}{2}}(C_{F,t}(h))^{1-\frac{v}{2}} \tag{3.32}$$

and $C_{N,t}(h)$ are non-tradable goods, and $0 < u < 2$.

The analogous price indices are given by:

$$P_t(h) = \frac{1}{(1-\frac{u}{2})^{1-\frac{u}{2}}\frac{u}{2}^{\frac{u}{2}}} P_{T,t}^{\frac{u}{2}} P_{N,t}^{1-\frac{u}{2}} \tag{3.33}$$

$$P_{T,t}(h) = \frac{1}{(1-\frac{v}{2})^{1-\frac{v}{2}}\frac{v}{2}^{\frac{v}{2}}} P_{H,t}^{\frac{v}{2}} P_{F,t}^{1-\frac{v}{2}} \tag{3.34}$$

The new first-order conditions replacing equations 3.10 and 3.11 are:

$$P_{H,t}C_{H,t} = \frac{u}{2}\frac{v}{2}P_tC_t \tag{3.35}$$

$$P_{F,t}C_{F,t} = \frac{u}{2}(1-\frac{v}{2})P_tC_t \tag{3.36}$$

$$P_{N,t}C_{N,t} = (1-\frac{u}{2})P_tC_t \tag{3.37}$$

The Euler equation, given by equation 3.14, remains unchanged. The market clearing condition for tradable goods remains the same, while for non-tradable goods it is:

$$Y_{N,t} = C_{N,t} + \eta C_{H,t} + \eta C_{F,t} \tag{3.38}$$

where η is the share of non-tradable goods the distribution sector requires to distribute goods from the dock to final consumers. The next section will elaborate on this. The first order conditions for the foreign country are analogous to the ones of the home country.

3.4.2 Firms

Non-tradable goods

Non-tradable goods are produced by perfectly competitive, profit-maximising firms. They take labour as an input and produce a single output, and there are no price rigidities. Their production function is given by

$$Y_{N,t} = A_{N,t} N_{H,t} \tag{3.39}$$

and they maximise profits according to

$$\Gamma_{N,t} = P_{N,t} C_{N,t} - W_t N_{N,t} \tag{3.40}$$

The non-tradable goods sector has the same properties in the foreign economy.

Parameter	Description (Reference)	Value
v	Home bias (Engel, 2011)	1.50
$1 - theta$	Price reset probability (Engel, 2011)	0.75
$rrho$	Persistence of shock (Engel, 2011)	0.90
$beta$	Discount factor (Engel, 2011)	0.90
xi	Elasticity of substitution (Engel, 2011)	0.50
u	Share of tradables (Corsetti et al., 2008)	1.50
eta	Share of transport cost (Corsetti et al., 2008)	1.50

Distribution Sector

To incorporate distribution costs, the model is fitted with a distribution sector, as is the case in e.g. Corsetti et al. (2008). This sector takes non-tradable goods as an input to deliver imported tradable goods from the dock to the final consumer. Firms in the distribution sector are perfectly competitive firms. They make zero profits and face no costs of production.

The distribution sector introduces a wedge between the producer price and the consumer price of each good. Firms set prices $\bar{P_{T,t}}$, and the distribution sector then transforms this into a consumer good using a proportion η of non-tradable goods, such that the consumer price of traded goods is:

$$P_{T,t} = \bar{P_{T,t}} + \eta P_{N,t} \tag{3.41}$$

The distribution sector works in the same way in the foreign economy.

3.4.3 Simulation Results

This section outlines the extended model's impulse responses and compares its moments to those observed in the data. The distribution sector and the relative importance of the non-tradable sector are calibrated in line with Corsetti et al. (2008) and the remainder of the model remains calibrated to match the model of Engel (2011). The simulation focuses on the impulses responses under LCP in order to have non-perfect nominal exchange rate pass-through. The impulse responses for the extended model under LCP are qualitatively similar to the baseline model and are shown in figure 3.3. However, the addition of the distribution sector and non-tradable goods add a new dimension to the behaviour underlying the

real exchange rate. Another obvious change is that the use of a Taylor rule for monetary policy, rather than optimal policy, means that CPI inflation is no longer unaffected by the shocks. Under optimal policy consumer price inflation is held constant, while the trade-off between the output gap and consumer price inflation becomes obvious in a Taylor Rule framework.

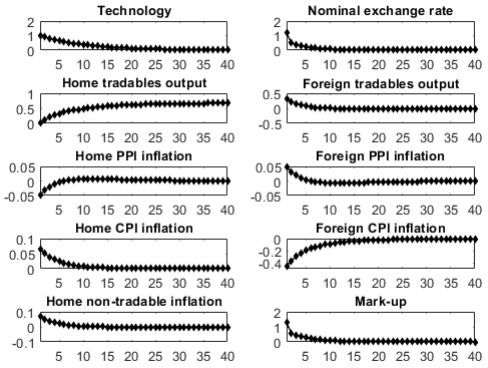


Figure 3.3: Impulse responses to a one per cent point temporary home technology shock in the model with local currency pricing. Inflation rates are quarterly.

Decomposing the real exchange rate

In this set-up, a home technology shock implies a negative home output gap as home potential output is increased, but output rises. Consumers wish to consume both home and foreign tradable goods, therefore the foreign tradable output gap, and output, increases. Producer price inflation follows a similar pattern. The nominal exchange rate depreciates from the home perspective, as before, pushing up home CPI inflation. Another factor in the increase in home inflation is that the price of non-tradable goods increases, as more is demanded both by consumers and for distribution purposes. The mark-up home firms can charge abroad decreases, as home goods become relatively more abundant.

The decomposition of the real exchange rate is shown in equation 3.29. In line with previous analyses of real exchange decompositions (see for example Bache et al. (2013) and Betts and Kehoe (2006)) and the previous chapter, this paper computes three summary statistics: a variance decomposition, the correlation, and the relative standard deviation. More explicitly, these are given by:

- Sample correlation,

$$corr(RER_{H,F}, RER^D_{H,F}) = \frac{cov(RER_{H,F}, RER^D_{H,F)}}{\sqrt{var(RER_{H,F}) \times var(RER^D_{H,F})}}$$

- Ratio of sample standard deviations,

$$\frac{std(RER^D_{H,F})}{std(RER_{H,F})} = \sqrt{\frac{var(RER^D_{H,F})}{var(RER_{H,F})}}$$

- Variance decomposition,

$$vardec(RER^D_{H,F}, RER_{H,F}) = \frac{var(RER^D_{H,F})}{var(RER^D_{H,F} + var(RER^T_{H,F}) + var(RER^N_{H,F}))}$$

The sample correlation enables an overview of co-movements of the distribution wedge and the real exchange rate. The ratio of sample standard deviations gives in insights into the relative volatility of the two series, while the variance decomposition shows the proportion of the overall variance accounted for by the measure considered.

	$corr(RER_{H,F}, RER^D_{H,F})$	$vardec(RER^D_{H,F}, RER_{H,F})$	$\frac{std(RER^D_{H,F})}{std(RER_{H,F})}$
Data	0.55	0.44	1.48
LCP mark-up shock	-0.04	0.26	4.34
LCP non-tradable productivity shock	0.07	1.00	22.90
LCP mark-up and productivity shock	0.08	0.31	1.53

Table 3.1: Comparison of model and data moments.

Table 3.1 presents the results of a simulation of the model under PCP and LCP for 1000 periods with home productivity shocks. The results are somewhat mixed, and neither producer currency pricing, nor local currency pricing can fully account for the dynamics of the real exchange rate.

The current simulation features cost-push shocks that have twice the variance of technology shocks. This is of course an assumption and future work could estimate this model to further refine this. Further work could also be undertaken so explore the importance of other shocks. The recent supply-chain shocks - e.g. lorry driver shortages - could be implemented, for example via shocks to the distribution sector to investigate the effect of these.

While the variance decomposition under LCP is fairly close numerically to that seen in the data, the relative standard deviation is too high and the correlation is negative in the model, as opposed to positive in the data. The low correlation can be explained by the distribution sector, which adds a wedge in between at-the-dock prices and final consumer prices. The correlation of profit margins and the real exchange rate under LCP in the baseline model was 0.51, suggesting that a lower transport wedge parameter than proposed by Corsetti et al. (2008) is needed to restore the positive correlation. Overall, a version of the model with a mix of LCP and PCP, with lower importance placed on the distribution sector seems promising, in that it should be able to match the data moments more accurately.

3.5 Conclusion

This paper argues that a model featuring a combination of local currency and producer currency pricing produces real exchange rate dynamics that are consistent with empirical findings. The paper argues that this can be achieved by modifying a baseline model based on work by Clarida et al. (2002) and Engel with non-tradable goods and a distribution sector that takes these non-tradable goods as an input and thereby introduces a wedge between at-the-dock prices and final consumer prices of tradable goods. While the model does not fit the data perfectly, a modified set-up is proposed to match the empirical moments more closely.

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3.A Model overview and first-order conditions

3.A.1 Households

- Consumption aggregator:

$$C_t(h) = (C_{T,t}(h))^{\frac{u}{2}}(C_{N,t}(h))^{1-\frac{u}{2}} \tag{3.42}$$

- Tradable goods aggregator:

$$C_{T,t}(h) = (C_{H,t}(h))^{\frac{v}{2}}(C_{F,t}(h))^{1-\frac{v}{2}} \tag{3.43}$$

- Price indices:

$$P_t(h) = \frac{1}{(1-\frac{u}{2})^{1-\frac{u}{2}}\frac{u}{2}^{\frac{u}{2}}} P_{T,t}^{\frac{u}{2}} P_{N,t}^{1-\frac{u}{2}} \tag{3.44}$$

$$P_{T,t}(h) = \frac{1}{(1-\frac{v}{2})^{1-\frac{v}{2}}\frac{v}{2}^{\frac{v}{2}}} P_{H,t}^{\frac{v}{2}} P_{F,t}^{1-\frac{v}{2}} \tag{3.45}$$

- First-order conditions:

$$P_{H,t}C_{H,t} = \frac{u}{2}\frac{v}{2}P_tC_t \tag{3.46}$$

$$P_{F,t}C_{F,t} = \frac{u}{2}(1-\frac{v}{2})P_tC_t \tag{3.47}$$

$$P_{N,t}C_{N,t} = (1-\frac{u}{2})P_tC_t \tag{3.48}$$

$$\beta R_t E_t \left(\frac{C(\nabla^{t+1})^{-\sigma}}{C(\nabla^t)} \frac{P_t}{P_{t+1}}\right) = 1 \tag{3.49}$$

3.A.2 Firms

- Tradable goods firms - analogous in both home and foreign:

  Home prices:

$$P_{H,t} = [\theta(P_{H,t-1})^{1-\xi} + (1-\theta)(P^0_{H,t})^{1-\xi}]^{\frac{1}{1-\xi}} \tag{3.50}$$

  Export prices:

$$P^*_{H,t} = [\theta(P^*_{H,t-1})^{1-\xi} + (1-\theta)(P^{0*}_{H,t})^{1-\xi}]^{\frac{1}{1-\xi}} \tag{3.51}$$

- Non-tradable goods firms:

$$W_t = P_{N,t}C_{N,t} \tag{3.52}$$

  where wages are given by:

$$\frac{W_t}{P_{H,t} = (1+\frac{1}{\eta_t - 1}) * C_t^{\sigma} N \frac{P_{F,t}}{P_{H,t}}^{(}1 - v/2)} \tag{3.53}$$

3.A.3 Market Clearing

- Goods market clearing for tradable goods:

$$Y_t = C_{H,t} + C^*_{H,t} = \frac{v}{2}\frac{P_t C_t}{P_{H,t}} + (1-\frac{v}{2})\frac{P^*_t C^*_t}{P^*_{H,t}} \tag{3.54}$$

$$Y^*_t = C_{F,t} + C^*_{F,t} = (1-\frac{v}{2})\frac{P_t C_t}{P_{F,t}} + \frac{v}{2}\frac{P^*_t C^*_t}{P^*_{F,t}} \tag{3.55}$$

- Goods market clearing for non-tradable goods:

$$Y_{N,t} = C_{N,t} + \eta C_{H,t} + \eta C_{F,t} \tag{3.56}$$

The model is closed with a rule for monetary policy (Taylor Rule).

4

Forecasting Nominal Exchange Rates Using The Distribution Margin Real Exchange Rate

Abstract

This paper uses a subcomponent of the real exchange rate decomposition, the distribution margin real exchange rate, to forecast nominal exchange rates. The results show that forecast performance can be improved by using the distribution margin real exchange rate, especially at longer horizons. The results are robust to different specifications, such as using the distribution real exchange rate as a single predictor and in a wider Taylor rule framework. The distribution real exchange rate, however, only improves forecast performance at the one-quarter ahead horizon a little, a conclusion in line with the existing literature that macro fundamental predictors aid forecasting performance mainly at longer horizons.

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4.1 Introduction

The question of whether macroeconomic fundamentals are useful for forecasting nominal exchange rates changes has received significant attention in the literature. Broadly speaking, two questions have been considered: over what horizon can macroeconomic fundamentals aid forecasting of nominal exchange rates, and what economic fundamentals are most useful for this task. This paper contributes to both of these questions by proposing the distribution real exchange rate, which the first paper has shown to be a significant factor in the overall real exchange rate, as a new macroeconomic fundamental, thereby having implications for our understanding of the drivers of nominal exchange rates.

Previous empirical work has found that economic fundamentals hold little information for forecasting nominal exchange rates at short horizons. However, at longer horizons economic fundamentals can statistically significantly improve forecasting performance. In a seminal paper, Engel et al. (2007) reviews the literature and shows that at long horizons, both economics fundamentals based on purchasing power parity, as well as those based on augmented Taylor rules can help forecasting performance sixteen quarters ahead. Moreover, Engel shows that using panel models yields stronger results than using single equation forecasts, likely because information is used more efficiently in a panel setting.

In a critique of Engel's work, Rogoff (2008) argues that the real challenge lies in forecasting nominal exchange rate at shorter horizons (e.g. one month to one year ahead), and not at longer horizons. Moreover, Rogoff highlights the issue of coefficient instability across samples. He therefore proposes that the baseline model, against which results are compared, should be a simple random walk model, arguing that the parameter instability affecting structural models also impacts the random walk with drift model.

The overarching question runs deeper though: is it even theoretically possible to outperform a random walk model at any horizon? As Engel and West (2005) show, under fairly straightforward assumptions changes in the nominal exchange rate should approximately follow a random walk, and therefore rejecting the random

walk hypothesis is difficult given that most datasets available have limited history.[1] Engel et al. (2007) also provide another example based on the work of Dornbusch (1976), showing that while the predictability of exchange rates should improve at longer horizons, it peaks after about six quarters before falling again. The odds when trying to predict nominal exchange rate changes therefore appear to be stacked against the researcher.

Having said that, the results of Engel et al. (2007) also provide a glimmer of hope: nominal exchange rates changes should become more predictable, the stronger the relationship between the economic fundamental and the nominal exchange rate change. This paper therefore utilises previously used forecasting methodologies but tests the forecast performance of a new predictor: the distribution real exchange rate based on my previous work and the work of Bache et al. (2013). A large share of the variance of the real exchange rate can be attributed to the distribution real exchange, which measures a mix of relative profit margins across two economies and the relative costs of getting traded goods from the dock to the consumer.

The rationale for utilising the distribution real exchange rate is simple: a shock to a country's profit margins affects the distribution real exchange rate but should also affect that country's monetary policy (Corsetti and Pesenti (2005)). Since a large body of literature has shown that interest rate differentials, proxied for by so-called "Taylor-Rule" fundamentals, can aid nominal exchange rate forecast performance, any factor that gives a steer on future monetary policy ought to therefore also help predict nominal exchange rate changes. Given that the distribution real exchange rate is a subcomponent of the overall real exchange rate, it might be that using the distribution real exchange rate directly can provide a cleaner measure of open-economy monetary policy considerations than that overall real exchange rate. Nominal exchange rate forecast performance could therefore be improved.

This paper makes therefore three key contributions to the literature: first, the results show that focusing on the distribution real exchange rate, rather

[1] I review a simplified version of this result in the section 4.2.

than the overall real exchange rate as an economic fundamental, can improve forecast performance.

Second, this improvement in forecast performance is across all horizons considered, from two quarters to sixteen quarter ahead, though most of the improvement is at long horizons. This, to some extent, therefore addresses Rogoff's criticism that the real challenge lies in forecasting nominal exchange rates up to one year ahead.

Third, by replicating Engel's analysis as a baseline and then changing the sample to match the sample over which data for the distribution real exchange rate exists, the results illustrate Rogoff's argument of coefficient instability across samples. In fact, Engel's methodology performs worse in the more recent sample considered in this paper, thereby suggesting that economic fundamentals were a better predictor since 2000 than they were in earlier samples. Despite this higher bar, the distribution real exchange rate provides an improved forecast performance, both relative to the updated Engel results, and the original results over 1973-2005.

The remainder of this paper is structured as follows: section 4.2 explores the existing literature in more depth. Section 4.3 discusses the empirical set-up and data. Section 4.4 shows that the results are robust to different specifications, while section 4.5 concludes.

4.2 Related Literature

The starting point of the current debate on forecast performance of models based on economic fundamentals was arguably started by Meese and Rogoff (1983) and Meese et al. (1983), where the authors showed that some part of long-term nominal exchange rate movements can be explained by economic fundamentals. More than twenty years later, Sarno et al. (2003) state, "Overall, the conclusion emerges that, although the theory of exchange rate determination has produced a number of plausible models, empirical work on exchange rates still has not produced models that are sufficiently satisfactory to be considered reliable and robust. In particular, although empirical exchange rate models occasionally generate apparently satisfactory explanatory power in-sample, they generally fail badly in out-of-sample

forecasting tests in the sense that they fail to outperform random walk." This raises three questions: first, what is the appropriate benchmark model, i.e. is it a random walk with drift? Second, can economically founded models outperform the alternative of a random walk out of sample, and third, how should forecast performance be assessed.

Starting with the appropriate benchmark model, this paper takes the work of Engel et al. (2007) and Engel and West (2005) as the starting point. These papers show that the exchange rate should almost follow a random walk, and that it might be difficult to successfully beat the random walk hypothesis with datasets typically available to open-economy researchers. Starting with a model that relates economic fundamentals, the nominal exchange rate, and the expected future nominal exchange rate:

$$s_t = (1-\beta)x_t + \beta E_t s_{t+1} \tag{4.1}$$

where $0 < b < 1$. This is a general form, used in many types of economic fundamentals forecasting regressions (Engel et al. (2007)). To illustrate a reduced version of the theorem in Engel and West (2005), assume that x_t is integrated of order one:

$$x_t - x_{t-1} = \theta(x_{t-1} - x_{t-2}) + \epsilon_t$$

where $\epsilon \sim i.i.d.$ Computing the no-bubbles forward solution of the expectational difference equation in 4.1 yields:

$$s_t - s_{t-1} = \frac{(1-\beta)\theta}{1-\beta\theta}(x_{t-1} - x_{t-2}) + \frac{1}{1-\beta\theta}\epsilon_t$$

If β, the discount factor, becomes sufficiently large, or close to one, then the change in the nominal exchange rate approximately follows a random walk. Given the power of statistical tests available, a researcher might therefore not be able to distinguish between a random walk and the competing model with economic fundamentals. Two conclusions emerge from this: first, one should try to maximise the sample size available, thereby justifying the use of panel methods to forecast

nominal exchange rate changes in this paper. Second, given that the theory predicts that a random walk might be difficult to reject given the available data, a random walk is a good baseline specification.

Turning to the second question whether models with economic fundamentals can actually outperform a random walk model, a growing body of literature has shown that in particular Taylor rule type fundamentals can aid the fit of exchange rate models. An important channel here is the change in expectations. Engel and West (2006) for example express an interest rate rule in terms of the present value of inflation and output gap differentials. They then go on to show that this can explain some of the behaviour of the Deutschmark-Dollar real exchange rate. Again using Deutschmark data, Mark (2009) uses a learning model in conjunction with a Taylor rule to show that his model can capture the volatility and major swings in the real exchange rate of Germany and the US in a sample from 1976 to 2007. Molodtsova and Papell (2012) test the performance of several augmented Taylor rules in forecasting the Euro-Dollar exchange rate around the time of the financial crisis. They find that augmenting the Taylor rule with credit spreads or financial conditions improves the performance of the model, and all Taylor rule specifications outperform simpler specifications based on interest rate differentials, monetary and purchasing power parity models.

At very short-horizon forecast performance, Rogoff (2008) and Engel et al. (2007) argue that, perhaps ironically, some of the best successes of economic fundamentals are at very short horizons, in particular for Taylor rules. Clarida and Waldman (2008) and Faust et al. (2007) use high frequency data to estimate the impact of news shocks on exchange rates. The results from these studies are in line with the predictions of a Taylor rule framework. More broadly, however, economic fundamentals tend to not help much in forecasting exchange rate movements up to one year ahead, as highlighted by Rogoff (2008).

Turning to the final question of assessing forecast performance, Wang and Wu (2009) show that for a sample of twelve OECD economies, Taylor Rule fundamentals outperform the random walk hypothesis. They measure outperformance using

forecast intervals and demonstrate the Taylor rule fundamentals produce tighter forecast intervals than the random walk alternative. They conclude that "economic variables contain information useful in forecast the distributions of exchange rates". To keep the results in this paper comparable to the body of literature that evaluates specific fundamentals, such as the Taylor rule, this paper will focus on Theil's U statistic and the Clark West (Clark and West (2007)) test. The Clark West test is chosen because it corrects for the bias in favour of the random walk model when comparing forecast performance. Clark and West develop and adjustment to correct for this bias, though as Rogoff (2008) points out, this correction might be too big: there can be instances where the Clark West test concludes that there is a significant forecast performance improvement while Theil's U statistic is greater than one. To my knowledge there is currently no better test and this paper will therefore proceed by jointly taking into consideration the Clark West test and Theil's U statistic.

4.3 Methodology

We start by defining the distribution real exchange rate, the proposed signal to improve nominal exchange rate forecast performance. Bache et al. (2013) has shown that the real exchange rate can be decomposed into a real exchange rate based on tradable goods' prices, a real exchange rate based on the relative price of tradable and non-tradable goods, and a distribution real exchange rate, which is based on the relative mark-up charged in final consumer prices over at-the-dock prices.

$$rer_{i,j,t} = ner_{i,j,t}\frac{P_{j,t}}{P_{i,t}} = \underbrace{(ner_{i,j,t}\frac{\bar{P^T_{j,t}}}{\bar{P^T_{i,t}}})}_{rer^T_{i,j,t}}\underbrace{(\frac{P^T_{i,t}}{P_{i,t}}/\frac{P^T_{j,t}}{P_{j,t}})}_{rer^N_{i,j,t}}\underbrace{(\frac{P^T_{j,t}}{\bar{P^T_{j,t}}}/\frac{P^T_{i,t}}{\bar{P^T_{i,t}}})}_{rer^D_{i,j,t}}$$

Bache at al's and my previous work has shown that the distribution real exchange rate accounts for a large proportion of the variation in the overall real exchange rate. Given the motivation outlined earlier, the question therefore arises whether the distribution real exchange rate is also a good predictor of changes in the nominal exchange rate.

4.3.1 Empirical Set-Up

The empirical set-up is similar to that used in the empirical exchange rate forecasting literature, and in particular is based on equation 4.1. As in Engel et al. (2007), the baseline framework is:

$$s_{i,t+k} - s_{i,t} = \beta_k x_{i,t} + \epsilon_{i,t+k}$$

where $x_{i,t}$ is an economic fundamental. Based on the motivation for using the distribution real exchange rate as an additional predictor, it is most natural to employ Taylor rule fundamentals, which have also shown promising results in previous studies. The motivation for Taylor rule fundamentals is as followed: uncovered interest parity stipulates that the expected change in the exchange rate is equal to the interest rate differential, or:

$$E_t s_{i,t+1} = i_{0,t} - i_{i,t} + s_{i,t} \tag{4.2}$$

Next we stipulate that the monetary policy rule in a country is given by equation 4.3 as in Engel et al. (2007).

$$i_t = \alpha_q q_t + \alpha_\pi E_t \pi_{t+1} + \alpha_y y_t + \mu_t \tag{4.3}$$

The central bank reacts to the output gap (y_t), expected inflation deviation from target ($E_t \pi_{t+1}$), and the deviation of the real exchange rate from purchasing power parity (q_t). The real exchange rate term is included for all economies but the US (the "foreign" country in this study) based on evidence by Clarida et al. (1998) that some central banks tend to raise policy rates in response to a currency depreciation.

Combining equations 4.2 and 4.3, assuming the same policy coefficients across countries, and calibrating the model as in Engel et al. (2007) yields our fundamental forecasting framework in equation 4.4.

$$x_{i,t} \equiv 1.5(\pi_{i,t} - \pi_{0,t}) + 0.1(y^s_{i,t} - y^s_{0,t}) + 0.1(rer_{i,0,t}) + s_{i,t} \tag{4.4}$$

Here i refers to a country, and 0 is the US as the baseline economy. Molodtsova and Papell (2012) and Engel et al. (2007) find that such a Taylor rule model is able to forecast nominal exchange rates well at short and long horizons, but the evidence for other fundamental forecasting rules such as PPP and or monetary differential models is mixed.

The methodology follows Engel et al. (2007) in calibrating, rather than estimating, the parameters of the Taylor rules. The coefficient on the output gap is slightly smaller than typically found, on the ground that, as Engel et al argue, many of the countries in the sample have announced pure inflation targeting regimes.

We start by pitting three models in a horserace against each other. As the baseline model we use the specification of Engel et al. (2007) with the overall real exchange rate:

$$rer_{i,0,t} = s_{i,t} + p_{i,t} - p_{0,t}$$

where $p_{i,t}$ is country i's CPI.

In the first competitor model, the real exchange rate is not measured by the CPI-based real exchange rate but instead by the distribution real exchange rate:

$$rer_{i,0,t} \equiv rer^{D}_{i,0,t} = (p^{T}_{j,t} - \bar{p^{T}_{j,t}}) - (p^{T}_{i,t} - \bar{p^{T}_{i,t}})$$

In the following results, this model will be referred to as the "Naive" model, as it simply replaces the real exchange rate based on consumer prices with the distribution real exchange rate.

A concern with these specifications is that there is endogeneity bias. The real exchange rate is correlated with the interest rate differential and the current nominal exchange rate. To correct for this, in the second competitor model, we instrument for the real exchange using the distribution real exchange rate, and use the resulting instrumented output in the Taylor Rule fundamentals:

$$rer_{i,0,t} \equiv \hat{rer}_{i,0,t} = \hat{\beta}_0 + \hat{\beta}_1 rer^{D}_{i,0,t}$$

The distribution real exchange rate is caused by different transport costs and firms' pricing power in different markets, and therefore should be unrelated to the interest rate differential. Furthermore, the impact on the nominal exchange rate should only come through the distribution real exchange rate's effect on the overall real exchange rate, therefore satisfying both the relevance and exogeneity criteria of an instrumental variable.

To construct forecasts, the model is re-estimated using quasi-real time data at each point in time with the sample covering 1999Q1 to 2016Q4. The forecast is evaluated and the model re-estimated each quarter from 2006Q1 to 2016Q4, and forecasts are evaluated up to sixteen quarters ahead. The out of sample forecast performance is judged in two ways: first through Theil's U-statistic, the ratio of the root-mean-squared prediction error of the model to the benchmark model, a driftless random walk. A U-statistic less than one therefore indicates a relative forecast improvement. Second, forecast performance is measured using the t-statistic from the Clark and West procedure (Clark and West (2007)). Under the null, both (nested) models have equal predictive ability, and a test statistic in excess of 1.282 rejects this hypothesis at the ten percent level using a one-sided test.

The data for the distribution real exchange rate is the same as in previous chapters of this thesis. The sample covers fourteen countries: Australia, Austria, Belgium, Canada, Denmark, Spain, France, Ireland, Italy, Japan, Germany, New Zealand, the United Kingdom, and the US. The data is quarterly and covers the period 1999Q1 until 2016Q4, driven by data availability limitations.

For inflation, in the first step this paper uses headline CPI inflation for all countries, though a robustness check with core inflation is performed in section 4.4. The output gap is computed using a Hodrick-Prescott filter, with a lambda of 1600, as suggested for quarterly data, as in Engel et al. (2007). Section 4.4 replaces this measure of the output gap with a bandwidth filter as a robustness check.

4.3.2 Baseline Results

Table 4.1 shows the results of this horserace for one-quarter and sixteen-quarters ahead.

	Baseline		Naive		2SLS	
	u(1)	u(16)	u(1)	u(16)	u(1)	u(16)
Denmark	1.020	**0.792**	1.058	**0.497**	1.064	**0.449**
Spain	1.009	**0.707**	1.065	**0.491**	1.074	**0.450**
Austria	1.016	**0.778**	1.068	**0.500**	1.074	**0.445**
Germany	1.006	**0.727**	1.066	**0.494**	1.075	**0.450**
Australia	**0.936**	**0.645**	**0.951**	**0.426**	**0.954**	**0.395**
Canada	1.013	**0.635**	1.107	**0.439**	1.126	**0.404**
Japan	1.043	**0.434**	1.103	**0.276**	1.113	**0.251**
France	1.006	**0.709**	1.064	**0.486**	1.075	**0.453**
Italy	1.010	**0.745**	1.064	**0.488**	1.075	**0.452**
United Kingdom	**0.899**	**0.902**	**0.860**	**0.636**	**0.856**	**0.651**
New Zealand	**0.858**	**0.510**	**0.834**	**0.369**	**0.831**	**0.352**
Average	**0.983**	**0.689**	1.022	**0.464**	1.029	**0.432**
Median	1.008	**0.708**	1.064	**0.487**	1.074	**0.447**

The "u(1)" and "u(16)" columns report Theil U-statistics, relative to the baseline random walk with drift. Values less than one are highlighted in bold face.

Table 4.1: Theil's U-statistic across different specifications

Starting with the Baseline model, which uses the original specification in Engel et al. (2007), we see that qualitatively the results are similar in this sample as in Engel's original work.[2] Specifically, the baseline model struggles to consistently outperform a random walk at short-horizons (one-quarter ahead), but forecast performance improves significantly sixteen-quarters ahead.

However, in this sample the baseline specification generally produces more favourable results than in Engel et al. (2007), suggesting that Taylor rule fundamentals have gotten better at forecasting real exchange rate developments in recent years. This provides additional evidence for the hypothesis of Rogoff (2008) of unstable coefficients across different samples, supporting the approach taken here that the reference model should be a random walk without drift.

[2]To cross-check the computation, I also replicate Engel's results over the original sample. The results of this exercise are shown in the appendix. There are some small discrepancies, likely caused by data revisions to GDP, but the results overall closely match those of Engel over the original sample.

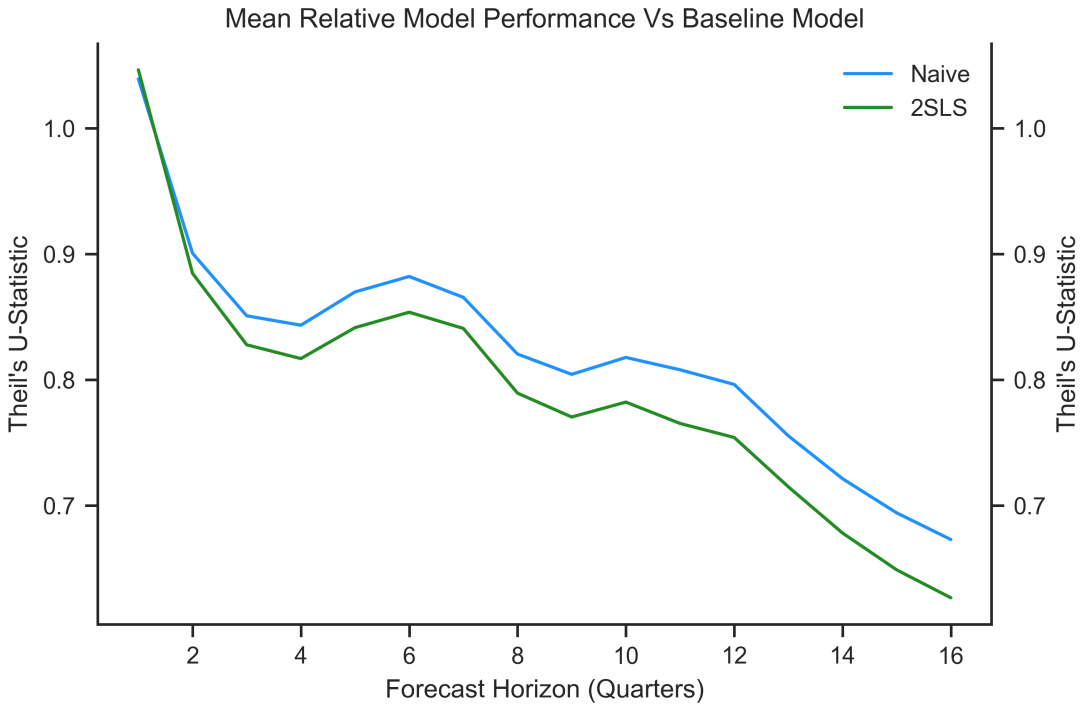


Figure 4.1: Relative RMSPE Across Specifications

Forecast performance in particular at longer horizons improves in the Naive model relative to the Baseline model. However, the forecast improvement is not just limited to long horizons. Figure 4.1 shows Theil's U-statistic across all horizons. The Naive model outperforms the baseline regression at all horizons from two quarters ahead onwards. The difficulty in forecasting nominal exchange rates at very short horizons still persists, but the evidence presented here suggests that using the distribution margin can improve forecast performance even at the one-year horizon, a challenge Rogoff argued remained unsolved (Rogoff (2008)).

Instrumenting for the real exchange rate to overcome any potential endogeneity issues present, produces similar results to the Naive approach, when judging forecast performance using Theil's U-statistic. However, table 4.2 shows the Clark-West test statistics of the various models. When judging the forecast performance using this metric, the instrumented model performs better at long horizons across countries than the naive version.

	Baseline		Naive		2SLS	
	cw(1)	cw(16)	cw(1)	cw(16)	cw(1)	cw(16)
Denmark	0.084	-1.370	0.099	-1.273	-0.145	**2.640****
Spain	0.084	-1.277	0.094	-1.696	-0.145	-0.457
Austria	0.084	-1.389	0.097	-1.307	-0.146	**2.879****
Germany	0.084	-1.279	0.092	-1.613	-0.147	**2.127****
Australia	0.084	**1.437***	0.103	**1.733****	0.147	**1.545***
Canada	0.084	1.231	0.103	0.936	-0.146	**1.989****
Japan	0.084	**1.437***	0.103	**1.498***	0.147	1.244
France	0.084	-1.086	0.095	-1.595	-0.147	-1.880
Italy	0.084	-1.364	0.098	-1.554	-0.146	0.081
United Kingdom	0.084	**1.419***	0.103	**1.656****	0.106	**1.507***
New Zealand	0.084	**1.449***	0.103	**1.783****	-0.146	**1.767****

The "cw(1)" and "cw(16)" columns report the Clark West test statistic (Clark and West (2007)). A test statistic in excess of 1.282 rejects the null hypothesis that both models have equal predictive power at the ten percent level using a one-sided test. A test statistic in excess of 1.645 rejects the null hypothesis that both models have equal predictive power at the five percent level using a one-sided test. Statistically significant values are highlighted in bold face and denoted with * if they are statistically significant at the ten percent level, and with ** if they are statistically significant at the five percent level.

Table 4.2: Clark West test statistics across different specifications.

4.4 Robustness Tests

This section explores the sensitivity of the results to a number of key inputs. First, the inflation measure is changed to core inflation rather than headline inflation. Headline inflation can be very volatile on account of commodity prices, while core inflation strips out these effects. It could be that too much of the forecast improvement is attributed to the distribution real exchange rate, simply because the Baseline model produces too noisy a signal.

Second, the measure of the output gap is varied from a Hodrick-Prescott filter to the band pass filter, developed by Christiano and Fitzgerald (2003). As Nilsson and Gyomai (2011) show, the band pass filter outperforms the Hodrick-Prescott filter in terms of absolute numerical precision, though it has weaker turning point signal stability.

Third, to abstract from other macro-covariates, the distribution real exchange rate is used as a pure "Purchasing Power Parity" fundamental, as proposed by Engel to test the forecast performance on its own relative to a consumer price based

real exchange rate. This is a similar cross-check as the one used in Molodtsova and Papell (2012).

4.4.1 Varying the Inflation Measure

We use data from the OECD on core inflation across countries to gauge the sensitivity of our results to the specific inflation measure used. We choose core inflation, as opposed to, for example, the GDP deflator, because measures of core inflation strip out most of the volatility related to energy and food prices. As one would expect that volatility in energy and food prices is driven mainly by global factors, measures of core inflation ought to be a better gauge of domestically generated inflation.

Another reason for using core inflation rather than headline inflation is linked to the empirical set-up: the economic reasoning behind the framework is that the Taylor rule provides a proxy for (future) interest rate differentials. Many central banks around the world, and in particular in our sample (e.g. the Federal Reserve, ECB, Bank of England) place more weight on core inflation than on headline inflation when making monetary policy decisions. The reason for this is that a temporary oil prices shock, could, for example, push up headline inflation but leave core inflation largely unchanged. The Taylor Rule framework based on headline inflation would therefore predict a larger interest rate differential, though typically central banks tend to look through these temporary disturbances and not alter the monetary stance. A Taylor rule based on core inflation would predict just that, and therefore, using core inflation in our framework should improve the forecast results.

	Baseline		Naive		2SLS	
	u(1)	u(16)	u(1)	u(16)	u(1)	u(16)
Denmark	1.045	**0.558**	1.063	**0.459**	1.064	**0.436**
Spain	1.045	**0.515**	1.072	**0.454**	1.075	**0.441**
Austria	1.050	**0.565**	1.073	**0.462**	1.074	**0.434**
Germany	1.047	**0.518**	1.073	**0.457**	1.075	**0.437**
Australia	**0.951**	**0.465**	**0.952**	**0.395**	**0.952**	**0.382**
Canada	1.080	**0.481**	1.122	**0.407**	1.129	**0.390**
Japan	1.081	**0.299**	1.113	**0.250**	1.119	**0.239**
France	1.046	**0.512**	1.072	**0.452**	1.075	**0.440**
Italy	1.049	**0.537**	1.072	**0.454**	1.075	**0.439**
United Kingdom	**0.874**	**0.702**	**0.854**	**0.623**	**0.850**	**0.621**
New Zealand	**0.844**	**0.408**	**0.828**	**0.348**	**0.825**	**0.336**
Average	1.010	**0.505**	1.027	**0.433**	1.028	**0.418**
Median	1.046	**0.514**	1.072	**0.453**	1.074	**0.435**

The "u(1)" and "u(16)" columns report Theil U-statistics, relative to the baseline random walk with drift. Values less than one are highlighted in bold face.

Table 4.3: Theil's U-Statistic Across Different Forecast Specifications Using Core Inflation

Table 4.3 repeats the same analysis as before. The Baseline model is based on equation 4.4, but replaces the inflation measure with core inflation rather than headline inflation. Specifically, this version forecasts nominal exchange rate changes based on the economic fundamental:

$$x_{i,t} \equiv 1.5(\pi_{i,t}^{core} - \pi_{0,t}^{core}) + 0.1(y_{i,t}^{s} - y_{0,t}^{s}) + 0.1(rer_{i,0,t}) + s_{i,t}$$

As in the main analysis, the Naive specification includes the distribution real exchange $rer_{i,0,t}^{D}$ rate rather than the CPI-based real exchange rate $rer_{i,0,t}$, while the 2SLS version instruments for the CPI-based real exchange rate with the distribution real exchange rate.

The results are broadly as expected: using core inflation rather than headline inflation improves the forecast performance at long-horizons, particularly sharply in the baseline model. While the forecast improvement from the distribution real exchange rate is now more limited, the improvement is most marked when considering Theil's U-statistic, but is also clearly visible in the Clark-West test results in table 4.7 in the appendix. Moreover, the instrumental variable model

appears to be doing best. At the short-horizon, the model based on core inflation does not outperform the model based on headline inflation.

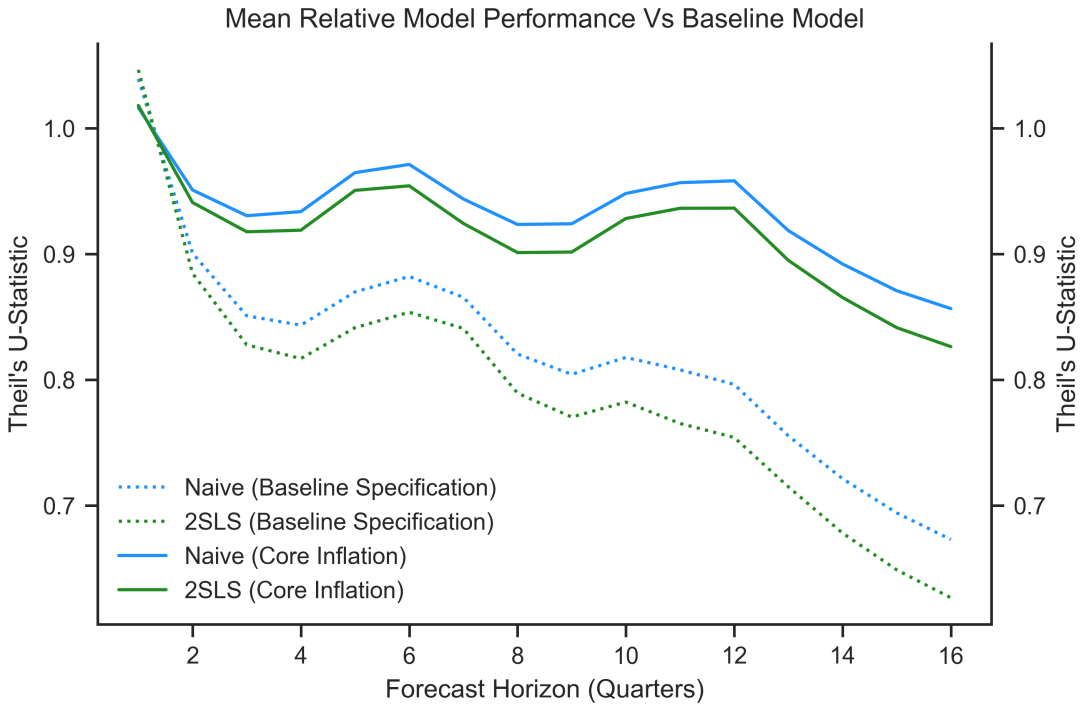


Figure 4.2: Relative RMSPE Across Specifications

Based on this analysis, three conclusions emerge: first, the qualitative result remains that using the distribution real exchange rate aides the forecast performance of the model relative to the consumer prices based real exchange rate. Second, the model's forecast performance improves sharply with core inflation. Third, the results continue to support the literature's finding that interest rate differentials are not statistically significant predictors of short-run exchange rate movements.

4.4.2 Varying the Output Gap Measure

As a second robustness test I turn to the measure of the output gap. While it would be ideal to use an output gap generated by a structural model, the options for this are limited by data availability. The OECD's output gap measure, for example, is only available at an annual frequency, while the measure developed by Holston et al. (2017) has a limited cross-sectional dimension. I therefore turn to another statistical measure, the band pass filter. Given that Nilsson and Gyomai (2011) have found

that the trade-off between the two filters is one of precision versus turning point stability, ex ante it is difficult to say which predictor should perform better.

	Baseline		Naive		2SLS	
	u(1)	u(16)	u(1)	u(16)	u(1)	u(16)
Denmark	1.044	**0.580**	1.062	**0.460**	1.065	**0.437**
Spain	1.042	**0.543**	1.071	**0.457**	1.076	**0.439**
Austria	1.046	**0.575**	1.072	**0.462**	1.076	**0.436**
Germany	1.041	**0.555**	1.072	**0.459**	1.076	**0.438**
Australia	**0.944**	**0.486**	**0.951**	**0.397**	**0.953**	**0.383**
Canada	1.072	**0.490**	1.120	**0.408**	1.130	**0.391**
Japan	1.082	**0.315**	1.114	**0.251**	1.119	**0.239**
France	1.042	**0.547**	1.071	**0.455**	1.076	**0.440**
Italy	1.044	**0.561**	1.071	**0.456**	1.076	**0.439**
United Kingdom	**0.872**	**0.748**	**0.853**	**0.624**	**0.851**	**0.630**
New Zealand	**0.840**	**0.410**	**0.827**	**0.347**	**0.825**	**0.339**
Average	1.006	**0.528**	1.026	**0.434**	1.029	**0.419**
Median	1.042	**0.545**	1.071	**0.456**	1.076	**0.437**

The "u(1)" and "u(16)" columns report Theil U-statistics, relative to the baseline random walk with drift. Values less than one are highlighted in bold face.

Table 4.4: Theil's U-Statistic Across Different Forecast Specifications Using The Band Pass Filter

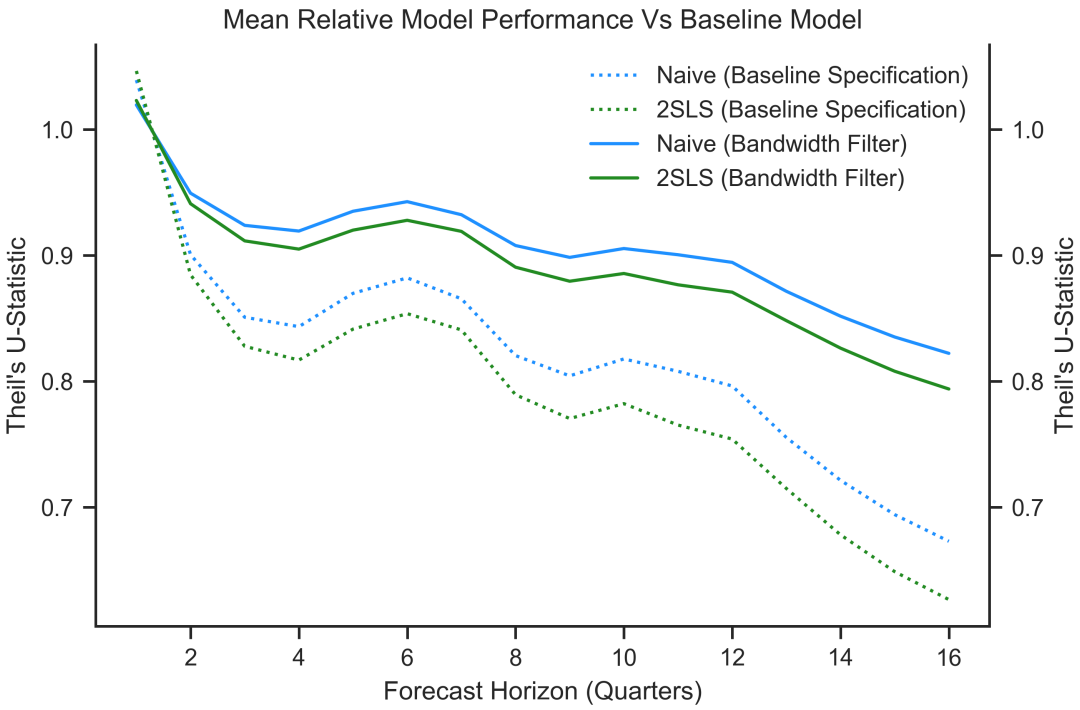


Figure 4.3: Relative RMSPE Across Specifications

As in the previous section, table 4.4 repeats the main analyis for the three models considered, while table 4.8 in the appendix presents the Clark West test statistic for this exercise. Three conclusions emerge: first, as before, qualitatively the results still hold that utilising the distribution real exchange rate improves forecast performance. Second, based on Theil's U-statistic the improvement from using the band pass filter output gap is broadly similar to that when switching the inflation measure to core inflation. However, third, this forecast improvement is not reflected in the test results based on the Clark-West test. This is an anomaly that Rogoff (2008) also points out: because the Clark-West test adjusts for a bias in the competitor model, it can, at times, give unintuitive results, where the conclusions based on U-statistics and the Clark-West test differ. Rogoff (2008) argues that this might be because the adjustment in the Clark-West test is too large, though more work is needed to verify this. In any case, the results presented here based on the two competing statistics are inconclusive in terms of which model is the single best one for forecasting changes in the nominal exchange rate.

4.4.3 Varying the Economic Fundamentals

As a final robustness check, we abstract from the relative output gap and inflation rates as predictors, and instead focus on whether the distribution real exchange rate on its own can aid forecast performance. Engel et al. (2007) proposed "Purchasing Power Parity" fundamentals, by changing the fundamental predictor to:

$$x_{i,t} = (p^T_{j,t} - \bar{p^T_{j,t}}) - (p^T_{i,t} - \bar{p^T_{i,t}}) - s_{i,t}$$

Using this specification to account for the distribution real exchange rate, we can use the following forecasting model:

$$s_{i,t+k} - s_{i,t} = \beta_k(rer^D_{i,t} - s_{i,t}) + \epsilon_{i,t+k}$$

Table 4.5 shows the results of this specification. We again see that real exchange rate fundamentals appear to be better at forecasting nominal exchange rate changes in our newer sample than in the older sample of Engel et al. (2007). The results also

indicate that the distribution real exchange rate is a better predictor of nominal exchange rate changes than the overall real exchange rate at long horizons. At short horizons, the real exchange rate performs somewhat better as a predictor than the distribution real exchange rate based on Theil's U-statistic. This improvement is not, however, statistically significant as the Clark-West test shown in table 4.9 in the appendix cannot reject the null hypothesis of equal forecast performance.

	RER Baseline		RER^D	
	u(1)	u(16)	u(1)	u(16)
Denmark	**0.907**	**0.735**	**0.983**	**0.529**
Spain	**0.898**	**0.675**	**0.986**	**0.478**
Austria	**0.908**	**0.756**	**0.980**	**0.491**
Germany	**0.914**	**0.868**	**0.984**	**0.494**
Australia	**0.920**	**0.706**	**0.929**	**0.539**
Canada	**0.927**	**0.624**	1.024	**0.470**
Japan	**0.937**	**0.686**	1.061	**0.331**
France	**0.914**	**0.868**	**0.999**	**0.608**
Italy	**0.908**	**0.767**	**0.996**	**0.629**
United Kingdom	**0.961**	**0.800**	**0.898**	**0.747**
New Zealand	**0.932**	**0.607**	**0.868**	**0.459**
Average	**0.921**	**0.736**	**0.973**	**0.525**
Median	**0.917**	**0.735**	**0.983**	**0.510**

The "u(1)" and "u(16)" columns report Theil U-statistics, relative to the baseline random walk with drift. Values less than one are highlighted in bold face.

Table 4.5: Theil's U-Statistic Across Different Forecast Specifications With PPP-Fundamentals

While, looking across models, the forecast performance of this specification is worse than that of specifications using Taylor rule fundamentals, this exercise is nonetheless a good cross check because it shows that the distribution real exchange rate by itself is a helpful predictor for the nominal exchange rate. The fact that a Taylor Rule framework that incorporates this new predictor performs better than the distribution real exchange rate on its own is not surprising. The results are in fact in line with the literature's results that a Taylor Rule framework based on interest rate differentials is the best forecasting method for exchange rate movements at long horizons.

4.5 Conclusion

This paper analyses the predictive power of the distribution real exchange rate for changes in the nominal exchange rate. Three main conclusions emerge: first, a model that includes the distribution real exchange rate outperforms both a driftless random walk and also the higher bar of competing models that are based on the consumer prices based real exchange rate. The analysis shows that this result is robust to different formulations, both across different macro fundamentals and when just using the distribution real exchange rate as a sole predictor.

Second, the robustness analysis suggests that a Taylor Rule framework using core inflation paired with the distribution real exchange rate yields the most promising results. The exact specification of the output gap remains unclear, and more work is needed to solve this.

Third, there is tentative evidence that in more recent samples, macro fundamentals, including the distribution real exchange rate, have been better predictors of nominal exchange rate movements. While this speaks to the critique of coefficient instability, a possible explanation could be that more central banks have turned towards inflation targeting than is the case in earlier samples, that cover, for example, the 1980s and 1990s.

The analysis also raises questions for future work: first, given the empirical importance of the distribution real exchange rate for both the variation in the consumer price-based real exchange (e.g. my previous work and Bache et al. (2013)), more work is needed to explicitly incorporate this into theoretical open economy models. This could provide a further theoretical basis for the results presented here. Second, more work is needed to understand the drivers and determinants of the distribution wedge. Previous work has shown the distribution real exchange rate can be decomposed further into logistics costs and relative profit margins, though testing which one of these is the "true" driver of nominal exchange rates is impossible at this point because of data limitations. Early tentative evidence from my previous work, however, suggests that it is indeed relative profit margins that drive this relationship. Finally, there appears to be a need for a definitive statistical

test of forecast performance. The results in this paper are not unique in that Theil's U-statistic and the Clark West test provide conflicting signals, something that needs to be addressed as Rogoff (2008) also points out.

Overall, it appears though as if further research into the distribution real exchange rate is a promising avenue for future work.

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4.A Replication of Engel et al. (2007) Analysis

These tables replicate the analysis in Engel et al. (2007) with Taylor rule fundamentals with the different sample used in this study. The results are broadly in line with those reported in the paper, though some small discrepancies remain, which are likely caused by revisions to GDP data.

	Baseline			
	u(1)	u(16)	cw(1)	cw(16)
Australia	**0.989**	1.208	0.117	**1.915****
Austria	**0.986**	**0.942**	0.117	**1.950****
Belgium	**0.990**	1.131	0.117	-1.983
Canada	**0.979**	1.027	0.117	**1.482***
Denmark	**0.994**	1.195	0.116	-1.925
Finland	**0.990**	1.075	0.117	-0.901
France	**0.997**	1.315	0.116	-2.055
Germany	**0.986**	**0.970**	0.117	**1.782****
Greece	**0.923**	**0.816**	0.117	**2.272****
Italy	1.002	1.327	0.116	-0.793
Japan	**0.974**	**0.818**	0.117	**2.135****
Korea, Rep. of	**0.989**	1.081	0.116	**1.613***
Netherlands, The	**0.987**	1.003	0.117	0.615
Norway	**0.988**	1.121	0.117	-0.491
Spain	1.008	1.389	0.116	-1.336
Sweden	**0.987**	1.190	0.117	-0.237
Switzerland	**0.988**	**0.888**	0.116	**2.114****
United Kingdom	**0.988**	1.225	0.117	-1.835
Average	**0.986**	1.096	-	-
Median	**0.988**	1.096	-	-

See notes to tables 4.1 and 4.2.

Table 4.6: Replication of Engel et al. (2007) analysis.

4.B Clark West Test Statistics for Robustness Tests

This section reports the Clark West test statistics for the results shown in the paper where those are not reported in the main text.

4.B.1 Varying the Inflation Measure

These are the Clark West test statistics accompanying section 4.4.1.

	Baseline		Naive		2SLS	
	cw(1)	cw(16)	cw(1)	cw(16)	cw(1)	cw(16)
Denmark	0.246	-1.351	0.079	-3.310	0.262	**2.229****
Spain	0.264	**2.849****	0.236	-1.964	-0.139	-1.316
Austria	0.255	-2.043	0.071	-3.546	0.257	**2.738****
Germany	0.262	**1.730****	0.138	-3.279	0.184	**1.388***
Australia	0.259	**2.005****	0.253	**1.924****	0.265	**1.692****
Canada	0.264	**1.305***	0.261	-0.061	-0.216	**2.268****
Japan	0.262	**3.497****	0.263	1.094	0.264	**1.809****
France	0.263	**2.508****	0.233	-0.475	-0.222	-2.369
Italy	0.258	-0.076	0.187	-2.351	0.128	-0.062
United Kingdom	0.261	**1.865****	0.261	**1.602***	0.260	**1.500***
New Zealand	0.264	**2.158****	0.262	**2.236****	-0.099	**2.630****

The "cw(1)" and "cw(16)" columns report the Clark West test statistic (Clark and West (2007)). A test statistic in excess of 1.282 rejects the null hypothesis that both models have equal predictive power at the ten percent level using a one-sided test. A test statistic in excess of 1.645 rejects the null hypothesis that both models have equal predictive power at the five percent level using a one-sided test. Statistically significant values are highlighted in bold face and denoted with * if they are statistically significant at the ten percent level, and with ** if they are statistically significant at the five percent level.

Table 4.7: Clark West test statistics for the specification varying the inflation measure.

4.B.2 Varying the Output Gap Measure

These are the Clark West test statistics accompanying section 4.4.2.

	Baseline		Naive		2SLS	
	cw(1)	cw(16)	cw(1)	cw(16)	cw(1)	cw(16)
Denmark	0.258	-2.279	0.235	-3.372	-0.256	**2.367****
Spain	0.265	-0.551	0.250	-2.657	-0.252	0.213
Austria	0.262	-3.134	0.234	-4.101	-0.260	**3.510****
Germany	0.264	-0.717	0.250	-3.274	-0.262	**1.489***
Australia	0.264	**2.038****	0.264	**2.010****	0.206	0.550
Canada	0.264	1.167	0.262	0.115	-0.254	0.733
Japan	0.261	**2.877****	0.261	1.139	0.261	0.332
France	0.264	-0.114	0.258	-1.098	-0.262	-1.003
Italy	0.263	-1.389	0.258	-1.742	-0.260	-0.062
United Kingdom	0.258	**1.815****	0.259	**1.806****	-0.189	0.759
New Zealand	0.263	**2.260****	0.261	**2.291****	-0.254	0.430

The "cw(1)" and "cw(16)" columns report the Clark West test statistic (Clark and West (2007)). A test statistic in excess of 1.282 rejects the null hypothesis that both models have equal predictive power at the ten percent level using a one-sided test. A test statistic in excess of 1.645 rejects the null hypothesis that both models have equal predictive power at the five percent level using a one-sided test. Statistically significant values are highlighted in bold face and denoted with * if they are statistically significant at the ten percent level, and with ** if they are statistically significant at the five percent level.

Table 4.8: Clark West test statistics for the specification varying the output gap measure.

Varying the Economic Fundamentals

These are the Clark West test statistics accompanying section 4.4.3.

	RER Baseline		RER^D	
	cw(1)	cw(16)	cw(1)	cw(16)
Denmark	0.076	-0.461	0.095	0.114
Spain	0.076	0.877	0.095	-0.243
Austria	0.076	-0.659	0.095	0.122
Germany	0.076	0.631	0.095	0.166
Australia	0.076	**1.298***	0.095	**1.634***
Canada	0.076	1.258	0.095	**1.430***
Japan	0.076	**1.302***	0.095	**1.599***
France	0.076	0.325	0.095	-1.025
Italy	0.076	-0.527	0.095	-0.974
United Kingdom	0.076	**1.289***	0.095	**1.598***
New Zealand	0.076	**1.299***	0.095	**1.651****

The "cw(1)" and "cw(16)" columns report the Clark West test statistic (Clark and West (2007)). A test statistic in excess of 1.282 rejects the null hypothesis that both models have equal predictive power at the ten percent level using a one-sided test. A test statistic in excess of 1.645 rejects the null hypothesis that both models have equal predictive power at the five percent level using a one-sided test. Statistically significant values are highlighted in bold face and denoted with * if they are statistically significant at the ten percent level, and with ** if they are statistically significant at the five percent level.

Table 4.9: Clark West test statistics for the specification using the distribution real exchange rate as a sole predictor.

5 Conclusion

This thesis highlights the importance of the distribution real exchange rate both for empirical questions relating to both real and nominal exchange rates, but also to modelling choices in the open-economy literature. It shows that the distribution real exchange rate is a key determinant for the overall real exchange rate, and that local currency pricing, both tradable and non-tradable goods, as well as a distribution sector are needed to enable theoretical models to match empirical observations.

These results open up a number of avenues for future work: on the empirical side, the main restricting factor at this point for the top-down methodology employed here is data availability for the transport share across countries. While this constraint should naturally ease over time as data collection is expanded, an alternative approach could see the estimates from micro-data used to study further the importance of profit margins on the real exchange rate. This could also be potentially used to further improve forecasting models for nominal exchange rates presented in the last chapter.

On the theoretical side, future work could, for example, explore the implications of the distribution real exchange rate for optimal policy. The literature has studied the implications of different pricing strategies, such as local and producer currency pricing, but little attention has been paid to whether monetary policy makers should factor in the distribution real exchange rate into their policy rule. Moreover, future

work could expand on the analysis presented here to build even more realistic models of real exchange rate determination, and its response to domestic and foreign shocks.