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A PRISM INTO THE PPP PUZZLES:
THE MICRO-FOUNDATIONS OF BIG MAC REAL EXCHANGE RATES

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ABSTRACT

The real exchange rate (RER) has been called the single most important price, yet its behavior exhibits several puzzles. In this project, we use Big Mac prices as a unique prism to study the movement of real exchange rates. Part of our innovation is to match these prices to the prices of individual ingredients. There are a number of advantages associated with our approach. First, unlike the CPI RER, we can measure the Big Mac RER in levels. Second, unlike the CPI RER, for which the attribution to tradable and non-tradable components involves assumptions on the weights and the functional form, we (almost) know the exact composition of a Big Mac, and can estimate the tradable and non-tradable components relatively precisely. Third, we can study the dynamics of the RER in a setting free of: the product-aggregation bias, the temporal aggregation bias, and the bias generated by non-compatible consumption baskets across countries. Fourth, we show that Engel's result that deviations from the law of one price are sole explanation for RER movements does not hold generally. We offer some evidence that departure from the Engel effect can be systematically linked to economic factors.

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"In most economies, the exchange rate is the single most important relative price, one that potentially feeds back into a large range of transactions." Obstfeld and Rogoff (2000).

1. General advertisement

The real exchange rate's central importance in an economy has long been recognized (see, for example, Milton Friedman, 1953; and more recently, Maurice Obstfeld and Kenneth Rogoff, 2000). Despite considerable attention, two key aspects of real exchange rate movements evade convincing explanation. First, estimated mean reversion seems too slow (or, equivalently, the deviations from purchasing power parity seem too persistent). After surveying a long list of papers on the subject, Rogoff (1996) observed that a "remarkable consensus view" exists on the estimated half-life of deviations from PPP; which he concluded is on the order of three to five years. But this seems too long, based on economic theories with a plausible size of arbitrage costs (e.g., Chari, Kehoe, and McGratten, 2002). Second, we used to think that differentials in the relative price of non-tradable goods across countries (e.g., through the Balassa-Samuelson effect) are the primary driver of medium- to long-run movements in real exchange rates.[1] However, a recent much-cited paper by Engel (1999) seriously undermines this view; he finds that nearly 100% of real exchange rate variation is explained by deviations from the law of one price, and none by the differentials in the relative price of non-tradables across countries.

Four different types of explanations have been suggested for the persistence puzzle in (CPI-based) real exchange rates. First, there may be an important misspecification in the common linear estimation of the persistence parameter (e.g., Obstfeld and Taylor, 1997; Taylor, 2001; Taylor and Sarno, 2002; O'Connell and Wei 2002). These authors argue that arbitrage costs dictate a non-linear specification. Arbitrage costs lead to a band of no-arbitrage, within which the real exchange rate can behave as a random walk (i.e., the half-life can be infinite). But once outside the no-arbitrage zone, the force of arbitrage may drive the real exchange rate back at a relatively fast speed (i.e., low persistence). In empirical work, once this non-linearity is taken into account, the real exchange rate is typically found to be much less persistent (the estimated half-life usually falls in a range of

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[1] Froot and Rogoff (1995) provide a comprehensive survey of studies investigating the long run determinants of purchasing power parity.

1-2 years). Second, there may exist a time-aggregation bias in some studies. Taylor (2001) shows that when price or nominal exchange rate data are averages of data collected at different points in time, the persistence of the real exchange rate may be over-estimated. Third, there may exist a bias due to product-aggregation. Imbs et al 2002, show that the estimated persistence of an aggregate, such as the CPI-based real exchange rate, is biased upwards relative to the "true" average of the levels of persistence of the components of the aggregate. Fourth, CPI baskets across different countries are not identical, and the components in each country's basket change over time as new products are added and through quality change. These differences also include cross-country variation in mixtures of traded and nontraded goods in the indexes (e.g., 'home bias' in price indexes), and cross-country differences in the weights for the included prices. More generally, 'substitution-bias' (substitution across products in the basket) is amplified since it is occurring in each country to an unknown extent.[2] As a result, arbitrage across countries on these consumption baskets is not easy (and cannot be fast).[3] Finally, these four explanations are not mutually exclusive; each can play a role in explaining the long persistence of the real exchange rate. Collectively, they illustrate the confounding factors that can complicate existing studies of CPI-based real exchange rates. Studies at the individual good level can directly control for all of these limitations inherent in aggregate data.

In this paper, we adopt a different approach to study the movement of real exchange rates by using information on the prices of Big Macs. We will show that the resulting 'Big Mac' real exchange rates are highly correlated with the CPI-based real exchange rates (both in levels and in first differences). So the lessons from the Big Macs have general implications for CPI-based real exchange rates. Our innovation is to match these prices to the prices of individual ingredients, e.g., ground beef, bread, lettuce, labor, etc., and to design the thought experiments in such a way as to circumvent the problems discussed above that have confounded much of the existing literature.

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[2] It is useful to stress that simply analyzing real exchange rates using more disaggregated price indexes will not adequately address these problems. Studies using price indexes – irrespective of the level of aggregation – are able to test only the joint hypothesis that PPP held in the base year, and that changes in international relative prices equal zero.

[3] One component of the CPI basket is food. As an example, the French basket may have a relatively heavy weight on cheese, which the Chinese may not care much about; while the Chinese basket may contain lots of tofu, which may be a small portion of French consumption. It is not particularly meaningful to speak of arbitrage between cheese prices in France and tofu prices in China.

To be more specific, there are five advantages associated with our approach. First, the Big Mac is a composite good (in this sense, like a CPI index). However, unlike the consumption baskets that go into the CPI calculation, which may not be comparable across countries, the Big Mac composite has a (nearly) identical and transparent production technology in all countries and across time periods (at least over the last 13 years in our sample). In fact, due to McDonalds' global advertising strategy, millions of people world-wide can actually sing the production function.[4]

Second, unlike the CPI-based real exchange rate, we can measure the Big Mac real exchange rate in *levels* in an economically meaningful way.

Third, unlike the CPI real exchange rate for which the attribution to tradable and non-tradable parts involves many assumptions on weights and functional form of the underlying components, we (almost) know the *exact* composition of a Big Mac, and can estimate its tradable and non-tradable components relatively precisely.

Fourth, we can study the dynamics of the real exchange rate in a setting that is free of the product-aggregation bias (argued to be important by Imbs, et al, 2002) or the temporal aggregation bias (argued to be important by Taylor, 2001). To address other biases that affect persistence estimation, we implement both linear, and non-linear, convergence specifications.

Finally, the combination of the prices of the Big Mac and those of its ingredients offers a unique opportunity to re-examine Engel's (1999) proposition concerning the role of deviations from the law of one price in real exchange rates, and to explore whether departures from his result can be systematically explained.

Aside from the literature on real exchange rates referenced above, there is a collection of recent papers that makes use of the Big Mac prices reported in the *Economist* magazine, including Pakko and Pollard (1996), Click (1996), Cumby (1997), Ong (1997), and Lutz (2001). They have typically showed that relative Big Mac prices between countries resemble CPI-based real exchange rates in many ways. However, as far as we know, none of these papers match Big Mac prices with the prices of its underlying ingredients. We use these matched data sets, which are part of our innovation, to

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[4] We refer to the well known jingle "two all beef patties, special sauce, lettuce, cheese, pickles, onions, on a sesame seed bun". There are however, some differences in Big Macs around the globe. For example, in India (not in our data set) no beef products are sold, and in Israel (in our data set) the beef is kosher.

decompose Big Mac real exchange rates into tradable and non-tradable components relatively precisely, and to address a range of questions beyond those typically studied using more aggregated data.

The rest of the paper is organized as follows. In the next section, we provide a more detailed description of the data sets, including their sources and coverage across time, countries and items. Section 3 contains the core of our statistical analysis, which is presented in four steps. First, we establish a connection between CPI-based and Big Mac-based real exchange rates. Second, we apportion the price of a big Mac into its constituent parts. Third, we study the dynamics of the Big Mac real exchange rates; in particular, by comparing its 'aggregate' convergence speed with those of its ingredients. Fourth, we examine the fraction of Big Mac price disparities attributable to deviations from the law of one price and we explore factors that may explain variation in this fraction across countries and over time. The final section offers some concluding remarks.

2.   Data: sources and ingredients

<u>Key variables</u>

Two "matching" data sets are used in this study: prices of the Big Mac and prices of its various ingredients in 34 countries over 13 years (1990-2002). The local currency data for Big Mac prices was obtained from various editions of the *Economist* magazine. In the original data set, the country coverage has varied over time.

The second data set covers city specific local-currency prices of various ingredients of the Big Mac – ground beef, bread, labor cost, etc. -- in the same set of countries and years, compiled by the *Economist Intelligence Unit (EIU)*. Appendix table 1 lists the countries reported in the Economist, and the corresponding cities reported in the *EIU* data set. A sense of the global distribution of countries is highlighted in Table 1.

The *EIU* data comes from the *Worldwide Cost of Living Survey*, and is designed for use by human resource managers in implementing compensation policies. The *EIU* official description is at http://eiu.e-numerate.com/asp/wcol_HelpWhatIsWCOL.asp. Some of the goods in the *EIU* data set appear twice – differing by the type of establishment where the price was recorded. When there was a choice between two prices, we selected the

lower price; these generally are supermarket prices. In particular, we selected local currency price data on the following five traded inputs: ground beef, cheese, lettuce, onions, and bread. We also include three nontraded inputs: hourly labor costs, rent for a two-bedroom unfurnished moderate apartment, and electricity charges.

To ensure that our subsequent results are not driven by some peculiarities of the data sets, we undertake some basic "data cleaning." First, we exclude "high inflation episodes" from our analysis, specifically, Argentina (1990-91), Brazil (1990-94), Mexico (1990-92), and Poland (1990-94). Second, we visually checked the data for possible coding errors via scatter plots. More concretely, we looked for unreasonably large fluctuations in local currency prices, or price changes greater than 60%, which were subsequently reversed in the next period. We took the ten instances (lettuce (7), onions (2), and rent (1)) where this occurred in our data set to be coding mistakes and used the average (t-1, t+1) value instead. We have experimented with other cut-offs for coding errors, and found the results not too sensitive to the choice of the cut-off points.

<u>Other variables</u>

In addition to the price data, we use data on tariffs, sales and value added tax rates. The first source of tariffs is simple mean tariff rates, from Table 6.6 of the World Bank publication *World Development Indicators 2001*. For each country the tariff data are available for two years – once in the early 1990s and once for the late 1990s. We use the first reported value in our bilateral tariff rate calculations for the years 1990-95. Similarly, we use the most recent value for the years 1996-2002. Sales tax and VAT rates were collected from primary sources. For Europe, the European Commission publication: "VAT Rates Applied in the Member States of the European Community" (2002), was quite helpful. The remaining countries and cities data were obtained from web searches, emails, and phone calls directly to national (and state) tax authorities.

3. Digesting the Big Mac

This section contains the core of our statistical analysis. We proceed in four steps. First, we check the connection between CPI-based and the Big Mac-based real exchange rates. Second, we take advantage of the simplicity of the Big Mac structure to link its price to the costs of its underlying ingredients. Third, we examine the speed of convergence to law of one price for the Big Mac real exchange rate and compare it with

those of its ingredients. We employ both non-linear as well as linear specifications. Fourth, we re-examine the Engel (1999) question, with an emphasis on trying to identify factors that may systematically affect the importance of the deviations from law of one price in explaining real exchange rate movement.

3.a. The Big Mac versus CPI-based real exchange rates

We first compare Big Mac, and the more standard, CPI-based real exchange rates. The idea is to see if Big Mac real exchange rates are informative about CPI-based real exchange rates, or alternatively, are too unique and narrow to be useful. As shown in Figure 1, Big Mac real exchange rates are typically highly correlated with aggregate real exchange rates – both in levels, and in first differences. The overall impression from the figure is that there is indeed a high correlation between aggregate and Big Mac real exchange rates. Nonetheless, for this study we make an effort to err on the conservative side and hence we restrict our attention to only those bilateral cases where both correlation coefficients are greater than 0.65. In our sample, 61% (=343) of the 561 possible real exchange rates meet these two criteria simultaneously (the percentages for each of the criteria separately are: 74% in levels; and 80% in 1st differences). To convey an idea of what the restriction implies for the resulting sample, Table 2 presents the correlation coefficients for only the twenty-one included bilateral U.S. dollar real exchange rates. As is evident from the averages, the result is a sample of Big Mac real exchange rates that are very highly correlated with the more traditional CPI based measures of the real exchange rate.

3.b. Reverse-engineering the recipe

Our first task is to relate the price of a Big Mac to the cost of its ingredients. Suppose there are exactly n inputs; and the production function is Leontief:

$$1 \text{ Big Mac} = \min \{x_1, x_2, ..., x_n\} \tag{1}$$

Let $P_{k,t}^{\text{Big Mac}}$ be the price of a Big Mac in country k at time t, and $P_{k,j,t}$ be the price of input j in country k at time t. Then,

$$P_{k,t}^{\text{Big Mac}} = \sum_j P_{k,j,t} \, x_j \tag{2}$$

To be precise, here we use the term "input" broadly to also include an additive profit markup – which, without loss of generality, can be the last "input." That is, we could let $x_n = 1$, and $P_{k,n,t}$ = the additive profit markup in country k at time t. Expressed in this way, Equation (2) is an identity.

Suppose we observe $P_{k,t}^{\text{Big Mac}}$ and $\{P_{k,j,t}\}$ for a sufficient number of time periods and countries, (or, to be precise, when # locations X # time periods $\geq n$), then it is a matter of simple algebra to solve for all x_i, i=1,2,..., n. In fact, under our assumptions, a convenient way to solve for $\{x_1, x_2, ..., x_n\}$ would be simply to perform a linear regression of $P_{k,t}^{\text{Big Mac}}$ on $\{P_{k,j,t}\}$. The regression in this case is not a statistical tool, but an algebraic one. Since (2) is an identity, the $R^2 = 100\%$.

Of course, we do not literally have price information on every single ingredient of a Big Mac. For example, we do not have information on cooking oil, pickles, sesame seeds, or "special sauce" in the data set. However, we assume that, in terms of their shares in the total cost of a Big Mac, these missing items are relatively unimportant when compared with the items for which we do have information, such as labor, rent, bread, ground beef, lettuce, and three other inputs. This assumption will be verified later.

The most serious "missing input" is probably the profit markup, which might vary by country and year. This and other "missing inputs" would go into the residual of a regression. In subsequent analyses when the role of the "missing inputs" may matter, we experiment with various assumptions about them to ensure that our key results are robust. These robustness checks will be explained later when relevant.

With these points in mind, we regress the price of a Big Mac on the prices of the eight main inputs for which we do have information, and report the results in Table 3. We report only the coefficients from the random effects estimator since a Hausman test that the covariance between the independent variables and the error term is equal to zero is not rejected. Failure to reject this hypothesis indicates that random effects estimator is the efficient estimator. As reported in the table, the computed value of the test statistic is $\chi^2(8) = 5.6$, with a significance level = 0.69.

All of the coefficients and the implied shares seem reasonable. What stands out in Table 3 is the importance of nontraded inputs – especially labor – for the price of Big Macs. According to the table, the total nontraded goods share is 55%, i.e.,

$\alpha = 0.456 + 0.046 + 0.051 \approx 0.55$. Alternatively, if we normalize the non-tradable share by the total amount explained by all observed inputs, then, non-tradables collectively explain 64% of the Big Mac price ($\alpha = 0.553/0.869 \approx 0.64$).

We also implement a regression where all variables are expressed in percentage change form (last column in Table 3). The results qualitatively reinforce the conclusions from the levels regression – especially the fact that nontraded goods prices are a very important component of Big Mac prices. We will use the estimates presented in Table 3 when we explicitly allocate shares of real exchange rate movement to traded and non-traded goods components. Before doing so, however, we estimate the persistence of 'aggregate' Big Mac real exchange rates and compare them with those for the ingredients of a Big Mac.

3.c. Fast food: how fast is convergence?

In this sub-section we extend the analysis to study the size and persistence of cross-country price differences, i.e., real exchange rates. As a point of departure, note that previously (Section 3a) we examined U.S. dollar prices across the 34 countries. In this section we focus on all <u>bilateral</u> price differences in U.S. dollars, and we reiterate that our focus is on the *level* of real exchange rates. Hence, we do not presume a base year where parity holds.

Define the (log) real exchange rate at time t as: $q_t = s_t + p_t^* - p_t$, where s_t is the domestic currency price of foreign exchange, p_t^* is the foreign price of Big Macs, and p_t is the domestic price of Big Macs; all variables are expressed in natural logarithms. In Table 4, we provide estimates of $\hat{\beta}$ from equation 1 for the Big Mac, and each of the eight input real exchange rates.

$$\Delta q_{i,t} = \beta \, q_{i,t-1} + \text{country \& time dummies} + \varepsilon_{i,t} \tag{3}$$

Immediately apparent in the table is the fact that *Tradables*, as a group, have the least persistence and the shortest half lives. Indeed, the average half life for *Non-tradables* (3.4 years) is more than twice that for *Tradables* (1.4 years) and the half life of Big Mac deviations (1.8 years) lie somewhere in between. To gauge the sensitivity of the results to outliers, the analysis was repeated – but excluding observations associated with the largest 5 percent of the residuals from the corresponding regression in Table 4. These results are

reported in Appendix Table 2. Nearly all the half lives rise – an aspect we explore below. The general pattern however, remains; namely, the half life of Big Mac deviations is bounded by that of *Tradables* from below, and of *Non-tradables* from above.

In Appendix Table 3, we report the results of a different estimation method, i.e., we use the random effects estimator. Though the Hausman test suggests the fixed effects estimator is efficient, (i.e., the null hypothesis is rejected at the 10% level in all cases) we report the random effects estimates for comparison. Again, the general pattern remains. Specifically, the half life of Big Mac deviations is bounded by that of *Tradables* from below, and of *Non-tradables* from above.

In Appendix Table 4, we restrict the sample again; this time to make an explicit comparison with Cumby (1997). In these regressions we examine only those countries in Cumby's sample, and we also restrict the time period to be closer to his by dropping the final three years from our sample period. Considering the reduced set of countries, the results are very similar to those for the full sample of countries – except that estimated convergence is generally slightly faster than for the full sample – a result similar to that found by Cumby. Overall however, the same general pattern emerges across the nine real exchange rates in the table.

In Appendix Table 5, we present the estimates from an alternate regression specification. Specifically, we tabulate the coefficient estimates from an augmented Dickey-Fuller regression, including one lag of the dependent variable, as in equation 1'. As can be seen in the table, the lagged dependent variables are generally insignificant, and our conclusions about relative convergence speeds are unaffected.

$$\Delta q_{i,t} = \beta\, q_{i,t-1} + \gamma \Delta q_{i,t-1} + \text{country \& time dummies} + \varepsilon_{i,t} \qquad (1')$$

Finally, before turning to non-linear estimates of persistence, we consider the effects of taxes. It is well known that taxes and other transaction costs can create a wedge – within which, real exchange rates need not display convergence tendencies. Moreover, time variation in these transaction costs can, in effect, present a 'moving target' for mean reversion estimates. Additionally, arbitrage might occur on a pre-tax or tax-inclusive basis. The regressions presented in Table 4 (and Appendix Tables 2-5) may therefore embody considerable measurement error since they use prices inclusive of VAT and sales taxes. Hence, in Table 5, we repeat the analysis after subtracting VAT and sales taxes.

It should be noted that this adjustment may introduce error into the estimation since the sales tax data has been taken from a number of sources – many of which present the information in 'simplified' form only. For example, some countries tax 'agricultural products' while others tax them at a reduced rate, while others do not. Moreover, 'agricultural products' may include beef for some countries, while in other countries 'agricultural' may be taken to be 'vegetable'. While we have made considerable effort in compiling accurate data, we recognize the potential for error such ambiguities introduce. Parsley and Wei (1996) is the only study we know of that considers the effects of taxes on convergence rates. In their study of intra-national (U.S.) real exchange rates, they find that taxes have virtually no effect on their persistence estimates since there is simply not much variation over time in sales tax rates within the United States. Our results, shown in Table 5, are similar; the adjustment for VAT and sales taxes seem to matter little for estimated convergence rates. The most notable aspect of the regressions is that the estimated standard errors always rise, and the adjusted R-squared nearly always declines.

As noted in the introduction, recent research by O'Connell (1998), Obstfeld and Taylor (1997), Taylor (2001), Taylor and Sarno (2001), and O'Connell and Wei (2002) suggests that standard regressions, such as equation (1) or (1') are misspecified due to the assumed linearity. These authors have argued that estimates of real exchange rate persistence obtained from a linear regression are biased upward, since such estimates are essentially averages of two regimes: very high persistence for deviations smaller than transaction costs, and possibly much lower persistence for larger deviations. These authors have addressed the problem of lumping data from two regimes by estimating a threshold autoregression (TAR) model. As O'Connell and Wei (2002) note, if transaction costs create a band of no-arbitrage, TAR models provide a more powerful way to detect global stationarity – even if the true price behavior does not conform to the TAR specification. We consider two such models of non-linear price adjustment – an Eq-TAR (for "equilibrium threshold autogressive model"), and a Band-TAR – both of which can be represented by restrictions on equation 4. According to the Eq-TAR model, convergence occurs toward the center of the band, hence the implied restriction is $b=0$. On the other hand, mean reversion in the Band-TAR model is assumed to be sufficient to push the price differences only toward the outer edge of the bands, hence this model imposes $b=c$.

$$\Delta q_t = \begin{cases} \rho(q_{t-1} - b) + \varepsilon_t, & \text{if } q_{t-1} > c \\ q_{t-1} + \varepsilon_t, & \text{if } -c \le q_{t-1} \le c \\ \rho(q_{t-1} + b) + \varepsilon_t, & \text{if } q_{t-1} < -c \end{cases} \quad (4)$$

According to these models, the real exchange rate process has a unit-root inside the transaction cost band. Once the real exchange rate exceeds the transaction cost parameter (c), the real exchange rate reverts at rate, $1-\rho$. In the Eq-TAR model, reversion is toward the center of the transaction cost band [-c, c], while in the Band-TAR model reversion is toward the edge of the threshold. The Eq-TAR model would characterize behavior if fixed costs are an important part of impediments to arbitrage. Similarly, if the impediments to arbitrage take the form of variable costs only, then the Band-TAR model would be appropriate. Currently, there is no consensus as to which model is uniformly 'best', and there does not exist a good way to estimate a general model that would nest both as special cases. As a result, we present estimates from both models. As it turns out, our conclusions are similar for either model.[5]

Estimation of these models can be done via maximum likelihood or sequential conditional least squares. Franses and van Dijk (2000) demonstrate the equivalence of the two methods. Procedurally, we estimate the pooled model using the fixed effects panel estimator by performing a grid search over possible values of c. In the first estimation, $c = \min(q) + 0.003$. Each successive iteration adds 0.003 to c and the model is re-estimated. We stop the grid search at the 75th fractile of the distribution of q. This results in roughly 100 estimations per good. The model with the minimum residual sum of squares is reported in Table 6.

For comparison, we present the Eq-Tar and Band-Tar results in the two sets of columns. Overall, the estimates of convergence are faster in these non-linear specifications, as one would expect. However, in both estimation specifications, the same pattern prevails as before. Namely, the median tradable good converges fastest, while non-tradables have the greatest persistence, with the Big Mac 'sandwiched' in between. Also, the size of the threshold is of interest. Obstfeld and Taylor (1997) report

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[5] Of course, the reason our conclusions are unaffected by the estimation method is that we compare reversion across inputs. As long as the estimation method is the same across ingredients and for the Big Mac, any biases are likely to be "proportional" to all equations. Hence, the relative order of persistence is unlikely to be affected.

thresholds of between 8 and 10 percent – while those in the table are generally less than half that.

We now turn to a formal decomposition of movements in Big Mac real exchange rates into parts attributable to movements in tradables and non-tradables separately.

3.d. Two for the price of one: new accounting versus old theory

In most models of the real exchange rate, the relative price of non-tradable goods in terms of tradables plays a key role. For example, according to the well-known Harrod-Balassa-Samuelson effect, currencies from countries experiencing relatively faster tradable goods productivity growth will tend to appreciate. Indeed, many have attributed the post-war secular rise in the yen/dollar real exchange rate (at least to 1990) to this effect.[6] Productivity growth however, is not the only source of movements in the relative price of non-tradables across countries. For example, Dornbusch (1989) and Froot and Rogoff (1991) argued that the difference in the relative price of non-tradables caused by different government macroeconomic policies can also be important in explaining real exchange rate movements.

This view of the role of the relative price of non-tradables in real exchange rate determination has recently come under assault. In an influential and much-cited paper, Engel (1999) concludes that movements in relative prices of nontraded goods appear to account for essentially *none* of the movements in aggregate U.S. based CPI real exchange rates.[7] Instead movements in real exchange rates are almost completely due to deviations from the law of one price for tradable goods. In subsequent discussion, we refer to this stark result as the Engel effect.[8] The nature of the challenge is clear; namely, under this view, neither the Harrod-Balassa-Samuelson effect, nor the Dornbusch-Froot-Rogoff effect, help to explain movements in real exchange rates.

In this subsection, we examine whether it is possible that the Engel effect is important under some conditions but less so under others, and what these conditions are.

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[6] For textbook treatments, see, e.g., Caves, Jones, and Frankel (2002, p. 372-3), or Obstfeld and Rogoff (1996, p. 210-214).

[7] Engel's (1999) study examines five high-income countries (for CPI based real exchange rates), but finds similar results using output price indexes (seven countries) and producer price indexes (sixteen countries).

[8] Parsley (2001) reaches a similar conclusion for a sample consisting of smaller, more open, and generally faster growing Asian-Pacific economies.

Mendoza (2000) provides one hint that the Engel effect may sometimes be less than 100 percent.[9] In his study of the Mexican peso/US dollar real exchange rate, Mendoza found the Engel effect is present when the country's nominal exchange rate was on a floating regime; but the effect declines to between 30% and 50% when the nominal exchange rate was tightly managed. A reasonable conjecture from the Mendoza study is that exchange rate volatility and/or the nominal exchange rate regime may play a role in determining the relative importance of international deviations in traded goods prices in explaining real exchange rate movements.

One important drawback to the Engel (1999), Mendoza (2000), or Parsley (2001) decompositions is that they rely on highly aggregated measures of traded and nontraded goods. A key concern is whether the traded and nontraded price components are accurately compartmentalized in the resulting indexes. Indeed, Engel acknowledges this problem and devotes considerable effort to robustness checks. In the end however, he still must conclude that the traded goods indexes actually contain nontraded items, and the nontraded indexes contain nontrivial traded components. Since these aggregate indices are themselves weighted averages of hundreds of underlying prices, the ultimate impact on the decompositions is unknown. Additionally, one must make an assumption on the specific functional form that combines tradable and non-tradable prices into the aggregate price index. The conventional practice makes the simplifying assumption that traded and non-traded components are combined in a Cobb-Douglas fashion. In this study, we examine the robustness of the Engel effect for the case of Big Mac (aggregate) real exchange rates, where there is very little room for substitution across inputs either within or across countries. Hence, the decomposition is arguably more straightforward.

Another drawback to using aggregate CPI data is the well-known price index problem, i.e., price indexes tell us something about the change in prices from the base period. Assuming PPP held in the base period, observing changes in price indexes would convey the same information as examining price levels in each period. However, if PPP

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[9] Engel's finding is consistent with sticky local currency prices. Recently, Parsley and Popper (2002) apply Engel's methodology and decompose aggregate real exchange rate movements into two portions: one attributable to deviations in the law of one price for an individual good and another that combines everything else. They find that whichever individual good is chosen for the first portion (be it haircuts, eggs, or indeed *any* of the goods they examine), that good will account for virtually all the variation. Hence, they advise caution in interpreting such decompositions.

did not hold in the base period this link is severed, and movements in price indexes may not convey useful information about the level of the real exchange rate.

We begin by decomposing movements of Big Mac real exchange rates into shares attributable to traded- and non-traded inputs directly. An important goal of this analysis is to examine the robustness of these earlier studies in the context of a single "aggregate" good, where we know the production technology reasonably well. Our methodological approach differs from previous studies as we explore a much greater cross-section dimensionality (though shorter time series with lower frequency).

We begin by describing the decomposition of real exchange rates into traded and nontraded components. Express the Big Mac real exchange rate (Q^{BM}) as:

$$Q^{BM} = \frac{SP^{BM^*}}{P^{BM}}.$$ (5)

Where, P^{BM^*} is the foreign currency price of a Big Mac abroad, and P^{BM} is the U.S. dollar price of a Big Mac in the United States. The nominal exchange rate (foreign currency/U.S dollar) is designated by S, and we have suppressed time subscripts. Since $P^{BM^*} = P^{T^*} + P^{N^*}$ and $P^{BM} = P^T + P^N$, we can write the log real exchange rate as:

$$q^{BM} = \log(S) + \log(P^{T^*}) - \log(P^T) + \left[\log\left(1 + \frac{P^{N*}}{P^{T*}}\right) - \log\left(1 + \frac{P^N}{P^T}\right) \right]$$

The first part of this expression is simply the deviation from the law of one price for traded inputs (x), and the second part is the relative-relative price of non-traded goods, i.e.,

$$q^{BM} = x + y, \text{ where}$$
$$x = \log(S) + \log(P^{T^*}) - \log(P^T) \quad , \text{ and} \quad (6)$$
$$y = \log\left(1 + \frac{P^{*N}}{P^{*T}}\right) - \log\left(1 + \frac{P^N}{P^T}\right)$$

Unlike previous studies, a distinctive feature of this study is that traded goods prices can be computed directly as $P^T = \sum \hat{\beta}_i^T P_i^T$, where the summation is over the i traded inputs (*beef*, *cheese*, *lettuce*, *onions*, *and bread*) and the $\hat{\beta}$ estimates are computed previously in Table 3. A similar computation can be made for P^{*T}, P^N, and P^{*N} . Here, as in Engel (1999), the log Big Mac real exchange rate is the sum of deviations from the law of one

price among traded ingredients, and the relative-relative price of nontraded inputs abroad and at home.

Armed with empirical counterparts to x and y, Engel's (1999) approach was to decompose movements in aggregate real exchange rates to shares attributable to movements in each. Using more than thirty years of monthly data he focused on (among other measures) the mean squared error of changes in the real exchange rate at all horizons, e.g., 1-month, 2-months, up to the highest n-month difference the data would allow. In our case we have annual observations for thirteen years. The annual frequency and relatively short time span forces us to take a different approach than in Engel. Hence, we propose an alternative, time-dependent, way to construct the shares attributable to x and y. Since we observe prices (and not price indexes) we construct absolute (i.e., levels) measures of x and y, as well as for aggregate Big Mac deviations, at each point in time. We have a potential cross-section of 561 real exchange rates with 13 time series observations each (without missing values).[10] Our approach has the advantage that we can systematically relate these shares to observable country-pair and time-specific factors. For comparison with previous studies, we also present results using annual changes.

Generically, we construct the time-dependent measure of the share of Big Mac real exchange rates at time t attributable to x as the ratio of the squared deviation of x from its country-pair specific mean, to the sum of that for x and y together, i.e.,

$$x\text{-}share_t = \frac{\left(x_t - \overline{x}\right)^2}{\left(x_t - \overline{x}\right)^2 + \left(y_t - \overline{y}\right)^2} \,, \tag{7a}$$

We label this as 'share in variance' since it most closely approximates Engel's variance decomposition, though equation 7a preserves the time-series dimension; below we also consider an approximate mean-squared error version. Unfortunately, the denominator of equation 7a does not equal the squared Big Mac real exchange rate. First, this is because our cost share regressions did not allocate 100% of the variation of Big Mac prices to the

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[10] Since we have 34 countries, we have 561 (=34x33/2) real exchange rates. However, we continue to focus on only those 343 good level real exchange rates highly correlated with aggregate real exchange rates. As described above, the restriction requires the correlation coefficients of both the level and the first-difference of the good-level real exchange rates with their corresponding aggregate real exchange rates must exceed 0.65.

ingredients we included. Hence we must also account for this unexplained portion for completeness. We adopt an agnostic view and experiment with three separate approaches, namely, (a) ignoring the unexplained portion, (b) attributing the entire unexplained portion to x, and (c) attributing the entire unexplained portion to y. As it turns out, the three approaches yield qualitatively similar results with regard to our key conclusions.

Figure 2 plots the histograms of these three measures of *x-share*. Note these figures use all available cross-section and time series data points. That is, without missing values there will be 13 observations for each of the 343 'highly-correlated' real Big Mac exchange rates that we have been focusing on previously, i.e., those with correlation coefficients > 0.65 between CPI and Big Mac real exchange rates in both levels and in first differences (i.e., nearly 4500 observations). The x-axis records the share of traded-goods deviations in the aggregate Big Mac real exchange rate. The x-axis labels indicate the lower bound of each bin, e.g., 80% stands for the percent above 80%. The height of the bars measures the percentage of real exchange rates meeting that criterion. The figure indicates that there is considerable heterogeneity across the 343 real exchange rates. In particular, in less than 40% of the cases do we get the result that *x* accounts for more than 80% of real exchange rates. This is true whether we attribute the unexplained portion to *x*, or to *y* or whether we ignore it and focus on the 'pure' version of equation 7a. Moreover, it is apparent that *x* accounts for a relatively small portion of real exchange rates for a non-trivial proportion of the real exchange rates in our sample. Thus using direct measures of the size of traded goods deviations relative to overall real exchange rate deviations, we see that the Engel effect is substantially smaller than documented in previous studies based on aggregate data.

We now turn to a more systematic panel-regression analysis using both the cross-sectional and time series information in our data. Inspired by Mendoza (2000), we explicitly consider the effect of the exchange rate regime. We begin by incorporating a dummy variable for the U.S. dollar pegs of Argentina, and Hong Kong. This dummy (*$peg*) takes the value one corresponding to these four country-pairs for all time periods in the data set. We also include a dummy variable (*Euro*) for the Euro countries during the 1999-2002 time periods. However, a more general (i.e., continuous) way to capture exchange rate effects is to incorporate exchange rate variability – defined as the standard

deviation of monthly exchange rate variability within the year – directly into the specification.

Thus, the basic specification we report in Table 7 includes the three variables ($*peg*, *xrvol*, and *Euro*). In the second column of the table we add time and city dummies. In the final specification we add controls for membership in a trade bloc, sharing a common language, the level of tariffs between the country-pair (= the sum of tariffs in countries i and j), and the (log) distance between their capital cities. The most general specification is shown as equation 8 below.

$$
\begin{aligned}
x\text{-}share_t = &\ \beta_1 xrvol_{ij,t} + \beta_2 \$peg + \beta_3 Euro + \beta_4 \ln(dist_{ij}) + \beta_5 Tariff_{ij} \\
&+ \beta_6 \text{Common Language} + \beta_7 Bloc_{ij} + city\ and\ time\ dummies + \varepsilon_{ij,t}
\end{aligned}
\tag{8}
$$

Distance is calculated using the great circle formula using each city's latitude and longitude data. Exchange rate variability is defined as the standard deviation of changes in the monthly bilateral exchange rate (between the country-pairs involved) during each year. Tariff is defined as the sum of the two average tariff rates in countries i and j, unless the two countries are both in the same free trade area or customs union (such as within the United States, or within the European Union). In these cases the value for tariff is set equal to zero. Results from this estimation are presented in Table 7. The first two columns (labeled *pure*) report the results where the variation in the unexplained portion of Big Mac prices is ignored. In the second group of columns (labeled *over-attribution to x*) the variation in the unexplained portion of Big Mac prices has been attributed to *x*, and in the third group of columns, this variation has been attributed to *y*.

The results in the table are quite stable across all specifications. First, higher exchange rate volatility is associated with a larger *x-share*, i.e., higher exchange rate volatility exaggerates the importance of traded goods deviation. Second, having a peg to the U.S. dollar lowers the contribution of deviations from the law of one price in traded goods to movements in 'aggregate' real exchange rates, as hypothesized by Mendoza (2000). Results for the Euro, however, are generally weaker – though also in the same direction. Tariffs are negative and statistically significant. Distance is strongly statistically significant across all specifications, which suggests that arbitrage is less important for more distant locations. Having a common language does not seem important. The trade blocs we include have some mixed results. The European Union dummy is negative (but

insignificant) when the *y-share* is over-attributed (i.e., it includes the entire unexplained portion), but positive and insignificant when *x-share* is over-attributed. Surprisingly, Mercosur, APEC, and ASEAN all seem to be positively associated with *x-share*. This may reflect the overall size of traded goods price disparities among these countries.

One may wonder if our results are specific to the subset of real exchange rates we are studying. Hence in Appendix Table 6, we include all Big Mac real exchange rates – i.e., even those with correlations with CPI real exchange rates below 0.65. The results hardly change, suggesting they are not limited to our specific subsample.

In Table 8 we examine a more comprehensive measure of variation in the real exchange rate. Equation 7b is approximately the share of the mean squared error (MSE) of the real exchange rate attributable to x.[11] In our case however, the MSE of each term (x and y) is computed as the sum of the time t squared deviation plus the time t deviation from the mean squared. As before, we present three different measures of 7b depending on how we treat potential covariation between x and y.

$$x\text{–}share_t = \frac{\left(x_t - \bar{x}\right)^2 + x_t^2}{\left(x_t - \bar{x}\right)^2 + \left(y_t - \bar{y}\right)^2 + x_t^2 + y_t^2}, \tag{7b}$$

The results in Table 8 are largely similar to those in Table 7. Namely, (1) higher exchange rate volatility is associated with a larger *x-share*; (2) having a peg to the U.S. dollar lowers the contribution of deviations from the law of one price in traded goods to movements in 'aggregate' real exchange rates; (3) x accounts for a higher proportion for countries that are farther apart; and (4) tariffs are negative and statistically significant. Finally, the results in Table 8 suggest that (when significant) x accounts for a higher proportion for countries that have adopted the euro, even after controlling for the European union, as well as countries in Mercosur and Asean.

One potential statistical problem is that the dependent variable, a share, is constrained to lie between zero and one. Strictly speaking, the normality assumption of the error term in the OLS specification is incompatible with this. We address this issue by taking a logistic transformation of *x-share*. This transformation allows the dependent

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[11] Our equation 7b corresponds to Engel's (1999) equation B1.

variable to take any positive or negative value (see Greene 1997, p.228). For the definition of *x-share* given in equation 7, the new dependent variable becomes:

$$x-share_t = \ln\left(\frac{(x_t - \overline{x})^2}{(x_t - \overline{x})^2 + (y_t - \overline{y})^2}\right) - \ln\left(1 - \frac{(x_t - \overline{x})^2}{(x_t - \overline{x})^2 + (y_t - \overline{y})^2}\right), \tag{9'}$$

Results using this specification (corresponding to equations 7a and 7b) are presented in Tables 9 and 10. Statistical significance generally rises using this specification, but other qualitative conclusions remain the same. The only notable changes are that the dummy for Common language is negative, though it is not generally statistically significant, and the trade bloc dummies (APEC and ASEAN) become statistically insignificant. All other conclusions hold under this transformation.

So far, we have studied the share of deviations from purchasing power parity attributable to deviations from the law of one price in traded goods. In contrast, previous studies have focused on share of *changes* in real exchange rates attributable to *changes* in deviations from the law of one price in traded goods. In previous studies, this emphasis was necessary since the level of the real exchange rate using aggregate (e.g., CPI) data is arbitrary. Thus the measure we study here is more direct. We have shown that deviations from the law of one price in traded goods generally account for a much smaller portion of real exchange rate movement than previous studies would have led us to expect. We have also shown that exchange rate variability is strongly positively related, and exchange rate pegs (especially the US dollar pegs in this sample) are strongly negatively related, to the fraction of absolute PPP deviations one can attribute to traded goods price disparities. Finally, we have found that the importance of law of one price deviations is often higher for countries participating in regional trading blocs.

In an effort to check whether our findings are made possible due to our ability to focus on real exchange rate levels, and for comparison with existing work we also examine first-differenced versions of 7a and 7b, given as 7c and 7d below.

$$x-share_t = \frac{(\Delta x_t - \Delta\overline{x})^2}{(\Delta x_t - \Delta\overline{x})^2 + (\Delta y_t - \Delta\overline{y})^2}, \tag{7c}$$

$$x-share_t = \frac{(\Delta x_t - \Delta\overline{x})^2 + (\Delta x_t)^2}{(\Delta x_t - \Delta\overline{x})^2 + (\Delta y_t - \Delta\overline{y})^2 + (\Delta x_t)^2 + (\Delta y_t)^2}, \tag{7d}$$

These results are reported in Appendix tables 7 and 8, and the logistic transformations of them are reported in Appendix tables 9 and 10. The message that exchange rate variability raises the importance of deviations from the law of one price in real exchange rate movements continues to hold. However, other conclusions are less apparent in this weaker version of the decomposition. That is, the formerly robust conclusions concerning the dollar peg, distance, the European Union, and tariffs, are no longer apparent. Since the level of real exchange rate can be meaningfully measured in our thought experiment, we regard the analyses on (7a) and (7b) as more informative.

4.   Thoughts at the checkout counter

This paper has studied one particular 'aggregate' real exchange rate – i.e., the Big Mac real exchange rate – where we know a great deal about how that aggregate is constructed. We have shown that Big Mac real exchange rates are generally highly correlated with the CPI-based real exchange rates. Thus, the lessons leant from the Big Mac real exchange rates are relevant for the CPI-based real exchange rates. Our main innovation is to match these prices to the prices of individual ingredients (ground beef, bread, lettuce, labor cost, rent, etc.) in 34 countries during 1990-2002, which allows us to do a number of useful thought experiments..

We have presented a number of interesting findings. First, the non-traded component of Big Mac prices is substantial, i.e., between 55% and 64%. Second, we study the persistence of the real exchange rate in a setting free of possible biases induced by non-comparability of consumption baskets across countries, product aggregation bias (Imbs, Mumtaz, Ravn, and Rey, 2002), and time aggregation bias (Taylor, 2001). We find that the speed of convergence for tradable inputs is sufficiently fast to be compatible with economic theories (Chari, Kehoe, and McGratten, 2002), and that for the Big Mac real exchange rates is slower than the speed for its tradable inputs, but faster than its non-tradable inputs. Finally, we show that Engel's result that all movements in real exchange rates are attributable to deviations from the law of one price in traded goods does not hold generally. In particular, reduced exchange rate volatility, lower transport cost, higher tariffs, and exchange rate pegs generally weaken the Engel effect.

Table 1: Countries and Regions

Europe	*Western Hemisphere*	*Asia, Pacific, and Africa*
Austria	Argentina	Australia
Belgium	Brazil	China
Czech Republic	Canada	Hong Kong
Denmark	Chile	Indonesia
England	Mexico	Israel
France	United States	Japan
Germany		Malaysia
Hungary		New Zealand
Ireland		Singapore
Italy		South Africa
Netherlands		South Korea
Poland		Taiwan
Spain		Thailand
Sweden		
Switzerland		

Table 2: Correlation of Big Mac and CPI based Real Exchange Rates
(In-Sample U.S. Dollar Bilateral Real Exchange Rates, 1990-2002)

Country	Correlation in levels	Correlation in changes
Australia	0.938	0.893
Austria	0.992	0.986
Belgium	0.657	0.886
Brazil	0.895	0.967
Denmark	0.966	0.866
France	0.941	0.704
Germany	0.956	0.878
Indonesia	0.727	0.967
Japan	0.886	0.927
Malaysia	0.912	0.846
Mexico	0.827	0.860
Netherlands	0.759	0.851
New Zealand	0.947	0.895
Singapore	0.783	0.732
South Africa	0.925	0.882
South Korea	0.932	0.909
Spain	0.954	0.778
Sweden	0.993	0.942
Switzerland	0.971	0.987
Taiwan	0.841	0.917
Thailand	0.906	0.670
Medians:		
U.S. bilateral rates	0.891	0.873
All bilateral	0.889	0.915

Table 3: Cost Function Estimation for Big Mac Production
(1990 – 2002)

| Ingredient | Regression in Levels | | Change Regression |
	Coefficient Estimates[1]	Implied Cost Share (%)[2]	Coefficient Estimates[3]
Traded:			
Beef	3.010	9.0	2.257
	(0.645)		(0.669)
Cheese	2.530	9.4	1.995
	(0.592)		(0.625)
Lettuce	1.546	0.7	6.017
	(3.645)		(3.476)
Onions	1.156	0.5	4.411
	(3.610)		(3.239)
Bread	13.428	12.1	11.256
	(3.053)		(3.200)
Nontraded:			
Labor	9.245	45.6	11.823
	(0.832)		(1.069)
Rent	0.008	4.6	0.010
	(0.003)		(0.004)
Electricity	0.085	5.1	0.078
	(0.027)		(0.039)
		Total = 86.9%	
# of observations	318		284
Adjusted R-squared	.95		.66

[1,3] Coefficient estimates and standard errors are multiplied by 100. Estimation method is random effects. Hausman test statistic for levels regression is $\chi^2(8) = 5.8$ (significance level =0.67), and the test statistic for the change regression (1st differences) is $\chi^2(8) = 3.3$ (significance level =0.91

[2] The share attributed to the ith ingredient is computed as: $\hat{\beta}_i \overline{P}_i / \overline{P}_{Big\ Mac}$, where $\overline{P}_i$ is the average price of the ith input.

Table 4: Persistence Estimates

Tradables	$\hat{\beta}$	Half-life	# obs	$\overline{R}^2$	$H_0 : \lambda_i = 0$	$H_0 : \lambda_i = 0$ $\theta_t = 0$
Beef	-0.431 (0.056)	1.2	256	0.17	00.747 (0.999)	0.925 (0.889)
Cheese	-0.451 (0.055)	1.2	252	0.22	1.127 (0.025)	1.347 (0.000)
Lettuce	-0.358 (0.055)	1.6	246	0.13	0.794 (0.999)	0.959 (0.745)
Onions	-0.609 (0.060)	0.7	256	0.27	0.851 (0.994)	0.955 (0.767)
Bread	-0.252 (0.049)	2.4	256	0.08	0.664 (1.000)	0.918 (0.909)
Median		1.2				
Non-Tradables						
Labor	-0.250 (0.052)	2.4	227	0.09	0.844 (0.993)	0.953 (0.762)
Rent	-0.157 (0.040)	4.1	253	0.03	0.989 (0.559)	1.143 (0.019)
Electricity	-0.177 (0.035)	3.6	256	0.16	1.485 (0.000)	1.622 (0.000)
Median		3.6				
Big Mac	-0.326 (0.061)	1.8	203	0.12	0.615 (1.000)	0.704 (0.999)
Country fixed effects			yes			
Time fixed effects			yes			

This table reports the results of estimating the following equation, using a fixed-effects estimator: $\Delta q_{i,t} = \beta\, q_{i,t-1} + \sum \lambda_i \text{country}_i + \sum \theta_t \text{time}_t + \varepsilon_{i,t}$

Table 4: Persistence Estimates
(Net of VAT and Sales Taxes)

Tradables	$\hat{\beta}$	Half-life	# obs	$\overline{R}^2$	$H_0: \lambda_i = 0$	$H_0: \lambda_i = 0$ $\theta_t = 0$
Beef	-0.445	1.2	228	0.17	0.650	0.810
	(0.060)				(1.000)	(0.999)
Cheese	-0.452	1.1	224	0.21	1.050	1.219
	(0.058)				(0.217)	(0.001)
Lettuce	-0.342	1.7	220	0.11	1.020	1.213
	(0.057)				(0.358)	(0.001)
Onions	-0.608	0.7	228	0.27	0.854	0.953
	(0.063)				(0.992)	(0.769)
Bread	-0.263	2.3	228	0.07	0.669	0.885
	(0.052)				(1.000)	(0.971)
Median		1.4				
Big Mac	-0.322	1.8	180	0.12	0.740	0.787
	(0.065)				(0.999)	(0.999)
Country fixed effects			yes			
Time fixed effects			yes			

This table reports the results of estimating the following equation, using a fixed-effects estimator: $\Delta q_{i,t} = \beta\, q_{i,t-1} + \sum \lambda_i \text{country}_i + \sum \theta_t \text{time}_t + \varepsilon_{i,t}$

Table 6: Persistence Estimates Compared
(TAR specifications)

	EQ-TAR				Band-TAR			
Tradables	$\hat{\beta}$	Threshold	Half-life	# obs	$\hat{\beta}$	Threshold	Half-life	# obs
Beef	-0.462 (0.061)	0.024	1.12	237	-0.466 (0.061)	0.042	1.11	221
Cheese	-0.488 (0.058)	0.024	1.04	226	-0.459 (0.056)	0.039	1.13	216
Lettuce	-0.430 (0.065)	0.051	1.23	207	-0.419 (0.063)	0.060	1.27	200
Onions	-0.680 (0.055)	0.065	0.61	237	-0.673 (0.067)	0.063	0.62	210
Bread	-0.280 (0.053)	0.018	2.11	233	-0.296 (0.056)	0.030	1.98	217
Median			1.12				1.13	
Non-Tradables								
Labor	-0.265 (0.057)	0.009	2.25	214	-0.264 (0.058)	0.015	2.26	204
Rent	-0.200 (0.049)	0.036	3.10	208	-0.201 (0.050)	0.048	3.09	189
Electricity	-0.180 (0.036)	0.015	3.49	241	-0.192 (0.042)	0.036	3.25	200
Median			3.10				3.09	
Big Mac	-0.407 (0.072)	0.018	1.33	176	-0.476 (0.083)	0.033	1.07	150
Country fixed effects		yes					yes	
Time fixed effects		yes					yes	

This table reports estimates of equation (2) and (2') in the text.

Table 7: Contribution of Traded Good Deviations to
Big Mac Real Exchange Rate Movements (1990-2002)
(Share in variance: levels of real exchange rate)

	"pure" measure		Over attribution to "x"		Over attribution to "y"	
Exchange Rate	1.429	1.408	1.523	1.293	1.512	0.773
Volatility	(0.267)	(0.282)	(0.256)	(0.268	(0.237)	(0.254)
$ Peg	-0.415	-0.440	-0.250	-0.279	-0.134	-0.162
	(0.127)	(0.132)	(0.098)	(0.096)	(0.126)	(0.129)
Euro	-0.130	-0.128	-0.065	-0.065	-0.014	0.032
	(0.080)	(0.082)	(0.049)	(0.049)	(0.181)	(0.180)
Distance		0.038		0.041		0.069
		(0.006)		(0.005)		(0.005)
Sum Tariffs		-0.008		-0.008		-0.010
		(0.003)		(0.002)		(0.002)
Common		-0.047		0.000		0.012
Language		(0.027)		(0.021)		(0.022)
European		-0.012		0.040		-0.041
Union		(0.041)		(0.032)		(0.037)
Mercosur		0.245		0.199		0.420
		(0.065)		(0.041)		(0.057)
Apec		0.119		0.011		0.076
		(0.033)		(0.029)		(0.027)
Asean		0.183		0.164		0.187
		(0.089)		(0.070)		(0.102)
Nafta		0.000		0.000		-0.071
		(0.000)		(0.000)		(0.069)
Observations	2304	2115	2404	2214	2948	2742
Adjusted R-squared	0.304	0.312	0.110	0.130	0.027	0.087
Time Dummies	yes	yes	yes	yes	yes	yes
Country Dummies	yes	yes	yes	yes	yes	yes

This table presents results using the definition of x-share given in equation 7a in the text.

Table 8: Contribution of Traded Good Deviations to
Big Mac Real Exchange Rate Movements (1990-2002)
(Share in MSE: levels of real exchange rate)

	"pure" measure		*Over attribution to "x"*		*Over attribution to "y"*	
Exchange Rate	1.002	1.145	0.227	0.013	1.006	0.989
Volatility	(0.271)	(0.267)	(0.240)	(0.245)	(0.211)	(0.221)
$ Peg	-0.744	-0.720	-0.266	-0.296	-0.273	-0.254
	(0.059)	(0.066)	(0.037)	(0.041	(0.038)	(0.040)
Euro	0.098	0.070	0.151	0.055	-0.101	-0.184
	(0.032)	(0.036)	(0.036)	(0.035	(0.142)	(0.142)
Distance		-0.005		0.053		0.043
		(0.005)		(0.003		(0.004)
Sum Tariffs		-0.009		-0.004		-0.002
		(0.002)		(0.002		(0.002)
Common		-0.085		0.019		0.017
Language		(0.022)		(0.017		(0.018)
European		0.045		0.192		0.128
Union		(0.034)		(0.026		(0.029)
Mercosur		0.415		0.139		0.277
		(0.060)		(0.041		(0.069)
Apec		-0.038		0.125		0.199
		(0.029)		(0.024		(0.023)
Asean		0.236		0.259		0.214
		(0.088)		(0.091		(0.091)
Nafta		0.000		0.000		0.026
		(0.000)		(0.000		(0.076)
Observations	2304	2115	2404	2214	2948	2742
Adjusted R-squared	0.346	0.331	0.117	0.208	0.259	0.326
Time Dummies	yes	yes	yes	yes	yes	yes
Country Dummies	yes	yes	yes	yes	yes	yes

This table presents results using the definition of *x-share* given in equation 7b in the text.

Table 9: Contribution of Traded Good Deviations to
Big Mac Real Exchange Rate Movements (1990-2002)
(Share in variance: levels of real exchange rate, logistic specification)

	"pure" measure		Over attribution to "x"		Over attribution to "y"	
Exchange Rate	13.545	14.595	13.713	13.843	11.949	8.675
Volatility	(3.207)	(3.355)	(2.829)	(2.950)	(2.287)	(2.522)
$ Peg	-4.115	-3.811	-1.994	-1.755	-0.487	-0.771
	(1.038)	(1.054)	(0.937)	(0.915)	(1.044)	(1.063)
Euro	-2.214	-2.137	0.248	0.401	-0.925	-0.546
	(1.750)	(1.799)	(0.359)	(0.394)	(1.574)	(1.564)
Distance		-0.042		-0.043		0.216
		(0.056)		(0.045)		(0.046)
Sum Tariffs		-0.087		-0.081		-0.086
		(0.025)		(0.019)		(0.020)
Common		-0.757		-0.298		-0.277
Language		(0.262)		(0.185)		(0.196)
European		-0.443		-0.370		-0.555
Union		(0.398)		(0.299)		(0.342)
Mercosur		3.835		2.973		1.474
		(0.804)		(1.030)		(0.527)
Apec		0.321		-0.575		0.040
		(0.328)		(0.268)		(0.252)
Asean		1.293		0.988		1.237
		(0.878)		(0.764)		(0.981)
Nafta		0.000		0.000		-1.423
		(0.000)		(0.000)		(0.692)
Observations	2304	2115	2404	2214	2948	2742
Adjusted R-squared	0.301	0.304	0.149	0.149	0.061	0.071
Time Dummies	yes	yes	yes	yes	yes	yes
Country Dummies	yes	yes	yes	yes	yes	yes

This table presents results using the definition of *x-share* given in equation 7a in the text, and the logistic transformation described in equation 9.

**Table 10: Contribution of Traded Good Deviations to
Big Mac Real Exchange Rate Movements (1990-2002)
(Share in MSE: levels of real exchange rate, logistic specification)**

	"pure" measure		*Over attribution to "x"*		*Over attribution to "y"*	
Exchange Rate	7.429	10.365	1.279	1.872	5.365	6.744
Volatility	(2.120)	(1.940)	(1.701)	(1.736)	(1.429)	(1.516)
$ Peg	-6.886	-6.396	-2.856	-2.655	-2.923	-2.674
	(0.599)	(0.628)	(0.280)	(0.304)	(0.431)	(0.446)
Euro	-0.249	-0.361	1.041	0.530	-0.382	-0.793
	(0.857)	(0.863)	(0.193)	(0.188)	(0.760)	(0.763)
Distance		-0.336		0.033		0.017
		(0.035)		(0.020)		(0.025)
Sum Tariffs		-0.056		-0.026		-0.012
		(0.015)		(0.012)		(0.011)
Common		-0.881		-0.020		-0.058
Language		(0.153)		(0.103)		(0.120)
European		-0.051		0.804		0.366
Union		(0.240)		(0.171)		(0.174)
Mercosur		3.251		1.725		1.078
		(0.523)		(0.404)		(0.371)
Apec		-0.447		0.247		0.947
		(0.200)		(0.149)		(0.147)
Asean		1.603		1.575		1.069
		(0.583)		(0.647)		(0.721)
Nafta		0.000		0.000		-0.633
		(0.000)		(0.000)		(0.373)
Observations	2304	2115	2404	2214	2948	2742
Adjusted R-squared	0.371	0.396	0.207	0.224	0.291	0.324
Time Dummies	yes	yes	yes	yes	yes	yes
Country Dummies	yes	yes	yes	yes	yes	yes

This table presents results using the definition of *x-share* given in equation 7b in the text, and the logistic transformation described in equation 9.
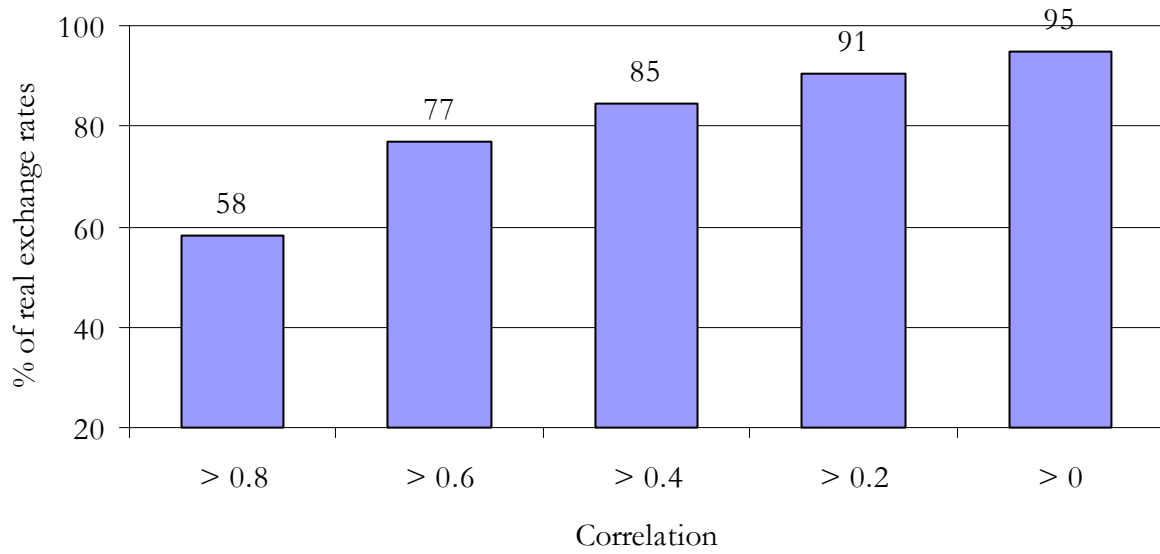
Figure 1

Correlation of Big Mac and CPI Real Exchange Rates
(levels)

Correlation of Big Mac and CPI Real Exchange Rates
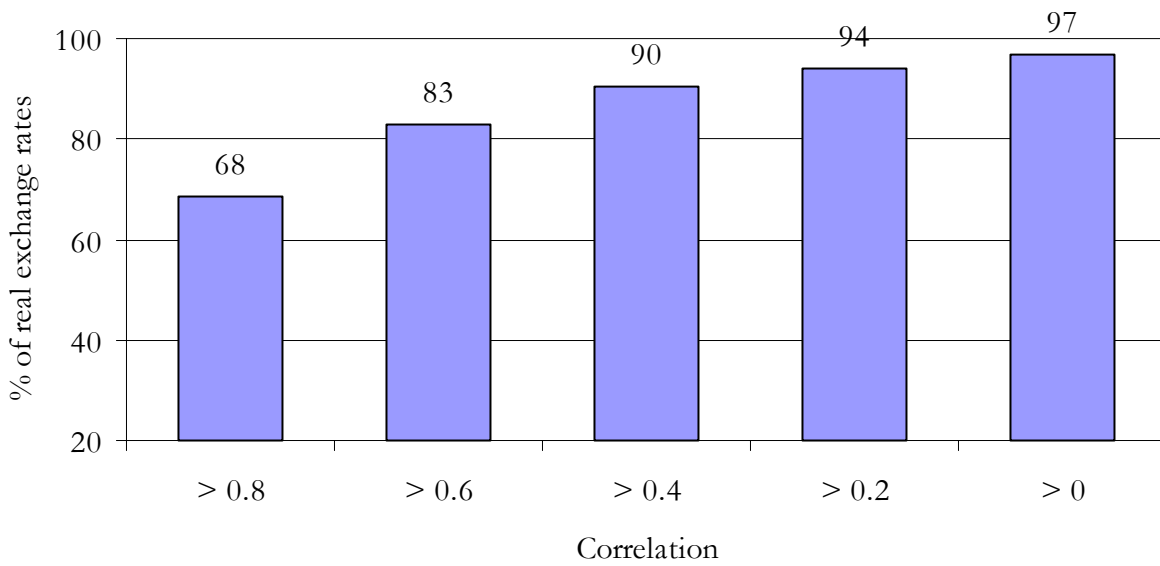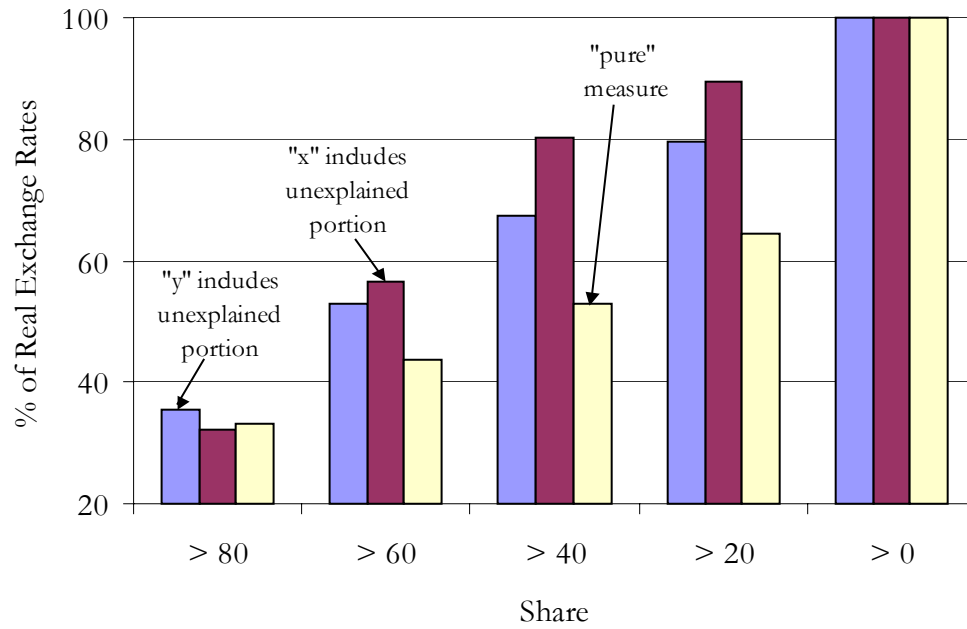(1st differences)

Figure 2

Share of Traded Goods Price Deviations in
Big Mac Real Exchange Rates
(343 real exchange rates, all years)

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Appendix Table 1: Cities Matched to Countries

1	Amsterdam, Netherlands	18	Mexico City, Mexico
2	Auckland, New Zealand	19	Paris, France
3	Bangkok, Thailand	20	Prague, Czech Republic
4	Beijing, China	21	Rome, Italy
5	Berlin, Germany	22	Santiago, Chile
6	Brussels, Belgium	23	Sao Paulo, Brazil
7	Budapest, Hungary	24	Seoul, Korea
8	Buenos Aires, Argentina	25	Singapore
9	Copenhagen, Denmark	26	Stockholm, Sweden
10	Dublin, Ireland	27	Sydney, Australia
11	Hong Kong, SAR	28	Taipei, Taiwan
12	Chicago, USA[1]	29	Tel Aviv, Israel
13	Jakarta, Indonesia	30	Tokyo, Japan
14	Johannesburg, South Africa	31	Toronto, Canada
15	Kuala Lumpur, Malaysia	32	Vienna, Austria
16	London, England	33	Warsaw, Poland
17	Madrid, Spain	34	Zurich, Switzerland

[1] To correspond with the Economist's Big Mac Index, data for the U.S. is an average of Atlanta, Chicago, San Francisco, and Washington, D.C.

Appendix Table 2: Persistence Estimates
(Dropping influential observations)

Tradables	$\hat{\beta}$	Half-life	# obs	$\overline{R}^2$
Beef	-0.431 (0.053)	1.2	243	0.23
Cheese	-0.370 (0.051)	1.5	239	0.22
Lettuce	-0.347 (0.050)	1.6	233	0.19
Onions	-0.618 (0.056)	0.7	243	0.35
Bread	-0.227 (0.045)	2.7	243	0.08
Median		1.4		
Non-Tradables				
Labor	-0.265 (0.053)	2.3	215	0.21
Rent	-0.141 (0.036)	4.6	240	0.10
Electricity	-0.137 (0.032)	4.7	243	0.18
Median		3.9		
Big Mac	-0.277 (0.056)	2.1	192	0.17
Country fixed effects	yes			
Time fixed effects	yes			

This table reports the results of estimating equation 1 using a fixed-effects estimator. For this table, the observations associated with the largest 5% of the residuals from the regressions reported in Table 4 were eliminated prior to estimation. The half-life is computed as $\log(.5)/\log(1+\hat{\beta})$.

Appendix Table 3: Persistence Estimates
(Random Effects Estimator)

Tradables	$\hat{\beta}$	Half-life	# obs	$\overline{R}^2$	$Ho: \mathrm{cov}(X,e) = 0$
Beef	-0.306 (0.046)	1.9	256	0.23	0.024
Cheese	-0.350 (0.047)	1.6	252	0.27	0.062
Lettuce	-0.232 (0.043)	2.6	246	0.19	0.018
Onions	-0.505 (0.055)	1.0	256	0.33	0.074
Bread	-0.145 (0.038)	4.4	256	0.15	0.027
Median		2.3			
Non-Tradables					
Labor	-0.125 (0.037)	5.2	227	0.17	0.017
Rent	-0.075 (0.030)	8.9	253	0.09	0.039
Electricity	-0.115 (0.027)	5.6	256	0.22	0.072
Median		6.6			
Big Mac	-0.189 (0.045)	3.3	203	0.21	0.025

This table reports the results of estimating equation 1 using a random effects estimator. The final column reports the significance level of a Hausman test that the covariance between the independent variables and the error term is equal to zero. Failure to reject this hypothesis indicates that random effects estimator is the efficient estimator. The half-life is computed as $\log(.5)/\log(1+\hat{\beta})$.

Appendix Table 4: Persistence Estimates
(Cumby's Sample of Countries: 1990-1999)

Tradables	$\hat{\beta}$	Half-life	# obs	$\overline{R}^2$
Beef	-0.540 (0.053)	0.9	72	0.07
Cheese	-0.543 (0.122)	0.9	72	0.28
Lettuce	-0.685 (0.0128	0.6	72	0.24
Onions	-0.819 (0.125)	0.4	72	0.40
Bread	-0.540 (0.122)	0.9	72	0.12
Median		0.7		
Non-Tradables				
Labor	-0.622 (0.141)	0.7	72	0.16
Rent	-0.057 (0.065)	4.3	71	-0.76
Electricity	-0.396 (0.091)	1.4	72	0.26
Median		2.1		
Big Mac	-0.398 (0.128)	1.4	71	0.07
Country fixed effects	yes			
Time fixed effects	yes			

This table reports the results of estimating equation 1 using a fixed-effects estimator. The half-life is computed as $\log(.5)/\log(1+\hat{\beta})$.

Appendix Table 5 Persistence Estimates
(Augmented Dickey-Fuller Specification)

Tradables	$\hat{\beta}$	$\hat{\gamma}$	Half-life[*]	# obs	$\overline{R}^2$
Beef	-0.401 (0.068)	-0.077 (0.071)	1.4	234	0.18
Cheese	-0.377 (0.067)	-0.075 (0.068)	1.5	229	0.16
Lettuce	-0.324 (0.063)	-0.044 (0.071)	1.8	224	0.14
Onions	-0.534 (0.079)	-0.077 (0.068)	0.9	234	0.22
Bread	-0.291 (0.058)	0.047 (0.073)	2.0	234	0.11
Median			1.5		
Non-Tradables					
Labor	-0.325 (0.064)	0.180 (0.081)	1.8	207	0.11
Rent	-0.210 (0.043)	0.157 (0.070)	2.9	231	0.11
Electricity	-0.205 (0.040)	0.100 (0.069)	3.0	234	0.17
Median			2.6		
Big Mac	-0.357 (0.076)	-0.033 (0.089)	1.6	181	0.16

Country fixed effects   yes
Time fixed effects   yes

This table reports the results of estimating the following equation for each real exchange rate:

$$\Delta q_{i,t} = \beta \, q_{i,t-1} + \gamma \Delta q_{i,t-1} + \text{country \& time dummies} + \varepsilon_{i,t}, \text{ using a fixed-effects estimator.}$$

[*]The half-life is computed as $\log(.5)/\log(1+\hat{\beta})$.

**Appendix Table 6: Contribution of Traded Good Deviations to
Big Mac Real Exchange Rate Movements (1990-2002)
(Share in variance: levels of real exchange rate)**

	"pure" measure		Over attribution to "x"		Over attribution to "y"	
Exchange Rate	1.315	1.351	1.595	1.415	1.797	0.900
Volatility	(0.236)	(0.255)	(0.185)	(0.198)	(0.210)	(0.232)
$ Peg	-0.160	-0.226	0.070	-0.031	0.046	-0.127
	(0.065)	(0.064)	(0.047)	(0.044)	(0.051)	(0.051)
Euro	-0.131	-0.139	-0.026	-0.033	-0.121	-0.087
	(0.049)	(0.052)	(0.030)	(0.031)	(0.060)	(0.059)
Distance		0.033		0.035		0.063
		(0.005)		(0.004)		(0.004)
Sum Tariffs		-0.007		-0.006		-0.009
		(0.002)		(0.002)		(0.002)
Common		0.001		0.028		0.018
Language		(0.019)		(0.014)		(0.015)
European		0.028		0.064		-0.033
Union		(0.031)		(0.023)		(0.026)
Mercosur		0.258		0.250		0.458
		(0.041)		(0.032)		(0.040)
Apec		0.104		0.042		0.057
		(0.025)		(0.021)		(0.022)
Asean		0.106		0.051		0.129
		(0.065)		(0.052)		(0.061)
Nafta		0.047		0.108		0.052
		(0.099)		(0.061)		(0.060)
Observations	3863	3390	4148	3658	4703	4181
Adjusted R-squared	0.284	0.293	0.090	0.104	0.047	0.096
Time Dummies	yes	yes	yes	yes	yes	yes
Country Dummies	yes	yes	yes	yes	yes	yes

This table presents results using the definition of x-share given in equation 7a in the text. This table can be compared directly to Table 7. Unlike in Table 7 however, regressions in this table focus on all Big Mac real exchange rates – i.e., including those where the correlation with CPI real exchange rates is *below* than 0.65 in both levels, and in 1st differences.

Appendix Table 7: Contribution of Traded Good Deviations to Big Mac Real Exchange Rate Movements (1990-2002)
(Share in variance: 1ˢᵗ differences of real exchange rate)

	"pure" measure		Over attribution to "x"		Over attribution to "y"	
Exchange Rate Volatility	2.123	2.106	1.509)	0.939	0.801	1.173
	(0.284)	(0.303)	(0.247)	(0.279)	(0.280)	(0.258)
$ Peg	0.078	0.122	0.110	-0.002	-0.046	0.075
	(0.149)	(0.153)	(0.126)	(0.083)	(0.084)	(0.132)
Euro	-0.140	-0.081	-0.095	-0.125	-0.117	-0.028
	(0.041)	(0.048)	(0.186)	(0.064)	(0.068)	(0.187)
Distance		-0.002		0.044		0.033
		(0.006)		(0.005)		(0.005)
Sum Tariffs		-0.001		0.005		-0.009
		(0.004)		(0.003)		(0.003)
Common Language		-0.001		-0.002		0.023
		(0.029)		(0.022)		(0.024)
European Union		-0.087		0.056		-0.077
		(0.047)		(0.036)		(0.039)
Mercosur		0.306		0.153		0.058
		(0.072)		(0.050)		(0.095)
Apec		-0.027		0.019		-0.020
		(0.036)		(0.028)		(0.029)
Asean		0.021		0.177		-0.002
		(0.103)		(0.069)		(0.088)
Nafta		0.000		0.000		0.006
		(0.000)		(0.000)		(0.078)
Observations	1939	1782	2615	2050	1892	2439
Adjusted R-squared	0.331	0.327	0.061	0.071	0.122	0.085
Time Dummies	yes	yes	yes	yes	yes	yes
Country Dummies	yes	yes	yes	yes	yes	yes

This table presents results using the definition of x-share given in equation 7c in the text.

Appendix Table 8: Contribution of Traded Good Deviations to
Big Mac Real Exchange Rate Movements (1990-2002)
(Share in MSE: 1ˢᵗ differences of real exchange rate)

	"pure" measure		Over attribution to "x"		Over attribution to "y"	
Exchange Rate	1.996	2.002)	0.728	0.522	1.445	1.070
Volatility	(0.254)	(0.267)	(0.250)	(0.245)	(0.227)	(0.236)
$ Peg	0.015	0.069	0.024	-0.020	-0.053	-0.089
	(0.146)	(0.151)	(0.049)	(0.051)	(0.101)	(0.106)
Euro	-0.081	-0.029	-0.137	-0.103	-0.095	-0.020
	(0.037)	(0.041)	(0.067)	(0.070)	(0.159)	(0.160)
Distance		-0.003		0.043		0.030
		(0.006)		(0.004)		(0.005)
Sum Tariffs		-0.003		0.002		-0.009
		(0.004)		(0.002)		(0.003)
Common		0.021		0.015		0.022
Language		(0.027)		(0.019)		(0.022)
European		-0.086		0.004		-0.096
Union		(0.043)		(0.028)		(0.037)
Mercosur		0.295		0.109		0.056
		(0.063)		(0.034)		(0.097)
Apec		-0.034		0.003		-0.033
		(0.034)		(0.024)		(0.027)
Asean		0.013		0.151		0.006
		(0.099)		(0.067)		(0.082)
Nafta		0.000		0.000		-0.026
		(0.000)		(0.000)		(0.076)
Observations	1939	1782	2051	1893	2615	2439
Adjusted R-squared	0.379	0.374	0.089	0.159	0.081	0.105
Time Dummies	yes	yes	yes	yes	yes	yes
Country Dummies	yes	yes	yes	yes	yes	yes

This table presents results using the definition of x-share given in equation 7d in the text.

Appendix Table 9: Contribution of Traded Good Deviations to
Big Mac Real Exchange Rate Movements (1990-2002)
(Share in variance: 1ˢᵗ differences of real exchange rate, logistic specification)

	"pure" measure		*Over attribution to "x"*		*Over attribution to "y"*	
Exchange Rate	16.865	17.846	6.062	6.841	8.252	7.415
Volatility	(2.964)	(3.110)	(2.317)	(2.499)	(2.021)	(2.113)
$ Peg	-0.610	0.188	-0.082	0.038	1.507	1.436
	(1.298)	(1.343)	(0.962)	(1.002)	(1.146)	(1.198)
Euro	-1.592	-0.850	-0.923	-0.772	-0.939	-0.290
	(1.015)	(1.083)	(0.377)	(0.419)	(1.385)	(1.406)
Distance		-0.381		-0.051		-0.062
		(0.057)		(0.040)		(0.047)
Sum Tariffs		-0.017		0.005		-0.088
		(0.039)		(0.025)		(0.027)
Common		-0.385		-0.194		-0.022
Language		(0.274)		(0.190)		(0.206)
European		-1.333		-0.075		-1.113
Union		(0.425)		(0.305)		(0.327)
Mercosur		3.619		1.576		-0.143
		(1.192)		(0.810)		(0.631)
Apec		-0.671		-0.363		-0.572
		(0.336)		(0.251)		(0.249)
Asean		-0.840		0.304		-1.343
		(1.091)		(0.499)		(0.974)
Nafta		0.000		0.000		-0.245
		(0.000)		(0.000)		(0.776)
Observations	1939	1782	2050	1892	2615	2439
Adjusted R-squared	0.268	0.285	0.134	0.127	0.069	0.082
Time Dummies	yes	yes	yes	yes	yes	yes
Country Dummies	yes	yes	yes	yes	yes	yes

This table presents results using the definition of *x-share* given in equation 7c in the text, and the logistic transformation described in equation 9.

Appendix Table 10: Contribution of Traded Good Deviations to
Big Mac Real Exchange Rate Movements (1990-2002)
(Share in MSE: 1ˢᵗ differences of real exchange rate, logistic specification)

	"pure" measure		Over attribution to "x"		Over attribution to "y"	
Exchange Rate	14.904	15.904	4.415	4.632	7.513	6.377
Volatility	(2.279)	(2.350)	(1.683)	(1.763)	(1.469)	(1.544)
$ Peg	-1.032	-0.188	0.215	0.376	-0.322	-0.402
	(1.204)	(1.225)	(0.595)	(0.608)	(0.592)	(0.624)
Euro	-1.546	-0.882	-0.815	-0.551	-0.687	-0.032
	(1.158)	(1.207)	(0.343)	(0.351)	(0.892)	(0.903)
Distance		-0.364		-0.024		-0.074
		(0.048)		(0.030)		(0.038)
Sum Tariffs		-0.038		-0.006		-0.080
		(0.029)		(0.015)		(0.023)
Common		-0.218		-0.066		-0.049
Language		(0.215)		(0.131)		(0.156)
European		-1.295		-0.220		-1.193
Union		(0.332)		(0.185)		(0.264)
Mercosur		3.570		1.779		-0.199
		(0.767)		(0.492)		(0.496)
Apec		-0.767		-0.464		-0.580
		(0.272)		(0.178)		(0.194)
Asean		-0.317		0.357		-0.671
		(0.753)		(0.461)		(0.563)
Nafta		0.000		0.000		-0.513
		(0.000)		(0.000)		(0.578)
Observations	1939	1782	2051	1893	2615	2439
Adjusted R-squared	0.353	0.378	0.211	0.202	0.095	0.113
Time Dummies	yes	yes	yes	yes	yes	yes
Country Dummies	yes	yes	yes	yes	yes	yes

This table presents results using the definition of *x-share* given in equation 7d in the text, and the logistic transformation described in equation 9.