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The Micro-foundations of Big Mac Real Exchange Rates

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BIG MAC REAL EXCHANGE RATES**

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The Micro-foundations of Big Mac Real Exchange Rates

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THE MICRO-FOUNDATIONS OF BIG MAC REAL EXCHANGE RATES

BY DAVID C. PARSLEY AND SHANG-JIN WEI

Abstract

The real exchange rate is said to be the single most important price in an economy. While we used to think that we knew what explained its movements (e.g., the Balassa-Samuelson effect), the recent much-cited result by Engel (1999) proposes a serious reinterpretation – i.e., nearly 100% of the movements in the U.S. real exchange rate are explained by deviations from the law of one price. Engel's finding holds even in the medium run, when movements in the relative price of non-tradables between countries, were thought to be of paramount importance.

In this project, we study the movement of real exchange rates based on the prices of Big Macs (which we show are highly correlated with 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. There are a number of advantages associated with our approach. First, unlike the CPI real exchange rate, we can measure the Big Mac real exchange rate in levels in an economically meaningful way. Second, unlike the CPI real exchange rate 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 real exchange rate in a setting that is free of the product-aggregation bias (argued by Imbs, Mumtaz, Ravn, and Rey, 2002, to be important in studies on CPI real exchange rates), the temporal aggregation bias (argued to be important by Taylor, 2001), or the bias generated by non-compatible consumption baskets across countries. Fourth, we show that Engel's result that deviation from the law of one price is all that matters does not hold generally. Furthermore, deviations from his result can be systematically explained.

Keywords: Real exchange rates; TAR models

JEL Classification Codes: F31

DAVID C. PARSLEY – SHENG-JIN WEI

A BIG MAC ALAPÚ REÁLÁRFOLYAM MIKROÖKONÓMIAI ALAPJAI**Összefoglaló**

A gazdaságban a reálárfolyam az egyik legfontosabb relatív ár. Miközben azt gondoltuk, hogy tudjuk, hogy mi magyarázza a reálárfolyam mozgásait (például a Balassa-Samuelson hatás), Engel (1999) sokat hivatkozott tanulmányának eredményei véleményünk ártértékelésére késztettek. Engel ugyanis azt találta, hogy az amerikai dollár reálárfolyamának mozgásait majdnem teljes mértékben az „egyetlen ár törvényétől” való eltérés magyarázza. Ez a magyarázat még középtávon is érvényes, szemben azzal az általánosan elfogadott elmélettel, hogy középtávon a külfölddel nem versenyző jóságok két ország között tapasztalt relatív árainak mozgása tekinthető a meghatározó tényezőnek.

Ebben a tanulmányban a Big Mac áron alapuló reálárfolyamok (amelyekről megmutatjuk, hogy erősen korreláltak a CPI-alapú reálárfolyamokkal) mozgását tanulmányozzuk. A vizsgálat legfontosabb újítása az, hogy a Big Mac árait az egyes összetevőinek (darált marhahús, kenyér, saláta, munkaköltség, bérleti díj, stb.) 1990–2002 között 34 országban mért áraival vetjük össze. Megközelítésünknek számos előnye van. Először, szemben a CPI-alapú reálárfolyammal, a Big Mac reálárfolyamot közgazdaságilag is értelmezhető módon tudjuk kifejezni nominális értékben (vagyis szintekben). Másodszor, a Big Mac összetételét (majdnem) pontosan ismerjük, és így viszonylag precízen meg tudjuk becsülni annak külfölddel versenyző és nem versenyző összetevőit. Ellentétben ezzel, amikor a CPI-alapú reálárfolyamot szeretnénk kettéválasztani külfölddel versenyző és nem versenyző összetevőkre, a súlyokra és a függvényformára nézve feltevéseket kell tennünk. Harmadszor, módszerünk révén a reálárfolyam ingadozásának dinamikáját egy olyan keretben tanulmányozhatjuk, amely mentes a termék-aggregálási torzítástól (amelyről Imbs, Mumtaz, Ravn és Rey (2002) megmutatta, hogy fontos a CPI-alapú reálárfolyam tanulmányozásához), az időbeli aggregálási torzítástól (melynek fontosságát Taylor (2001) mutatta meg), illetve attól a torzítástól, amely az országonként eltérő fogyasztási kosarak összevetéséből származik. Negyedszer, meg tudjuk mutatni, hogy Engel eredménye, miszerint csak az egyetlen ár törvényétől való eltérés számít, általánosságban nem érvényes, és az eredményétől való eltérést is megmagyarázhatjuk.

“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. Introduction (General promotion)

The importance of real exchange rate in an economy has been long recognized (see, for example, Milton Friedman, 1953; and Maurice Obstfeld and Kenneth Rogoff, 2000). However, several aspects of the real exchange rate are still in the “puzzle” category. First, movements in the real exchange rate (or, equivalently, the deviations from the purchasing power parity) seem too persistent. After surveying a long list of papers on the subject, Rogoff (1996) described a “remarkable consensus view” on the estimated half-life of deviations from PPP which he concluded is on the order of three to five years. This seems too slow relative to economic theories with a plausible size of the costs of arbitrage (Chari, Kehoe, and McGratten, 2002). Second, we used to think that differentials in the relative price of non-tradable goods across countries (i.e. through the Balassa-Samuelson effect) are the primary explanation for medium- to long-run movements in the real exchange rate. However, a recent much-cited paper by Charles Engel (1999) seriously undermines this view; he finds that nearly 100% of real exchange rates 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 a misspecification in the common linear estimation of the persistence parameter (e.g., Obstfeld and Taylor, 2000; Taylor, 2001; Taylor and Sarno, 2002; O’Connell and Wei 2002). With the presence of arbitrage costs, the proper specification may be a non-linear one. Within a band of no-arbitrage, the real exchange rate can be a random walk (i.e., the half-life can be infinite). But once it moves outside the no-arbitrage zone, the force of arbitrage may drive it 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 the range of 1-2 years). Second, there may exist a time-aggregation bias in some studies (Taylor 2001). 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 product-aggregation bias. 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 comparable, and the components in each country change over time. It is uncertain how important these non-comparability issues (across countries of aggregate price indexes and of quality change over time) are in practice. Non-comparability includes not only differences in the types of products in the CPI baskets across countries¹, but also cross-country variation in mixtures of traded and nontraded goods in the indexes (aka ‘home bias’ in price indexes), and cross-country differences in the weights for the included prices. More generally, the ‘substitution-bias’ issue (substitution across products in the basket) is amplified since it is occurring in each country to an unknown extent. As a result, arbitrage across countries on these consumption baskets is not easy (and cannot be fast). 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 cloud studies of CPI-based real exchange rates. Studies at the individual good level can directly control for all of these questions².

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, which we will show are highly correlated with the CPI-based real exchange rates (both in levels and in first differences). Our main innovation is to match these prices to the prices of individual ingredients, e.g., ground beef, bread, lettuce, labor, etc.

There are a number of advantages associated with our approach. First, the Big Mac is a composite good (in this sense, like a CPI index). However, unlike the consumption

¹ It is useful to stress that simply analyzing real exchange rates using more disaggregated price indexes will not adequately address these problems. That is, 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.

²One component of the CPI basket is food. The French basket may contain lots of 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.

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.³

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, we re-examine Engel's (1999) question concerning the role of deviations from the law of one price, and 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 made 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. One finding, consistent with the aggregation biases (Taylor, 2001, or Imbs, et al, 2002), is that the speed of convergence to parity tends to be somewhat faster for the Big Mac real exchange rates (Cumby, 1997; and Lutz, 2001). 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 our innovation, to decompose the Big Mac real exchange

³ 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.

rates into tradable and non-tradable components relatively precisely, and to address a range of questions that could not be studied otherwise.

The rest of the paper is organized as follows. In Section 2, we provide a more detailed description of the data sets, including their sources and coverage across time, countries and products. 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 the Big Mac real exchange rates 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

Key variables

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.

Other variables

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 take a look at the relationship between the Big Mac prices 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 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 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.

3b: 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:

$$1 \text{ Big Mac} = \min \{x_1, x_2, \dots, x_n\} \quad (1)$$

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,

$$P_{k,t}^{\text{Big Mac}} = \sum_i P_{k,i,t} x_i \quad (2)$$

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 $\{P_{k,i,t}\}$ for a sufficient number of time periods and countries, (or, to be precise, when # locations \times # time periods $\geq n$), then it is a matter of simple algebra to solve for all x_i , $i=1,2,\dots, n$. In fact, under our assumptions, a convenient way to solve for $\{x_1, x_2, \dots, x_n\}$ would be simply to perform a linear regression of $P_{k,t}^{\text{Big Mac}}$ on $\{P_{k,i,t}\}$. 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 on 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 that we do have information on, 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 (α) is between 55% and 64%, i.e., $\alpha = 0.456 + 0.046 + 0.051 \approx 0.55$ or, if we normalize by the total amount explained by all observed inputs, $\alpha = 0.553/0.869 \approx 0.64$.

We also implement a regression when all variables are 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.

3c. 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 3.a) we examined U.S. dollar prices across the 34 countries. In this section we focus on all bilateral price differences in U.S. dollars. 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.

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

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 7% level in all cases – most rejections are above the 5% level) 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 that studied by Cumby 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.

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

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 we also may be introducing 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 (1996), 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 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, 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 $b=0$. Mean reversion in

the Band-TAR model is sufficient to push the price differences only toward the outer edge of the bands, hence this model imposes $b=c$.

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

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, 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, then the Band-TAR model would be appropriate. Currently, there is no consensus as to which model is uniformly ‘best’, so we present estimates from both models; as it turns out, our conclusions are similar for either model.

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, tradable converge fastest on Median, 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 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.

3d. Two for the price of one: Balassa-Samuelson versus Engel

In many models of 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, countries with a faster growth in the productivity of tradable goods will experience a real appreciation of its currency. Indeed, the post-war secular rise in the yen/dollar real exchange rate (at least to 1990) has been attributed by many as an example of this effect.⁴ Productivity growth is not the only source for movement 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 the 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 (for a sample of high-income OECD countries over the past thirty years) that movements in relative prices of nontraded goods appear to account for essentially *none* of the movements in aggregate U.S. based real exchange rates. That is, breakdowns in PPP (or movements in real exchange rates) are almost completely due to deviations from the law of one price for tradable goods rather than to movement in the relative price of non-tradables between countries. In subsequent discussion, we will label the part of the real exchange rate movement that is explained by the deviations from the law of one price as the Engel effect⁵. In this case, there is essentially no room for the Harrod-Balassa-Samuelson effect or the Dornbusch-Froot-Rogoff effect 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. One hint that the Engel effect may be less important under some conditions was

⁴ For textbook treatments, see, e.g., Caves, Jones, and Frankel (2002, p. 372-3), or Obstfeld and Rogoff (1996, p. 210-214).

⁵ Parsley (2001) reaches a similar conclusion for a sample consisting of smaller, more open, and generally faster growing Asian-Pacific economies.

provided by Mendoza (2000) who studies the case of Mexican real exchange rate.⁶ Specifically, he found that the Engel effect explains near 100% of the Mexican real exchange rate when the country's nominal exchange rate was on a floating regime but 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 nominal exchange rate regime play a role in determining the relative importance of the Engel effect in explaining real exchange rate movement.

One important drawback to the decompositions in Engel, Parsley, and Mendoza, is that they rely on highly aggregated measures of traded and nontraded goods. 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. Another drawback is the assumption on the functional form that combines tradable and non-tradable prices into the aggregate price index. Typically, these authors make the simplifying assumption that the traded and non-traded components are combined in a Cobb-Douglas fashion. In contrast, in the case of the Big Mac there is very little room for substitution across inputs either within or across countries. Hence, the decomposition is more straightforward.

In this section we decompose movements in Big Mac real exchange rates into shares attributable to traded and nontraded inputs directly. An important goal of this analysis is to examine the robustness of these earlier studies in the context of a single 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 rate into traded and nontraded components. Express the Big Mac real exchange rate (Q^{BM}) as:

⁶ 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 LOP for an individual good and another that combines everything else. They find that whichever individual good is isolated accounts for virtually all the variation. Hence, they advise caution in interpreting such decompositions.

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

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.,

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

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 in Table 3. A similar computation can be made for P^{*T} , P^N , and P^{*N} . Thus, 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.

Engel's (1999) approach was to decompose movements in aggregate real exchange rates to shares attributable to x and y . Using more than thirty years of monthly data he focused on 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 only thirteen years of annual observations. Hence, we propose an alternative, time-dependent, way to construct the shares attributable to x and y . In particular, we focus on annual changes in real exchange rates. Thus we have a potential cross-section of 561 real exchange rates with 13 time series observations each (without

missing values).⁷ Our approach has the advantage that we can systematically relate these shares to observable country-pair and time-specific factors. Finally, note that Engel's results applied equally to *all* horizons; hence our focus on annual changes is not as restrictive as it first appears.

Generically, we construct the time-dependent measure of the share of Big Mac real exchange rate movements attributable to x as:

$$x\text{-share}_t = \frac{(x_t - \bar{x})^2}{(x_t - \bar{x})^2 + (y_t - \bar{y})^2}, \quad (7a)$$

Note that since x and y may be negative, we focus on squared terms, and x and y have the cross-section means removed. Unfortunately, the denominator of equation 7a does not equal the squared Big Mac real exchange rate. That is, our cost share regressions did not allocate 100% of the variation of Big Mac prices to the ingredients we included. Hence we must also account for this unexplained portion for completeness. We take an agnostic approach and alternatively attribute it to x , and then to y , and report our results both ways. In appendices to be added we repeat the analysis ignoring the unexplained portion.

Figure 2 plots the histograms of these two measures of $x\text{-share}$ over time for the 343 real Big Mac exchange rates (with correlation coefficients > 0.65 between CPI and Big Mac real exchange rates in both levels and in first differences). The x-axis records the amount of variation in the Big Mac real exchange rate accounted for by variation in traded-goods inputs. 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 rate movements. This is true whether we attribute the unexplained portion to x , or to y in equation 7a. Moreover, it is apparent that x accounts for a relatively small portion of

⁷ Since we have 34 countries, we have 561 ($=34 \times 33/2$) real exchange rates. However, we continue to focus on only those 343 good level real exchange rates highly correlated with aggregate real exchange rates. Specifically, 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.

real exchange rate movements for a non-trivial proportion of the real exchange rates in our sample.

One problem with Equation 7a, is that it ignores potential covariation between x and y . In equation 7b, we propose a time-varying measure, similar to Engel's, that attributes half the comovements to x and the other half to y . For completeness however, we examine first-differenced versions of 7a and 7b, given as 7c and 7d below.

$$x\text{-share}_t = \frac{(x_t - \bar{x})^2 + x_t^2}{(x_t - \bar{x})^2 + (y_t - \bar{y})^2 + x_t^2 + y_t^2}, \quad (7b)$$

$$x\text{-share}_t = \frac{(\Delta x_t - \Delta \bar{x})^2}{(\Delta x_t - \Delta \bar{x})^2 + (\Delta y_t - \Delta \bar{y})^2}, \quad (7c)$$

$$x\text{-share}_t = \frac{(\Delta x_t - \Delta \bar{x})^2 + (\Delta x_t)^2}{(\Delta x_t - \Delta \bar{x})^2 + (\Delta y_t - \Delta \bar{y})^2 + (\Delta x_t)^2 + (\Delta y_t)^2}, \quad (7d)$$

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 by incorporating two dummy variables. The first takes the value 1 for the U.S. dollar Pegs of Argentina, Hong Kong, and the United States. We also include a dummy variable 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 distance between their capital cities. The most general specification is shown as equation 8 below.

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

Distance is calculated using the great circle formula using each city's latitude and longitude data obtained from the UN web site www.un.org/Depts/unsd/demog/ctry.htm. Exchange rate variability is defined as the standard deviation of changes in the monthly bilateral exchange rate (between the city-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 cities 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 using the definition of x -share given in equations 7 and 8, are presented in Tables 7 and 8. 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*) this variation 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 and generally (though not always) support the idea that factors that segment markets raise the proportion of variation in real exchange rates that can be attributed to deviations from the LOP in traded goods. First, higher exchange rate volatility is associated with a larger x -share. 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, while having a common language never is. The trade blocs we include have some mixed results. The European Union dummy is negative (but insignificant) when the x -share is over-attributed (i.e., it includes the entire unexplained portion), but positive and insignificant when x -share is under-attributed. Mercosur, APEC, and ASEAN all seem to be positively associated with x -share.

One wonders what effect focusing on only a reduced subset of real exchange rates has on these results. 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 Interestingly, the results are strengthened in the full sample.

One potential statistical problem is that the dependent variable, a share, is constrained to lie between zero and one. This is an apparent violation of one of the basic assumptions of the classical linear regression model. Hence, we address this issue by taking a logistic transformation of $x\text{-share}$. This transformation allows the dependent variable to take any positive or negative value (see Greene 1997, p.228). For the definition of $x\text{-share}$ given in equation 7, the new dependent variable becomes:

$$x\text{-share}_t = \ln\left(\frac{x_t^2}{x_t^2 + y_t^2}\right) - \ln\left(1 - \frac{x_t^2}{x_t^2 + y_t^2}\right), \quad (9)'$$

Results for equations 7a and 7b are presented in Tables 9 and 10. Here too, statistical significance generally rises. The only notable changes are that the dummy for Common language is negative, though it remains statistically insignificant, and the trade bloc dummies (APEC and ASEAN) become statistically insignificant. All other conclusions hold under this transformation.

Finally, in Appendix tables 7 and 8, we present the results for the first-differenced versions of equations 7 and 8. Similarly, in Appendix tables 9 and 10 we present the results for the logistic transformations. Again, the general pattern of results is similar to those discussed above.

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. 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.

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 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 deviations from the law of one price are all that matters does not hold generally. Furthermore, departure from his result can be systematically explained. In particular, deviations from the law of one price are more important for real exchange rate movements when market segmentation – especially, exchange rate volatility – increases.

Table 1: Countries and Regions

<i>Europe</i>	<i>Western Hemisphere</i>	<i>Asia, Pacific, and Africa</i>
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)**

<u>Country</u>	<u>Correlation in levels</u>	<u>Correlation in changes</u>
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
<i>Medians:</i>		
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)**

<u>Ingredient</u>	<u>Regression in Levels</u>		<u>Change Regression</u>
	<u>Coefficient</u> <u>Estimates¹</u>	<u>Implied Cost</u> <u>Share (%)²</u>	<u>Coefficient</u> <u>Estimates³</u>
<i>Traded:</i>			
Beef	3.010 (0.645)	9.0	2.257 (0.669)
Cheese	2.530 (0.592)	9.4	1.995 (0.625)
Lettuce	1.546 (3.645)	0.7	6.017 (3.476)
Onions	1.156 (3.610)	0.5	4.411 (3.239)
Bread	13.428 (3.053)	12.1	11.256 (3.200)
<i>Nontraded:</i>			
Labor	9.245 (0.832)	45.6	11.823 (1.069)
Rent	0.008 (0.003)	4.6	0.010 (0.004)
Electricity	0.085 (0.027)	5.1	0.078 (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 i^{th} ingredient is computed as: $\hat{\beta}_i \bar{P}_i / \bar{P}_{\text{Big Mac}}$, where \bar{P}_i is the average price of the i^{th} input.

Table 4: Persistence Estimates

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

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

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

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

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

	<i>"pure" measure</i>		<i>Over attribution to "x"</i>		<i>Over attribution to "y"</i>	
Exchange Rate	13.540	14.590	12.168	9.068	13.711	13.841
Volatility	(3.207)	(3.355)	(2.272)	(2.486)	(2.828)	(2.949)
\$ Peg	-4.114	-3.811	-0.474	-0.743	-1.994	-1.755
	(1.038)	(1.054)	(1.045)	(1.062)	(0.937)	(0.915)
Euro	-2.213	-2.137	-1.017	-0.643	0.248	0.401
	(1.750)	(1.799)	(1.572)	(1.561)	(0.359)	(0.394)
Distance		-0.042		0.211		-0.043
		(0.056)		(0.046)		(0.045)
Sum Tariffs		-0.087		-0.077		-0.081
		(0.025)		(0.018)		(0.019)
Common Language		-0.757		-0.270		-0.298
		(0.262)		(0.196)		(0.185)
European Union		-0.440		-0.516		-0.370
		(0.399)		(0.340)		(0.299)
Mercosur		3.836		1.502		2.974
		(0.804)		(0.525)		(1.030)
Apec		0.320		0.015		-0.575
		(0.328)		(0.251)		(0.268)
Asean		1.295		1.262		0.988
		(0.879)		(0.979)		(0.764)
Nafta		0.000		-1.429		0.000
		(0.000)		(0.691)		(0.000)
Observations	2304	2115	2947	2741	2404	2214
Adjusted R-squared	0.300	0.304	0.061	0.070	0.149	0.149
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.

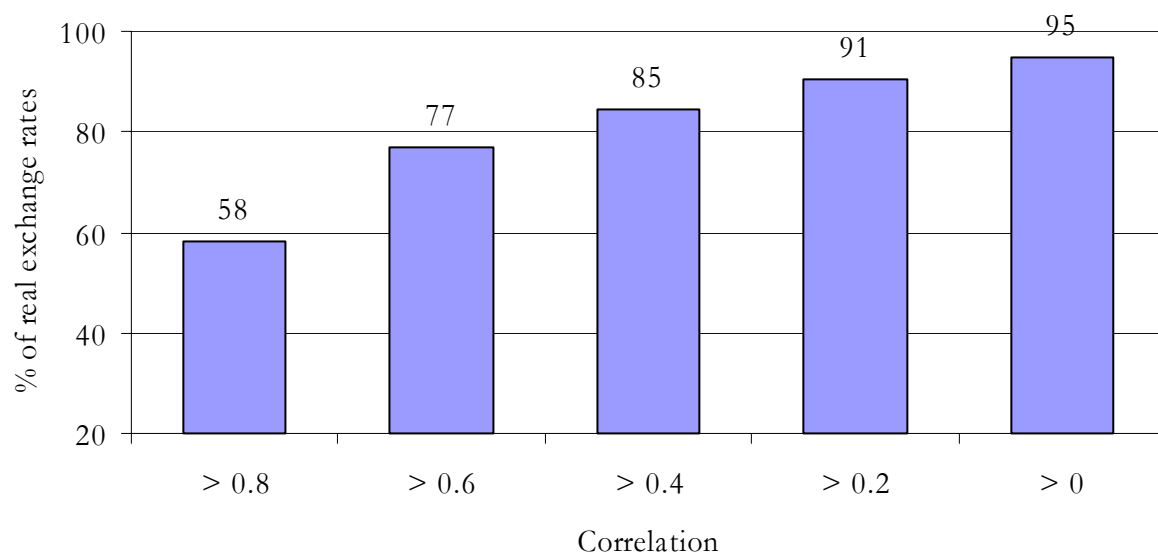
**Table 10: Contribution of Traded Good Deviations to
Big Mac Real Exchange Rate Movements (1990-2002)
(Logistic)**

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

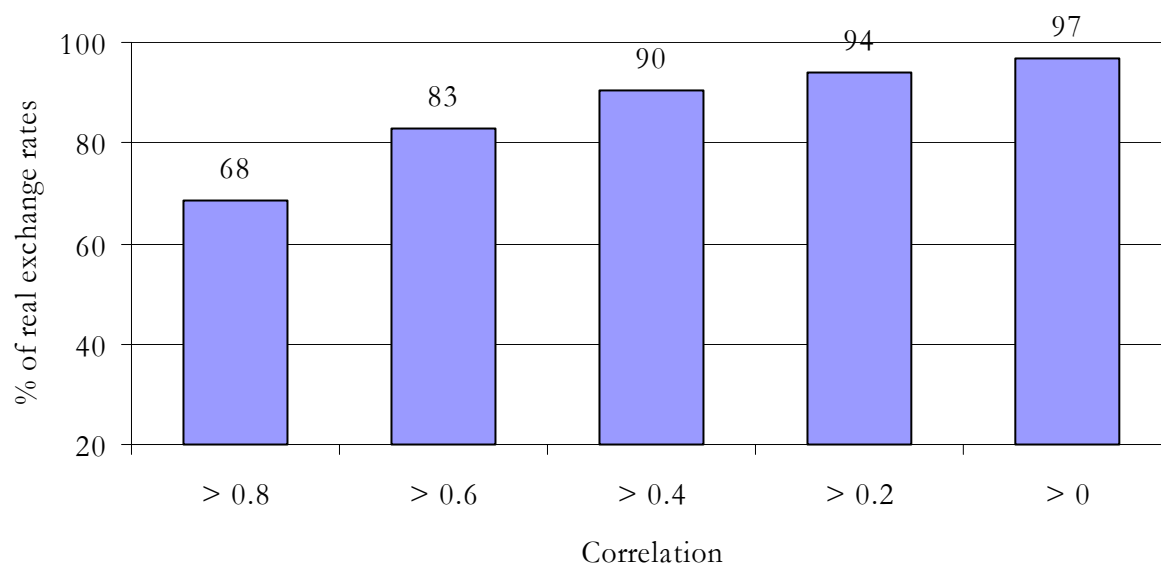
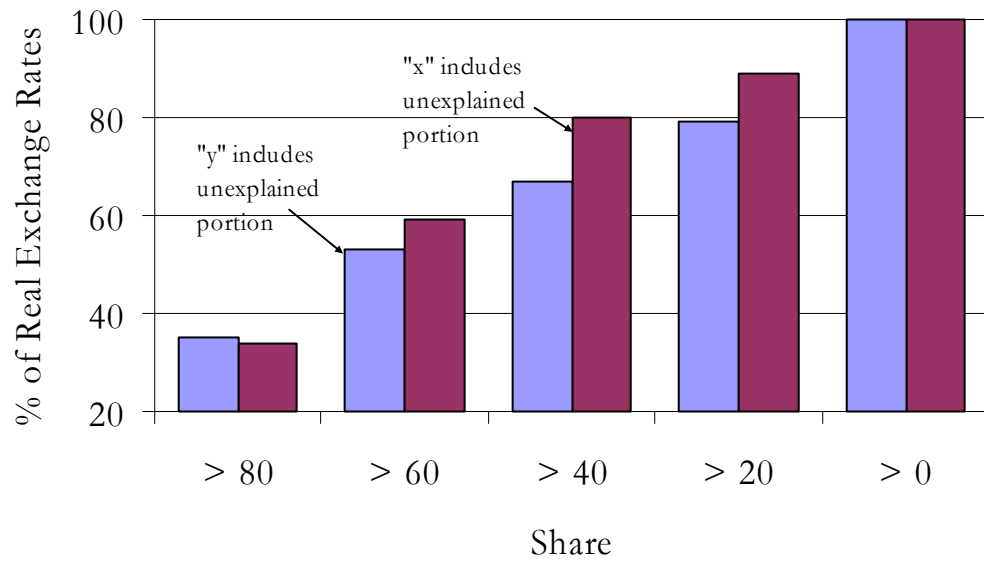


Figure 2

Share of Big Mac Real Exchange Rate Movements
(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)**

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

<i>Tradables</i>	$\hat{\beta}$	Half-life	# obs	\bar{R}^2	$H_0 : \text{cov}(X, e) = 0$
<i>Beef</i>	-0.306 (0.046)	1.9	256	0.23	0.024
<i>Cheese</i>	-0.350 (0.047)	1.6	252	0.27	0.062
<i>Lettuce</i>	-0.232 (0.043)	2.6	246	0.19	0.018
<i>Onions</i>	-0.505 (0.055)	1.0	256	0.33	0.074
<i>Bread</i>	-0.145 (0.038)	4.4	256	0.15	0.027
<i>Median</i>		2.3			
<i>Non-Tradables</i>					
<i>Labor</i>	-0.125 (0.037)	5.2	227	0.17	0.017
<i>Rent</i>	-0.075 (0.030)	8.9	253	0.09	0.039
<i>Electricity</i>	-0.115 (0.027)	5.6	256	0.22	0.072
<i>Median</i>		6.6			
<i>Big Mac</i>	-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)**

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

<i>Tradables</i>	$\hat{\beta}$	$\hat{\gamma}$	Half-life *	# obs	\bar{R}^2
<i>Beef</i>	-0.401 (0.068)	-0.077 (0.071)	1.4	234	0.18
<i>Cheese</i>	-0.377 (0.067)	-0.075 (0.068)	1.5	229	0.16
<i>Lettuce</i>	-0.324 (0.063)	-0.044 (0.071)	1.8	224	0.14
<i>Onions</i>	-0.534 (0.079)	-0.077 (0.068)	0.9	234	0.22
<i>Bread</i>	-0.291 (0.058)	0.047 (0.073)	2.0	234	0.11
<i>Median</i>			1.5		
<i>Non-Tradables</i>					
<i>Labor</i>	-0.325 (0.064)	0.180 (0.081)	1.8	207	0.11
<i>Rent</i>	-0.210 (0.043)	0.157 (0.070)	2.9	231	0.11
<i>Electricity</i>	-0.205 (0.040)	0.100 (0.069)	3.0	234	0.17
<i>Median</i>			2.6		
<i>Big Mac</i>	-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: Factors influencing traded goods contribution to
Big Mac real exchange rate movements (1990-2002)**

	<i>Over attribution to "x"</i>			<i>Over attribution to "y"</i>		
	<i>Col. 1</i>	<i>Col. 2</i>	<i>Col.3</i>	<i>Col. 1</i>	<i>Col. 2</i>	<i>Col.3</i>
<i>Exchange Rate Vol.</i>	1.797 (0.210)	0.900 (0.232)	0.932 (0.232)	1.595 (0.185)	1.415 (0.198)	1.402 (0.197)
<i>\$ Peg</i>	0.046 (0.051)	-0.127 (0.051)	-0.166 (0.044)	0.070 (0.047)	-0.031 (0.044)	-0.035 (0.043)
<i>Euro</i>	-0.121 (0.060)	-0.087 (0.059)	-0.078 (0.060)	-0.026 (0.030)	-0.033 (0.031)	-0.028 (0.031)
<i>Distance</i>		0.063 (0.004)	0.065 (0.004)		0.035 (0.004)	0.031 (0.004)
<i>Sum of Tariffs</i>		-0.009 (0.002)	-0.010 (0.002)		-0.006 (0.002)	-0.009 (0.002)
<i>Common Language</i>		0.018 (0.015)	0.019 (0.015)		0.028 (0.014)	0.028 (0.014)
<i>European Union</i>		-0.033 (0.026)	-0.047 (0.025)		0.064 (0.023)	0.053 (0.023)
<i>Mercosur</i>		0.458 (0.040)	0.480 (0.040)		0.250 (0.032)	0.236 (0.031)
<i>Apec</i>		0.057 (0.022)	0.056 (0.021)		0.042 (0.021)	0.027 (0.021)
<i>ASEAN</i>		0.129 (0.061)	0.105 (0.059)		0.051 (0.052)	0.014 (0.050)
<i>NAFTA</i>		0.052 (0.060)	0.029 (0.059)		0.108 (0.061)	0.122 (0.061)
Number of Obs.	4703	4181	4139	4148	3658	3621
Adjusted R-Squared	0.05	0.10	0.12	0.09	0.10	0.13
Time Dummies	yes	yes	yes	yes	yes	yes
Country Dummies	yes	yes	yes	yes	yes	yes

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. The columns labeled ‘over-attribution to *x*’ attribute variation in the unexplained portion of Big Mac prices to *x*. And, the columns labeled ‘under-attribution to *x*’ attribute variation in the unexplained portion of Big Mac prices to *y*. For both sets of columns, Col. 3 drops observations associated with the largest 1% of residuals in Col. 2.

**Appendix Table 7: Contribution of Traded Good Deviations to
Big Mac Real Exchange Rate Movements (1990-2002)
(First-Differences)**

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

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

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

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