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THE BMI, EXCHANGE RATES AND FUNDAMENTALS*

by

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Abstract

We show that the Big Mac Index published by The Economist magazine is a seriously biased predictor of future currency movements. But once this bias is allowed for, the BMI does a surprisingly good job in forecasting exchange rates, beating the widely-accepted benchmark -- the random walk model. Instead of treating the equilibrium exchange rate as constant, as in previous research, we investigate its dependence on economic fundamentals.

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1. Introduction

In 1972, just prior to the collapse of the Bretton-Woods system of fixed exchange rates, the US dollar cost about 40 British pence. By 1985, the dollar had appreciated to 90 pence, but by the start of June 2008 it had fallen back to 51 pence. As such substantial changes in currency values over the longer term are commonplace in a world of floating exchange rates, the understanding of the valuation of currencies is a significant intellectual challenge and of great importance for economic policy, the smooth functioning of financial markets, and the financial management of international companies.

While exchange-rate economics is a controversial area, a substantial body of research now finds that over the longer term exchange rates are "anchored" by price levels. This idea is embodied in purchasing power parity (PPP) theory, which states that the exchange rate is proportional to the ratio of prices in the two countries. A new and simple way of making PPP comparisons was introduced in 1986 by The Economist magazine. This involves using the price of a Big Mac hamburger at home and abroad as the price ratio that reflects the underlying value of the currency. This price ratio is known as the "Big Mac Index" (BMI), which forms the basis for "burgernomics". When compared to the actual exchange rate, the BMI purports to give an indication of the extent to which a currency is over- or under-valued according to the law of one price. While an informal currency pricing model, the BMI is rooted in PPP theory and provides a fascinating example of the productive interplay between fundamental economic research, journalism and financial markets.

The literature on PPP in general is large and growing, and several good surveys are available, including Froot and Rogoff (1995), Lan and Ong (2003), MacDonald (2007), Rogoff (1996), Sarno and Taylor (2002), Taylor and Taylor (2004) and Taylor (2006). Early contributors to academic research on the BMI include Annaert and Ceuster (1997), Click (1996), Cumby (1996), Ong (1997) and Pakko and Pollard (1996), while more recent papers include Chen et al. (2005), Clements and Lan (2006), Lan (2007) and Parsley and Wei (2007).

This paper shows that the Big Mac Index published by The Economist magazine is a seriously biased predictor of future currency movements. But once this bias is allowed for, we demonstrate that the Index offers considerable insight into the operation of the currency markets. In particular, it does a surprisingly good job in forecasting exchange rates, beating the widely-accepted benchmark -- the random walk model. Instead of treating the equilibrium exchange rate (EER) as a constant, as in previous research, this paper incorporates economic fundamentals into exchange-rate modeling and sheds light on whether the EER is time-varying. We consider in this paper the world's six major currencies relative to the dollar; for a related treatment of 24 currencies, see Clements et al. (2007).

The organisation of the paper is as follows. In Section 2, we set the scene by discussing PPP theory in some detail. Then follows in Section 3 an account of the workings of the BMI, where it is established that it is subject to a serious bias. We show in Section 4 that once the Index is adjusted for this bias, exchange rates tend to revert to the mean over the medium term of more than three years. Section 5 examines the predictive ability of the BMI and establishes that over- (under-) valued currencies subsequently depreciate (appreciate). Section 6 extends the analysis by allowing the EER to vary with incomes and interest rates.

2. Three Versions of PPP

This section gives an account of PPP theory by presenting the three versions: (i) absolute PPP; (ii) relative PPP; and (iii) stochastic deviations from relative PPP. This material provides the theoretical underpinnings for the remainder of the paper.

Let P_i denote the domestic price of good i in terms of domestic currency and P_i^* the price of the same good in the foreign country in terms of foreign currency. With zero transaction costs and no barriers to international trade, arbitrage equalises the cost of the good expressed in terms of a common currency:

$$P_i = SP_i^* \tag{2.1}$$

where S is the spot exchange rate (the domestic currency cost of a unit of foreign currency). Equation (2.1) is known as the law of one price. The 2×2 structure of prices can be summarised as follows:

Currency	Location	
	Home	Foreign
Home	P_i	SP_i^*
Foreign	P_i / S	P_i^*

As prices in a given row are expressed in terms of the same currency, they are comparable "row-wise", not "column-wise".

Further, let w_i and w_i^* denote the share of good i in the economy at home and abroad, with $\sum_{i=1}^{n} w_i = \sum_{i=1}^{n} w_i^* = 1$, where n is the number of goods. Then multiplying both sides of equation (2.1) by w_i and summing over $i = 1,\ldots,n$, we obtain $\sum_{i=1}^{n} w_i P_i = S\sum_{i=1}^{n} w_i P_i^*$. As the left-hand side of this equation is a share-weighted average of the n prices at home, it is interpreted as a price index, which we write as $P = \sum_{i=1}^{n} w_i P_i$. But as the right-hand side of the above equation applies domestic weights to foreign prices, it is not a conventional price index. To make some progress, we need the simplifying assumption that the foreign and domestic weights coincide, so that $\sum_{i=1}^{n} w_i P_i^* = \sum_{i=1}^{n} w_i^* P_i^* = P^*$, an index of the price level abroad. Thus we have

$$P = SP^*, \tag{2.2}$$

which is an economy-wide version of condition (2.1). We can interpret P as the domestic currency cost of a basket of goods at home, while P^* is the cost of the same basket abroad. Thus SP^* converts this foreign currency cost into domestic currency units and the ratio $P/(SP^*)$ is a measure of the relative price of the two baskets. Expressing equation (2.2) as $S = P/P^*$, we obtain the <u>absolute version of PPP</u>, whereby the exchange rate is the ratio of domestic to foreign prices. Using lowercase letters to denote logarithmic values of variables, we obtain

$$s = p - p^*. \tag{2.3}$$

Writing $r = p - p^*$ for relative prices, the above can be expressed as $s = r$.

Next, we define the home country's <u>real exchange rate</u> as

$$q = \log \frac{P}{SP^*}, \tag{2.4}$$

which is the logarithmic relative price of the two baskets. According to absolute PPP, the real exchange rate $q = p - s - p^* = r - s = 0$, and is constant. When $q > 0$, prices at home are too high relative to those abroad, and the currency is said to be "overvalued in real terms", and vice-versa. If there is a tendency for the real rate to revert to its PPP value, a non-zero value of q signals some form of disequilibrium calling for future readjustments of prices and/or the exchange rate.

Before proceeding, it is worthwhile to emphasise the restrictive conditions under which absolute parity holds. The assumption of zero transport costs and other barriers to trade rules out a "wedge" between foreign and domestic prices. It also serves to exclude from PPP considerations all non-traded goods, those goods that do not enter into international trade due to prohibitive transport costs. As non-traded goods constitute approximately 70 percent of GDP in developed countries, their exclusion would seem to drastically limit the applicability of PPP theory, at least in its absolute form. Below we return to transport costs and in the next section, we return to the related issue of non-traded goods. A further restrictive condition underlying PPP is the assumption that the market basket associated with the price index is identical in the two countries.

We now present a geometric exposition of PPP theory. The left graph of Panel A of Figure 2.1 contains the absolute PPP relationship, which is a 45-degree line passing through the origin. As this PPP line has a unit slope, any combination of s and r that lies on the line satisfies $s = r$, so that the real exchange rate $q = r - s = 0$. On this PPP line, an increase in the relative price from r_1 to r_2, for example, leads to an equi-proportional depreciation of the nominal exchange rate s, as is illustrated by the movement from point A to B, whereby $s_2 - s_1 = r_2 - r_1$. The PPP ray acts as a boundary that divides up the exchange rate/price space into two regions of mispricing. As shown on the right-hand graph of Panel A, points above the ray indicate an undervaluation of the home-country currency $(q < 0)$, where s is too high and/or r is too low. In this region, the price of the domestic basket (P) is below that of the foreign basket SP^*. Conversely, points below the PPP ray represent an overvalued domestic currency $(q > 0)$. Only at the boundary between these two regions is the currency correctly priced $(q = 0)$.

Let us now consider transport costs and any other barriers to the free flow of goods across borders that inhibit the equalisation of prices. With transport costs and other barriers, rather than having equation (2.1), we now have $P_i = S(1+T_i)P_i^*$, where T_i measures the proportionate wedge between domestic and foreign prices, which for short we term "transport costs". If these costs are approximately constant over time, then

(2.5) $$\hat{P}_i = \hat{S} + \hat{P}_i^*,$$

where a circumflex ("^") represents relative change $(\hat{x} = dx/x)$. Equation (2.5) represents a weaker version of the law of one price as it is formulated in terms of changes not levels. We can then weight as before and aggregate over goods to obtain

(2.6) $$\hat{P} = \hat{S} + \hat{P}^*,$$

where $\hat{P} = \sum_{i=1}^{n} w_i \hat{P}_i$ is the change in the cost of the basket of goods at home and $\hat{P}^*$ is the corresponding change for the foreign country. As these measures are share-weighted averages of the changes in the n individual prices, they can be interpreted as Divisia price indexes. Integrating equation (2.6) we obtain $P = KSP^*$, where K is a constant of integration, or in logarithmic form

(2.7) $$s = p - p^* - k.$$

This is the <u>relative version of PPP</u>. As $\hat{x} = dx/x = d(\log x)$, equation (2.7) implies

(2.8) $$\hat{S} = \hat{P} - \hat{P}^*,$$

where $\hat{P}$ and $\hat{P}^*$ are interpreted as inflation at home and abroad, respectively. In words, the proportionate change in the exchange rate is equal to the inflation differential. Thus high-inflation countries experience depreciating currencies and vice-versa, which is the open-economy version of the quantity theory of money. It is to be noted that equation (2.8) is just a rearrangement of equation (2.6). Note also that relative PPP expressed in (2.7) includes absolute PPP as a special case where k = 0, or $K = 1$ in $P = KSP^*$. To summarise, relative parity implies that the exchange rate is proportional to the price ratio, with the factor of proportionality not necessarily equal to unity. Under absolute parity, the proportionality factor is unity so that the exchange rate equals the price ratio, and the equalisation of prices is complete.[1]

Geometrically, under relative PPP the relationship between s and the relative price $r = p - p^*$ is a straight line of the form $s = r - k$, which is presented on the left graph of Panel B of Figure 2.1. Along this line, the real exchange rate is $q = r - s = k$, which is constant. This relative PPP line also has a unit slope, but an intercept $-k \neq 0$. Again, as we move up the line from A to B, an increase in the relative price still leads to an equiproportional depreciation in the nominal exchange rate, so that $s_2 - s_1 = r_2 - r_1$. As before, points above the relative PPP line correspond to an undervaluation of the domestic currency $(q - k < 0)$ and those below the line correspond to an overvaluation $(q - k > 0)$, but in comparison with absolute PPP, the boundary between the two regions is now "vertically displaced", as indicated by the graph given on the right-hand side of Panel B in Figure 2.1.

Panel C for Figure 2.1 gives the case of stochastic PPP.[2] If we denote the stochastic deviation from relative parity by e with $E(e) = 0$ and variance σ^2, the real exchange rate is then the random variable $q = k - e$ with $\text{var}(q) = \sigma^2 > 0$, so that q is obviously no longer constant. Initially, suppose for simplicity that e is a discrete random variable and that $e_1 < 0$ and $e_2 > 0$ are its only possible values. When the shock is $e_1 < 0$, we obtain a new, lower 45-degree line, $s = -k + e_1 + r$, which has an intercept of $-k + e_1$; similarly, $e_2 > 0$ results in the upper line on the left graph of Panel C. Consider the situation in which $\underline{s}$ is the exchange rate and r_1 is the relative

[1] A further issue about the distinction between absolute and relative PPP should be noted. Almost invariably statistical agencies publish information on the cost of a basket of goods in the form of a price index that has an arbitrary base, which determines the proportionality constant K. Such indexes can only be used for calculations of relative parity, not absolute.

[2] For an earlier rendition of stochastic PPP, see Lan (2002). For related work, see MacDonald and Stein (1999). Note also that MacDonald (2007, p. 42) considers PPP within an environment in which there are transaction costs in moving goods from one country to another. According to this broader version of PPP, there exists a "neutral band" within which exchange rates and prices can fluctuate. Below, we derive a similar band, but it has a different foundation, viz., probabilistic.

price, so that we are located at the point W on the left graph of Panel C. If there is now the same increase in the relative price as before, so that r rises from r_1 to r_2, then, in the presence of the shock e_1, we move from W to the point X with the rate depreciating to s_0. But if the shock is e_2, the same relative price r_2 leads to an exchange rate of $\bar{s}$, as indicated by the point Y. More generally, if relative prices change within the range $[r_1, r_2]$ and if the shocks can now vary continuously within the range $[e_1, e_2]$, then the exchange-rate/relative-price points lie somewhere in the shaded parallelogram WXYZ. Thus the relationship between the exchange rate and prices is $s = r - k + e$, which is the stochastic version of PPP. Due to the random shocks e, the exchange rate and prices are no longer proportionate. Given the way in which it is drawn, the height of the shaded parallelogram exceeds the base, which accords with the idea that exchange rates are much more volatile than prices in the short run (Frenkel and Mussa, 1980). However in the long run, as $E(e) = 0$ and thus $E(s) = r - k$, relative PPP holds and the expected value of the real exchange rate $E(q) = k$ is constant. Here k is the long-run, or equilibrium value of the real exchange rate.

Therefore, in the case of stochastic PPP, the real exchange rate q is not constant and fluctuates around k, so that exchange rates and prices are scattered around the 45-degree line. This is in contrast to relative PPP, in which q is a constant value for any combination of s and r and all (s, r)-pairs locate exactly on the 45-degree line. In other words, stochastic PPP means that there exists a "neutral band" around the 45-degree line containing those values of the exchange rate and prices that identify the currency as being "correctly priced". Under relative PPP, these points are interpreted as deviations from parity. Obviously, the width of the band is the key to this approach: if it is sufficiently wide, then all possible configurations of exchange rates and prices would be contained in the band, and the approach would be vacuous. On the other hand, if the band is sufficiently narrow, all observations would locate outside it, and the approach would always be rejected.

One way to strike a balance between the "too wide" and "too narrow" band problems is to proceed probabilistically as follows. Consider the probability distribution of the real exchange rate q with $E(q) = k$ and $\mathrm{var}(q) = \sigma^2$. We commence with the symmetric case in which the probability of the exchange rate being undervalued $(q - k < 0)$ is $\alpha/2$ and the same $\alpha/2$ is the probability of the currency being overvalued $(q - k > 0)$, where $0 < \alpha < 1$. In other words, we can interpret $\alpha/2$ as the mass in each tail of the distribution, so that our task is to characterise the location of the tails. According to Chebyshev's inequality

$$\Pr\left(|q - k| > c \right) \le \frac{\sigma^2}{c^2},$$

where c is a positive constant. We interpret c as defining the boundary, so that $\alpha = \sigma^2 / c^2$, or $c = \sqrt{\sigma^2 / \alpha}$. Thus the lower bound is $k - \sqrt{\sigma^2 / \alpha}$ and the upper bound is $k + \sqrt{\sigma^2 / \alpha}$. The region of correct pricing is indicated in the area between the lines DD' and FF' on the right graph of Panel C, which is defined by

(2.9) $$k - \underline{z} \leq q \leq k + \overline{z},$$

where $\underline{z} = \overline{z} = \sqrt{\sigma^2 / \alpha}$. The points above the line DD', which correspond to the case $q < k - \underline{z}$, indicate that the currency is undervalued, while points below the line FF' $(q > k + \overline{z})$ identify overvaluation. Statistically, if we have a number of observations on q, $\alpha \times 100$ percent of these would lie outside the band and the remaining $(1-\alpha) \times 100$ percent inside it. In the above situation, the deviations are symmetric around the mean, so that undervaluation and overvaluation are equi probable and $\underline{z} = \overline{z}$. In the more general case, the distribution of q is asymmetric and the long-run relative PPP line, EE', does not lie mid-way between the two boundaries DD' and FF'.

As the above analysis is distribution free, it does not hinge on q following any particular probability distribution. However, if we additionally have information on the form of the distribution, then this can be used to tighten the neutral band. Consider for the purpose of illustration the case of the normal distribution whereby $q \sim N(k, \sigma^2)$ and $\alpha = 0.05$. Under normality

$$\Pr\left[-1.96 < \frac{q-k}{\sigma} < 1.96\right] = 1 - \alpha = 0.95,$$

so that the neutral band for q is $[k - 1.96\sigma, k + 1.96\sigma]$. Contrast the width of this band with that implied by the Chebyshev's inequality, expression (2.9). With $\alpha = 0.05$ as before, we have $\underline{z} = \overline{z} = \sqrt{\sigma^2 / \alpha} = \sqrt{20}\sigma = 4.47\sigma$, so that the neutral band is $[k - 4.47\sigma, k + 4.47\sigma]$. Thus the width of the band under normality is $2 \times 1.96\sigma$, while under Chebyshev's inequality, it is $2 \times 4.47\sigma$, so that the additional information that the distribution is normal results in a shrinkage of the band by about 50 percent.

To conclude this section, consider a combination of s and r, which is represented by the same point C in all three right-hand graphs of Figure 2.1. As C lies above the PPP ray in Panels A and B, both absolute and relative PPP indicate that the currency is undervalued. However, according to stochastic PPP (Panel C), the currency is correctly priced as the point C lies within the neutral band. This situation could be frequently encountered in practice with many apparent departures from parity simply associated with the inherent volatility of currency markets. For example, some departures may be insufficient to justify the costs of moving goods internationally and/or taking open currency positions, especially if they are expected to soon reverse themselves.

3. The Workings of the Big Mac Index

The previous section highlighted the restrictive conditions under which absolute parity holds, viz., (i) the absence of barriers to international trade, which also implies the absence of non-traded goods; and (ii) identical baskets underlying the price indexes in the home and foreign countries. The weaker condition of relative PPP largely avoids the first problem, which accounts for its more frequent use in practice, but the problem of identical baskets remains. Surprisingly, the Big Mac Index (BMI) uses absolute parity in the context of a single-good basket, a Big Mac hamburger. In this section, we illustrate the workings of the BMI and as it purports to have much to say about the workings of the real-world currency markets, we assess how the Index deals with the above two restrictive conditions and how it performs in practice.

Though just a single good, a McDonald's Big Mac hamburger has a variety of tradable ingredients such as ground beef, cheese, lettuce, onions, bread, etc., and non-tradable ingredients such as labour, rent, and electricity, as well as other ingredients such as cooking oil, pickles and sesame seeds. By estimating the Big Mac cost function using the prices of the various ingredients, Parsley and Wei (2007) recover the recipe in "broad" basket form. They find that the shares of important ingredients are:

Ingredient	Cost share (%)	
Tradable		
Beef	9.0	
Cheese	9.4	
Bread	12.1	
		30.5
Nontradable		
Labour	45.6	
Rent	4.6	
Electricity	5.1	
		55.3
Other		14.2
Total		100

We can thus regard the price of a Big Mac as being the cost of a basket of inputs, just like P of the previous section is the cost of a market basket of goods. By comparing the price of a Big Mac in the US and other countries, The Economist magazine judges whether currencies are correctly priced based on the idea that a Big Mac should cost the same everywhere around the world when using a common currency. As the basket associated with the prices can be considered as being close to being identical in the home and foreign countries, the BMI cleverly avoids problem (ii) above associated with absolute PPP. But as transport costs and other trade barriers are not allowed when comparing prices, this is an application of absolute PPP.

As discussed in the previous section, the arbitrage foundation of absolute parity applies to traded goods only. But non-traded goods prices can also be related across countries for at least two reasons. First, if there is substitution between traded and non-traded goods in production and consumption, then in a broad class of general equilibrium models, the change in the price of non-traded goods $\left(\hat{P}_N\right)$ is a weighted average of the changes in the prices of importables and exportables $\left(\hat{P}_M, \hat{P}_X\right)$: $\hat{P}_N = \omega\hat{P}_M + (1-\omega)\hat{P}_X$, where $0 \leq \omega \leq 1$. Thus if non-traded goods are good substitutes for importables, the weight ω is large, so that the relative price P_N/P_M is approximately constant, while a large value of $1-\omega$ implies P_N/P_X is approximately constant (see Sjaastad, 1980, for details). Provided the weight ω is approximately the same at home and abroad, if PPP equalises the prices of traded goods across countries, then there is at least a tendency for the same to be true for their weighted average, the price of non-traded goods. However, as this link is based on substitution in production and consumption, it could possibly take considerable time for these relative price changes to work themselves through the economy and for there to be full adjustment. Second, there is an expectations mechanism that may be quite rapid in its operation. If producers of non-traded goods know of the above link between their prices and those of traded goods, they may reasonably base their price expectations on it. This could then mean that in setting prices, these producers employ as a short-cut the rule that they change their prices as soon as the exchange rate varies. An example is the plumber in Buenos Aires who puts up his prices as soon as the peso falls. These arguments provide a possible rationale for the inclusion of elements of the cost of non-traded goods in PPP calculations, such as the Big Mac Index.

Table 3.1 reproduces part of the Big Mac article published in The Economist of 27th May 2007 that refers to the six major currency countries. Column 4 of the table shows that the implied PPP is simply the ratio of the domestic Big Mac price in domestic currency (column 2) to that in the US (the first entry in column 2). This ratio is the purchasing power of one US dollar in terms of Big Macs. However, the actual exchange rate, presented in column 5, may not be the same as the PPP rate and column 6 gives the deviations, a positive (negative) value of which indicates over (under) -valuation of the currency. Take as an example the case of Australia, the second country from the top of the list in the table. From column 2, it costs US$3.41 to buy a Big Mac in the US and A$3.45 in Australia. Thus the implied PPP exchange rate is 3.45/3.41 = 1.01, as indicated by the second entry of column 4. As the actual exchange rate is 1.17, the Australian dollar is undervalued by $(1.01-1.17)/1.17=-14$ percent (see the second entry in the column 6 of the table). Given US prices, Australian prices are too low, so that a movement towards parity requires some combination of a rise in Australian prices and an appreciation of the $A.

Under PPP, $P=SP^*$, or $P/SP^*=1$. It is convenient to measure disparity logarithmically, so that for country c in year t, we define $q_{ct}=\log\left(P_{ct}/S_{ct}P_t^*\right)$, as in equation (2.4) where we referred to this measure as the real exchange rate (RER). This q_{ct}, when multiplied by 100, is approximately the percentage difference between P_{ct}/P_t^* and S_{ct}, the measure of disparity (or under- or over-valuation) used by The Economist. Under absolute PPP, $q_{ct}=0$. Table 3.2 gives q_{ct} for each of the six countries since 1994 and as can be seen, there are frequent departures from absolute PPP. Additionally, in the majority of countries q_{ct} fluctuates substantially around its mean; the exceptions to this general rule is Britain, whose RER values fluctuates within the range of about 12 percentage points. The last row of Table 3.2 presents t-values of the test of the hypothesis that $q_{ct}=0$, and in five of the six cases the mean disparities are significant, and so we conclude that the BMI is biased. One striking pattern is the one-sided nature of the disparities. Australia always has an undervalued currency and the currencies of Britain and Switzerland are always overvalued. The Canadian dollar is undervalued in all but two years, while the euro is overvalued in all but three years. Only the Japanese yen has wide swings from overvaluation to undervaluation. Thus for five of the six cases, the BMI declares the currencies to be continuously (or almost continuously) over- or under-valued for each of the 14 years under consideration. These strings of persistent disparities over a fairly lengthy period raise serious questions about the credibility of the BMI as a pricing rule for currencies.

The BMI is meant to play the role of the long-term, or equilibrium exchange rate, to which the actual rate is attracted; in other words, an under- or overvaluation is meant to signal subsequent equilibrating adjustments of the exchange rate and/or prices. But lengthy periods of substantial, sustained and significant mispricing demonstrate that such a mechanism is not at work. In a fundamental sense the Big Mac Index fails, so that this popular metric of currency mispricing cannot be taken at face value. In large part, the reason for this failure is that the BMI relies on absolute PPP, which ignores barriers to international trade. Fortunately, a simple modification to the BMI restores its predictive power, as is shown in the section after the next.

4. The Bias-Adjusted BMI and the Speed of Adjustment

The above discussion implies that the BMI is a biased indicator of absolute currency values. Thus rather than absolute PPP holding in the form of $S = P/P^*$, we have $S = B\left(P/P^*\right)$, where B is the bias, or $s = b + p - p^*$ in logarithmic terms. This, of course, is just relative PPP of Section 2 with $B = 1/K$ or $b = -k$. In this section, we analyse the extent to which the bias-adjusted BMI tracks exchange rates by formulating it in terms of changes over time, $\Delta s = \Delta p - \Delta p^*$.

To proceed we have to specify the length of the horizon for exchange-rate and price changes.[3] For any positive variable X_t $(t = 1,\ldots,T)$, define $\Delta_{(h)} x_t = \log X_t - \log X_{t-h}$ as the logarithmic h-year change and $\Delta^{(h)} x_t = (1/h)\Delta_{(h)} x_t$ as the corresponding annualised change, $h = 1,\ldots, T-1$, $t = h+1,\ldots,T$. As $\Delta^{(h)} x_t = (1/h)\sum_{s=0}^{h-1}\Delta_{(1)} x_{t-s} = (1/h)\sum_{s=0}^{h-1}\left(x_{t-s} - x_{t-s-1}\right)$, the annualised change over a horizon of h years has the convenient property of being equal to the average of the h one-year changes. Writing $r_{ct} = p_{ct} - p_t^*$ for the Big Mac price in country c in terms of that in the US (as before), relative PPP implies that, for horizon h, $\Delta_{(h)} s_{ct} = \Delta_{(h)} r_{ct}$, or dividing both sides by h,

$$\Delta^{(h)} s_{ct} = \Delta^{(h)} r_{ct}. \tag{4.1}$$

Equation (4.1) states that exchange-rate changes are equal to the relative price changes. To examine the content of this equation, we initially set h = 1 and plot one-year exchange rates changes against the corresponding price changes for all countries. The graph on the top left-hand corner of Figure 4.1 contains the results. The 45-degree line passing through the origin corresponds to PPP and as can be seen, there is considerable dispersion around this parity line, with a root-mean-squared error (RMSE) of about 12 percent. This RMSE is the square root of the ratio of $\sum_c \sum_t \left(\Delta_{(1)} r_{ct} - \Delta_{(1)} s_{ct}\right)^2$ to the number of observations, which measures the dispersion of real exchange rate changes over a one-year horizon. In the other panels of the figure, the horizon h increases, the points become noticeably closer to the 45-degree line and the RMSE falls more or less continuously to end up at 3 percent for $h = 13$ years.

[3] For related analyses, see Flood and Taylor (1996), Isard (1995, p. 49), Lothian (1985) and Obstfeld (1995).

To shed more light on the decrease in volatility as the horizon increases, consider the following parsimonious data-generating process for the real exchange rate:

(4.2) $$q_t = \alpha + \beta q_{t-1} + \varepsilon_t,$$

where α and β are constants and the random disturbance term ε_t is iid, independent of q_{t-1}, with zero mean and variance σ_ε^2. Table 3.2 showed that there is considerable persistence in the behaviour of q over time, which could be consistent with model (4.2) with a high value of β. The stationarity of the real rate implies $0 < \beta < 1$, in which case the variance of q is $\sigma^2 = \sigma_\varepsilon^2 / (1-\beta^2)$. On the other hand, if q follows a random walk, $\beta = 1$, so that $q_t = \alpha + q_{t-1} + \varepsilon_t = (t - t_0)\alpha + q_{t_0} + \sum_{s=t_0+1}^{t} \varepsilon_s$, where q_{t_0} is the initial value. Hence, its variance at time t is $\sigma_t^2 = (t - t_0)\sigma_\varepsilon^2$, if the initial value is treated as fixed.

To examine the variance of the annualised change over horizon h, $\Delta^{(h)} q_t$, consider first the stationary case. Equation (4.2) implies $q_t - q_{t-h} = \beta(q_{t-1} - q_{t-h-1}) + \varepsilon_t - \varepsilon_{t-h}$ $(h > 0)$, or equivalently $\Delta^{(h)} q_t = \beta \Delta^{(h)} q_{t-1} + \Delta^{(h)} \varepsilon_t$, so that

$$\operatorname{var}\left[\Delta^{(h)} q_t\right] = \beta^2 \operatorname{var}\left[\Delta^{(h)} q_t\right] + \frac{2}{h^2}\sigma_\varepsilon^2 - \frac{2\beta}{h}\operatorname{cov}\left[\Delta^{(h)} q_{t-1}, \varepsilon_{t-h}\right].$$

The covariance term in the above is

$$\operatorname{cov}\left[\Delta^{(h)} q_{t-1}, \varepsilon_{t-h}\right] = \begin{cases} \operatorname{cov}\left[q_{t-1} - q_{t-2}, \varepsilon_{t-1}\right] = \operatorname{cov}\left[q_{t-1}, \varepsilon_{t-1}\right] = \sigma_\varepsilon^2 & \text{if } h = 1 \\ \operatorname{cov}\left[q_{t-1} - q_{t-h-1}, \varepsilon_{t-h}\right] = 0 & \text{if } h > 1, \end{cases}$$

so that

(4.3) $$\operatorname{var}\left[\Delta^{(h)} q_t\right] = \begin{cases} \dfrac{2(1-\beta)}{1-\beta^2}\sigma_\varepsilon^2 = \dfrac{2}{1+\beta}\sigma_\varepsilon^2 & \text{if } h = 1 \\ \dfrac{2}{h^2(1-\beta^2)}\sigma_\varepsilon^2 & \text{if } h > 1. \end{cases}$$

Therefore, we can see that $\operatorname{var}\left[\Delta^{(h)} q_t\right]$ decreases when the horizon h increases for the stationary case. This is represented in Panel A of Figure 4.2 by the point A and the reciprocal quadratic curve of the form $\operatorname{var}\left[\Delta^{(h)} q_t\right] \propto 1/h^2$, with $\beta = 0.6$.

If $\beta = 1$, equation (4.2) implies that $q_t - q_{t-h} = h\alpha + \sum_{s=t-h+1}^{t} \varepsilon_s$. When divided by h, we have $\Delta^{(h)} q_t = \alpha + \frac{1}{h}\sum_{s=t-h+1}^{t} \varepsilon_s$, so that

(4.4) $$\operatorname{var}\left[\Delta^{(h)} q_t\right] = \frac{1}{h^2}\operatorname{var}\left[\sum_{s=t-h+1}^{t} \varepsilon_s\right] = \frac{\sigma_\varepsilon^2}{h},$$

which is represented in Panel A of Figure 4.2 by the reciprocal curve of the form $\mathrm{var}\left[\Delta^{(h)}q_t\right] \propto 1/h$. We can see that here $\mathrm{var}\left[\Delta^{(h)}q_t\right]$ also declines, but at rate h, which is slower than the stationary case. This contrast is more apparent by considering total volatility over the interval [t, t+h], $\mathrm{var}\left[\Delta_{(h)}q_t\right] = h^2\,\mathrm{var}\left[\Delta^{(h)}q_t\right]$. From equations (4.3) for $h > 1$ and (4.4), we have

(4.5)
$$\mathrm{var}\left[\Delta_{(h)}q_t\right] = \begin{cases} \dfrac{2}{1-\beta^2}\sigma_\varepsilon^2 & \beta < 1 \\ h\sigma_\varepsilon^2 & \beta = 1, \end{cases}$$

which is constant when $\beta < 1$ and increases linearly when $\beta = 1$, as indicated in Panel B of Figure 4.2.

Equation (4.5) is a key result that shows that when the real rate is stationary, the total volatility is constant as the length of the horizon expands, while it increases proportionately in the non-stationary case. Although this is based on the simple AR(1) model, the implications carry over to more general cases. For a given horizon h, the RMSE of Figure 4.1 is the standard deviation of the annualised changes, or an estimate of $\sqrt{\mathrm{var}\left[\Delta^{(h)}q_t\right]}$. Thus $h \times \mathrm{RMSE}$ is the standard deviation of the total changes, $\sqrt{\mathrm{var}\left[\Delta_{(h)}q_t\right]}$, which under stationarity will also be constant with respect to h. We thus use the RMSEs from Figure 4.1 in Figure 4.3 to plot $h \times \mathrm{RMSE}$ against the horizon. The trajectory of total volatility is not perfectly flat, as predicted by stationarity; rather it seems to wobble gently upwards and then fall. For horizons of three to eleven years, it fluctuates within a band about 15 percentage points wide. Although the evidence is not overly strong, possibly due to a small sample size, it is arguably not unreasonable to interpret this as saying real rates are stationary, that is, relative purchasing parity holds at longer horizons. We will have more to say about stationarity in Section 6.

The above analysis shows that the speed of adjustment of exchange rates to prices is not rapid, which presumably reflects transaction costs, informational costs, sticky prices due to contracts and menu costs, etc. But over the medium-term of more than three years, the tendency for exchange rates to reflect PPP is fairly clear. In the context of the discussion of Section 2, it seems that stochastic PPP with a relatively a high value of the variance σ^2 is the appropriate way to think of the relationship between exchange rates and prices in the short term.

5. Does the BMI Predict Future Currency Movements?

In this section, we examine the predictive power of the Big Mac Index by asking the question, can a currency be expected to appreciate (depreciate) in the future if it is currently undervalued (overvalued)? And if it does mean revert in this manner, how long does it take? For an early analysis along these lines, see Cumby (1996).

As our objective is to examine the information contained in the current BMI regarding future currency values, we start by defining the horizon for future changes in the real rate as

(5.1) $$\Delta_{(h)}q_{t+h} = q_{t+h} - q_t,$$

which is the future change in q from the year t to $t+h$. Regarding current mispricing, the use of q_t would not be satisfactory due to the bias identified above. Instead we use

(5.2) $$d_t = q_t - \overline{q},$$

with $\overline{q}$ the sample mean, which can be interpreted as the equilibrium exchange rate. Thus now the currency is over (under) valued if $d_t > 0$ (< 0). Under PPP, deviations from parity die out, so that if $d_t > 0$ (< 0), the future value q_{t+h} decreases (increases) relative to the current value q_t. To examine whether this is the case, we plot in Figure 5.1 the subsequent changes $\Delta_{(h)}q_{t+h}$ against d_t using the 6-country Big Mac data for horizons of $h = 1,...,13$ years. PPP predicts that the points lie in the second and fourth quadrants of the graphs, and Figure 5.1 shows this is indeed mostly the case with the pattern becoming more pronounced as the horizon increases. To examine the statistical significance of this pattern, we first carry out a test of the independence of future currency movements and current mispricing. This involves a χ^2-test of the independence of $\text{sgn}\left(\Delta_{(h)}q_{t+h}\right)$ and $\text{sgn}\left(d_t\right)$, based on a 2×2 contingency table. The test statistic is contained in the box of each graph in Figure 5.1, and is significant for horizons of 3 to 9 years, so we can reject independence. Figure 5.2 plots the test statistic against the horizon h and it can be seen that a maximum is reached for a horizon of about $h = 6$ years. Evidently, the current deviation from parity conveys considerable information of future changes in currency values over the medium to longer term.

Each panel of Figure 5.1 also contains the least-squares estimates of the predictive regression

(5.3) $$\Delta_{(h)}q_{t+h} = \eta^h + \phi^h d_t + u_t^h,$$

where, for horizon h, η^h is the intercept, ϕ^h the slope and u_t^h a zero-mean disturbance term. To interpret equation (5.3), we combine equations (5.1), (5.2) and (5.3) to obtain

(5.4) $$q_{t+h} = \left(\eta^h - \phi^h\overline{q}\right) + \left(\phi^h + 1\right)q_t + u_t^h.$$

Under PPP, q_{t+h} converges to the equilibrium value $\overline{q}$, so that

(5.5) $$\eta^h = 0, \qquad \phi^h = -1.$$

A test of restriction (5.5) reveals whether or not there is full adjustment to mispricing over horizon h. The F-statistics for (5.5) are presented in column 7 of Table 5.1. For the purposes of testing, the results for the non-overlapping case are more reliable and as can be seen from Panel B, the F-statistic is minimised for a six-year horizon and is not significant. The F-statistic is highly significant for the one-year horizon, so the hypothesis of the complete elimination of mispricing over the subsequent year can be safely rejected. This result is consistent with the idea of PPP referring to the medium/long run. The F-values are insignificant for all other horizons other than eight, nine and twelve years. While we do not have an explanation for the three significant F values at long horizons other than the small number of underlying observations, it would seem not unreasonable to downplay them and interpret the results as saying that there appears to be some evidence of more or less full adjustment to mispricing over most horizons other than the shortest.

Since the work of Meese and Rogoff (1983a,b), the random walk model has become the gold standard by which to judge the forecast performance of exchange-rate models. Accordingly, we compare the forecasts from the Big Mac Index and the bias-adjusted BMI with those from a random walk. Under the BMI, absolute parity holds and the forecast exchange rate at any horizon h is zero, $q_{t+h} = 0$; the bias-adjusted BMI implies $q_{t+h} = \overline{q}$; and the random walk predicts no change, $q_{t+h} = q_t$. We compute the root-mean-squared error of the forecasts over all currencies and years for horizons $h = 1,...,13$, and Figure 5.3 shows that the random walk model outperforms the BMI for short to medium horizons, which is the familiar Meese-Rogoff result. However the figure also reveals that beyond one-year horizons the bias-adjusted BMI beats the random walk. For example, for a 4-year horizon, the RMSE is about 27 percent for the BMI, 20 percent for the random walk and 12 percent for the bias-adjusted BMI. This is an encouraging result for the bias-adjusted BMI.

6. Are Equilibrium Exchange Rates Constant?

In the above discussion, the exchange rate converges to its equilibrium value $\overline{q}$, a constant. In this section we investigate the validity of treating the equilibrium rate as a constant using two approaches, as well as test for stationarity.

A simple approach is to compare average exchange rates for sub-periods in sample. Due to the 1997 Asian financial crisis, it is natural to divide the whole 14-year period into sub-periods before and after 1997, as in Table 6.1. There are two notable features here. (i) In all countries, currencies become more undervalued (or less overvalued) following the Asian crisis. (ii) The changes in the means over the two periods are significant in four out of the six countries. This is evidence against the assumption of constant equilibrium rates.

A second approach to the equilibrium exchange rate extends the commonly-used time-series model of real exchange rates by taking into account the role of economic fundamentals (Soh, 2007). We return to the simple AR(1) model (4.2) and apply it to currency c, $q_{ct} = \alpha_c + \beta_c q_{c,t-1} + \varepsilon_{ct}$. Due to the short sample period, we constrain the speed-of-adjustment parameter to be the same across countries, $\beta_c = \beta$, and reformulate the equation as

(6.1) $$\Delta q_{ct} = \alpha_c + \rho q_{c,t-1} + \varepsilon_{ct},$$

where $\rho = \beta - 1$ is a new speed of adjustment parameter.[4] Under the null hypothesis of a unit root, $\rho = 0$, and the alternative of stationarity corresponds to $-1 < \rho < 0$. Taking expectations of both sides of equation (6.1), under stationarity we obtain the equilibrium exchange rate, $q_c^E = -\alpha_c / \rho$. As the long-run equilibrium value of a currency could be influenced by economic factors such as GDP and interest rates, we extend equation (6.1) by allowing the country intercept to depend on these factors,

(6.2) $$\Delta q_{ct} = \alpha_{ct} + \rho q_{c,t-1} + \varepsilon_{ct}, \qquad \alpha_{ct} = \alpha_c + \gamma_1 \cdot y_{ct} + \gamma_2 \cdot IRD_{ct}.$$

In the above, for country c and year t, y_{ct} is the logarithmic ratio of real GDP per capita in country c to that in the US; IRD_{ct} is the real interest rate differential between c and the US; α_c is a country intercept; and γ_1, γ_2 are parameters that measure the responsiveness of the currency to incomes and interest rates. The country intercepts α_c in model (6.2) allow for country-specific factors, such as whether or not the country has a commodity currency.[5] The equilibrium exchange rate is now no longer constant, but dependent upon fundamentals: $q_c^E = -\alpha_{ct}/\rho = -(\alpha_c + \gamma_1 \cdot y_{ct} + \gamma_2 \cdot IRD_{ct})/\rho$, which shows that the elasticity of the equilibrium rate with respect to GDP is $-\gamma_1/\rho$, while $-\gamma_2/\rho$ is the corresponding interest semi-elasticity. As under stationarity $\rho < 0$, we expect γ_1, γ_2 to be positive.

We estimate model (6.2) for $c = 1, \ldots, 6$ countries using the Big Mac data and the GDP and interest rate data discussed in the Appendix. We initially treat this as a seemingly unrelated regression and then, due the lagged rate on the right-hand side, use an iterative bias-adjustment procedure; see the Appendix for details. Looking at the bias-adjusted results of columns 5-7 of

[4] For evidence on a common speed of adjustment, see Lan (2006).

[5] We also experimented with time dummies to take account of common shocks to all currencies, such as a major depreciation of the base currency, the US dollar. These results were not too encouraging, possibly because such common shocks are already accounted for in the cross-currency covariances used in the SUR approach discussed below.

Table 6.2, it can be seen that the estimates of the income and interest rate coefficients are both positive, as expected, but using the simulated critical values given in the note to the table, neither is significantly different from zero. These results do not provide strong evidence in favour of the idea of the equilibrium rate depending on income and interest rates. The speed of adjustment coefficient ρ is significantly negative, so we can reject the null of a unit root. Model (6.2) means that deviations from parity have a half life of $-\log 2/\log(1+\rho)$; using the bias-adjusted estimate of ρ of -0.6395, the estimated half life is less than one year, which agrees reasonably well with prior Big Mac studies, but is faster than that obtained using broader price indices.[6] It should also be noted that the ranking of countries according to the estimated country intercepts is in broad agreement with the ranking by mean under/overvaluation of Table 6.1 -- Australia has the most undervalued currency, while Switzerland's is the most overvalued. Since cross-country income differences tend to change moderately slowly, the country intercepts could be picking up part of these differences, which may account for the insignificance of the GDP coefficient γ_1.

The results of this section are mixed. There is some evidence that equilibrium exchange rates vary over time. But an analysis of this time dependence in terms of variations in income and interest rates was not supportive of the role of these factors as determinants of exchange rates. On the other hand, we were able to reject the hypothesis of non-stationarity, which means that exchange rates converge to well-defined PPP equilibrium values.

[6] For surveys of the speed of adjustment, see Lan (2002) and Lan and Ong (2003).

APPENDIX

The Data

To estimate equation (6.2) for the six countries over the period 1994-2007 we used (i) the exchange-rate data contained in Table 3.2 and (ii) the following data on GDPs and interest rates.

We obtained real GDP per capita from the Penn World Table available at http://pwt.econ.upenn.edu. As these data are available only up to the year 2004, we extrapolate the three out-of-sample values (2005-2007) based on regressions using the 1994-2004 data. As the evolution of GDPs is meant to capture trends in incomes over the longer term, this extrapolation should not pose too much of a problem.

The interest rates are real, calculated as $(1+i)/(1+\pi)-1$, where i the nominal rate and π the inflation rate. The 10-year government bond yield corresponding to the publication month of the Big Mac data is used for i, and is obtained from the DataStream.[7] There are two problems regarding the inflation rates and interest rates:

(i) The Big Mac prices are not always published at 12-month intervals. To match the inflation rates with the Big Mac publication dates, we obtain the monthly inflation rate data for 5 countries (excluding the euro area) plus the US over the period 1994 to 2007 from DataStream. Then we compute the inflation and nominal interest rate using monthly data, according to $\left(\prod_{m=1}^{n}\sqrt[12]{1+x_{t+m}}\right)-1$, where n is the number of months between two successive publications of the Big Mac index by The Economist. The term x_{t+m} corresponds to the annual inflation rate or annual interest rate in month t+m. Taking the 12[th] root of $1+x_{t+m}$ gives the corresponding per month value. For example, the big Mac index is published in April 2003 and May 2004. In this case, we use n=13 when computing the inflation rate for May 2004.

(ii) The Big Mac price for the euro area is an unweighted average of the prices in six EU countries -- Belgium, France, Germany, Italy, the Netherlands and Spain. Thus we use GDP-weighted inflation rates of these six countries to calculate the inflation rate for the euro area. The GDP data used here are nominal, expressed in term of US dollars and are obtained from the European Commission Eurostat Yearbook, which is accessible from DataStream.

The data are listed in Table A1.

[7] For the long-term yield on European bonds, the yield on a 10-year Euro Benchmark Bond is used.

Estimation Procedures

We describe here the Monte Carlo procedures used in the context of model (6.2). We start by writing that model for country c for all years as $\mathbf{y}_c = \mathbf{X}_c\boldsymbol{\theta}_c + \boldsymbol{\varepsilon}_c$. We write this for all $c = 1,\ldots,6$ countries in SUR format as

(A1) $$\mathbf{y} = \mathbf{X}\boldsymbol{\theta} + \boldsymbol{\varepsilon}, \quad \mathrm{E}(\boldsymbol{\varepsilon}\boldsymbol{\varepsilon}') = \boldsymbol{\Sigma} \otimes \mathbf{I},$$

where the $(c,d)^{\text{th}}$ element of the covariance matrix $\boldsymbol{\Sigma}$ is $\mathbf{E}(\varepsilon_{ct}\varepsilon_{dt})$. The cross-equation constraints on the speed-of-adjustment coefficient and the time dummies can be expressed as $\mathbf{R}\boldsymbol{\theta} = \mathbf{r}$, where $\mathbf{R}$ is a restriction matrix and $\mathbf{r}$ is the associated vector. The presence of the lagged dependent variable in model (A1) means that the SUR-GLS estimates are biased. The existing literature derives analytical expressions for the approximate bias of estimators based on large-sample asymptotics (see, e.g., Kiviet et al., 1995, 1999). For the case of a small sample, Lan (2006) proposes a Monte Carlo approach to detect for the presence of bias and then adjust for it. We use a similar but modified procedure.

The estimation and testing of the model involves four steps:

1. *Bias detection*. We first estimate model (A1) by SUR-GLS and examine whether these estimates, $\hat{\boldsymbol{\theta}}^{\text{SUR}}$, are biased. Assume that the error vector $\boldsymbol{\varepsilon}$ is drawn from a multivariate normal distribution with zero mean vector and the covariance matrix $\boldsymbol{\Sigma}$, which we estimate by $\hat{\boldsymbol{\Sigma}}$, the matrix of mean squares and cross products of the residuals.[8] In the j^{th} trial ($j = 1, \ldots, 10{,}000$), the exchange rate changes $\mathbf{y}$ are then simulated from equation (A1) using $\hat{\boldsymbol{\theta}}^{\text{SUR}}$ as true values, the observed values of the right-hand side variables $\mathbf{X}$ and error terms drawn from $\mathrm{N}(\mathbf{0}, \hat{\boldsymbol{\Sigma}})$. Using these generated data, we re-estimate (A1) by SUR-GLS and obtain another vector of estimates $\hat{\boldsymbol{\theta}}_j^{(0)}$. Next we calculate the mean of the 10,000 vectors $\hat{\boldsymbol{\theta}}_j^{(0)}$, $j = 1, \ldots, 10{,}000$, denoted by $\overline{\boldsymbol{\theta}}^{(0)}$. Let $\boldsymbol{\theta}^*$ be the "true value" of the coefficient vector $\boldsymbol{\theta}$ in the simulation. Then the initial bias is $\mathbf{b}^{(0)} = \overline{\boldsymbol{\theta}}^{(0)} - \boldsymbol{\theta}^*$ with $\boldsymbol{\theta}^* = \hat{\boldsymbol{\theta}}^{\text{SUR}}$. It is found that SUR-GLS leads to biased estimates, with the elements of the bias vector $\mathbf{b}^{(0)}$ ranging from -14 to 13 percentage points.

2. Iterative scheme for *bias adjustment*. In iteration $k \geq 1$, we adjust $\hat{\boldsymbol{\theta}}^{\text{SUR}}$ by the bias detected at iteration k-1, and use the adjusted vector as the "true" value for the simulation, $\boldsymbol{\theta}^{*(k)}$.

[8]The multivariate normal distribution rather than the bootstrap is used in the simulation because it can better capture the cross-currency correlations.

That is, $\boldsymbol{\theta}^{*(k)} = \hat{\boldsymbol{\theta}}^{SUR} + \mathbf{b}^{(k-1)}$. Note that $\boldsymbol{\theta}^{*(0)} = \hat{\boldsymbol{\theta}}^{SUR}$. As before, in the j^{th} trial ($j = 1, ..., 10,000$) we generate **y** in model (A1) using these true values, **X** and generated errors to re-estimate (A1) by SUR-GLS. Then we calculate the mean of the 10,000 vectors, denoted by $\overline{\boldsymbol{\theta}}^{(k)}$. The procedure ends when from one iteration to the next the absolute change in all elements of the bias vector is sufficiently small, i.e., $\mathbf{b}^{(k)} \approx \mathbf{b}^{(k-1)}$. The true values in the final iteration are treated as the bias-adjusted estimates, denoted as $\hat{\boldsymbol{\theta}}^{\mathbf{ba}}$.

3. *Correction of standard errors* of the bias-adjusted estimate. Suppose the above procedure converges in k^* iterations. There are 10,000 simulated values of the converged estimate of the coefficient vector $\hat{\boldsymbol{\theta}}_j^{(k^*)}$ and the corresponding asymptotic covariance matrix $\text{var}\left(\hat{\boldsymbol{\theta}}_j^{(k^*)}\right)$, $j = 1, ..., 10,000$. For the i^{th} element of the coefficient vector, consider the ratio of the root-mean-square of the 10,000 estimates around their true value to the root-mean-square of the 10,000 asymptotic standard errors, defined as the square roots of the i^{th} diagonal element of $\text{var}\left(\hat{\boldsymbol{\theta}}_j^{(k^*)}\right)$. Write ϕ_i for this ratio. If the estimation procedure is working satisfactorily, then ϕ_i should be close to unity. However, it is quite different from one for the majority of cases, indicating that the conventionally-defined SUR-GLS asymptotic standard errors do not reflect the true sampling variability of the estimates. We thus correct the asymptotic standard error for the i^{th} estimate by multiplying its asymptotic standard error by ϕ_i. To assess the validity of this adjustment, we conducted another Monte Carlo simulation experiment and confirmed that this correction procedure works satisfactorily.

4. *Testing*. When the exchange rate has a unit root, the speed of adjustment parameter in equation (6.2), ρ, is zero. We use three steps similar to those above to obtain the distribution of the estimates under the null of $\rho = 0$. In iteration $k \geq 1$, we still use the simulated means of each estimate (other than ρ) from iteration k-1 to be the "true" values for the simulation, that is, $\boldsymbol{\theta}^{*(k)} = \overline{\boldsymbol{\theta}}^{(k-1)}$. The only difference is that instead of using $\rho^{*(k)} = \overline{\rho}^{(k-1)}$, in each iteration k we fix $\rho^{*(k)}$ at its value under the null, which we approximate with a small value, viz., -0.005. However, preliminary investigation shows that the simulated mean $\overline{\rho}^{(k)}$ always settles at about -0.75, which shows that it is seriously biased; the other estimates are also biased. Our solution is to reduce the dimensionality by replacing the dependent variable vector in model (A1), **y**, with its demeaned counterpart $\mathbf{y}'$, which for country c and year t is defined as $y'_{ct} = y_{ct} - \alpha_c^{ba}$, where α_c^{ba}

are the bias-adjusted estimates of the country effects from Step 2 above. This allows us to focus on the convergence of the three most important coefficients -- the speed of adjustment ρ, and the income and interest rate coefficients λ_1 and λ_2. Let $\boldsymbol{\theta}_{\text{null,i,j}}^{\text{ba}}$ be the i$^{\text{th}}$ element of the converged coefficient vector under the null in trial j. Consider the ratio of an estimate to its standard error as a test statistic. As the distribution of this ratio is non-standard under the null, we derive its critical values by simulating 10,000 values under the null and use the α-percentile of the simulated values corresponding to the $(100-\alpha)$-percent confidence level. That is, we simulate this distribution by computing $\boldsymbol{\theta}_{\text{null,i,j}}^{\text{ba}} \Big/ \sqrt{\text{var}\left(\boldsymbol{\theta}_{\text{null,i,j}}^{\text{ba}}\right)}$, $j=1, \ldots, 10{,}000$, where $\sqrt{\text{var}\left(\boldsymbol{\theta}_{\text{null,i,j}}^{\text{ba}}\right)}$ is the corresponding corrected standard error. The critical values contained in the note to Table 6.2 are derived from the tail of this distribution.

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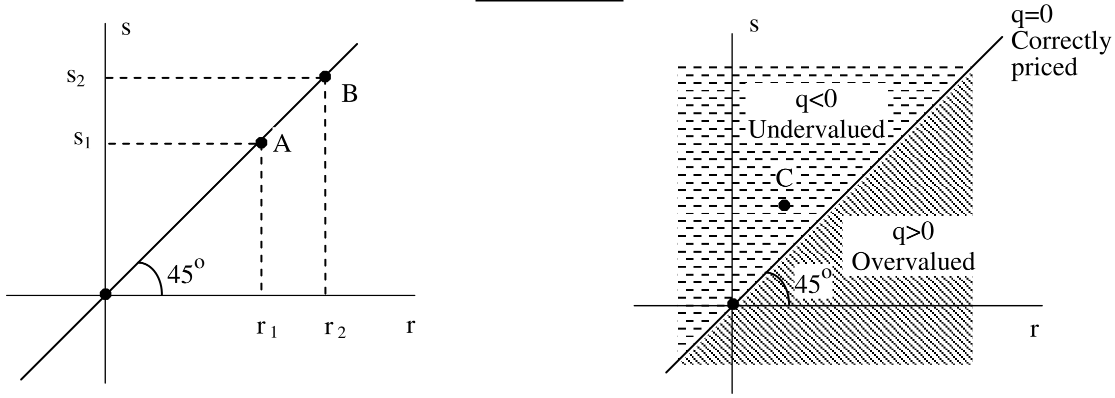
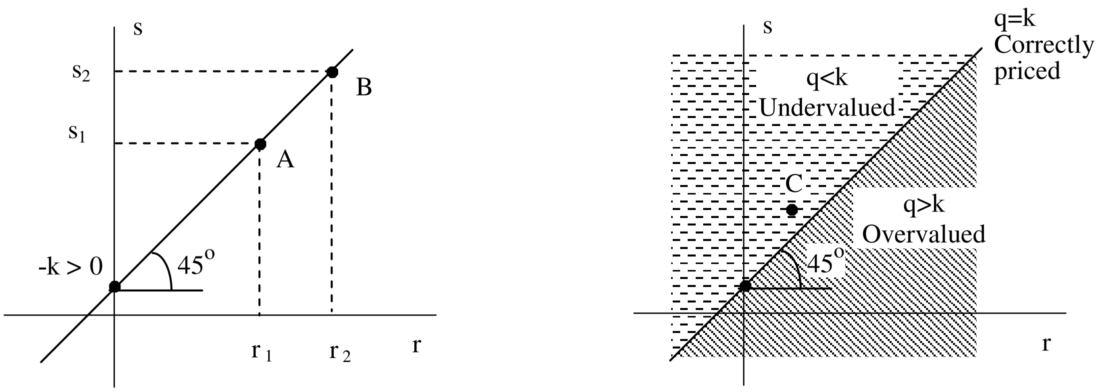
FIGURE 2.1

THREE VERSIONS OF PPP

A. Absolute PPP



B. Relative PPP



C. Stochastic PPP

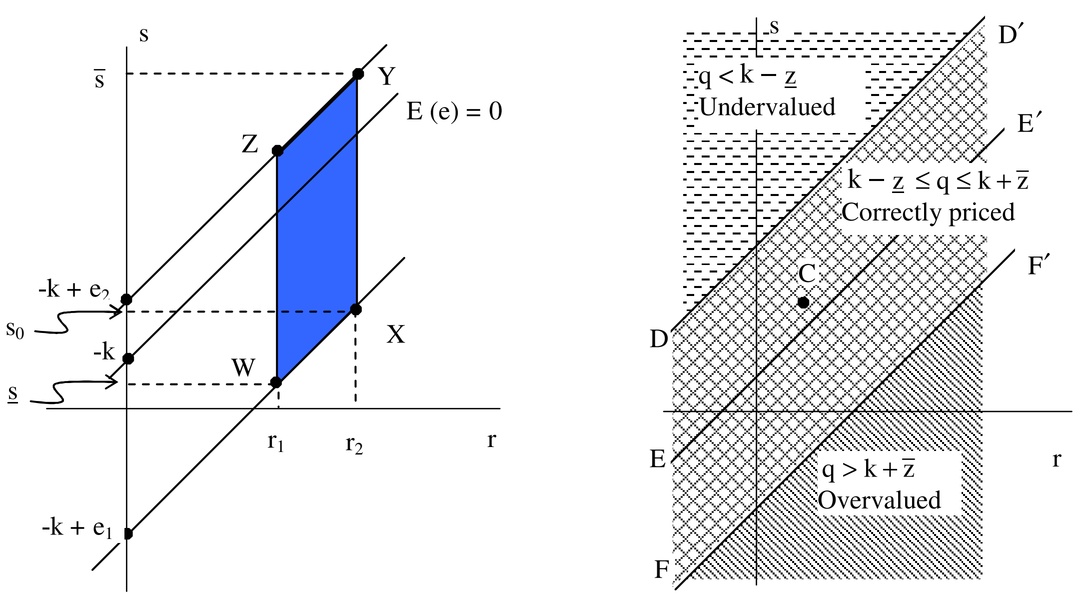


TABLE 3.1

THE BIG MAC DATA, 2007

Country	Big Mac prices		Implied PPP of the dollar	Actual dollar exchange rate July 2nd	Under(-)/over(+) valuation against the dollar, %
	In local currency	In dollars			
(1)	(2)	(3)	(4)	(5)	(6)
United States	$3.41	3.41	-	-	-
Australia	A$3.45	2.95	1.01	1.17	-14
Britain	£1.99	4.01	1.71	2.01	+18
Canada	C$3.88	3.68	1.14	1.05	+8
Euro area	€ 3.06	4.17	1.12	1.36	+22
Japan	¥280	2.29	82.1	122	-33
Switzerland	SFr 6.30	5.20	1.85	1.21	+53

Note: For Britain, the PPP and actual exchange rates are expressed in terms of dollars per pound; for the euro, rates are dollars per euro; and for all other countries, rates are domestic currency cost of one dollar.

Source: The Economist (2007).

TABLE 3.2

REAL EXCHANGE RATES, 1994 TO 2007

Year	Country					
	Australia	Britain	Canada	Euro	Japan	Switzerland
1994	-28.75	14.61	-11.14	21.52	49.14	54.29
1995	-24.56	19.04	-15.20	37.58	69.63	81.12
1996	-18.14	13.91	-11.53	30.53	13.15	70.93
1997	-22.21	20.39	-15.53	17.18	-3.65	50.59
1998	-37.76	18.06	-26.46	3.54	-21.05	41.62
1999	-37.71	23.20	-20.47	10.89	0.82	49.50
2000	-48.74	18.36	-25.82	-5.72	9.99	32.40
2001	-51.66	11.26	-17.39	-11.93	-6.89	36.03
2002	-43.42	14.69	-16.04	-4.35	-21.15	42.14
2003	-37.46	15.32	-20.54	9.43	-21.61	52.88
2004	-25.07	14.64	-22.68	12.96	-22.38	52.74
2005	-20.21	11.07	-16.47	14.82	-27.91	49.90
2006	-23.79	16.62	1.37	19.55	-32.84	51.85
2007	-14.53	15.96	8.03	19.92	-39.59	42.32
Mean	-31.00	16.22	-14.99	12.56	-3.88	50.59
SE	3.14	0.90	2.57	3.69	8.34	3.43
t-value	-9.88	18.06	-5.83	3.41	-0.47	14.77

Notes:

1. The real exchange for country c in year t is defined as $q_{ct} = \log\left(P_{ct}/S_{ct}P_t^*\right)$, where P_{ct} is the price of a Big Mac hamburger in country c during t, P_t^* is the corresponding price in the US and S_{ct} is the nominal exchange rate, defined as the domestic currency cost of $US1. A positive value of q_{ct} implies that the domestic currency is overvalued and vice versa.
2. All entries, except those in the last row, are to be divided by 100.
3. SE is standard error of the mean. The t-values provide a test of the hypothesis that the means are zero.

FIGURE 4.1

SCATTER PLOTS OF EXCHANGE RATES AND PRICES, 6 COUNTRIES, 1994-2007

(Annualised logarithmic changes×100)

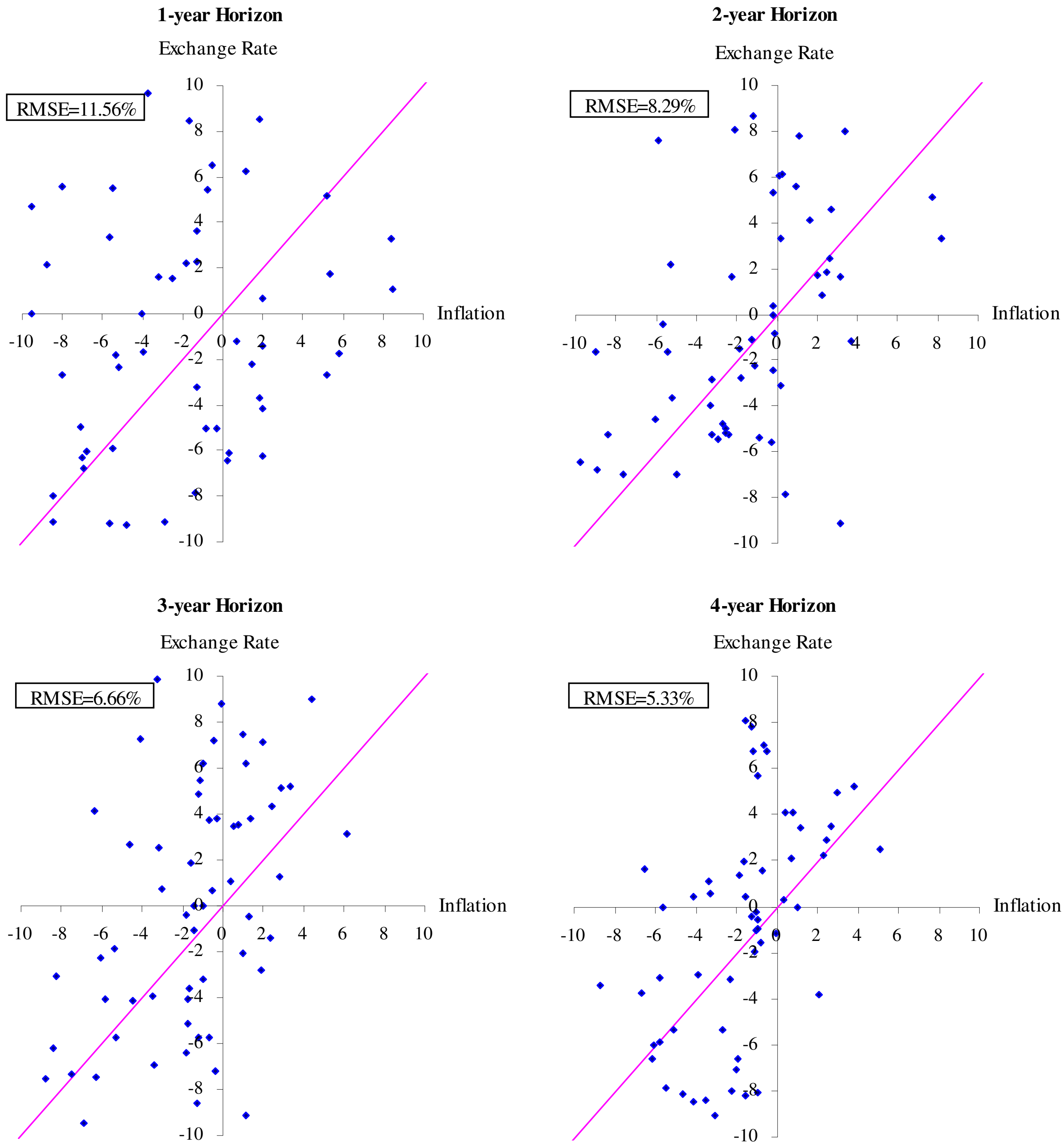


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FIGURE 4.1 (continued)

SCATTER PLOTS OF EXCHANGE RATES AND PRICES, 6 COUNTRIES, 1994-2007

(Annualised logarithmic changes×100)

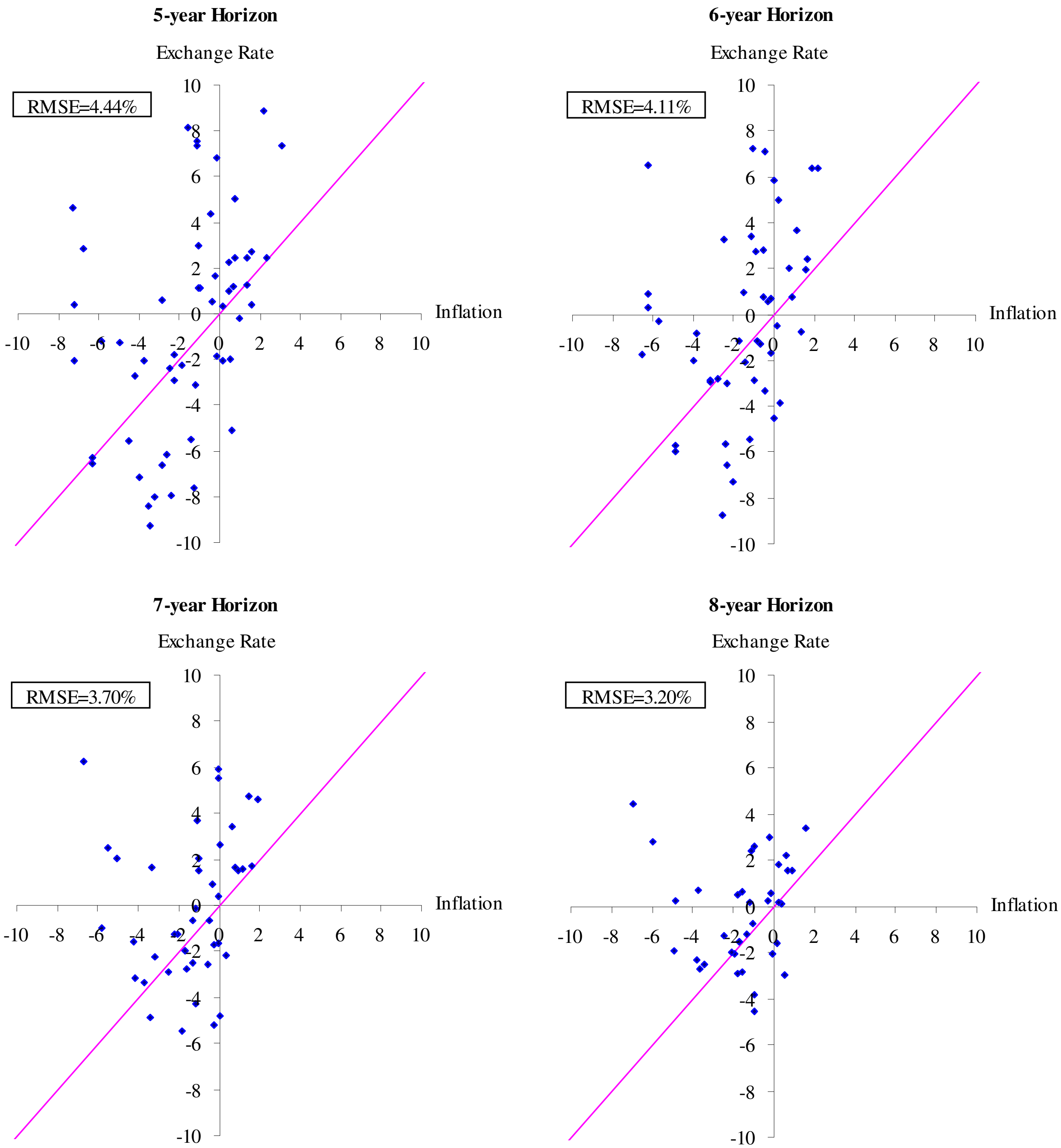

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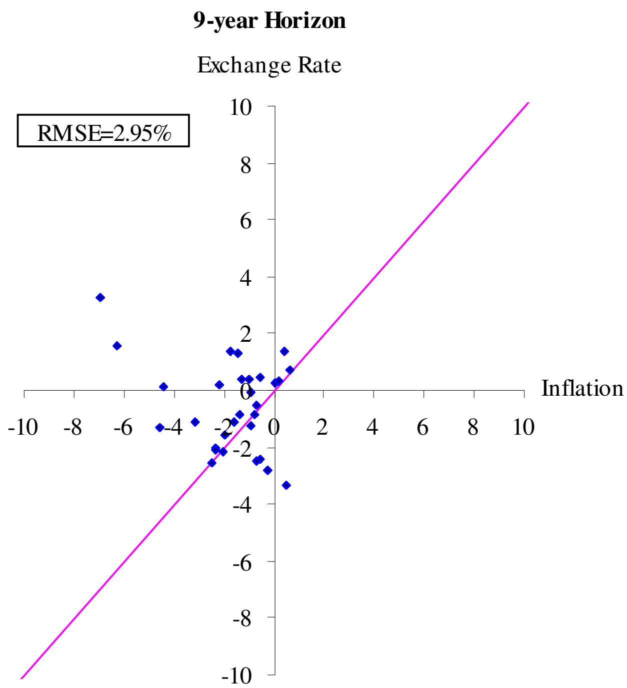
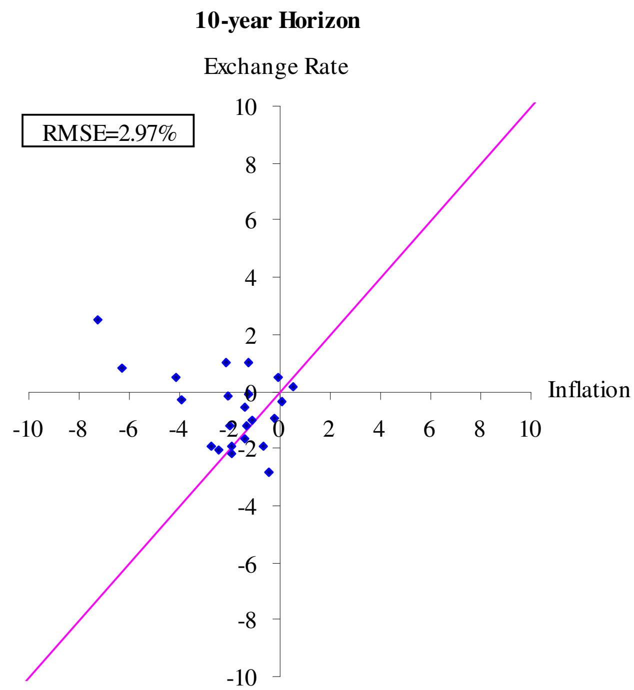
FIGURE 4.1 (continued)

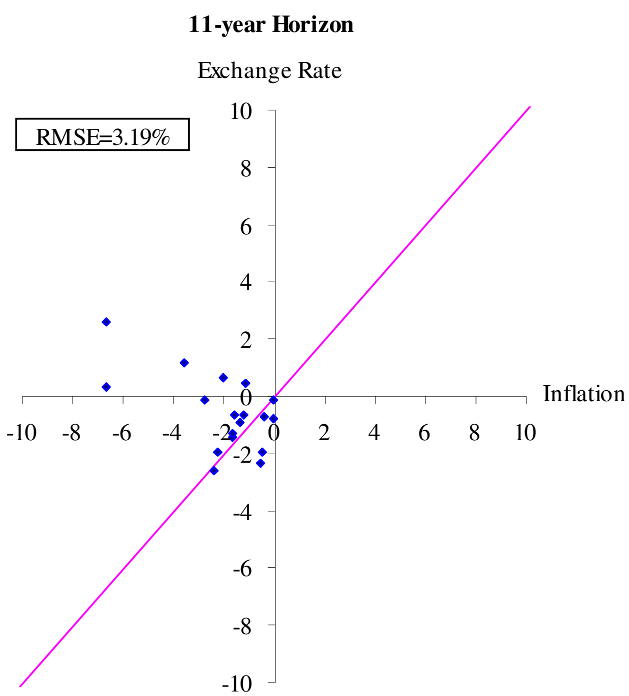
SCATTER PLOTS OF EXCHANGE RATES AND PRICES,

6 COUNTRIES, 1994-2007

(Annualised logarithmic changes×100)







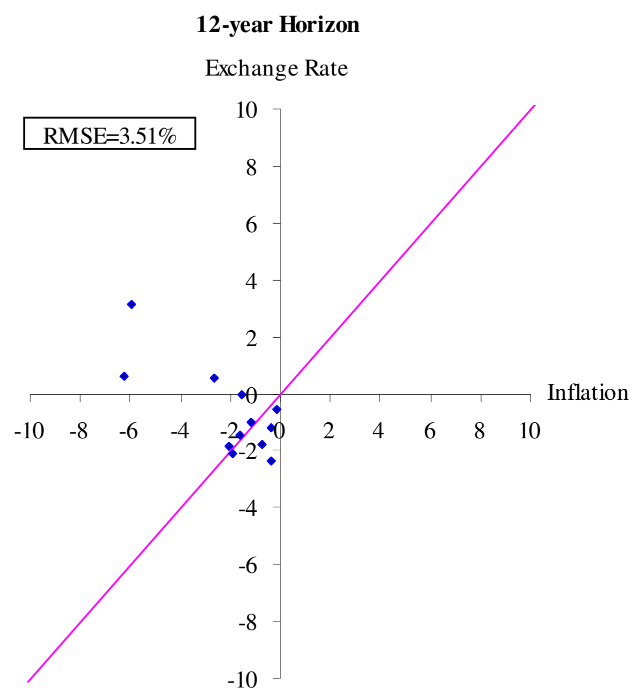


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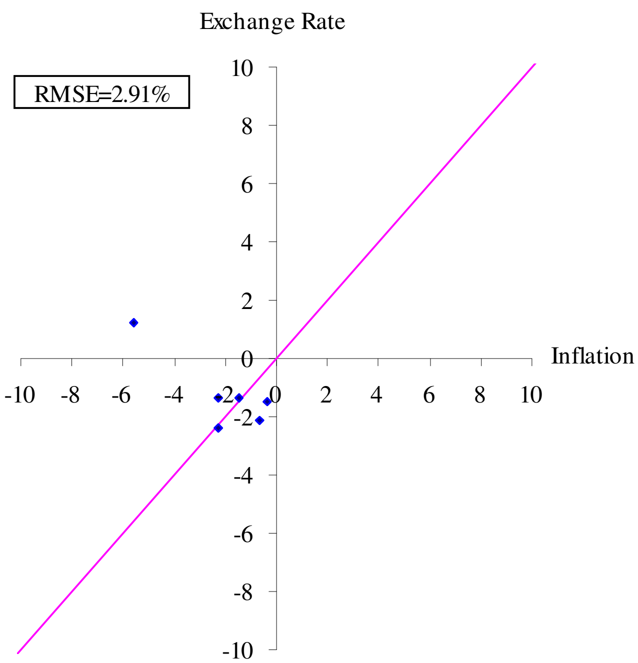
FIGURE 4.1 (continued)

SCATTER PLOTS OF EXCHANGE RATES AND PRICES, 6 COUNTRIES, 1994-2007

(Annualised logarithmic changes×100)

13-year Horizon



Note: To facilitate the presentation, observations greater than 10 percent in absolute value are omitted. These observations are included in the RMSE.

FIGURE 4.2

VARIANCES OF EXCHANGE RATE CHANGES

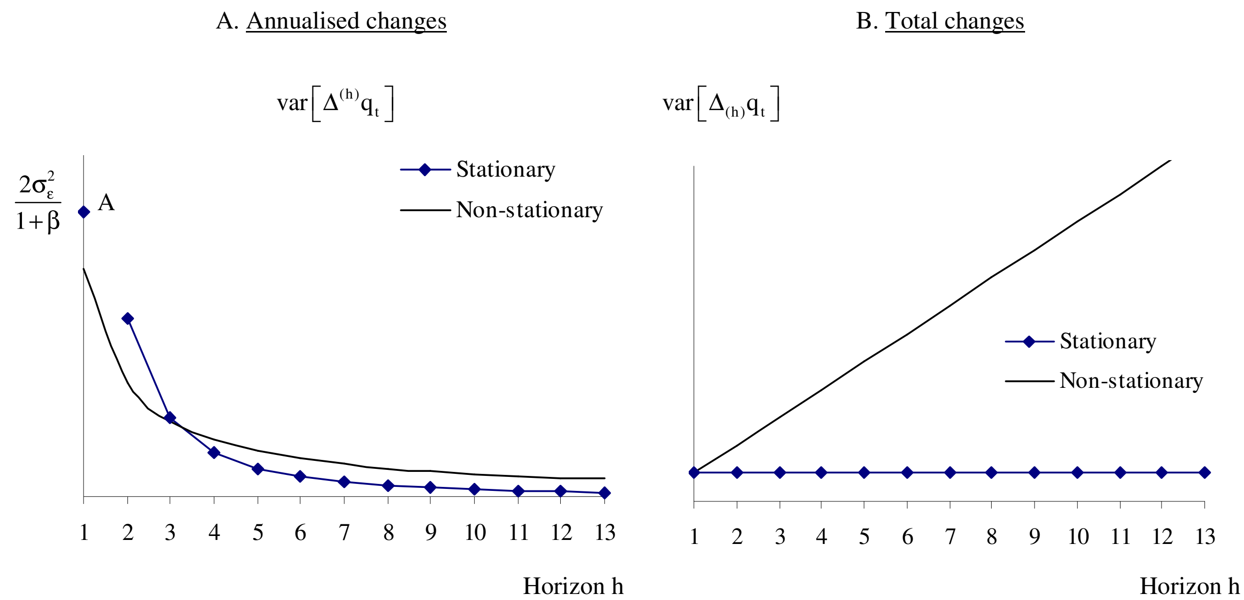


FIGURE 4.3

TOTAL VOLATILITY AND THE HORIZON

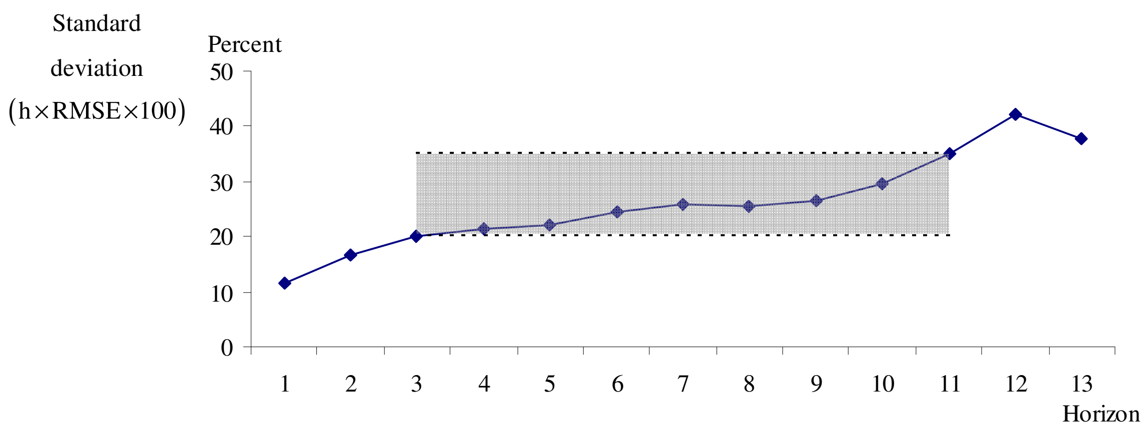


FIGURE 5.1

SCATTER PLOTS OF FUTURE REAL EXCHANGE RATES AGAINST CURRENT DEVIATIONS FROM PARITY, 6 COUNTRIES, 1994-2007

(Logarithmic changes×100)

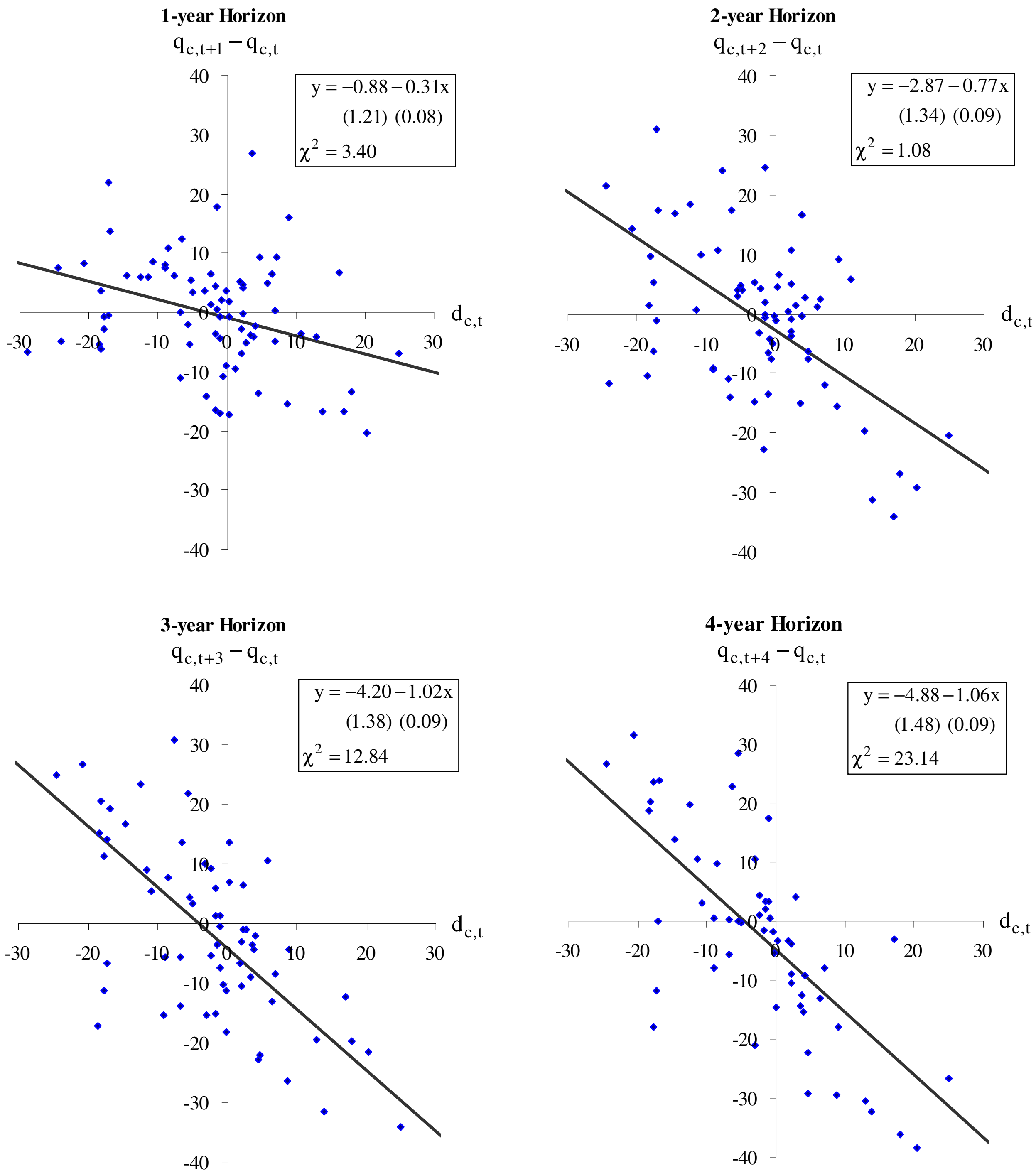


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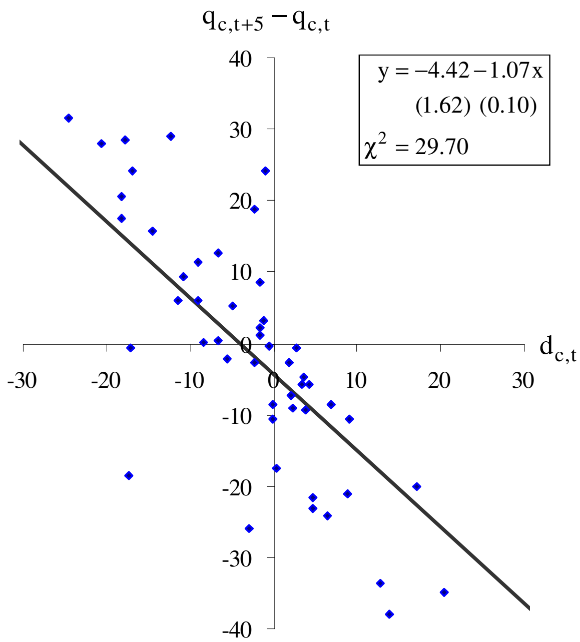
FIGURE 5.1 (continued)

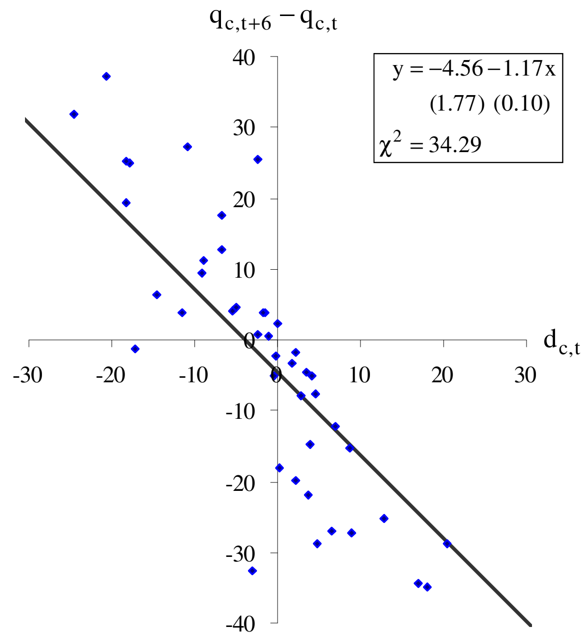
SCATTER PLOTS OF FUTURE REAL EXCHANGE RATES AGAINST CURRENT DEVIATIONS FROM PARITY, 6 COUNTRIES, 1994-2007

(Logarithmic changes×100)

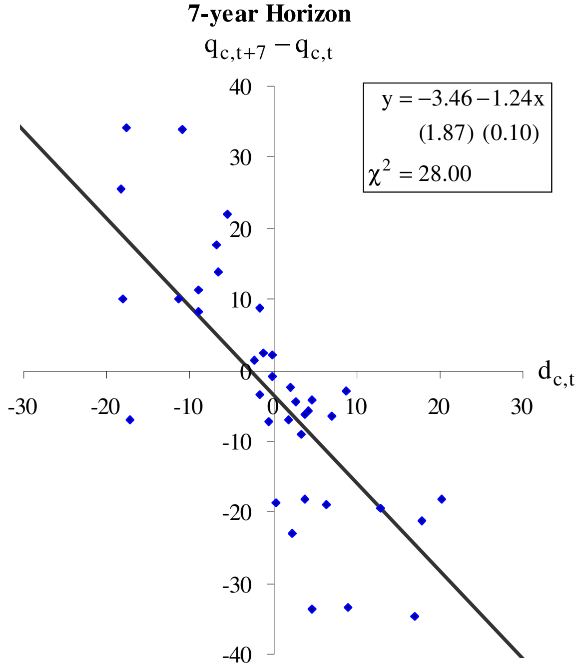
5-year Horizon



6-year Horizon



7-year Horizon



8-year Horizon

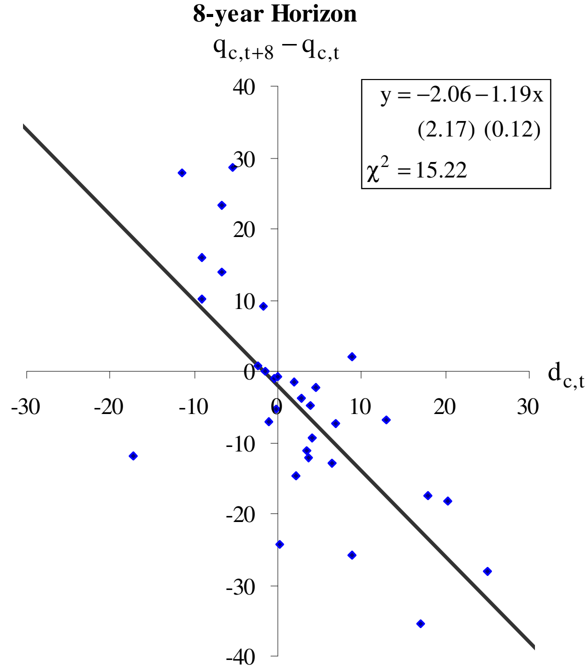


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FIGURE 5.1 (continued)

SCATTER PLOTS OF FUTURE REAL EXCHANGE RATES AGAINST CURRENT DEVIATIONS FROM PARITY, 6 COUNTRIES, 1994-2007

(Logarithmic changes×100)

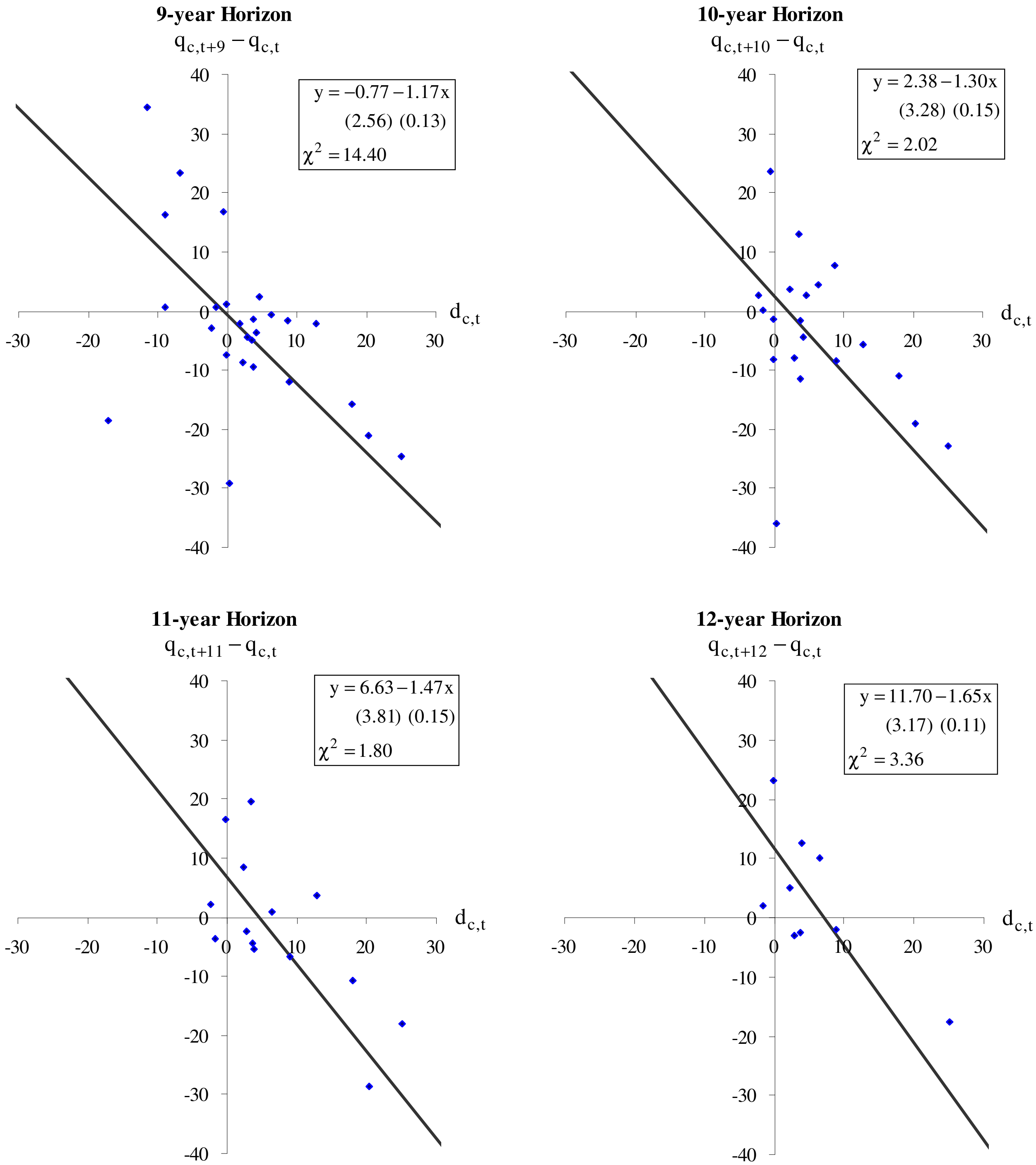

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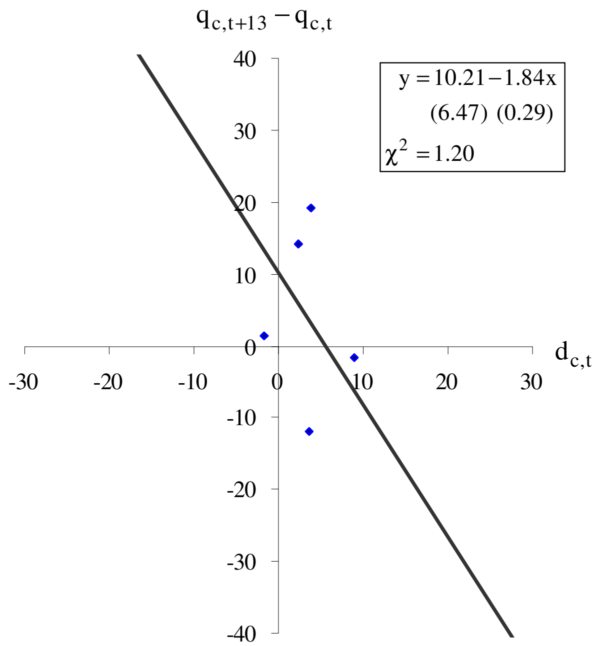
FIGURE 5.1 (continued)

SCATTER PLOTS OF FUTURE REAL EXCHANGE RATES AGAINST CURRENT DEVIATIONS FROM PARITY, 6 COUNTRIES, 1994-2007

(Logarithmic changes×100)

13-year Horizon



Notes: 1. To facilitate the presentation, observations for which $|q_{c,t+h} - q_{c,t}| > 0.4$ and $|d_{ct}| > 0.3$ are omitted. These observations are included for the regression and the χ^2 value.

2. The χ^2 value tests the independence of the signs of d_{ct} and those of $q_{t+h} - q_t$ based on a 2×2 contingency table. Under the null, χ^2 has one degree of freedom. The critical value of $\chi^2_{.05}(1)$ is 3.8 and $\chi^2_{.01}(1)$ is 6.6.

FIGURE 5.2
PREDICTIVE VALUE OF DEVIATIONS FROM PARITY:
CHI SQUARE VALUE AGAINST HORIZON

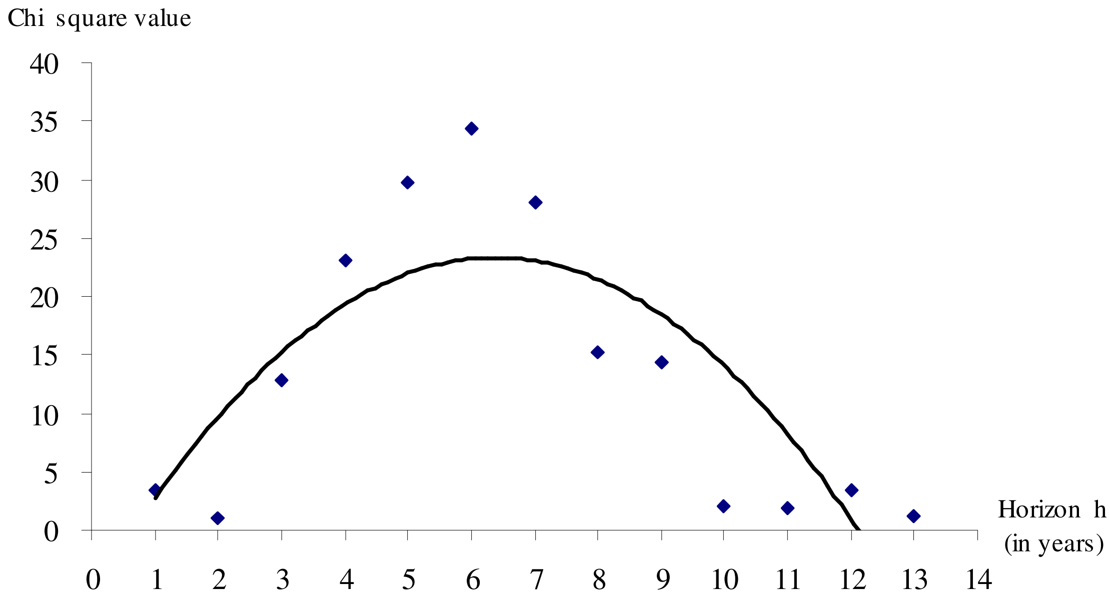


TABLE 5.1

PREDICTIVE REGRESSIONS, REAL EXCHANGE RATES, 6 COUNTRIES, 1994-2007

$$q_{c,t+h} - q_{c,t} = \eta^h + \phi^h d_{c,t} + u^h_{c,t}$$

(Standard errors in parentheses)

Horizon h (1)	Intercept $\eta^h \times 100$ (2)	Slope ϕ^h (3)	No of observations (4)	R^2 (5)	χ^2 (6)	F (7)
		A. With overlapping observations				
1	-0.876 (1.208)	-0.306 (0.079)	78	0.165	3.405	38.805**
	-	-0.306 (0.079)	78	-	-	-
2	-2.874 (1.337)	-0.774 (0.087)	72	0.531	1.076	5.707**
	-	-0.773 (0.089)	72	-	-	-
3	-4.202 (1.385)	-1.022 (0.088)	66	0.677	12.841	4.645*
	-	-1.025 (0.094)	66	-	-	-
4	-4.881 (1.483)	-1.063 (0.091)	60	0.701	23.143	5.736**
	-	-1.073 (0.099)	60	-	-	-
5	-4.424 (1.622)	-1.069 (0.096)	54	0.705	29.700	4.140*
	-	-1.088 (0.101)	54	-	-	-
6	-4.563 (1.765)	-1.174 (0.101)	48	0.745	34.286	5.571**
	-	-1.211 (0.106)	48	-	-	-
7	-3.460 (1.870)	-1.239 (0.105)	42	0.777	28.000	5.761**
	-	-1.289 (0.104)	42	-	-	-
8	-2.062 (2.169)	-1.194 (0.119)	36	0.749	15.220	2.725
	-	-1.235 (0.110)	36	-	-	-
9	-0.769 (2.556)	-1.165 (0.128)	30	0.746	14.403	1.237
	-	-1.181 (0.115)	30	-	-	-
10	2.382 (3.275)	-1.302 (0.151)	24	0.771	2.021	2.111
	-	-1.239 (0.123)	24	-	-	-
11	6.631 (3.813)	-1.475 (0.153)	18	0.853	1.800	4.831*
	-	-1.310 (0.127)	18	-	-	-
12	11.695 (3.170)	-1.646 (0.110)	12	0.957	3.360	17.204**
	-	-1.401 (0.129)	12	-	-	-
13	10.213 (6.475)	-1.836 (0.293)	6	0.908	1.200	4.074
	-	-1.592 (0.283)	6	-	-	-

TABLE 5.1 (continued)

PREDICTIVE REGRESSIONS, REAL EXCHANGE RATES, 6 COUNTRIES, 1994-2007

$$q_{c,t+h} - q_{c,t} = \eta^h + \phi^h d_{c,t} + u^h_{c,t}$$

(Standard errors in parentheses)

Horizon h	Intercept $\eta^h \times 100$	Slope ϕ^h	No of observations	R²	χ²	F
(1)	(2)	(3)	(4)	(5)	(6)	(7)
		B. Without overlapping observations				
1	-0.876 (1.208)	-0.306 (0.079)	78	0.165	3.405	38.805**
	-	-0.306 (0.079)	78	-	-	-
2	-2.657 (1.999)	-0.755 (0.140)	36	0.461	1.800	2.600
	-	-0.741 (0.141)	36	-	-	-
3	-2.511 (2.331)	-0.966 (0.166)	24	0.607	8.224	0.596
	-	-0.970 (0.166)	24	-	-	-
4	-6.105 (2.656)	-1.101 (0.170)	18	0.723	7.200	2.680
	-	-1.047 (0.189)	18	-	-	-
5	-2.313 (2.252)	-0.922 (0.141)	12	0.811	8.400	0.549
	-	-0.973 (0.132)	12	-	-	-
6	-3.667 (4.396)	-1.085 (0.234)	12	0.682	12.000	0.447
	-	-1.104 (0.230)	12	-	-	-
7	-13.564 (4.843)	-0.839 (0.219)	6	0.785	N/A	4.310
	-	-1.164 (0.286)	6	-	-	-
8	-7.088 (3.064)	-1.215 (0.139)	6	0.950	6.000	8.035*
	-	-1.385 (0.161)	6	-	-	-
9	-1.773 (1.726)	-1.297 (0.078)	6	0.986	6.000	13.638*
	-	-1.340 (0.067)	6	-	-	-
10	0.986 (2.517)	-1.359 (0.114)	6	0.973	2.400	6.107
	-	-1.336 (0.088)	6	-	-	-
11	2.582 (3.255)	-1.482 (0.147)	6	0.962	0.240	5.958
	-	-1.420 (0.120)	6	-	-	-
12	8.464 (3.726)	-1.678 (0.169)	6	0.961	1.200	8.081*
	-	-1.475 (0.194)	6	-	-	-
13	10.213 (6.475)	-1.836 (0.293)	6	0.908	1.200	4.074
	-	-1.592 (0.283)	6	-	-	-

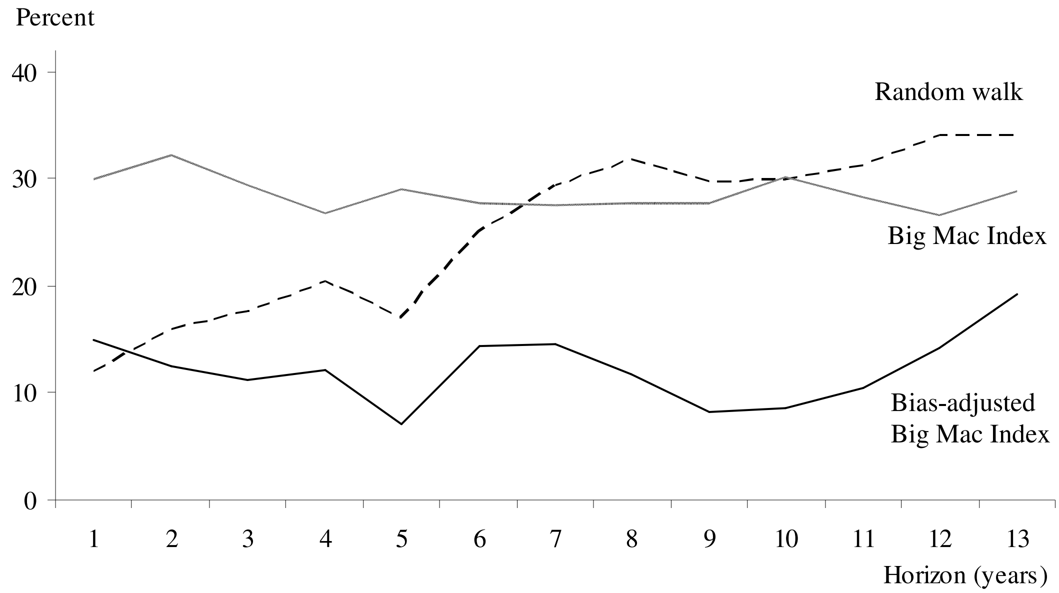
Notes:
1. The χ² statistics of column 6 test the hypothesis of the independence of $q_{c,t+h} - q_{c,t}$ and $d_{c,t}$. Under the null, χ² has 1 degree of freedom.
2. The F statistics of column 7 test the joint hypothesis of $\eta^h = 0$ and $\phi^h = -1$. Under the null, F has degrees of freedom equal to 2 and N-2, where N is the number of observations.
3. Asterisks (*) and (**) respectively indicate significant at the 5 and 1 percent levels.

FIGURE 5.3

THE QUALITY OF THREE SETS OF EXCHANGE-RATE FORECASTS

(Root-Mean-Squared Errors)

A. With overlapping observations



B. Without overlapping observations

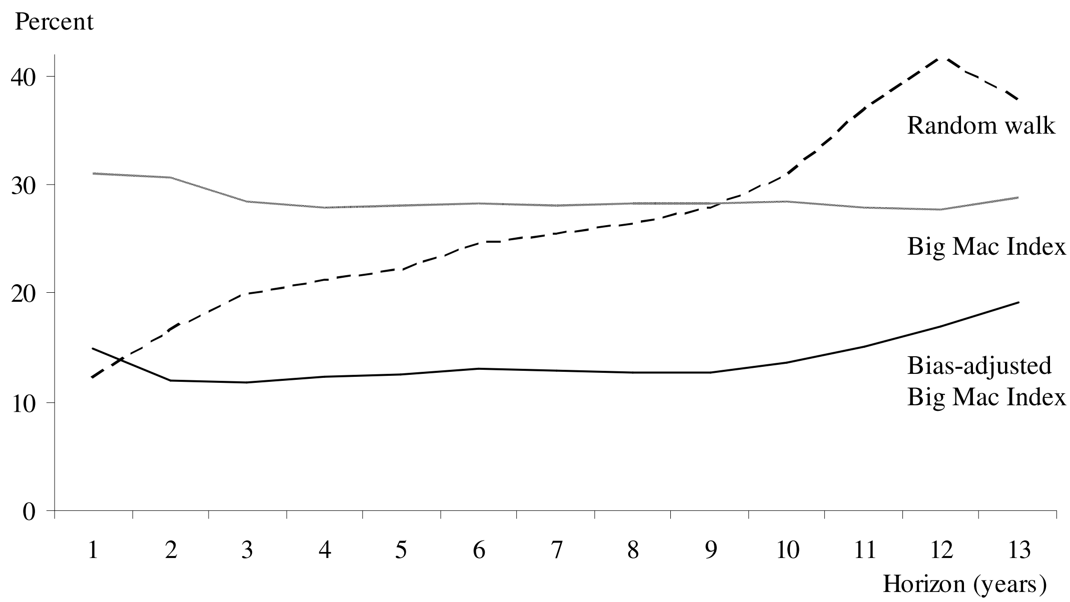


TABLE 6.1
MEAN REAL EXCHANGE RATES
(Logarithmic ratios $\times$ 100; standard errors $\times$ 100 in parentheses)

Country	Period			t-value for equality of means
	1994-1997	1998-2007	1994-2007	
(1)	(2)	(3)	(4)	(5)
Australia	-23.41 (2.22)	-34.04 (3.96)	-31.00 (3.14)	2.34
Britain	16.98 (1.60)	15.92 (1.12)	16.22 (0.90)	0.55
Canada	-13.35 (1.17)	-15.65 (3.61)	-14.99 (2.57)	0.61
Euro	26.70 (4.57)	6.91 (3.50)	12.56 (3.69)	3.44
Japan	32.07 (16.67)	-18.26 (4.83)	-3.88 (8.34)	2.90
Switzerland	64.23 (7.16)	45.14 (2.31)	50.59 (3.43)	2.54
Mean	17.20 (6.69)	0.00 (3.65)	4.92 (3.32)	2.26

TABLE 6.2

ESTIMATES OF EXTENDED BIG MAC MODEL

$$\Delta q_{ct} = \alpha_c + \rho q_{c,t-1} + \gamma_1 \Delta y_{ct} + \gamma_2 \Delta IRD_{ct} + \varepsilon_{ct}$$

Variable/coefficient	SURE			Bias-adjusted SURE			Ratio		
	Estimate	Standard error	t-stat	Estimate	Standard error	t-stat	Estimate	Standard error	t-stat
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)=(2)/(5)	(9)=(3)/(6)	(10)=(4)/(7)
Country dummies, α_c									
Australia	.0666	.0861	.77	.0725	.1700	.43	.92	.51	1.81
Britain	.3018	.0558	5.40	.3723	.0846	4.40	.81	.66	1.23
Canada	.0772	.0258	2.99	.0966	.0325	2.97	.80	.79	1.01
Euro area	.3223	.0587	5.49	.3995	.0982	4.07	.81	.60	1.35
Japan	.1858	.0721	2.58	.2387	.1075	2.22	.78	.67	1.16
Switzerland	.3493	.0804	4.34	.4409	.1241	3.55	.79	.65	1.22
Speed of adjustment, ρ	-.5115	.0865	-5.91	-.6395	.1339	-4.78	.80	.65	1.24
Economic Variables							.83	.49	1.69
Relative GDP, γ_1	.9167	.3074	2.86	1.0993	.6481	1.70	.94	.46	2.06
Interest rate differential, γ_2	1.0405	.6250	1.60	1.1076	1.4272	.78	.92	.51	1.81

Note: The simulated critical values of the t-statistics for the bias-adjusted estimates ρ, γ_1 and γ_2 are as follows:

	1%	5%	10%
ρ	-3.11	-1.90	-1.47
γ_1	22.57	17.66	15.20
γ_2	4.26	3.19	2.58

TABLE A1

EXCHANGE RATES, GDPs AND INTEREST RATES

Year	RER		GDP				Interest Rates (IR) and Inflation						Real IR differential
							Local			US			
	RER	Change	Local	US	y/y*	log(y/y*)	IR	Inflation	Real IR	IR	Inflation	Real IR	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
						1. Australia							
1994	-28.75		21,982	28,803	76.32	-27.02	7.08	1.84	5.14	6.36	2.71	3.56	1.59
1995	-24.56	4.19	22,614	29,249	77.32	-25.73	9.78	2.75	6.84	7.35	2.75	4.49	2.36
1996	-18.14	6.42	23,252	30,098	77.25	-25.81	8.63	4.48	3.97	6.11	2.77	3.25	0.72
1997	-22.21	-4.07	24,000	31,238	76.83	-26.36	7.90	1.77	6.02	6.62	2.95	3.56	2.46
1998	-37.76	-15.54	24,944	32,298	77.23	-25.84	6.31	-0.08	6.40	5.97	1.88	4.01	2.38
1999	-37.71	0.05	25,653	33,444	76.71	-26.52	5.32	1.24	4.03	5.09	1.67	3.36	0.67
2000	-48.74	-11.04	25,835	34,365	75.18	-28.53	6.46	2.02	4.35	6.15	2.64	3.42	0.94
2001	-51.66	-2.92	26,528	34,163	77.65	-25.29	5.85	5.50	0.34	5.64	3.43	2.13	-1.80
2002	-43.42	8.24	27,121	34,286	79.10	-23.44	5.85	3.38	2.40	5.03	2.16	2.81	-0.41
2003	-37.46	5.97	27,872	34,875	79.92	-22.42	5.59	3.12	2.40	4.19	2.04	2.11	0.28
2004	-25.07	12.39	27,994	36,098	77.55	-25.43	6.00	2.61	3.30	4.44	2.26	2.12	1.18
2005	-20.21	4.86	28,998	36,963	78.45	-24.27	5.94	2.65	3.20	4.62	3.29	1.29	1.92
2006	-23.79	-3.58	29,622	37,686	78.60	-24.08	4.91	2.86	1.99	4.16	3.44	0.69	1.30
2007	-14.53	9.26	30,246	38,408	78.75	-23.89	6.82	3.42	3.29	5.64	3.15	2.42	0.87
Mean	-31.00	1.09	26190	33712	77.63	-25.33	6.60	2.68	3.83	5.53	2.65	2.80	1.03
						2. Britain							
1994	14.61		20,742	28,803	72.01	-32.83	7.32	1.81	5.41	6.36	2.71	3.56	1.85
1995	19.04	4.43	21,249	29,249	72.65	-31.95	8.49	2.80	5.54	7.35	2.75	4.49	1.05
1996	13.91	-5.13	21,789	30,098	72.40	-32.30	7.92	3.18	4.60	6.11	2.77	3.25	1.34
1997	20.39	6.48	22,457	31,238	71.89	-33.00	7.70	2.43	5.14	6.62	2.95	3.56	1.58
1998	18.06	-2.33	23,181	32,298	71.77	-33.17	6.53	3.44	2.98	5.97	1.88	4.01	-1.03
1999	23.20	5.14	23,799	33,444	71.16	-34.02	5.04	2.92	2.06	5.09	1.67	3.36	-1.30
2000	18.36	-4.84	24,666	34,365	71.78	-33.16	5.33	1.69	3.58	6.15	2.64	3.42	0.16
2001	11.26	-7.10	25,134	34,163	73.57	-30.69	5.10	2.89	2.15	5.64	3.43	2.13	0.01
2002	14.69	3.43	25,518	34,286	74.43	-29.54	4.96	1.47	3.44	5.03	2.16	2.81	0.63
2003	15.32	0.63	26,046	34,875	74.68	-29.19	4.61	2.23	2.34	4.19	2.04	2.11	0.22
2004	14.64	-0.68	26,762	36,098	74.14	-29.92	5.06	2.97	2.03	4.44	2.26	2.12	-0.10
2005	11.07	-3.57	27,430	36,963	74.21	-29.83	5.12	3.43	1.63	4.62	3.29	1.29	0.34
2006	16.62	5.55	28,042	37,686	74.41	-29.56	3.92	2.34	1.54	4.16	3.44	0.69	0.85
2007	15.96	-0.66	28,654	38,408	74.60	-29.30	5.67	4.71	0.92	5.64	3.15	2.42	-1.50
Mean	16.22	0.10	24676	33712	73.12	-31.32	5.91	2.74	3.10	5.53	2.65	2.80	0.29

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TABLE A1 (continued)

EXCHANGE RATES, GDPs AND INTEREST RATES

	RER		GDP				Interest Rates (IR) and Inflation						Real IR
							Local			US			
Year	RER	Change	Local	US	y/y*	log(y/y*)	IR	Inflation	Real IR	IR	Inflation	Real IR	differential
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
							3. Canada						
1994	-11.14		22,133	28,803	76.84	-26.34	7.61	1.34	6.19	6.36	2.71	3.56	2.63
1995	-15.20	-4.06	22,589	29,249	77.23	-25.84	8.86	0.59	8.22	7.35	2.75	4.49	3.73
1996	-11.53	3.67	22,756	30,098	75.61	-27.96	7.64	2.04	5.49	6.11	2.77	3.25	2.24
1997	-15.53	-4.00	23,709	31,238	75.90	-27.58	6.95	1.76	5.10	6.62	2.95	3.56	1.54
1998	-26.46	-10.93	24,454	32,298	75.71	-27.82	5.72	1.29	4.38	5.97	1.88	4.01	0.37
1999	-20.47	5.99	25,670	33,444	76.76	-26.45	5.18	0.99	4.14	5.09	1.67	3.36	0.78
2000	-25.82	-5.35	26,821	34,365	78.05	-24.78	5.92	2.25	3.59	6.15	2.64	3.42	0.18
2001	-17.39	8.43	26,951	34,163	78.89	-23.71	5.68	2.86	2.74	5.64	3.43	2.13	0.61
2002	-16.04	1.35	27,513	34,286	80.24	-22.01	5.51	2.08	3.36	5.03	2.16	2.81	0.55
2003	-20.54	-4.50	27,845	34,875	79.84	-22.51	5.16	3.08	2.02	4.19	2.04	2.11	-0.09
2004	-22.68	-2.14	28,398	36,098	78.67	-23.99	5.11	1.98	3.07	4.44	2.26	2.12	0.95
2005	-16.47	6.20	29,465	36,963	79.72	-22.67	4.85	2.30	2.50	4.62	3.29	1.29	1.21
2006	1.37	17.85	30,151	37,686	80.01	-22.30	3.79	2.23	1.53	4.16	3.44	0.69	0.84
2007	8.03	6.66	30,837	38,408	80.29	-21.95	4.97	2.16	2.74	5.64	3.15	2.42	0.32
Mean	-14.99	1.47	26378	33712	78.13	-24.71	5.93	1.92	3.93	5.53	2.65	2.80	1.13
							4. Euro Area						
1994	21.52		20,718	28,803	71.93	-32.95	7.14	3.51	3.51	6.36	2.71	3.56	-0.05
1995	37.58	16.06	21,151	29,249	72.31	-32.42	8.85	2.83	5.85	7.35	2.75	4.49	1.37
1996	30.53	-7.05	21,339	30,098	70.90	-34.39	8.08	2.69	5.25	6.11	2.77	3.25	1.99
1997	17.18	-13.35	21,799	31,238	69.79	-35.97	6.71	2.11	4.51	6.62	2.95	3.56	0.95
1998	3.54	-13.64	22,382	32,298	69.30	-36.67	5.55	1.64	3.84	5.97	1.88	4.01	-0.17
1999	10.89	7.36	22,955	33,444	68.64	-37.63	4.32	1.06	3.23	5.09	1.67	3.36	-0.13
2000	-5.72	-16.62	23,732	34,365	69.06	-37.02	5.17	1.42	3.70	6.15	2.64	3.42	0.28
2001	-11.93	-6.20	24,065	34,163	70.44	-35.04	5.26	2.22	2.98	5.64	3.43	2.13	0.84
2002	-4.35	7.58	24,136	34,286	70.40	-35.10	5.04	2.38	2.60	5.03	2.16	2.81	-0.21
2003	9.43	13.78	24,176	34,875	69.32	-36.64	4.57	2.00	2.52	4.19	2.04	2.11	0.41
2004	12.96	3.53	24,558	36,098	68.03	-38.52	4.49	2.02	2.42	4.44	2.26	2.12	0.30
2005	14.82	1.86	25,292	36,963	68.42	-37.94	4.11	2.20	1.88	4.62	3.29	1.29	0.59
2006	19.55	4.73	25,702	37,686	68.20	-38.27	3.21	1.91	1.28	4.16	3.44	0.69	0.59
2007	19.92	0.37	26,113	38,408	67.99	-38.58	4.82	2.05	2.71	5.64	3.15	2.42	0.29
Mean	12.56	-0.12	23437	33712	69.62	-36.22	5.52	2.14	3.31	5.53	2.65	2.80	0.50

(continued on next page)

TABLE A1 (continued)

EXCHANGE RATES, GDPs AND INTEREST RATES

	RER		GDP				Interest Rates (IR) and Inflation						
							Local			US			Real IR
Year	RER	Change	Local	US	y/y*	log(y/y*)	IR	Inflation	Real IR	IR	Inflation	Real IR	differential
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
						5. Japan							
1994	49.14		22,500	28,803	78.12	-24.70	4.04	1.26	2.74	6.36	2.71	3.56	-0.82
1995	69.63	20.49	22,878	29,249	78.22	-24.57	4.39	0.32	4.05	7.35	2.75	4.49	-0.44
1996	13.15	-56.49	23,625	30,098	78.49	-24.22	3.12	-0.21	3.34	6.11	2.77	3.25	0.08
1997	-3.65	-16.79	23,958	31,238	76.70	-26.53	2.86	0.51	2.34	6.62	2.95	3.56	-1.22
1998	-21.05	-17.40	23,588	32,298	73.03	-31.43	2.13	2.00	0.13	5.97	1.88	4.01	-3.88
1999	0.82	21.87	23,466	33,444	70.17	-35.43	1.50	0.10	1.40	5.09	1.67	3.36	-1.96
2000	9.99	9.17	23,971	34,365	69.75	-36.02	1.71	-0.52	2.25	6.15	2.64	3.42	-1.17
2001	-6.89	-16.87	23,948	34,163	70.10	-35.53	1.63	-0.66	2.31	5.64	3.43	2.13	0.17
2002	-21.15	-14.26	23,760	34,286	69.30	-36.68	1.35	-1.01	2.39	5.03	2.16	2.81	-0.42
2003	-21.61	-0.46	24,037	34,875	68.92	-37.22	1.04	-0.53	1.58	4.19	2.04	2.11	-0.53
2004	-22.38	-0.77	24,661	36,098	68.32	-38.10	1.28	-0.29	1.58	4.44	2.26	2.12	-0.54
2005	-27.91	-5.53	24,556	36,963	66.43	-40.90	1.59	0.08	1.51	4.62	3.29	1.29	0.22
2006	-32.84	-4.94	24,703	37,686	65.55	-42.23	1.43	-0.29	1.73	4.16	3.44	0.69	1.04
2007	-39.59	-6.75	24,851	38,408	64.70	-43.54	2.04	0.23	1.80	5.64	3.15	2.42	-0.62
Mean	-3.88	-6.83	23893	33712	71.27	-34.08	2.15	0.07	2.08	5.53	2.65	2.80	-0.72
						6. Switzerland							
1994	54.29		26,813	28,803	93.09	-7.16	4.34	2.62	1.67	6.36	2.71	3.56	-1.88
1995	81.12	26.83	26,841	29,249	91.77	-8.59	5.15	0.81	4.31	7.35	2.75	4.49	-0.18
1996	70.93	-10.19	26,783	30,098	88.99	-11.67	4.28	1.67	2.57	6.11	2.77	3.25	-0.68
1997	50.59	-20.34	27,082	31,238	86.69	-14.28	3.93	0.70	3.22	6.62	2.95	3.56	-0.35
1998	41.62	-8.97	27,851	32,298	86.23	-14.81	3.29	0.29	2.99	5.97	1.88	4.01	-1.02
1999	49.50	7.88	27,973	33,444	83.64	-17.86	2.74	0.14	2.60	5.09	1.67	3.36	-0.76
2000	32.40	-17.10	28,831	34,365	83.90	-17.56	3.28	1.20	2.06	6.15	2.64	3.42	-1.36
2001	36.03	3.62	29,022	34,163	84.95	-16.31	3.66	1.40	2.23	5.64	3.43	2.13	0.10
2002	42.14	6.12	28,989	34,286	84.55	-16.78	3.32	0.87	2.43	5.03	2.16	2.81	-0.38
2003	52.88	10.73	28,792	34,875	82.56	-19.17	2.65	0.73	1.91	4.19	2.04	2.11	-0.20
2004	52.74	-0.14	29,276	36,098	81.10	-20.95	2.74	0.46	2.27	4.44	2.26	2.12	0.15
2005	49.90	-2.84	29,747	36,963	80.48	-21.72	2.55	1.27	1.27	4.62	3.29	1.29	-0.02
2006	51.85	1.95	30,034	37,686	79.70	-22.69	1.97	1.08	0.88	4.16	3.44	0.69	0.19
2007	42.32	-9.53	30,321	38,408	78.95	-23.64	3.12	0.76	2.34	5.64	3.15	2.42	-0.08
Mean	50.59	-0.92	28454	33712	84.76	-16.66	3.36	1.00	2.34	5.53	2.65	2.80	-0.46

Note:
1. Entries in columns 2, 3, 6 and 7 are to be divided by 100.
2. Interest and inflation rates are in percent and refer to the (variable) number of months between publication dates of successive issues of The Economist that contain the Big Mac Index.