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The Purchasing Power Parity Debate

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> *Our willingness to pay a certain price for foreign money must ultimately and essentially be due to the fact that this money possesses a purchasing power as against commodities and services in that country. On the other hand, when we offer so and so much of our own money, we are actually offering a purchasing power as against commodities and services in our own country. Our valuation of a foreign currency in terms of our own, therefore, mainly depends on the relative purchasing power of the two currencies in their respective countries.*
>
> Gustav Cassel, economist (1922, pp. 138–39)

> *The fundamental things apply*
> *As time goes by.*
>
> Herman Hupfeld, songwriter (1931; from the film *Casablanca*, 1942)

Purchasing power parity (PPP) is a disarmingly simple theory that holds that the nominal exchange rate between two currencies should be equal to the ratio of aggregate price levels between the two countries, so that a unit of currency of one country will have the same purchasing power in a foreign country. The PPP theory has a long history in economics, dating back several centuries, but the specific terminology of purchasing power parity was introduced in the years after World War I during the international policy debate concerning the appropriate level for nominal exchange rates among the major industrialized countries after the large-scale inflations during and after the war (Cassel, 1918). Since then, the idea of PPP has become embedded in how many international economists think about the world. For example, Dornbusch and Krugman (1976) noted: "Under the skin of any international economist lies a deep-seated belief in some variant of the PPP theory of the exchange rate." Rogoff (1996) expressed much the same

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sentiment: "While few empirically literate economists take PPP seriously as a short-term proposition, most instinctively believe in some variant of purchasing power parity as an anchor for long-run real exchange rates."

The question of how exchange rates adjust is central to exchange rate policy, since countries with fixed exchange rates need to know what the equilibrium exchange rate is likely to be and countries with variable exchange rates would like to know what level and variation in real and nominal exchange rates they should expect. In broader terms, the question of whether exchange rates adjust toward a level established by purchasing power parity helps to determine the extent to which the international macroeconomic system is self-equilibrating.

Should PPP Hold? Does PPP Hold?

The general idea behind purchasing power parity is that a unit of currency should be able to buy the same basket of goods in one country as the equivalent amount of foreign currency, at the going exchange rate, can buy in a foreign country, so that there is parity in the purchasing power of the unit of currency across the two economies. One very simple way of gauging whether there may be discrepancies from PPP is to compare the prices of similar or identical goods from the basket in the two countries. For example, the *Economist* newspaper publishes the prices of McDonald's Big Mac hamburgers around the world and compares them in a common currency, the U.S. dollar, at the market exchange rate as a simple measure of whether a currency is overvalued or undervalued relative to the dollar at the current exchange rate (on the supposition that the currency would be valued just right if the dollar price of the burger were the same as in the United States). In January 2004, the cheapest burger was in China, at $1.23, compared with an average American price of $2.80. According to the Big Mac index, therefore, this implied that China's yuan was 56 percent undervalued. The average price of a Big Mac in the euro area countries was $3.48, suggesting that the euro was 24 percent overvalued against the dollar. In contrast, the Japanese yen was 12 percent undervalued on the Big Mac PPP standard. The Big Mac index has proved so popular that the *Economist* has also started to publish prices around the world of another globally invariable standard of value: a tall latte cup of coffee from Starbucks.

While the Big Mac and tall latte indices are an immediately engaging and fun way to think about exchange rates, it is easy to come up with good reasons why the prices of coffee and burgers might differ internationally, most of which are related to the fact that many of the inputs into a tall latte or a Big Mac cannot be traded internationally or not easily at least: each good contains a high service component—the wages of the person serving the food and drink—and a high property rental component—the cost of providing you with somewhere to sit and sip your coffee or munch your two beef patties on a sesame seed bun with secret-recipe sauce. Neither the service-sector labor nor the property (nor the trademark sauce) is easily arbitraged internationally, and advocates of PPP have generally based their view largely on arguments relating to international goods arbitrage. Thus, while these indices may give a lighthearted and suggestive idea of the relative value of currencies, they should be treated with caution.

The idea that purchasing power parity may hold because of international goods arbitrage is related to the so-called Law of One Price, which holds that the price of an internationally traded good should be the same anywhere in the world once that price is expressed in a common currency, since people could make a riskless profit by shipping the goods from locations where the price is low to locations where the price is high (for example, by arbitraging). If the same goods enter each country's market basket used to construct the aggregate price level—and with the same weight—then the Law of One Price implies that a PPP exchange rate should hold between the countries concerned.

Possible objections to this line of reasoning are immediate. For example, the presence of transactions costs—perhaps arising from transport costs, taxes, tariffs and duties and nontariff barriers—would induce a violation of the Law of One Price. Engel and Rogers (1996), for example, looked at the price differentials between similar goods in cities across the United States and Canada and reported evidence broadly in support of this hypothesis: they found that the volatility of the price differential tended to be larger the greater the distance between the cities concerned, and it increased substantially when prices in cities in different countries were compared (the so-called "border effect").

Moreover, not all goods are traded between all countries, and the weight attached to similar goods in aggregate price indices will differ across countries. In addition, different countries tend to produce goods that are differentiated rather than perfectly substitutable. Some of these problems could be addressed, at least in principle, with better data. Also, since PPP is based on traded goods, it might be more usefully tested with producer price indices that tend to contain the prices of more manufactured tradables, rather than consumer price indices, which tend to reflect the prices of relatively more nontradables, such as many services. A recent theoretical and empirical literature, discussed below, has attempted to allow for short-run deviations from PPP arising from sources such as these, while retaining PPP in some form as a long-run average or equilibrium.

These objections notwithstanding, however, it is often asserted that the PPP theory of exchange rates will hold at least approximately because of the possibility of international goods arbitrage. There are two senses in which the PPP hypothesis might hold. *Absolute* purchasing power parity holds when the purchasing power of a unit of currency is exactly equal in the domestic economy and in a foreign economy, once it is converted into foreign currency at the market exchange rate. However, it is often difficult to determine whether literally the same basket of goods is available in two different countries. Thus, it is common to test *relative* PPP, which holds that the percentage change in the exchange rate over a given period just offsets the difference in inflation rates in the countries concerned over the same period. If absolute PPP holds, then relative PPP must also hold; however, if relative PPP holds, then absolute PPP does not necessarily hold, since it is possible that common changes in nominal exchange rates are happening at different levels of purchasing power for the two currencies (perhaps because of transactions costs, for example).

To get a feel for whether PPP in either its relative or its absolute versions is a moderately good approximation to the real world, start with Figure 1. The top panel plots data on the U.S. and UK consumer price indices (CPIs) over the period 1820–2001. Both are expressed in U.S. dollar terms, which means that the UK CPI was multiplied by the number of U.S. dollars exchanging for one UK pound at that point in time. The bottom panel shows the comparison using producer price indices, using data for a slightly longer period 1791–2001.[1] We have (arbitrarily) normalized each of the series to be equal to zero in 1900.

At least three points are worth raising from a consideration of these graphs. First, absolute PPP did *not* hold perfectly and continuously: the correlation between the two lines is less than perfect in both cases. In other words, there are substantial short-run deviations from PPP. Second, the national price levels of the two countries, expressed in a common currency, *did* tend to move together over these long periods. Third, the correlation between the two national price levels is much greater with producer prices than with consumer prices.

Figure 2 shows several graphs using data for a large number of countries over the period 1970–1998.[2] Consider first the two graphs in the top row of Figure 2. For each country we calculated the one-year inflation rate in each of the 29 years and subtracted the one-year U.S. inflation rate in the same years to obtain a measure of relative inflation (using consumer price indices for the figures on the left and producer price indices for the figures on the right). We then calculated the percentage change in the dollar exchange rate for each year and, finally, we plotted relative annual inflation against exchange rate depreciation for each of the 29 years for each of the countries. If relative PPP held perfectly, then each of the scatter points would lie on a 45° ray through the origin. In the second row, we have carried out a similar exercise, except we have taken averages: we have plotted 29-year annualized average relative inflation against the average annual depreciation of the currency against the U.S. dollar over the whole period, so that there is just one scatter point for each country.

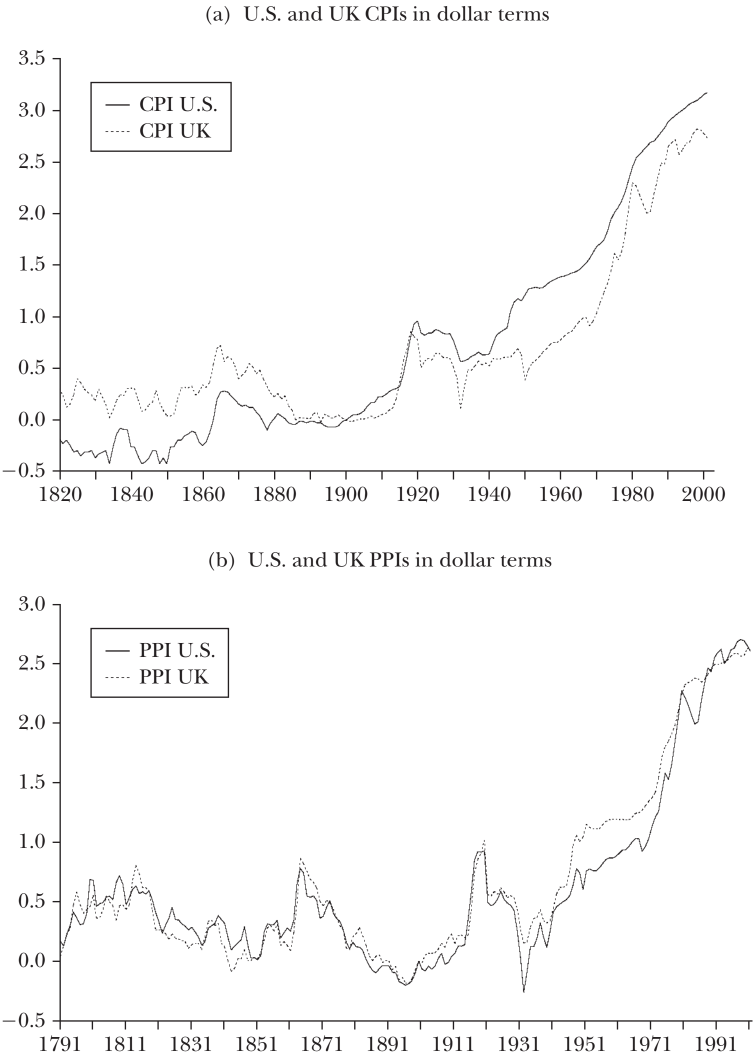
Figure 2 confirms some of the lessons of Figure 1. For small differences in annual inflation between the United States and the country concerned, the correlation between relative inflation and depreciation in each of the years seems low. Thus, relative PPP certainly does *not* appear to hold perfectly and continuously in the short run, although it appears to hold more closely for countries experiencing relatively high inflation.

When we take 29-year averages, however, the scatter plots tend to collapse onto the 45° ray. (This effect is only slightly less marked if we take averages over shorter

[1] See Lothian and Taylor (1996, 2004) for a guide to the sources for these data series.

[2] Data are from the IMF's *International Financial Statistics* database over the period 1970–1998 (data were not available after 1998 for some countries). The sample included data on consumer price indices for 20 industrialized countries and 26 developing countries, while that based on producer price indices includes 14 industrialized countries and twelve developing countries. The data set is identical to that used in Coakley, Flood, Fuertes and Taylor (2004), which contains more precise details.

Figure 1
Dollar-Sterling PPP Over Two Centuries

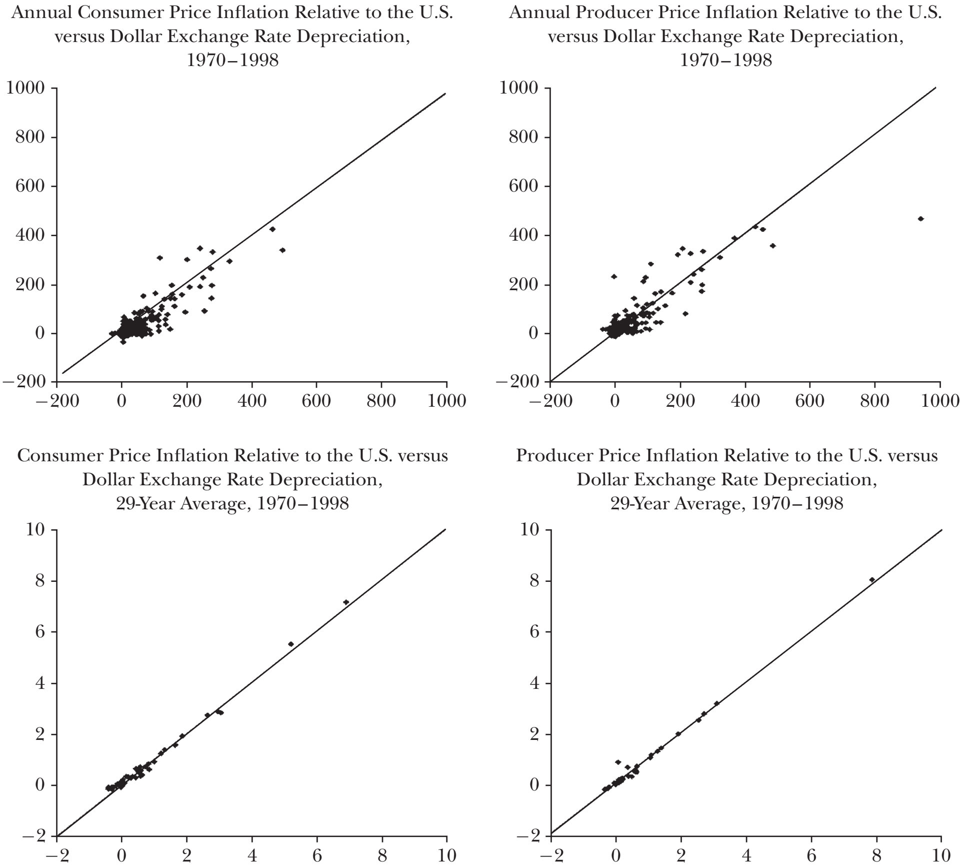


Notes: This figure shows U.S. and UK consumer and producer price indices expressed in U.S. dollar terms over roughly the last two centuries using a log scale with a base of 1900 = 0.

periods of ten years or so.) Thus, *relative* PPP seems to hold in a long-run sense. With the longer-run averages, the degree of correlation between relative inflation and exchange rate depreciation again seems higher when using PPIs than when using CPIs.

So the conclusions emerging from our informal eyeballing of Figures 1 and 2 seem to be the following. Neither absolute nor relative PPP appear to hold closely in the short run, although both appear to hold reasonably well as a long-run average and when there are large movements in relative prices, and both appear to hold better between producer price indices than between consumer price indices.

Figure 2
PPP at Various Time Horizons



Notes: This figure shows countries' cumulative inflation rate differentials against the United States in percent (vertical axis) plotted against their cumulative depreciation rates against the U.S. dollar in percent (horizontal axis). The charts on the left show CPI inflation, those on the right PPI inflation. The charts in the top row show annual rates, those in the bottom row 29-year average rates from 1970 to 1998.

In other words, as far as exchange rates are concerned, the fundamental things—relative price levels—apply increasingly as time goes by. These conclusions are in fact broadly in line with the current consensus view on PPP. So where does all the controversy arise?

The PPP Debate: A Tour of the Past Three Decades

The Rise and Fall of Continuous PPP

Under the Bretton Woods agreement that was signed after World War II, the U.S. dollar was tied to the price of gold, and then all other currencies were tied, or "pegged," to the U.S. dollar. However, in 1971, President Nixon ended the convertibility of the U.S. dollar to gold and devalued the dollar relative to gold. After the failure of attempts to restore a version of the Bretton Woods agreement, the major currencies of the world began floating against each other in March 1973.

At this time, the dominant approach to determination of exchange rates was called the "monetary approach." This approach assumed that the purchasing power parity exchange rate held continuously (Frenkel, 1976; Taylor, 1995; Frankel and Rose, 1995). Advocates of this approach argued that since the exchange rate is the relative price of two monies, that relative price should be determined by the relative balance of supply and demand in the respective money markets in an asset market equilibrium. Exactly how percentage changes in relative money supplies translated, other things equal, into exactly matching exchange rate movements was not immediately obvious, however, unless one resorted to the earlier argument based on goods arbitrage: that is, changes in the relative money supply affect relative prices, including relative traded goods prices, which then leads to international goods arbitrage.

A wave of empirical studies in the late 1970s tested whether continuous purchasing power parity did indeed hold, as well as other implications of the monetary approach to the exchange rate, and the initial results were encouraging (Frenkel and Johnson, 1978). With the benefit of hindsight, it seems that these early encouraging results arose in part because of the relative stability of the dollar during the first two or three years or so of the float (after an initial period of turbulence) and in part because of the lack of a long enough run of data with which to test the theory properly. Toward the end of the 1970s, however, the U.S. dollar did become much more volatile and more data became available to the econometricians, who subsequently showed that both continuous PPP and the simple monetary approach to the exchange rate were easily rejected. One did not have to be an econometrician, however, to witness the "collapse of purchasing power parity" (Frenkel, 1981): one could simply examine the behavior of the real exchange rate.

The real exchange rate is the nominal exchange rate (domestic price of foreign currency) multiplied by the ratio of national price levels (domestic price level divided by foreign price level); since the real exchange rate measures the purchasing power of a unit of foreign currency in the foreign economy relative to the purchasing power of an equivalent unit of domestic currency in the domestic economy, PPP would, in theory, imply a *real*, relative-price-level-adjusted exchange rate of one (although the *nominal* rate—the rate that gets reported in the *Wall Street Journal* or the *Financial Times*—could, of course, differ from one even if PPP held). In practice, if we are working with aggregate real exchange rates and hence aggregate price indices with arbitrary base periods, it may be difficult to pin down exactly when PPP held true, in order to normalize the measured real exchange rate to unity. What is clear, however, is that there will be *some* level of the measured real exchange rate that is consistent with PPP and—most importantly—that variation in the *real* exchange rate must indicate deviations from PPP (since otherwise it would be constant at the level consistent with PPP). The real trade-weighted value of the

U.S. dollar didn't change too much from 1973 to 1976, thus lending a degree of plausibility to the continuous PPP argument. But the real value of the dollar dropped sharply starting in 1977, and from then on it became increasingly clear that continuous PPP could not hold as nominal exchange rates were patently far more volatile than relative national price levels.

Formal Tests of (the Failure of) Long-Run PPP: Random Walks and Unit Roots

One reaction to the failure of purchasing power parity in the short run was a theory of exchange rate overshooting, in which PPP is retained as a *long-run* equilibrium while allowing for significant short-run deviations due to sticky prices (Dornbusch, 1976). However, the search for empirical evidence of *long-run* PPP also met with disappointment.

Formal tests for evidence of PPP as a long-run phenomenon have often been based on an empirical examination of the real exchange rate. If the real exchange rate is to settle down at *any* level whatsoever, including a level consistent with PPP, it must display reversion toward its own mean. Hence, mean reversion is only a *necessary* condition for long-run PPP: to ensure long-run absolute PPP, we should have to know that the mean toward which it is reverting is in fact the PPP real exchange rate. Still, since much of this research has failed to reject the hypothesis that even this necessary condition does not hold, this has not in general been an issue.

Early empirical studies, such as those by Roll (1979) or Adler and Lehmann (1983), tested the null hypothesis that the real exchange rate does not mean revert but instead follows a random walk, the archetypal non–mean reverting time series process where changes in each period are purely random and independent. Some authors even argued that the random walk property was an implication of the efficiency of international markets, in the sense of prices and exchange rates reflecting all available information and all arbitrage opportunities being quickly exploited. Under this "efficient markets PPP" view, Roll (1979), for example, argued that the *change* in the real exchange rate, since it is effectively a measure of the one-period real return from arbitraging goods between countries, should have an expected value of zero if markets are efficient. However, this early strand of the empirical literature suffered from logical and econometric weaknesses. The theoretical underpinnings of "efficient markets PPP" failed to adjust the expected return for the real cost of financing goods arbitrage (Taylor and Sarno, 2004). Once this arbitrage adjustment is made, efficiency requires that the expected real exchange rate change be equal to the expected real interest rate differential, and long-run PPP will be implied if the latter differential is stationary.[3] On the empirical

[3] See Obstfeld and Taylor (2004) for evidence on the stationarity of real interest rate differentials. Under reasonable assumptions, the real interest rate differential will be negatively correlated with the level of the real exchange rate if a loss in international competitiveness (a real appreciation) has a net deflationary impact on the economy, reducing inflation and, other things equal, raising the real interest rate. This in turn implies mean reversion of the real exchange rate, since it implies that *changes* in the real exchange rate are negatively correlated with the *level* of the real exchange rate.

side, the evidence in favor of a random walk was at best mixed, and results depended on the criteria employed (Cumby and Obstfeld, 1984). Sharper econometric tools were still being fashioned, but—as we discuss below—they also suffered from low power just like these early tests, so for many years researchers were unlikely to reject the null hypothesis of a random walk even if it were false.

In the late 1980s, a more sophisticated econometric literature on long-run PPP developed, at the core of which was the concept of a "unit root process." If a time series is a realization of a unit root process, then while *changes* in the variable may be to some extent predictable, the variable may still never settle down at any one particular *level*, even in the very long run. For example, suppose we estimated the following regression equation for the real exchange rate q_t over time, where ε_t is a random error and α and β are unknown parameters:

$$q_t = \alpha + \beta q_{t-1} + \varepsilon_t.$$

If $\beta = 1$, we say that the process generating the real exchange rate contains a unit root. In that case, *changes* in the real exchange rate would be predictable—they would be equal on average to the estimated value of α. The *level* of the real exchange rate would, however, not be predictable, even in the long run: since the change each period would be equal to a constant plus an unpredictable random element, the long-run level will be equal to the sum of the constant changes each period plus the sum of a large number of random elements. As these random shocks get cumulated, there is no way of telling in advance what they will add up to. (In fact, the real exchange rate would be following a random walk with drift, which is an example of a so-called unit root process.) Thus, testing the null hypothesis that $\beta = 1$ is a test for whether the path of the real exchange rate over time does not return to any average level and thus that long-run PPP did not hold.

The flurry of empirical studies employing these types of tests on real exchange rate data among major industrialized countries that emerged toward the end of the 1980s were unanimous in their failure to reject the unit root hypothesis for major real exchange rates (for example, Taylor, 1988; Mark, 1990), although—as we shall see—this result was probably due to the low power of the tests.

In any case, at the time, this finding created great uncertainty about how to model exchange rates. At a theoretical level, there was still a consensus belief in *long-run* PPP coupled with overshooting exchange rate models; now the data were raising the possibility that even long-run PPP was a chimera. Some economists posited theoretical models to explain why the real exchange rate could in fact be non–mean reverting (as in Stockman, 1987). Others questioned the empirical methodology.

The Power Problem

Frankel (1986, 1990) noted that while a researcher may not be able to reject the null hypothesis of a random walk real exchange rate at a given significance level, it does not mean that the researcher must then accept that hypothesis. Furthermore, Frankel pointed out that the statistical tests typically employed to examine the long-run stability of the real exchange, at that time based on data covering just 15 years or so since 1973, may have low power to reject the null hypothesis of a unit root even if it is indeed false. This criticism would apply both to the early random walk studies and to the subsequent literature testing more formally for unit roots. It was further taken up and examined by other authors (Froot and Rogoff, 1995; Lothian and Taylor, 1996, 1997). The argument is that even if the real exchange rate tends to revert toward its mean over long periods of time, examination of one real exchange rate over a relatively short period may not yield enough information to detect this mean reversion. Using simulations in which the real exchange rate is assumed to mean revert by about 11 percent per year, the probability of rejecting at the 5 percent level the null hypothesis of a random walk real exchange rate, when in fact the real rate is actually mean reverting, is extremely low—somewhere between about 5 and 8 percent—when using 15 years of data (Lothian and Taylor, 1997; Sarno and Taylor, 2002a). With the benefit of the additional 10 to 15 years or so of data that are now available, the power of the test increases by only a couple of percentage points, and even with a century of data, there would be less than an even chance of correctly rejecting the unit root hypothesis.

Moreover, increasing the sample size by increasing the frequency of observation—moving from, say, quarterly to monthly data—won't increase the power because increasing the amount of detail concerning short-run movements can only give you more information about short-run as opposed to long-run behavior (Shiller and Perron, 1985).

More Statistical Power: More Years, More Countries

If you want to get more information about the long-run behavior of a particular real exchange rate, one approach is to use more years of data. However, long periods of data usually span different exchange rate regimes, prompting questions about how to interpret the findings. Also, over long periods of time, real factors may generate structural breaks or shifts in the equilibrium real exchange rate. Once these issues are recognized, there are ways to look for possible effects of different regimes and structural shifts.

In one early study in this spirit, using annual data from 1869 to 1984 for the dollar-sterling real exchange rate, Frankel (1986) estimates a first-order autoregressive process for the real exchange rate q of the form

$$(q_t - \tilde{q}) = \varphi(q_{t-1} - \tilde{q}) + \varepsilon_t,$$

where $\tilde{q}$ is the assumed constant equilibrium level of q, ε_t is a random disturbance, and φ is the autocorrelation coefficient—an unknown parameter governing the speed of mean reversion. Notice that a proportion of φ times the random shock at time $t - 1$, ε_{t-1}, will still be part of the real exchange rate deviation at time t. Hence, we can say that shocks die out—or the real exchange rate reverts toward its mean of $\tilde{q}$—at the rate of $(1 - \varphi)$ per period. (If the real exchange rate followed a random walk, then $\varphi = 1$ and shocks would *never* die out.) Frankel's point estimate of φ is 0.86, and he is able to reject the hypothesis of a random walk at the 5 percent level.

Similar results to Frankel's were obtained by Edison (1987), based on an analysis of data over the period 1890–1978, and by Glen (1992), using a data sample spanning the period 1900–1987. Lothian and Taylor (1996) use two centuries of data on dollar-sterling and franc-sterling real exchange rates, reject the random walk hypothesis and find point estimates of φ of 0.89 for dollar-sterling and of 0.76 for franc-sterling. Moreover, they are unable to detect any significant evidence of a structural break between the pre– and post–Bretton Woods period. Taylor (2002) extends the long-run analysis to a set of 20 countries over the 1870–1996 period and also finds support for PPP and coefficients that are stable in the long run. Studies such as these provide the formal counterpart to the informal evidence of long-run relative PPP like eyeballing Figure 1.

Another approach to providing a convincing test of real exchange rate stability, while limiting the timeframe to the post–Bretton Woods period, is to use more countries. By increasing the amount of information employed in the tests *across* exchange rates, the power of the test should be increased. In an early study of this type, Abuaf and Jorion (1990) examine a system of 10 first-order autoregressive regressions for real dollar exchange rates over the period 1973–1987, where the autocorrelation coefficient is constrained to be the same in every case. Their results indicate a marginal rejection of the null hypothesis of *joint* non–mean reversion at conventional significance levels, which they interpret this as evidence in favor of long-run PPP. An academic cottage industry sprang up in the 1990s to apply unit root tests to real exchange rate data on panels of countries for the post–Bretton Woods period. A number of these studies claimed to provide evidence supporting long-run PPP. Taylor and Sarno (1998), however, issued an important warning in interpreting these findings. The tests typically applied in these panel-data studies test the null hypothesis that *none* of the real exchange rates under consideration are mean reverting. If this null hypothesis is rejected, then the most that can be inferred is that *at least one* of the rates *is* mean reverting. However, researchers tended to draw a much stronger inference that *all* of the real exchange rates were mean reverting—and this broader inference is not valid. Some researchers have sought to remedy this shortcoming by designing alternative tests; for example, Taylor and Sarno (1998) suggest testing the hypothesis that at least one of real exchange rates is non–mean reverting, rejection of which would indeed imply that they are *all* mean reverting. However, such alternative tests are generally less powerful, so that their application has not led to clear-cut conclusions (Taylor and Sarno, 1998; Sarno and Taylor, 1998).

PPP Puzzles

The research on the evolution of exchange rates from the 1970s to the turn of the century has generally been interpreted as supporting the hypothesis that exchange rates adjust to the PPP level in the long run. But the evidence is weak. For example, rejecting at standard levels of statistical significance the null hypothesis that a unit root exists certainly doesn't prove that a long-run PPP exchange rate exists, either. The long-span studies raise the issue of possible regime shifts and whether the recent evidence may be swamped by history. The panel-data studies raise the issue of whether the hypothesis of non–mean reversion is being rejected because of just a few mean-reverting real exchange rates within the panel. If exchange rates do tend to converge to PPP, economists have—at least so far—had a hard time presenting strong evidence to support the claim. Following Taylor, Peel and Sarno (2001), we see the puzzling lack of strong evidence for long-run PPP—especially for the post–Bretton Woods period—as the first PPP puzzle.

A second related puzzle also exists. In the mid-1980s, Huizinga (1987) and others began to notice that even the studies that were interpreted as supporting the thesis that PPP holds in the long run also suggested that the speed at which real exchange rates adjust to the PPP exchange rate was extremely slow. A few years later, Rogoff (1996, p. 647) presented the puzzle this way: "The purchasing power parity puzzle then is this: How can one reconcile the enormous short-term volatility of real exchange rates with the extremely slow rate at which shocks appear to damp out?"

As we noted above, this speed is related to the estimated coefficient in the autoregressive process described earlier: a proportion of φ of any shock will still remain after one period, φ^2 of it remains after two periods, and in general, φ^n of the shock will remain after n periods. One way to get a feel for how fast the real exchange rate mean reverts is by asking how long it would take for the effect of a shock to die out by 50 percent—in other words, we can compute the *half-life* of shocks to the real exchange rate.

Based on a reading of the panel unit root and long-span investigations of long-run PPP, Rogoff (1996) notes a high degree of consensus concerning the estimated half-lives of adjustment: they mostly tend to fall into the range of three to five years. Moreover, most such estimates were based on ordinary least squares methods, which may be biased because ordinary least squares will tend to push the estimated autocorrelation coefficient away from one to avoid nonstationarity; using different estimation methods to correct for bias, but still in a linear setting, some authors have argued that half-lives are even longer (for example, Murray and Papell, 2004; Chen and Engel, 2004). Now, although real shocks to tastes and technology might plausibly account for *some* of the observed high volatility in real exchange rates (Stockman, 1988), Rogoff argues that most of the slow speed of adjustment must be due to the persistence in *nominal* variables such as nominal wages and prices. But nominal variables would be expected to adjust much faster than a half-life of three to five years for exchange rates would suggest.

The apparently very slow speed of adjustment of real exchange rates—from 0 to about 10 percent or so per annum—has been the source of considerable theoretical and empirical research in recent years.

Nonlinearity?

One approach to resolving the PPP puzzles lies in allowing for nonlinear dynamics in real exchange rate adjustment. In a linear framework, the adjustment speed of PPP deviations from parity is assumed to be uniform at all times and, in particular, for all sizes of deviation, and implicitly the econometric problem is reduced to the estimation of a single parameter—the half-life. While this framework is very convenient, there are good reasons for suspecting that the speed of convergence toward the PPP exchange rate should be greater as the deviation from PPP rises in absolute value. Indeed, some 90 years ago, Heckscher (1916) suggested that adjustment may be nonlinear because of transactions costs in international arbitrage. For example, if two goods differ in price (expressed in a common currency) in different countries because PPP does not hold, it won't be worth arbitraging and therefore correcting the price difference unless the anticipated profit exceeds the cost of shipping goods between the two locations. This insight began to be expressed more formally in the theoretical literature starting in the late 1980s (for example, Benninga and Protopapadakis, 1988; Williams and Wright, 1991; Dumas, 1992). The qualitative effect of such frictions is similar in all of the proposed models: the lack of arbitrage arising from transactions costs such as shipping costs creates a "band of inaction" within which price dynamics in the two locations are essentially disconnected. Such transactions costs might take the form of the stylized "iceberg" shipping costs ("iceberg" because some of the goods effectively disappear when they are shipped and the transaction cost may also be proportional to the distance shipped), fixed costs of trading operations or of shipments or time lags for the delivery of goods from one location to another.

In empirical work on mean reversion in the real exchange rate, nonlinearity can be examined through the estimation of models that allow the autoregressive parameter to vary. For example, transactions costs of arbitrage may lead to changes in the real exchange rate being purely random until a threshold equal to the transactions cost is breached, when arbitrage takes place and the real exchange rate reverts back toward the band through the influence of goods arbitrage (although the return is not instantaneous because of shipping time, increasing marginal costs or other frictions). This kind of model is known as "threshold autoregressive."

The model applies straightforwardly to individual commodities. Focusing on gold as foreign exchange, Canjels, Prakash-Canjels and Taylor (forthcoming) studied the classical gold standard using such a framework applied to daily data from 1879 to 1913; they found dollar-sterling exchange-rate adjustment consistent with a threshold autoregressive model. Examining subindices of the consumer price index, Obstfeld and Taylor (1997) modeled price adjustment in various international cities in the post-1973 period and also found significant nonlinearities. The implied transaction cost bands and adjustment speeds were also found to be of a reasonable size (consistent with direct shipping cost measures) and to vary systematically with impediments such as distance, tariffs, quotas and exchange-rate volatility. Sarno, Taylor and Chowdhury (2004) employ this approach with disaggregated data across a broad range of goods in the G-7 countries (Canada, France, Germany, Italy, Japan, the United Kingdom and the United States). Zussman (2003) uses a threshold autoregressive model with the postwar Penn World Table data to show nonlinear adjustment speeds for a very wide sample of countries.

Using a threshold autoregressive model for real exchange rates as a whole, however, could pose some conceptual difficulties. Transactions costs are likely to differ across goods, and so the speed at which price differentials are arbitraged may differ across goods (Cheung, Chinn and Fujii, 2001). Now, the *aggregate* real exchange rate is usually constructed as the nominal exchange rate multiplied by the ratio of national aggregate price level indices and so, instead of a single threshold barrier, a range of thresholds will be relevant, corresponding to the various transactions costs of the various goods whose prices are included in the indices. Some of these thresholds might be quite small (for example, because the goods are easy to ship) while others will be larger. As the real exchange rate moves further and further away from the level consistent with PPP, more and more of the transactions thresholds would be breached and so the effect of arbitrage would be increasingly felt. How might we address this type of aggregation problem? One way is to employ a well-developed class of econometric models that embody a kind of smooth but nonlinear adjustment such that the speed of adjustment increases as the real exchange rate moves further away from the level consistent with PPP.[4] Using a smooth version of a threshold autoregressive model, and data on real dollar exchange rates among the G-5 countries (France, Germany, Japan, the United Kingdom and the United States), Taylor, Peel and Sarno (2001) reject the hypothesis of a unit root in favor of the alternative hypothesis of nonlinearly mean-reverting real exchange rates—and using data just for the post–Bretton Woods period, thus solving the first PPP puzzle. They also find that for modest real exchange shocks in the 1 to 5 percent range, the half-life of decay is under three years, while for larger shocks the half-life of adjustment is estimated much smaller—thus going some way toward solving the second PPP puzzle.

While transactions costs models have most often been advanced as possible sources of nonlinear adjustment, other less formal arguments for the presence of nonlinearities have also been advanced. Kilian and Taylor (2003), for example, suggest that nonlinearity may arise from the heterogeneity of opinion in the foreign exchange market concerning the equilibrium level of the nominal exchange rate: as the nominal rate takes on more extreme values, a greater degree of consensus develops concerning the appropriate *direction* of exchange rate moves, and traders act accordingly. Taylor (2004) argues that exchange rate nonlinearity may also arise from the intervention operations of central banks: intervention is more likely to occur and to be effective when the nominal—and hence the real—exchange rate has been driven a long distance away from its PPP or fundamental equilibrium.

In sum, the nonlinear approach to real exchange rate modeling offers some resolution of the PPP puzzles. Moreover, simulations show that if the true data are

[4] The smoothly adjusting extension of the threshold autoregressive or TAR model is the aptly named smooth-transition autoregressive, or STAR, model (Granger and Teräsvirta, 1993) and the exponential STAR or ESTAR has proved very successful in the application to real exchange rates (Michael, Nobay and Peel, 1997; Taylor and Peel, 2000). The ESTAR model can be thought of as a TAR with an infinite number of regimes and a continuously varying and bounded adjustment speed; Sarno and Taylor (2002) offer a textbook treatment. Alternative treatments of the goods-aggregation problem are currently being explored, but not without controversy (Imbs, Mumtaz, Ravn and Rey, 2002; Chen and Engel, 2004).

generated by a nonlinear process, but then a linear unit root or other linear autoregressive model is estimated, problems can easily arise. Standard unit root tests, already weak in power, are further enfeebled in this setting and half-lives can be dramatically exaggerated (Granger and Teräsvirta, 1993; Taylor, 2001; Taylor, Peel and Sarno, 2001).

The transactions-cost approach to real exchange rates is also generating influential intellectual spillovers into current research flourishing at the nexus of the two fields of international trade and international macroeconomics. The study of international trade has currently been enlivened by a new focus on the role of physical and other barriers, such as distance, remoteness, borders or various policies (Anderson and van Wincoop, 2004). International macroeconomists are also now making explicit the role of these trading frictions in new models where such refinements may yet help us solve some of the major puzzles in the field (Obstfeld and Rogoff, 2001; Betts and Kehoe, 2001; Bergin and Glick, 2003; Ghironi and Melitz, 2003).

Remaining Puzzles: Short-Run Disturbances, Long-Run Equilibrium

Empirical work that focuses on the path of real exchange rates must grapple with three key factors: the reversion speed; the volatility of the disturbance term; and the long-run, or equilibrium, level of the real exchange rate. Most of our discussion to this point, in keeping with the focus of the literature, has pertained to the reversion speed, which is a medium-run phenomenon. But in the future, we expect to see more attention given to the disturbances, which are a short-run phenomenon measured over months and also to the very long run question of what is the equilibrium real exchange rate. Thus, questions about the real exchange rate are likely to shift—from not so much "how fast is it reverting?" to "how did it deviate in the first place?" and "what is it reverting to?"[5]

Exchange Rate Disturbances

Even if current work can establish that exchange rates do revert to the PPP rate over the medium term at a more reasonable speed, the volatilities present in the data in the short run, at least under floating rate regimes, still cause considerable mystification. Over short periods, nominal exchange rates move substantially and prices do not, so real and nominal exchange rate volatilities in the short term are correlated almost one for one, and the Law of One Price for traded goods is often violated (Flood and Rose, 1995). This pattern holds across different monetary regime types over a wide swathe of historical experience (Taylor, 2002). Despite

[5] Of course, with reference to the PPP puzzle, the literature on *real* exchange rates has generally been focused on monthly or lower frequencies, since this is where price index data are available. There are plenty of *nominal* exchange rate puzzles at even higher frequency—weekly, daily, even intraday—but these are more properly in the domain of finance than international macroeconomics and are outside the scope of this survey.

efforts to explain such phenomena as a result of taste or technology shocks in flexible price models, it is implausible that the patterns could be traced wholly to real factors. History shows that volatilities also differ systematically across monetary regimes.[6] Instead, it is likely that some combination of monetary policy and price stickiness plays a role in the short-run volatility of exchange rates, mechanisms that could be amplified by other types of frictions.

Various new strands in the literature seek to address these issues. One common theme recognizes the important role of frictions in trade, not just for generating no-arbitrage bands for traded goods, but for delineating traded from nontraded varieties. Economies may be more closed than we once thought, since large sectors like retailing, wholesaling and distribution are nontraded—even if the price of imports as measured in official data typically includes some element of these domestic costs (Obstfeld, 2001; Obstfeld and Rogoff, 2001; Burstein, Neves and Rebelo, 2003).

In an economy with price stickiness and a nontraded sector, small monetary shocks can generate high levels of exchange rate volatility. For example, Burstein, Eichenbaum and Rebelo (2003) model a price sticky nontraded sector with a share of the economy well above 0.5, which yields a large devaluation response of an emerging market country even for a small monetary shock. When the nontraded share of the economy rises, the economy is less "open" and the Law of One Price assumption applies to a smaller fraction of goods (here, imported varieties), implying a larger role for exchange rate overshooting and other sources of exchange rate volatility (Obstfeld and Rogoff, 2000; Hau, 2000, 2002). Considerable future research remains to be done in this area to establish a general framework that will apply to a wide range of cases.

Long-Run Movements of the Real Exchange Rate

The PPP exchange rate theory is built on the concept that the exchange rate is based on actual buying power over a basket of goods, and so changes in the nominal exchange rate should reflect changes in the price of goods—with the real exchange rate staying fixed. But a nation's equilibrium real exchange rate may not remain fixed forever.

One of the textbook explanations for changes in the level of the real exchange rate focuses on the net international asset position. Consider a small, open economy in long-run equilibrium. Now impose a shock in the form of an increase in external debt. The country must run a trade surplus in the future to service the interest payments due. To encourage foreign consumers to import more, and to encourage its own consumers to import less, the country's competitiveness must improve in equilibrium. With the nominal exchange rate defined as the domestic price of foreign currency, this means that the equilibrium level of the real exchange

[6] For example, it is hard to imagine that, say, the real shocks to the Argentine economy were small in the 1960s, suddenly became several times larger during the 1980s hyperinflations, then shrank again in the 1990s currency board epoch, only to mysteriously reappear in late 2001. But we do know that to a first approximation Argentina's turbulent monetary history matches the observed volatilities very closely.

rate must rise, making the country's exports cheaper to foreigners and its foreign imports more expensive to domestic residents. This example supposes differentiated goods at home and abroad, but the logic holds in a wide range of models (like the portfolio balance model of Taylor, 1995; Sarno and Taylor, 2002b).

Lane and Milesi-Ferreti (2002) present some empirical confirmation of this argument. They find that countries with larger positive net asset positions have more negative trade balances *and* stronger real exchange rates, controlling for other factors and allowing for real return differentials across countries. This result has implications for the study of real exchange rate dynamics. If the equilibrium PPP exchange rate changes as a result of changes in net wealth, and if these shifts are not controlled for in an autoregression, then the exchange rate will appear to deviate from what is falsely assumed to be a fixed PPP rate for too much or for too long.

The other textbook story for trending real exchange rates is built around nontraded goods. Standard arbitrage arguments may lead PPP to hold for traded goods, but these arguments fail for nontraded goods, so that we must either abandon PPP theory, or else modify it. The Harrod-Balassa-Samuelson model of equilibrium real exchange rates is attracting renewed interest as a desirable modification after languishing for some years in relative obscurity (Harrod, 1933; Balassa, 1964; Samuelson, 1964).

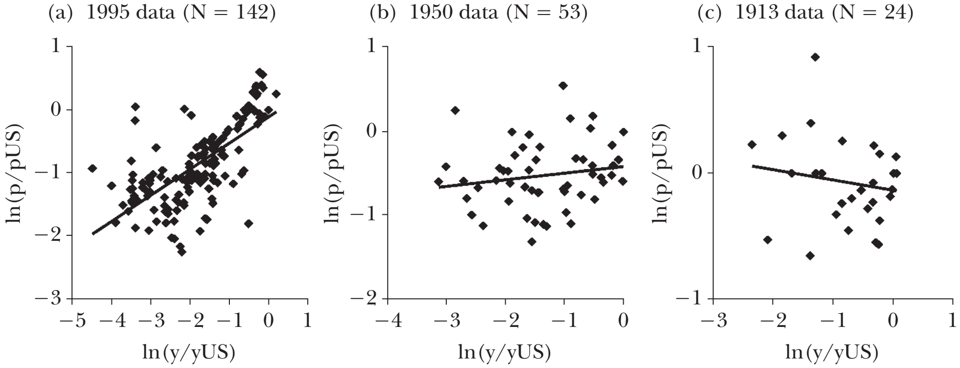
In this model, rich countries supposedly grow rich by advancing productivity in traded "modern" sectors (say, manufacturing). Meantime, all nontraded "traditional" sectors, in rich and poor countries alike, remain in technological stasis (say, haircuts). Suppose the Law of One Price holds among traded goods and we live in a world where labor is mobile intersectorally, but not internationally. As productivity in the modern sector rises, wage levels rise, so prices of nontraded goods will have to rise (as there has been no rise in productivity in that sector). If we measure the overall price index as a weighted average of traded and nontraded goods prices, relatively rich countries will tend to have "overvalued" currencies. The example of fast-growing Japan springs to mind, where the trend real exchange rate has steadily appreciated by about 1.5 percent per year since 1880; the opposite trend has sometimes been observed in slow growth eras, for example, in Argentina (Taylor, 2002; Froot and Rogoff, 1995; Rogoff, 1996).

Early studies of the Harrod-Balassa-Samuelson effect such as Officer (1982) found little support in the data from the 1950s to the early 1970s. But newer research dealing with later periods has often found support for this hypothesis, and it is now textbook material (for example, Micossi and Milesi-Ferreti, 1994; De Gregorio, Giovannini and Wolf, 1994; Chinn, 2000).

Why have more recent studies provided stronger evidence of the Harrod-Balassa-Samuelson effect? At some level, the reasons reflect developments in the PPP literature more broadly: more data, of longer span, for a wider sample of countries, coupled with more powerful univariate and panel econometric techniques, has allowed researchers to take a once-fuzzy relationship in the data and make it tighter.

In addition, recent work suggests that the magnitude of the Harrod-Balassa-

Figure 3
Harrod-Balassa-Samuelson Effects Emerge: Log Price Level versus Log Per Capita Income



Notes: This figure shows countries' log price level (vertical axis) against log real income per capita for 1995, 1950 and 1913, with the United States used as the base country.

Samuelson effect has been variable over time—certainly in the postwar period and perhaps going back several centuries (Bergin, Glick and Taylor, 2004). Consider the relationships in Figure 3. The horizontal axis shows the per capita income level of countries as a ratio of the U.S. per capita income level, expressed in log terms. The vertical axis shows the common currency Penn World Table Consumer Price Index price level of other countries as a ratio of the U.S. CPI price level—that is, the real exchange rate level—again expressed as a log. (Note that most countries have incomes and price levels lower than the United States, so the ratios are less than one, and the logs are negative.) The Harrod-Balassa-Samuelson hypothesis suggests that as per capita income rises, driven by productivity growth in tradables, then price levels should also rise: there should be a positive correlation in the scatterplot. The graphs show that the cross-country relationship between income per capita and the price level has been intensifying since 1950; once close to zero, and statistically insignificant, the elasticity is now over one half. The null hypothesis of a zero slope can be rejected beginning in the early 1960s when Balassa and Samuelson wrote their seminal papers (albeit with no knowledge of these hypothesis tests).

It is not clear why the Harrod-Balassa-Samuelson effect has altered over time. One possible explanation is that the nontraded share has increased over time, but this effect does not seem to have enough magnitude to match the changes that have occurred, nor to match the timing of the changes (remember that global trade in 1950, after world wars and depression, was a lower share of output than in 1913 or in 2000). Perhaps the productivity advances of traded and nontraded goods have differed at various times? This may better help us explain the data, but over long time frames begs the question of which goods are traded and why. Bergin, Glick and Taylor (2004) advance the hypothesis that trade costs determine tradability patterns, which allows a variety of possible productivity shocks to give rise eventually to an endogenous Harrod-Balassa-Samuelson effect.

But the key point here is that if the equilibrium exchange rate is moving gradually over time, and our statistical analysis presupposes that the PPP exchange rate is fixed over time, then estimates of the speed of reversion to the PPP will be biased. An allowance for such long-run trends can make a material difference in resolving the puzzles about whether and how fast the exchange rate moves to its PPP level. For example, Taylor (2002) finds relatively low half-lives in a 20-country panel when an allowance is made for long-run trends in the equilibrium exchange rate. Allowing for nonlinear time trends, Lothian and Taylor (2000) suggest that the half-life of deviations from PPP for the U.S.-UK exchange rate may be as low as $2\frac{1}{2}$ years. Lothian and Taylor (2004) show that the Harrod-Balassa-Samuelson effect may account for about a third of the variation in this real exchange rate.

The equilibrium real exchange rate could shift for a number of reasons over the very long run: wealth effects, productivity effects and other forces could all be important. Models that allow for a time-varying equilibrium real exchange rate, and permit an exploration of its causes and consequences, are likely to be a busy area for future research. Coordinated progress on these fronts will not only refine our resolution of the PPP puzzles, they will also help us address related puzzles in the macroeconomic literature. For example, Engel (1999, 2000) decomposed the variance of the real exchange rate into external traded goods prices and internal traded-versus-nontraded goods prices. The component related to external traded goods can be viewed as related to the Law of One Price in the basic version of the PPP theory where the real exchange rate is assumed to be fixed, while the component related to traded and nontraded goods can be related to the Harrod-Balassa-Samuelson effect or any approach where the real exchange rate has a trend. In looking at post–Bretton Woods samples of data, Engel found that *both* of these components have persistence, but the Law of One Price component seems to experience larger shocks. The two insights may also be unified, as in recent models of endogenous tradability (Betts and Kehoe 2001; Bergin and Glick, 2003). The researcher can use nonlinear models with trade costs to understand the volatility related to traded goods—as Parsley and Wei (2003) do with the Engel puzzle—and then use some version of the Harrod-Balassa-Samuelson effect to model and estimate the slower and often obscured drift in the prices of nontraded goods.

Conclusion

Since the early 1970s, the purchasing power parity theory of exchange rates has been the subject of an ongoing and lively debate. For much of that period, theoretical work suggested that exchange rates should be linked to relative changes in price levels with deviations that might be only minimal or momentary, while empirical work could find only the flimsiest evidence in support of purchasing power parity, and even these weak findings implied an extremely slow rate of reversion to PPP of, at best, three to five years.

After a struggle to find common ground, the gap between theory and empirics is being closed from both directions. After early disappointments with dynamic general equilibrium models, recent applications with nominal price rigidities show how monetary shocks may have large and long-lasting effects on the real exchange rate (Bergin and Feenstra, 2001). When such insights are combined with theoretical work on transactions costs and nonlinearity, we can now better understand the volatility and persistence of the real exchange rate. Going further, the presence of nontraded goods (a manifestation of extreme transaction costs) enriches our models further. A renewed attention to the Harrod-Balassa-Samuelson effect and wealth effects leads to a modified view of PPP where the equilibrium real exchange rate itself may move over time.

The idea that transaction costs matter for PPP is an old one. For Hume (1742–1752 [1987]), goods arbitrage caused countervailing flows of specie, with the analogy that "all water, wherever it communicates, remains always at a level," except that if markets are separated "by any material of physical impediment. . .there may, in such a case, be a very great inequality of money." Heckscher (1916) developed the idea further, introducing the concept of "commodity points." Keynes (1923, pp. 89–90, 91–92) highlighted transaction costs as a key substantive issue for the PPP theory:

> At first sight this theory appears to be one of great practical utility. . . . In practical applications of the doctrine there are, however, two further difficulties, which we have allowed so far to escape our attention,—both of them arising out of the words *allowance being made for transport charges and imports and export taxes.* The first difficulty is how to make allowance for such charges and taxes. The second difficulty is how to treat purchasing power of goods and service which *do not enter into international trade at all.* . . . For, if we restrict ourselves to articles entering into international trade and make exact allowance for transport and tariff costs, we should find that the theory is always in accordance with the facts. . . . In fact, the theory, stated thus, is a truism, and as nearly as possible jejune.

As these venerable ideas start to be incorporated into formal theory and empirics—in particular, via nonlinear adjustment—results are suggesting more strongly that exchange rates do revert to a certain level determined by the price level in the long run and that the half-life of this reversion is short enough, at perhaps one to three years for moderately sized shocks of more than 1 or 2 percent, to seem theoretically plausible.

Several new directions could now be taken. A very general theoretical model could be developed to incorporate all of the above refinements simultaneously and its predictions studied. Empiricists could attempt to include both nonlinearities and Harrod-Balassa-Samuelson effects to get even tighter estimates of convergence speeds. Introducing trade costs and real shocks into a Clarida and Galí (1994) decomposition might advance the potential for reconciliation even further.

In sum, however, our interpretation of the consensus view of the PPP debate—that short-run PPP does not hold, that long-run PPP may hold in the sense that there is significant mean reversion of the real exchange rate, although there may be factors impinging on the equilibrium real exchange rate through time—is highly reminiscent of the consensus view that held sway in the period before the 1970s. In that sense, this paper may be taken as evidence of mean reversion in economic thought.

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