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A Primer on Exchange Rate Behavior

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Introduction

An *exchange rate* is the relative price of one country's money in terms of another. What is being exchanged as money has varied over time with the particular assets that served as monies. For most of recorded history up until the early part of the last century, money generally consisted of a metallic coinage of one sort or another. Since then money has come increasingly to consist of currency notes and, more importantly, bank deposits.

Economists' key insight with regard to exchange rate behavior centers on the concept of purchasing power parity (PPP). Stated simply, the *PPP exchange rate* is the nominal exchange rate that equates the purchasing power of a unit of currency in the foreign economy and the domestic economy. So, for example, suppose the PPP exchange rate between the U.S. dollar and the British pound sterling is two dollars ($) per pound (£). Then, if the exchange rate that actually prevails in the market also is two dollars per pound, the same basket of goods that can be bought for $100 in the United States can be bought for £50 in the United Kingdom.

Over the past several decades the literature investigating PPP has become voluminous, according to one set of estimates growing at an average rate of 15 percent per annum over the period 1974 to 2003 (Clements and Lan 2004). The upshot of these studies is that over long periods, and for countries that have substantial differences in price-level behavior, the PPP hypothesis provides a tolerably good first approximation to actual behavior. The fourth section of this chapter reviews the major empirical findings from the literature supporting that interpretation. The second and third sections of this chapter set the stage for that discussion by presenting a brief overview of the theory underlying the PPP hypothesis and a review of its historical origins. The fifth section of the chapter discusses problems surrounding shorter-term exchange rate behavior—the PPP puzzle and the exchange rate disconnect puzzle—and the recent attempts by researchers to solve both. The last section of the chapter provides some summary remarks.

Absolute and Relative PPP

The PPP relation described verbally above can be written in algebraic terms as:

$$P_t = P_t^* S_t, \tag{2.1}$$

where P_t and P_t^* are the domestic and foreign prices of identical market baskets of goods, respectively; and S_t is the nominal exchange rate, the price in domestic currency of a unit of the foreign currency.

Taking logarithms of both sides of Equation 2.1 results in the alternate linear form:

$$p_t = p_t^* + s_t, \tag{2.2}$$

where lowercase letters represent the natural logarithms of the variables denoted by the uppercase letters in Equation 2.1. The relationship as stated in either of these two forms is known as *absolute PPP*.

Another way to think about PPP is in terms of the *real exchange rate*, which is the nominal exchange rate (again defined in units of domestic to foreign currency) divided by the ratio of the domestic to foreign price levels. This can be written in arithmetic form as:

$$Q_t = S_t/(P_t/P_t^*), \tag{2.3}$$

or in logarithmic form as:

$$q_t = \mathbf{s_t} - (\mathbf{p_t} - \mathbf{p_t}^*), \tag{2.4}$$

where Q_t denotes the real exchange rate and q_t denotes its logarithmic counterpart.

The two are measures of the purchasing power of the foreign currency in the foreign economy relative to the purchasing power of the domestic currency in the domestic economy. If absolute PPP holds, Q_t would be one and q_t would be zero. In actual empirical work researchers generally use price indices such as the consumer price index (CPI), which is based on an aggregate index of retail or consumer ("store checkout") prices, or the producer price index (PPI), which is based on wholesale or producer ("factory gate") prices. These are pure numbers, which are arbitrarily defined relative to some base year. Therefore, they only provide information on how the price level in one country behaves relative to the price levels in other countries over time. To pin down absolute PPP requires a price index that was relevant across countries, or some other information about particular periods in which absolute PPP actually held. Nevertheless, there will be a level of the measured real exchange rate that is consistent with PPP, in which case variations in the measured real exchange rate will provide information about deviations from PPP.

That results in an analogous but somewhat weaker version of PPP called *relative PPP*, which posits a one-to-one relationship between movements in domestic and foreign price levels expressed in terms of a common currency. This can be written in arithmetic form as

$$P_{t+}/P_t = (P_{t+1}{}^*S_{t+1})/(P_t{}^*S_t), \tag{2.5}$$

or, after taking logarithms of both sides of Equation 2.5 and rearranging terms, as

$$\Delta\, p_{t+1} = \Delta\, p_{t+1}{}^* + \Delta\, s_{t+1,} \tag{2.6}$$

where the symbol Δ denotes a first-difference operator.

The left-handside of Equation 2.6 is, of course, the domestic rate of inflation. The right-hand side is the foreign rate of inflation adjusted for growth in the nominal exchange rate. So if, for example, the exchange rate floated freely and the U.S. and U.K. rates of inflation were 5 percent per annum and 2 percent per annum, respectively, the change in the dollar-pound exchange rate would have to be 3 percent per annum for relative PPP to hold. In this case, the exchange rate change would exactly offset the differential between the two countries' inflation rates. If, in contrast, the dollar-pound exchange rate were fixed, the U.S. and U.K. rates of inflation would have to be equal for relative PPP to hold.

An obvious way to think about PPP, therefore, is as an application of the law of one price on a macroeconomic rather than as usual, on a microeconomic level. The law of one price is the simple observation that a similar good should sell for the same price in deferent locations, once converted to the same currency at the going exchange rate, since otherwise a profit could be made by arbitraging the price difference. That, however, raises an obvious set of objections. Transportation costs across countries are surely important for some goods. Other goods and many services are not internationally traded. Tariffs and other trade barriers can also drive a wedge between prices in different countries. All three sets of factors are reasons some prices will not be equalized via international trade. Because consumers' tastes are not the same in different countries, price levels as generally measured may also differ for that reason.

The law of one price, however, is not the full story. PPP is a macroeconomic equilibrium condition, the cross-country analogue of monetary neutrality within countries. Under fixed exchange rates, forces other than international price arbitrage affect prices of individual goods and services and ultimately price levels. The principal factor here is money flows.

About a century ago, Irving Fisher (1911) provided a particularly clear statement of the process. Underlying Fisher's analysis was a transactions version of the quantity theory of money. Milton Friedman (2008) provides a review of Fisher's and related quantity-theory models.

Fisher traced the links between price levels and money supplies in different economies, first using the example of Connecticut vis-à-vis surrounding states and then turning to countries adhering to the gold standard. With regard to the U.S. states, Fisher (1911, 92) noted:

> If the level of prices in Connecticut falls below that of the surrounding states, … the effect is to cause an export of money from those states to Connecticut, because people will buy goods wherever they are cheapest and sell them wherever they are dearest. With its low prices Connecticut becomes a good place to buy from, but a poor place to sell in. But if outsiders buy of Connecticut, they will have to bring money to buy with. There, therefore, will be a tendency for money to flow to Connecticut until the level of prices there rises to a level which will arrest the influx.

Across countries on the same monetary standard, a similar process operates following a shock. Fisher (1911, 92) argues that "it must not be inferred that prices of various articles or even the general level of prices will become precisely the same in different countries. Distance, ignorance as to where the best markets are to be found, tariffs and costs of transportation help to maintain price differences."

Fisher (1911, 93) went on to conclude, however, that:

> [A]lthough international and local trade will never bring about exact uniformity of price levels it will, to the extent that it exists, produce an adjustment of these levels toward uniformity by regulating in the manner already described the distribution of money.… And since the quantity of money itself affects prices for all sorts of commodities, the regulative effect of international trade applies not simply to the commodities which enter into that trade, but to all others as well.

Under floating exchange rates an analogous process operates. As Equation 2.6 indicates, the change in the exchange rate is related one-to-one to the differential in the two countries' inflation rates, which in turn are functions of domestic money supply growth in the countries involved. If relative PPP holds, the rate of growth in the exchange rate, therefore, exactly offsets the differential between the rate of growth in the domestic and foreign price levels. In this instance, a higher rate of money supply growth in one of the two countries results in a depreciation of that country's exchange rate rather than higher rates of money supply growth and inflation in the other country.

PPP and Monetary Equilibrium: A Historical Overview

The tie-in of PPP and the quantity theory of money has a long history in economics dating back to sixteenth-century Spain and the writings of the late scholastic theologians, philosophers, and legal theorists associated with the University of Salamanca, then one of the premier seats of learning in Europe. Priests and professors wrote on a broad spectrum of questions relevant to the European society of their time.

The direct motivation for their excursions into monetary theory was not economic analysis per se but moral philosophy and theology. They were trying to make sense of the phenomena that they were observing in the Europe of that era—the unprecedented increases in price levels and the currency depreciations that accompanied the inflows of specie (i.e., precious metals that could be minted into coins and expand the money supply), particularly silver, from the mines of the New World and the new developments in finance that were taking place. Lurking in the background were issues related to the Catholic Church's prohibition of usury and the fact that most foreign exchange transactions were forward transactions that involved bills of exchange and thus had a time dimension. The key questions of interest were whether these price increases, the related currency depreciations, and the new financial arrangements were morally justifiable.

As philosophical realists in the mold of St. Thomas Aquinas, their first concern was to ascertain the facts surrounding these developments and to fit them into a coherent analytical framework. This they did. They amassed detailed knowledge of financial economics of that era (D'Emic 2010) and produced a substantial body of literature that, as Grice-Hutchinson (1952, 4) puts it, "painted a vivid picture of the business life of the times." To explain the links between the specie inflows and the movements in prices and exchange rates, these priests and professors provided what arguably were the first clear expositions of the quantity theory of money and the PPP theorem.

A particularly lucid exposition of both is that of Martín de Azpilcueta in 1556 (quoted in Grice-Hutchinson 1978, 104):

> [O]ther things being equal, in countries where there is great scarcity of money all other saleable goods, and even the hands and labor of men, are given for less money than where it is abundant. Thus we see by experience that in France, where money is scarcer than in Spain, bread, wine, cloth and labor are worth much less. And even in Spain, in times when money was scarcer, saleable goods and labor were given for very much less than after the discovery of the Indies, which flooded the country with gold and silver. The reason for this is that *money is worth more where and when it is scarce than where it is abundant* [italics added].

This is a succinct statement of both the quantity theory of money and the monetary approach to exchange rates with PPP, the link between the two, as a key building-block. Similar statements can be found in the work of de Bañez and de Luego (Grice-Hutchinson 1952, 1978, 1993).

Now let us fast-forward close to three centuries to the period of the Napoleonic Wars and the Bullionist debate. Britain, as also Ireland—which had its own currency, the Old Irish Pound—suspended specie payment in 1797 in the midst of paper money inflations. The Old Irish Pound, which had been rigidly linked to sterling at a rate of 1.0833 Irish pounds per pound sterling, became decoupled. Bank note issuance in both countries increased and the two currencies depreciated, the Irish initially by more than the British. The debate at the time was whether these phenomena were linked. Arguing for the affirmative were the Bullionists—Francis Horner, David Ricardo, Henry Thornton, and John Wheatley.

In his first work on the subject, *Remarks on Currency and Commerce,* Wheatley (1803, 186) stated the position succinctly:

> Almost all the nations of Europe have augmented their currency by some addition of paper. The course of exchange is the best criterion how far the currency of one is increased beyond the currency of another. By the recent state of our unfavourable exchanges it is evident that our currency has been augmented in greater proportion than any.

In back of this view, and developed further in Wheatley's (1807, 1822) two-volume work *An Essay on the Theory of Money and Principles of Commerce,* were three propositions: (1) a strict quantity theory in which money was neutral and in which it alone determined the price level; (2) PPP in absolute form; and (3) a model of intercountry adjustment in which the activities of speculators in foreign exchange provided a rapid equilibrating force. In the face of an incipient disequilibrium, speculators engaged in arbitrage in the market for bills of exchange. Under a specie standard, these actions brought money supplies and price levels back to equilibrium; under a paper-money standard, they moved exchange rates into line with differences between price levels.

Now let us return briefly to Irving Fisher. In two notable instances—price behavior in countries with the same and with different monetary standards during the period 1873 to 1914 and the transmission of cyclical fluctuations during the Great Depression of the 1930s—Fisher used PPP as the basis of his empirical analysis (Fisher 1920, 1935). The PPP concept also was implicit in his analysis of interest rates under different monetary standards. Here Fisher was the first economist to state what is now called "uncovered *interest parity,*" the hypothesized one-to-one relation between the differential in nominal interest rates in two countries and the percentage change in the exchange rate linking their currencies. Given equality in their real interest rates, this relation reduces to relative PPP. Fisher was also the first to investigate this proposition empirically (Campbell et al. 2009).

The Swedish economist Gustav Cassel, however, was the man who actually coined the phrase "purchasing power parity" (Cassel 1918). Cassel went on to publish many articles and books on the topic in the period following World War I (e.g., Cassel 1916, 1918, 1922, 1928a, 1928b). Cassel sought to revive interest in the concept of PPP in the context of the policy debate concerning whether and how the major currencies should return to the Gold Standard, which had been suspended during the war, and in the specific context of discussion of the rate at which sterling should return to the Gold Standard.

With the rise of Keynesian economics, the fixed-price models of John Maynard Keynes's *The General Theory of Employment, Interest and Money* became the principal engine of macroeconomic analysis, one result of which was de-emphasis of PPP. The PPP concept did, however, remain a key element in the quantity-theory analysis that developed at the University of Chicago in the post–World War II years and that formed the theoretical backbone of Friedman and Schwartz's (1963) *Monetary History of the United States*. Although they uncovered sizable variations in real exchange rates over various subperiods, the authors nevertheless remained impressed by their relative stability over the bulk of their sample period. Friedman and Schwartz (1963, 678–679) wrote, "One striking example of the stability of basic economic relations is the stability of relative prices in the United States and Great Britain adjusted for changes in the exchange rate between the dollar and the pound [i.e., the reciprocal of the real exchange rate]." Their view was not at all atypical (see, e.g., Gailliot 1970).

Then in the early 1970s following the move to floating exchange rates, various researchers went much further positing stability over both the long run and the very short run. The papers in Frenkel and Johnson (1976) are prominent examples. Such excessive PPP optimism did not last very long, however. A scant decade later, many, if not most, researchers had reached very nearly the opposite conclusion. The role of PPP, as a rule-of-thumb predictive model and even as a long-run equilibrium condition, became increasingly questioned—PPP was seen to have "collapsed" (Frenkel 1981). One reason underlying the shift in sentiment was the finding that with the relatively short period of data then available for the new floating exchange rate regime (i.e., less than a decade), real exchange rates under the float could be characterized statistically as random walks (e.g., Roll 1979; Frenkel 1981; Adler and Lehman 1983; Darby 1983).

Reinforcing the change in views about real-exchange-rate stability and PPP were the well-known results of Meese and Rogoff (1983) that nominal exchange rates could be predicted better by a naive random-walk model than by reduced-form asset market models and, less formally, by the seemingly erratic behavior of both nominal and real exchange rates during the 1970s and 1980s. That is, real exchange rates—particularly those for the U.S. dollar and the pound sterling—showed substantially greater variability under the float than under the previous fixed exchange rate regime, and nominal exchange rates showed much greater variability than important macroeconomic fundamentals such as price levels and real incomes. This evidence suggests that forces other than macroeconomic fundamentals drive exchange rates in a floating rate regime.

Later Empirical Studies of Purchasing Power Parity: Unit Roots and Cointegration

Tests for evidence of PPP as a long-run phenomenon that have been conducted since the late 1980s very often have been based on an empirical examination of the real exchange rate. As previously shown, the logarithm of the real exchange rate should equal zero under absolute PPP and equal some nonzero constant under relative PPP. Movements in the real exchange rate, therefore, are indicative of deviations from PPP of one sort or the other. Hence, whether PPP holds over the long run can be investigated by examining the time-series properties of the real exchange rate to see whether its level reverts to some stable value. Generally, this has involved tests for mean reversion, the implicit assumption being that the mean provides an estimate of the long-term equilibrium value of the real exchange rate. A closely related body of research has tested cointegration between the price and nominal exchange rate components of real exchange rates.

To see what the unit-root tests entail, consider the following autoregressive model with a one-period lag—AR(1)—model of the real exchange rate:

$$q_t = \alpha + \beta q_{t-1} + \varepsilon_t, \tag{2.7}$$

where α and β are coefficients to be estimated and ε_t is an error term assumed to be stationary white noise. If β is less than one, shocks to the real exchange rate ultimately die out and the real exchange rate reverts to its mean at the speed of $(1 - \beta)$ per period. The lower the value of β, therefore, the quicker the shocks dissipate. If β equals one, however, q_t never mean reverts. Buffeted by shocks, it wanders off in one direction or the other depending upon the particular sequence of those shocks. In that case, q_t follows a random walk, a particular type of time-series process that is referred to as a unit-root process or a process that is "integrated of order one," I(1). A random walk is a specific example of an I(1) process. Hence, by estimating Equation 2.7 and testing the null hypothesis that $\beta = 1$, this is tantamount to testing for a unit root in the process driving q_t. This is the basis of the standard Dickey-Fuller test used in much of the empirical analysis over the past several decades. Rejection of the null hypothesis that β equals unity using that test amounts to rejecting the null hypothesis that the real exchange rate is not mean reverting and hence is evidence supporting PPP.

Another body of research has focused on changes rather than levels of the variables, examining empirical counterparts to Equation 2.6 and thus the validity of relative PPP. This approach makes sense if there are occasional one-time shocks to the real exchange rate that lead to persistent deviations from level equilibrium. Most of this research has been based on cross-country panel data and typically examined the relationship between the growth rates of nominal exchange rates and inflation differentials over successively longer horizons.

EVIDENCE FROM LONG-SPAN TIME SERIES

Several very early applications of unit-root tests to the real exchange rate, and related tests for cointegration of its components using data for the current float, produced negative results such as Taylor (1988) and Mark (1990). As several researchers such as Frankel (1986) and Lothian (1986) point out, such a short sample period was unlikely to be informative. Given the long-lived departures from PPP typically observed in the data, distinguishing between permanent and transient movements in real exchange rates would require using much longer time series than 15 or so years' worth of data that were then available for the float. It would be akin to trying to study behavior in business cycles, which in their expansion and contraction phases combined typically span five or more years, with a similarly short sample.

One obvious solution, which researchers beginning with Frankel (1986) adopted, was to turn to much longer historical data samples. An alternative approach to increasing degrees of freedom, which researchers beginning with Lothian (1985) adopted, was to use pooled multicountry data.

Frankel (1986) used annual data from 1869 to 1984 for the dollar-sterling real exchange rate and was able to reject the hypothesis of a random walk and obtain an estimated speed of mean reversion of 14 percent per year. Edison (1987), analyzing data for dollar-sterling for the period 1890 to 1978; Lothian (1990) using data for France, Japan, the United Kingdom, and the United States for the period 1875 to 1987; and Glen (1992) using data for the United States and nine other industrialized countries for the period 1900 to 1987, all find similar results to those of Frankel.

To address the sample period issue, Lothian and Taylor (1996) compiled data for dollar-sterling and franc-sterling real exchange rates spanning two centuries. They had two principal objectives: (1) to assess the stability of the two real exchange rates over this long, very eventful period; and (2) to see if, as was widely believed at the time, behavior had changed since the onset of floating exchange rates in the early 1970s. As it turned out, they were able to reject the unit-root hypothesis for both dollar-sterling and franc-sterling, obtaining point estimates of the speed of mean reversion of 11 percent per year and 24 percent per year for the two, respectively. Just as important, Lothian and Taylor (1996) could detect no significant evidence of a structural break between the pre– and post–Bretton Woods periods.

Taylor (2002) went on to extend long-run analysis to a set of 20 countries over the period 1870 to 1996. He found both support for PPP and temporally stable estimates of long-run coefficients. Earlier studies in this vein, besides those cited above, include Kim (1990), Diebold, Husted, and Rush (1991), and Cheung and Lai (1993).

In related work, Lothian and Taylor (1997) present formal statistical evidence on the link between the increased power in empirical tests and the increased data span in real-exchange-rate studies. To do so, they conduct Monte Carlo experiments calibrated on the basis of the results reported in their earlier (1996) study.

The results show standard tests for mean reversion to be of extremely low power. As an example, in a 20-year sample the probability of rejecting the unit-root null hypothesis (at the 5 percent significance level), when the real exchange rate is actually mean reverting, would only be somewhere between slightly less than 10 percent and 15 percent. That, of course, translates into an 85 to 90 percent chance of not rejecting it. For data similar to those used in Lothian and Taylor (1996), the rejection frequency only improved substantially with samples a century or more in length. Sarno and Taylor (2002a, 2002b) subsequently show that, even with the benefit of an additional decade or so of data, the power of the test increased only slightly. Moving from annual to quarterly, or even monthly, observations, moreover, would not help either because doing so would only increase the high-frequency component of the data and not the low-frequency component necessary for more powerful tests (Shiller and Perron 1985).

EVIDENCE FROM MULTICOUNTRY PANELS

As noted above, an alternative way to try to circumvent the problem of the low power of unit-root tests has been to use multicountry panel data, thus increasing the number of real exchange rates under consideration and in the process improving the information in the data and ultimately improving the test power. In an early study of this type, Abuaf and Jorion (1990) examine 10 real-dollar exchange rates over the period 1973 to 1987 and report results that are consistent with mean reversion of real exchange rates but are generally too weak to reject the unit-root hypothesis with any high degree of confidence. A whole body of literature in which researchers employ various multivariate generalizations of unit-root tests in order to increase the test power developed afterward (e.g., Frankel and Rose 1996; Jorion and Sweeney 1996; Oh 1996; Coakley and Fuertes 1997; O'Connell 1998). As a result of a concerted effort to develop and apply more powerful statistical tests, many of these studies provide evidence more supportive of long-run PPP than the Abuaf and Jorion study, some doing so with data for the post–Bretton Woods floating-rate period alone. Taylor and Taylor (2004) provide a survey of these studies.

One potential problem that arises in some of the panel-data studies stems from heterogeneity in the underlying relationships. The null hypothesis in these studies generally has been joint non-mean reversion of all of the real exchange rates in the sample. As -and Sarno (1998) demonstrate, this hypothesis can be rejected rather frequently if only one of the real exchange rates exhibits mean-reverting behavior.

Tests for unit roots, similar to classical statistical tests more generally, have a basic limitation. Failure to reject a hypothesis is not the same as finding evidence supporting it. The data can actually be consistent with PPP and at the same time not be inconsistent with a unit root at usual significance levels. Dwyer et al. (2011) address this issue using Bayesian techniques and data for the euro-bloc countries along with the data from Lothian and Taylor (1996). When they conduct classical unit-root tests for the real exchange rates of each of the euro-bloc countries viewed individually, they could only reject the unit-root null for one country and then only at the 10 percent level, a finding that is not at all surprising given the short span of those data. The results of their Bayesian analysis, in contrast, are nevertheless quite consistent with PPP holding in the euro-bloc countries. The data for those countries point to conclusions that are very similar to those reached with the Lothian and Taylor data concerning both the implausibility of a unit root and values of 0.85 or so for the autoregressive parameters.

Another group of studies using multicountry data focuses on relative PPP. Most of these studies are based on differenced data of one sort or another and take Equation 2.6 as their starting point. While these studies cannot speak to the question of level equilibrium, they remain informative about the movements in nominal exchange rates and in price levels. The results of these studies are universally supportive of PPP as a long-run relation. These studies include the following: Lothian (1985), Flood and Taylor (1996), Lothian (1997), Lothian and Simaan (1998), and Coakley et al. (2005).

Viewed as a whole, the evidence from both the long-span historical data and the shorter-span multicountry panels suggests that as a long-term equilibrium condition PPP retains a high degree of validity. It provides a long-run constraint on nominal-exchange-rate behavior under floating exchange rates and on international price behavior under fixed exchange rates, and thus is a useful tool for analyzing behavior under both regimes.

The Short Run: Puzzles and Attempted Solutions

Turning to two additional sets of issues, one involving the shorter-term behavior of real exchange rates and the other the effects of real variables on the equilibrium level of real exchange rates, is now useful. One aspect of shorter-term behavior that has generated much attention is the seemingly overly slow speed of adjustment of real exchange rates in the aftermath of shocks, the so-called PPP Puzzle. Estimates derived from autoregressions like Equation 2.7 generally show half-lives of adjustment (the time that it takes for 50 percent of a shock to the real exchange rate to dissipate) ranging from three to five years and occasionally longer.

In reality, however, those estimates very likely have been biased downward as a result of several factors. One such factor is differences in the speed of adjustment to large and small shocks—"nonlinearities," as they have come to be known. In the presence of transactions costs, opportunities for arbitrage may be quite limited if shock-induced deviations from the law of one price are small. This will become increasingly less so as the deviations become larger. The speed of adjustment, therefore, will be directly related to the magnitude of the particular shock. Estimated speeds of adjustment for real exchange rates that are only subjected to small shocks can appear to be glacially slow, and those real exchange rates may seem indistinguishable from unit-root processes. Various researchers over the past decade and a half report evidence showing just that (e.g., Michael, Nobay, and Peel 1997; Taylor and Peel 2000; Taylor, Peel, and Sarno 2001; Lothian and Taylor 2008).

Lothian and Taylor (2008), for example, report half-lives of adjustment for both franc-sterling and dollar-sterling rates of two years for shocks ranging from 10 percent to as small as 1 percent in magnitude when they condition on average initial history. For larger shocks to both real exchange rates, the estimated half-lives are one year or less. Only for small shocks occurring when the real exchange rate is near its equilibrium do their nonlinear models yield the long half-lives in the range of three to five years or more that are typical of linear models. Allowing for nonlinearity, therefore, goes a good way toward resolving the PPP puzzle.

A second source of downward bias is shifts in the real exchange rate. The important point here is that if the equilibrium exchange rate is moving gradually over time but statistical tests for real-exchange-rate stability assume that the equilibrium exchange rate is a constant, then estimates of the speed of reversion toward the mean will be biased. Studies that incorporate linear or nonlinear deterministic trends to take account of such shifts, including Lothian (1990), Lothian and Taylor (2000), and Taylor (2002), provide evidence suggesting that this is sometimes the case. In all instances, adjustment speeds increase, sometimes more than doubling.

One reason for this trend-like behavior is more rapid productivity growth in one country than another, a phenomenon known as the "Harrod-Balassa-Samuelson (HBS) effect," so dubbed after its three independent postulators—Sir Roy Harrod (1933) initially and Bela Balassa (1964) and Paul Samuelson (1964) three decades later. The basic argument here is that the country with the relatively high level of productivity will tend to have a less competitive equilibrium real-exchange rate or, alternatively, a higher exchange-rate-adjusted price level.

To understand the reasoning here, consider a country experiencing rapid productivity in its traded goods sector. Suppose that the law of one price holds among internationally traded goods in the long run. Productivity growth in the traded goods sector will lead to wage increases in that sector but without any increase in product prices. Workers in the nontraded goods sector, whose labor is a substitute for the labor of workers in the traded goods sector, will see their wages bid up too. The result will be an increase in the price of nontraded goods in that country and hence an increase in its overall price index, which is a weighted average of prices in the two sectors. Since the law of one price holds for traded goods and, by assumption, the nominal exchange rate has not changed, the increase in the overall price index in the country experiencing the productivity growth will not be matched by a change in the nominal exchange rate. So, if PPP initially held, the currency of the country with the more rapid productivity growth will now appear overvalued—that is, the currency would seem to have too high a price level when viewed in the same currency as the price level of the country that did not experience the productivity growth.

Evidence on the HBS effect is mixed. Lothian (1990, 1991) finds some evidence for several currencies versus the Japanese yen. Lothian and Taylor (2008) find evidence of an HBS effect for the dollar-sterling real exchange rate but not for the French franc -sterling rate. Bergin, Glick, and Taylor (2006) find effects that vary greatly in intensity over time as do Taylor and Taylor (2004), possibly due to the intensity of differences in productivity differentials between countries.

A final possible source of seemingly too slow an adjustment speed is aggregation bias due both to reliance on data averaged over time (e.g., average annual price indices) (Taylor 2001) and price indices that are a combination of prices of traded goods that are more closely linked across countries and non-traded goods that are less so (Imbs et al. 2005).

A second problem surrounding short-run behavior has been the apparent disconnect between movements in nominal exchange rates and movements in the "fundamental" variables that theory suggests as determinants of movements in exchange rates. The two major pieces of evidence supporting this notion are the observed greater variability of nominal exchange rates than fundamentals over shorter time horizons and the Meese and Rogoff (1983) results demonstrating poor out-of-sample performance of fundamentals-based models over time horizons ranging from a month to a year.

The passage of several decades and much additional research, moreover, did not overturn the Meese-Rogoff results (Cheung, Chinn, and Pascual 2005). Meanwhile, two developments took place. The first was the growth of a new body of literature on foreign-exchange-market microstructure focusing on exchange rate behavior over the very short term. This work uses data sets ranging in frequency from tick-by-tick to interday. One of the key findings to come out of this literature is the important influence of *order flow*, defined as signed transaction volume, on exchange rate dynamics. According to this research, order flow moved the market. Among the major studies in this vein are Lyons (1995), Evans (2002), Evans and Lyons (2002), and Payne (2003). Lyons (2001), Sager and Taylor (2008), and Evans (2011) provide recent surveys of this literature including its various extensions. Rime (2011) has compiled a bibliographical list of work in this general area with almost 370 entries.

This research, at least initially, was moot about why order flow mattered. Economists did, however, have some strong hunches that in one way or another it was a function of information on economic fundamentals in the countries involved that gave order flow its market power. Subsequent research shows that such a link exists. Various researchers (Evans and Lyons 2005a, 2005b, 2006; Berger et al. 2008; Dominguez and Panthaki 2006; Love and Payne 2008) all find a statistically significant impact on order flows of macro data releases, while Evans and Lyons (2008) show that one-third of the variance in order flow is attributable to the arrival of macro news.

The second important development was theoretical rather than empirical. Engel and West (2005) analyze the properties of forward-looking monetary models in which the nominal exchange rate is determined by the present discounted value of current and future fundamentals. They show that given rather reasonable assumptions about model parameters and the time-series process followed by the fundamentals—in particular, that the discount factor was close to unity and that the fundamentals were I(1)—the nominal exchange rate would be close to a random walk.

The reasoning here is straightforward. With a near-unity discount factor, what matters the most in terms of the exchange rate is the time pattern of fundamentals extending far into the future rather than simply fundamentals today. Those fundamentals, however, are I(1). Any I(1) process, in turn, can be decomposed into a stationary and a random-walk component. Since expectations of future fundamentals will be dominated by the random-walk component, short-term changes in exchange rates will be largely determined by changes in these expectations due to the arrival of "news." The Engel and West (2005) results, therefore, not only provide a potential explanation for the Meese and Rogoff (1983) findings but also have another important implication. They suggest that the "disconnect" between exchange rates and fundamentals might be more apparent than real.

Researchers quickly took the Engel and West (2005) analysis a step further, combining its insights with those that have come out of the microstructure literature. As Evans and Lyons (2005a, 405) stated the case, "[I]f there is little room for forecasting based on stationary components of fundamentals, then one needs to focus on where all the action is, namely, exchange rate dynamics that come from expectational surprises."

This is where the microstructure findings are relevant. Widely available public information is of no help in forecasting the expectational surprises unless there are issues associated with learning what the publicly available data actually are indicating. The well-documented link between order flow and exchange rate changes, however, suggests that learning is important. It also suggests that non-public information gradually finds its way into changes in order flow and via that channel moves the market. Empirical work based on micro-based models, some of it examining a broad spectrum of information and not just the standard data releases, suggests that this is indeed the case. Evans and Lyons (2008), Evans (2010), and Rime, Sarno, and Sojli (2010) all report findings supporting this line of thinking. The results of these exercises, in general, are quite striking.

Evans and Lyons (2008) examine both interday and intraday DM/USD spot exchange rates, order flow, and the wide range of economic news available on the Reuters Money Market Headline News screen over the period May 1 to August 31, 1996. In their analysis of the intraday data, they find both direct effects of this news and indirect effects operating via order flow on market-makers' quotes of spot exchange rates. Combined, the two effects account for more than a third of the variance of spot exchange rates.

Evans (2010) develops a sophisticated micro model of dealer behavior linking order flow and excess returns in the FX market. He investigates the performance of this model using weekly data on six types of end-user order flows, forecast errors for several key U.S. and German economic variables, and Citibank quotes for EUR/USD spot exchange rates over the period January1993 to June 1999. He finds, among other things, that the model explains between 20 percent and 30 percent of excess currency returns over both one-month and two-month horizons. These figures are substantially higher than those obtained with conventional macro-oriented models.

Rime, Sarno, and Sojli (2010) use daily interdealer data for spot EUR, GBP, and JPY versus USD exchange rates for the period February 13, 2004 to February 14, 2005 from the Reuters trading system. They find significant relations both between order flows and fundamentals and between order flows and daily exchange-rate changes.

The findings in this literature, therefore, shed light on the way in which news matters. Standard models posit instantaneous adjustment by traders to such news. The results reported in this new micro-based literature, in contrast, suggest that there is much more to the story: that traders take time to sort out what the news actually means and use trades in the markets as an importance source of this information.

Summary and Conclusions

Where does all of this leave us? A concise summary would be that our bottom-line knowledge of long-run behavior is much greater than was thought to be the case three decades ago. In contrast to the prevailing academic consensus of the 1980s, a now generally accepted belief is that real exchange rates do revert over long periods of time toward a mean consistent with PPP, perhaps adjusted slightly for productivity differentials. But while our knowledge of long-run real-exchange-rate behavior is greater than it was three decades ago, in many respects it is not all that much greater than was thought to be the case five decades ago, or for that matter five centuries ago. In that sense, our current belief in the long-run mean reversion of real exchange rates interestingly mirrors a long-run mean reversion in economic thought. At the most basic level, profligate monetary policies that lead to domestic inflation lead to their international analog, currency depreciations, while the converse is true for stable monetary policies. In that sense, PPP holds. Given the voluminous research on that subject conducted since the late 1980s, there is now much more confidence that this is the case. As a first approximation, therefore, PPP does a good job explaining such long-run behavior. It is, however, not at all a perfect explanation—real variables in theory can, and in practice sometimes do, alter the relationship between nominal exchange rates and price levels for extended periods. Using PPP as a tool for forecasting is hampered further by the considerable difficulties involved in forecasting monetary policies, which are the key variables underlying the PPP relationship.

Much less knowledge of exchange rate behavior is available over shorter time horizons, which translates into less confidence in the evidence pertaining to such behavior. Nevertheless, researchers have made considerable strides over the past decade in filling in the blanks and chipping away at two of the major puzzles surrounding exchange-rate behavior over shorter time horizons—the "PPP puzzle" of exceedingly slow estimated speeds of adjustment of real exchange rates and the "exchange rate disconnect puzzle" of no apparent link between fundamentals and nominal exchange rates over such periods.

Where is future research likely to concentrate? Given that we apparently still know so little about the short-run behavior of exchange rates but relatively more about their long-term behavior, future work might perhaps concentrate on the relationship between those two horizons. That is, how do short-term fluctuations translate into long-term mean reversion? Related to this question, while it remains extremely difficult to forecast exchange rates over the short term, hedge fund managers are nevertheless able to add significant value to tactical asset allocation. Future academic research might also profitably concentrate on analyzing exchange rate investment and speculation in an investment portfolio context (Pojarliev and Levich 2011).

Discussion Questions

1. Define absolute and relative purchasing power parity (PPP). Is PPP simply the macroeconomic analog of the law of one price?
2. Discuss the evidence on long-run PPP.
3. What is the PPP puzzle? Has it been solved?
4. What is the Harrod-Balassa-Samuelson effect? Describe how it may arise and discuss whether it has any empirical support.
5. What is meant by "exchange rate order flow"? Can it be used to explain and predict exchange rate movements?
6. What is the exchange rate disconnect puzzle? Has it been solved?

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