# 17

## The Determinants of the Exchange Rate

OVERVIEW

In this chapter, we learn:

● that the exchange rate is an asset price

● how monetary factors affect the nominal exchange rate when prices are flexible

● how expectations of future fundamentals can affect the exchange rate today

● how exchange rates behave when prices are not free to move in the short run

● how productivity differentials affect the real exchange rate

● why higher income countries have stronger inflation-adjusted currencies

## 17.1 Introduction

> *Pressure is mounting on the European Central Bank to take action against a persistently strong euro with a leading industrialist calling on Frankfurt to tackle the "crazy" strength of the currency.*
>
> *Fabrice Brégier, chief executive of Airbus's passenger jet business, said the ECB should intervene to push the value of the euro against the dollar down by 10 per cent from an "excessive" $1.35 to between $1.20 and $1.25.*
>
> -- Michael Stothard in Paris, Andrew Parker, Peggy Hollinger and Ferdinando Giugliano, *Financial Times*, July 7, 2014.

We learned in Chapter 12 how a strong currency makes it harder for domestic manufacturers to export goods. So we can understand why a European executive trying to sell commercial airplanes might worry that a strong euro was making his job harder. And it's a fact that in 2014, Airbus was registering disappointing sales compared to its rival across the Atlantic, Boeing. But why would it be "crazy" for the euro to be worth $1.35, and yet normal and acceptable for the euro to be worth 10 percent less than that? And how did Fabrice Brégier expect the European Central Bank to adjust the euro's value, when the euro is under a floating, rather than a fixed, exchange rate regime?

In Chapter 10, we described the exchange rate as the price of foreign currency, determined in the foreign exchange market. Characterizing the exchange rate as just a relative price of currencies determined by supply and demand factors was a powerful insight, but only abstract factors – such as increased demand for home goods or decreased supply of foreign assets – were tapped as determinants. We didn't explain in detail how those supply and demand factors were related to observable macroeconomic variables. That is the task this chapter takes on.

One of the key challenges for identifying the factors that determine exchange rates is the fact that the exchange rate seems to move a lot more than the variables one might think are important for exchange rate movements. Figure 17.1 depicts the month-to-month percent changes in the exchange rate for the most commonly traded currency pair in the world, dollars and euros. Also plotted are the changes in the ratio of the money supply to national income in the U.S. as compared to the euro area, and the difference between U.S. and euro area interest rates. Clearly the exchange rate is more volatile than the latter two economic variables.

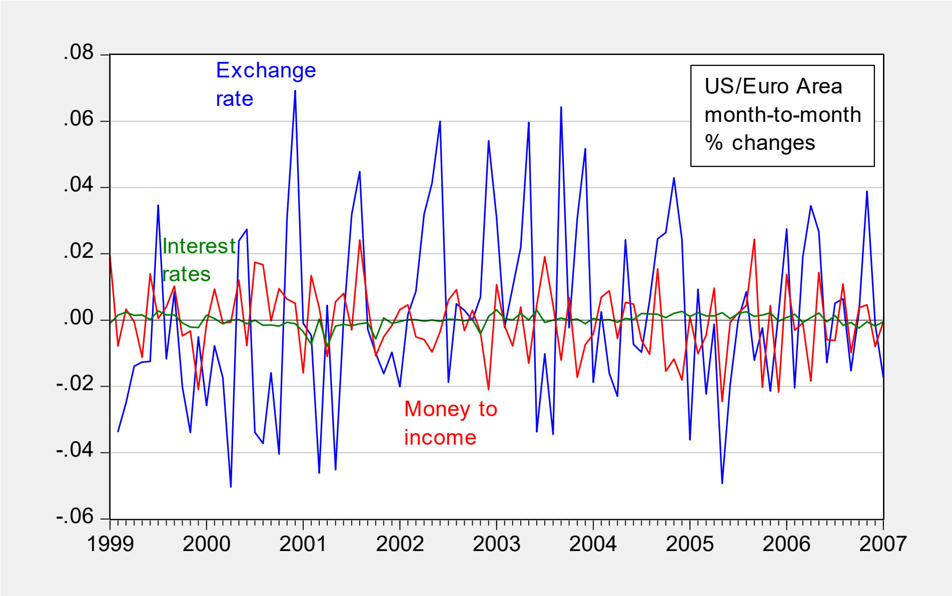



**Figure 17.1:** Month-to-month percentage changes in the U.S. dollar/euro exchange rate, the money-income ratio between the U.S. and the eurozone, and differences in the respective three-month interest rates. Money is measured as M2, income proxied by industrial production. Source: IMF, *International Financial Statistics.*

Here is something else that's interesting about Figure 17.1. Chapter 15 explained how a rising interest rate should stimulate foreign demand for dollar-denominated financial instruments and thereby boost the value of the dollar. And yet in the figure, sometimes the green and blue lines move in the same direction. When they move up together, the interest rate difference tilts in favor of the U.S., but the value of the dollar falls. When they move down together, the rate difference tilts against the U.S., and yet the dollar gains in value. The correlation between the interest rate differential and the movement of the dollar is just –0.04, not anywhere near statistically significant.

This seemingly idiosyncratic behavior of the currency suggests how difficult it would be for the European Central Bank (ECB) to determine how to help Airbus – and other euro area firms – by weakening the currency. Would it want to raise or drop the interest rate?

To resolve these puzzles, we need to look more closely at the determinants of a floating exchange rate, emphasizing the role of currencies as assets but also accounting more fully for the fact that expectations about what will happen in the future have ramifications for the exchange rate today. Incorporating this insight, and allowing for the fact that prices are not completely flexible, will help explain other puzzling aspects of exchange rate behavior, including the seemingly fickle relationship between exchange rates and interest rates.

We first examine a model in which prices are perfectly flexible, considering the implications for exchange rates and seeing how those implications stack up against real-world data. Then we will allow for price stickiness, and examine the characteristics of the resulting model. Finally, we will see how trend movements in real exchange rates are explained in terms of movements in the relative prices of nontraded goods, such as many services.

## 17.2 The Monetary Approach with Flexible Prices

*The exchange rate as a function of contemporaneous factors*

The **monetary approach** to exchange rate determination relies on interactions between money demand and money supply. We denote the spot exchange rate as *S*, measured in home currency units per foreign currency unit. For concreteness, let's take the foreign country to be the euro; then from the American perspective, *S* is the number of U.S. dollars required to purchase a single euro. This means that when *S* rises, the dollar is weakening against the euro.

To begin to impose some constraints that reflect how our various macroeconomic variables are related to one another, we now assume that the price of asteel beam, either in the U.S. or the euro area, is equal when both prices are expressed in dollars (or both prices are expressed in euros). In other words, the **Law of One Price** applies. In fact, we'll require that in the U.S. and the euro area, all goods—not just steel beams, but also cars, loaves of bread, and so on—are similarly priced the same, and that goods are consumed in the same proportions in the two respective economics. This means that at any given time *t*, the price in dollars of a representative bundle of American goods equals the price in dollars, converted from euros using the current exchange rate, of an identical euro area bundle:

(17.1) $$P_t = S_t \times P_t^*$$

This condition is called **purchasing power parity**. To illustrate the concept, consider a Big Mac sold in Chicago versus one sold in Berlin. They are composed of the same ingredients in the same proportions ("two all-beef patties, special sauce, lettuce, cheese, …" and so on, in the words of a 1970s ad jingle). According to purchasing power parity, the dollar price of an American Big Mac should equal the euro price of a euro-area Big Mac, multiplied by the exchange rate in dollars per euro. In July 2013, the euro-area Big Mac cost 3.62 euros, so at the then-current exchange rate of 1.286 dollars/euro, a euro-area Big Mac cost \$4.66. By comparison, an American Big Mac cost \$4.56 – a difference of only about 2 percent.

For what we will be doing, it turns out to be easier to use the natural log of the variables, denoted by lowercase letters: the natural log of *S* is denoted by *s*, and the log of the price level is denoted *p*. Equation (17.1) can be rearranged and re-written in log terms as:

(17.2) $$s_t = p_t - p_t^*$$

Next, we relate the real demand for money to income and interest rates. We'll assume that money demand looks like this:[1]

(17.3) $$(m_t - p_t)^d = \varphi y_t - \lambda i_t$$

The *d* superscript indicates demand; *m* is the money stock, *p* is the price level, and *y* is income—all in natural logs—and *i* is the interest rate, in percentage points. While Equation (17.3) looks different from the money demand equation used in Chapters 14 and 15, in terms of intuition it's the same: when income rises by 1%, then the demand for money (after adjusting for the price level) rises by φ percent; when the interest rate rises by 1 percentage point, the demand for real money drops by λ percent. For simplicity, we'll assume (as in the previous chapters) that the money supply is set exogenously by the central bank and that money supply equals money demand, and that all home conditions apply identically to the foreign country. This results in the following expression for the (log) exchange rate:

(17.4) $$s_t = (m_t - m_t^*) - \varphi(y_t - y_t^*) + \lambda(i_t - i_t^*)$$

The exchange rate, remember, is the relative price of currencies, which in turn depends upon the *relative* demand versus supply for money *between* countries. From the American perspective, when more dollars are printed (*m* rises), then the exchange rate depreciates (*s* rises). When U.S. income rises, the demand for money (U.S. dollars) rises, and this drives down, or appreciates, the exchange rate. Finally, the higher the U.S. interest rate, the weaker the exchange rate (*s* is higher), as higher interest rates reduce money demand – and the exchange rate depends on the balance between money supply and money demand.

Now, assume that individuals' reallocations of funds over assets denominated in different currencies move interest rates until no one expects to receive a higher rate of return saving in one country versus another. This condition, called uncovered interest parity, was discussed in Section 12.5:

(17.5) $$i_t - i_t^* = \Delta s_{t+1}^e \equiv s_{t+1}^e - s_t$$

On the left, $i_t$ and $i_t^*$ are, respectively, the domestic and foreign interest rates at time *t*. On the right, $s_{t+1}^e$ is what people at time *t expect* the (log) exchange rate to be at time *t* + 1, while $s_t$ is the *actual* exchange rate at time t. The equation says that the interest differential between the two countries, expressed in percent terms, equals the expected relative depreciation of the home currency, in percent terms.[2]

---

[1] Equation (17.3) looks different from the money demand equation we encountered in Chapter 12, but it possesses the same characteristics. When income rises, money demand rises, and when interest rate rise, it falls. The equation is equivalent to $\left(\frac{M^d}{P}\right) = Y^{\varphi} e^{-\lambda i}$.

[2] Notice log(*X*/*Z*) is the same as log(*X*) – log(*Z*), or in the notation where lowercase letters denote logged terms, *x* – *z*. The term *x* – *z* is a percent difference. When one replaces *x* and *z* with $s_{t+1}$ and $s_t$, respectively, then one has a percentage growth rate, or rate of change in percent terms.

To illustrate: suppose Home is the United States and Foreign is the euro area, the U.S. interest rate on a one-year bond is 4% while the counterpart euro area interest rate is 3%, and the expected depreciation of the dollar relative to the euro is 2% annually. Then an American bond buyer has two options: either (1) earn 4% by holding U.S. bonds for a year, or (2) convert dollars to euros, earn 3% by holding euro area bonds for a year, and then earn another 2% after converting back to dollars. Assuming the buyer isn't worried about uncertainty, the second option, with 5% total earnings, is better, and in fact it makes sense to borrow in the U.S. and save the borrowed money in the euro area.

Once investors figure this out (it won't take long), enough capital will flow from the U.S. to the euro area so that either euro area interest rates will fall, or U.S. interest rates will rise, or the expected dollar depreciation will decline. We don't know will occur, but suppose it is the second of those possibilities. Then we might end up with a U.S. interest rate on a one-year bond of 5%, and if the euro area rate stays at 3%, and the expected dollar depreciation remains at 2%, then Equation (17.5) is satisfied and there is no profit-making strategy available.

Substituting Equation (17.5) into Equation (17.4) yields:

(17.6) $s_t = (m_t - m_t^*) - \varphi(y_t - y_t^*) + \lambda(s_{t+1}^e - s_t)$

The last term tells us that the more the exchange rate is expected to depreciate in the future, the weaker the currency is today.

Contrast the results of this model with the predictions of the Mundell-Fleming model discussed in Chapter 15. In that approach, higher relative income results in a *weaker* currency, and a higher relative interest rate induces a *stronger* currency. Both of these predictions are opposite of those obtained in this monetary model.

The difference in predictions about how the interest rate affects the exchange rate stems from the assumption that prices are free to adjust without any friction. In a Mundell-Fleming model, a higher interest rate causes a financial capital inflow, with the resulting demand for home currency appreciating the currency. In the monetary approach, a higher interest rate causes a lower money demand, relative to money supply, and hence a weaker currency.[3]

*The Effect in the Present of Expectations About the Future*

One of the most important insights to be gained from the monetary approach is that the future

[3] The income variable has a different effect, as well. This stems from the fact that the monetary model focuses on stocks, while the Mundell-Fleming model focuses on flows. In the former, a higher income induces a higher money demand relative to supply (where money is a stock), strengthening the currency. In the latter, higher income induces higher imports (where imports is a flow), increasing the demand for foreign currency and hence weakening the home currency.

matters. This point is obscured in Equation 17.4, where the exchange rate in *this* period depends on the money supply, income and interest rates in *this* period. However, expectations about the future are actually present in that expression, as the present-time interest differential depends on what is expected to happen to the exchange rate over time, as shown in Equation (17.6), and hence depends on what is expected to happen to the fundamentals in the future.

The actual present exchange rate $s_t$ appears on both sides of Equation (17.6). By solving for $s_t$, we can make the dependence of $s_t$ on expectations fully explicit:

(17.7) $$s_t = \left(\frac{1}{1+\lambda}\right)\left[(m_t - m_t^*) - \phi(y_t - y_t^*)\right] + \left(\frac{\lambda}{1+\lambda}\right)s_{t+1}^e$$

The present exchange rate depends on the present **monetary fundamentals**—money and income—but also on expectations about the next period: the more valuable one expects the currency to be tomorrow, the more valuable it will be today.

Notice, now, what the preceding implies about $s_{t+1}^e$, the expected exchange rate in period $t + 1$: it in turn depends on the expected monetary fundamentals in period $t + 1$ and the expected exchange rate in period $t + 2$. This analysis can be repeated indefinitely far into the future. Representing the expected monetary fundamentals in period $t + i$ as $\hat{M}_{t+i}^e \equiv (m_{t+i}^e - m_{t+i}^{e*}) - \phi(y_{t+i}^e - y_{t+i}^{e*})$, we write:[4]

(17.8) $$s_t = \left(\frac{1}{1+\lambda}\right)\left[\hat{M}_t + \left(\frac{\lambda}{1+\lambda}\right)\hat{M}_{t+1}^e + \left(\frac{\lambda}{1+\lambda}\right)^2 \hat{M}_{t+2}^e + \left(\frac{\lambda}{1+\lambda}\right)^3 \hat{M}_{t+3\cdots}^e\right]$$

The exchange rate in the present period depends on *all* the expected future values of the monetary fundamentals. Notice, though, that the expected fundamentals in period $t + 20$ have a much smaller impact than those in period $t + 1$. In other words, our estimate of the monetary fundamentals twenty years from now matters a lot less for today's exchange rate than our estimate of the monetary fundamentals tomorrow.

The interpretation of the exchange rate as the present "discounted value" of current and future fundamentals helps explain why the exchange rate can move even if nothing substantial changes today. If people simply alter their *views* about what is going to happen in the future, then that will have an effect. We also see why seemingly negligible changes in today's observed fundamentals can induce big contemporaneous changes in the exchange rate. It's all (or mostly) in the expectations of the future.

Suppose, by way of illustration, that credible rumors suddenly begin to circulate about the central

[4] We also need that the value of the expected exchange rate in the infinite future does not go towards positive or negative infinity at too rapid a rate. Essentially, this assumption requires that there are no bubbles in exchange rates.

bank's plans to expand the money supply more rapidly in the near future. This will cause the exchange rate to devalue today, instantaneously. The bigger the sensitivity of money to the interest rate ($\lambda$), the bigger the jump. The disproportionate movement in the exchange rate is called the **magnification effect**.

### 17.3 Application: Hyperinflation in Zimbabwe

In the late 1990's, the government of Zimbabwe began running large budget deficits, as expenditures from its involvement in the Second Congo War collided with the collapse in tax revenues due to a shrinking economy.[5] Since the government was not able to borrow from international markets and domestically, the central bank purchased government debt, effectively printing money. This can be shown by referring back to the definition of the government's budget constraint. The budget deficit (*BuD*) is the excess of government spending over tax revenues:

(17.9) $$BuD \equiv G - T$$

The budget deficit must be financed, by selling government bonds to either the private market or the central bank. Expressed in nominal terms:

(17.10) $$P \times BuD = \Delta B + \Delta B_{CB} = \Delta B + \Delta MB$$

where $B$ is government bonds held by the private sector, and $B_{CB}$ is the bonds held by the central bank – in this case the Reserve Bank of Zimbabwe (RBZ). The RBZ purchased the bonds with money base $MB$, described in Chapter 14 as the sum of currency and bank reserves. In the case of Zimbabwe, few domestic and foreign lenders were willing to purchase bonds from the government, given fears that the government would be unwilling to honor the debt. As a consequence, the budget deficit was completely financed by "printing money." The change in the money supply, $\Delta M$, is a multiple of the change in the money base.

The deficits were so large that vast amounts of money had to be printed. Hyperinflation – inflation in excess of 50% -- was the result, with prices rising at an annualized rate of nearly 80 billion percent by the end of 2008.[6] Far before inflation reached these levels, prices were no longer sticky. It's easy to see why: when the prices of goods rise minute by minute, shopkeepers and workers will adjust what they charge very quickly.

This is a case where the flexible price monetary model applies, so that Equation 17.4 defines the exchange rate. At such high inflation rates, the interest rate is equal to inflation; in addition, the foreign country – in this case the US – can be ignored without too much concern. We then obtain:

[5] An intensification of the land redistribution program in the late 1990s led to a severe drop in agricultural output, as well as general economic activity, resulting in a severe drop in government revenues.

[6] Hanke and Kwok (2009).

(17.4') $$s_t = (m_t) - \varphi(y_t) + \lambda(\pi_t)$$

For simplicity, assume φ = 1. Depicted in the figure below are the exchange rate, (m-y) and price level, all normalized to 2000 values equal to 1. Because all the variables move so drastically, the series are graphed on a log scale. Notice that by purchasing power parity, the exchange rate *s* should move in a same way as the price level, *p*. The model implies that the series move together, more or less proportionately, and they do.

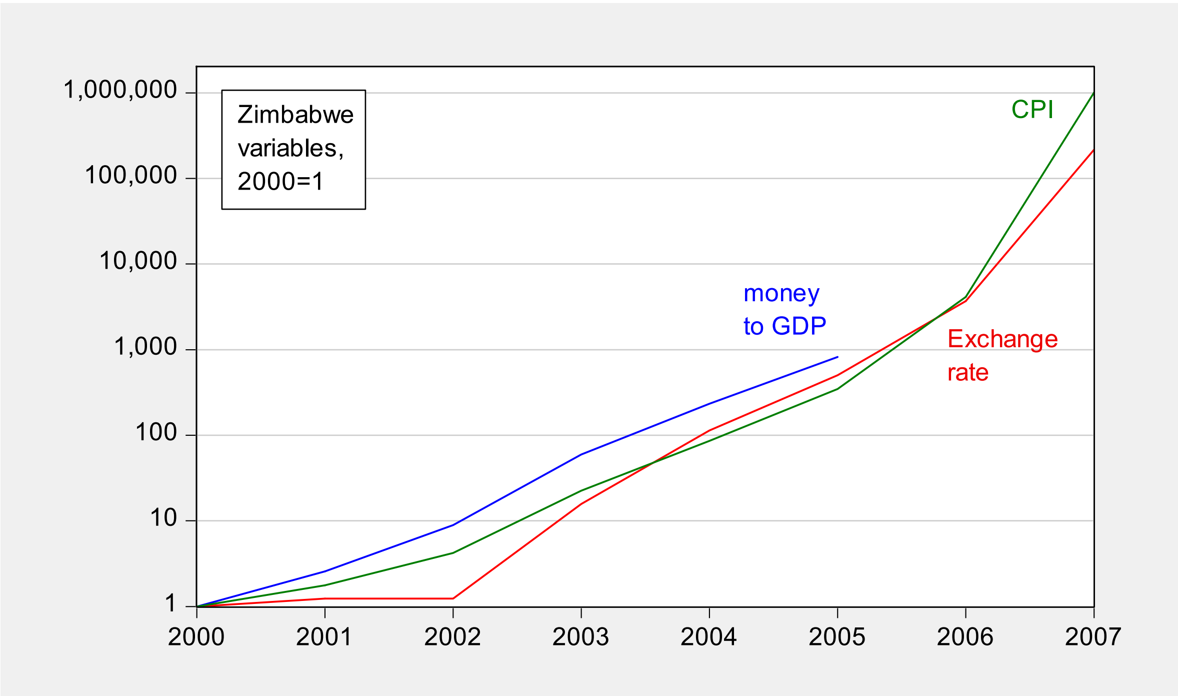



**Figure 17.2:** Ratio of Money to real GDP (blue line), Price level (green line) and exchange rate, Zimbabwe dollars to US dollar (red line), all normalized to a value of 1 in 2000, and on a log scale. Money is proxied by currency. Source: Penn World Tables, IMF (2005).

The exchange rate series depicted in the figure is the official, rather than actual market, exchange rate, so the pace of depreciation is understated. However, given the rapid pace of devaluations, movements in the official series give some indication of changes in the market (or parallel) rate. The point is that the pace of monetary fundamentals growth is proportional both to the rate which the price level rises and to the rate of exchange rate depreciation.

By 2008, the rate of inflation and currency depreciation were so rapid that the South African rand, the U.S. dollar, the pound and the euro substituted for the Zimbabwe dollar in most transactions. As part of an emergency plan to stabilize the economy, the government consented to the use of foreign currency in transactions in February of 2009, and in April, the U.S. dollar was adopted for transactions by the Zimbabwe government. Other currencies, like the rand, were allowed to circulate as well; the point is that monetary policy was taken out of the hands of the

Reserve Bank of Zimbabwe, and hyper-inflation and currency depreciation ceased to be an issue.

### 17.4 How Well Does the Flexible Price Monetary Model Work in Normal Times?

The current model provides insights into the determinants of exchange rates between currencies of advanced economies. However, this does not automatically mean that in the real world, our input variables affect the exchange rate in the way the model predicts. For instance, one can use a statistical technique called linear regression to estimate the relationship between the exchange rate, money stocks, incomes and interest rates implied by equation (17.4), for the dollar/euro exchange rate over the 1999Q1–2006Q4 period. Linear regression yields the following equation:

(17.11) $$s = -0.59m - 0.63m^{*} - 1.70y + 3.70y^{*} - 2.31(i - i^{*})$$

Notice that compared to Equation (17.4), one of the coefficients has the wrong sign: when the supply of dollars rises relative to that of euros, the dollar strengthens instead of weakening. Still, the other coefficients are as expected (although not always with statistical significance). Importantly, a higher U.S. interest rate means that the dollar gains, rather than loses, value relative to the euro.

The relationship predicted by Equation (17.4) appears to show up only in the long run. In particular, if one examines twenty-year changes in exchange rates ($\Delta s$) and corresponding twenty-year changes in the monetary fundamentals ($\Delta\widehat{M}$) across a large number of countries, one finds the positive relationship, as shown in Figure 17.3.

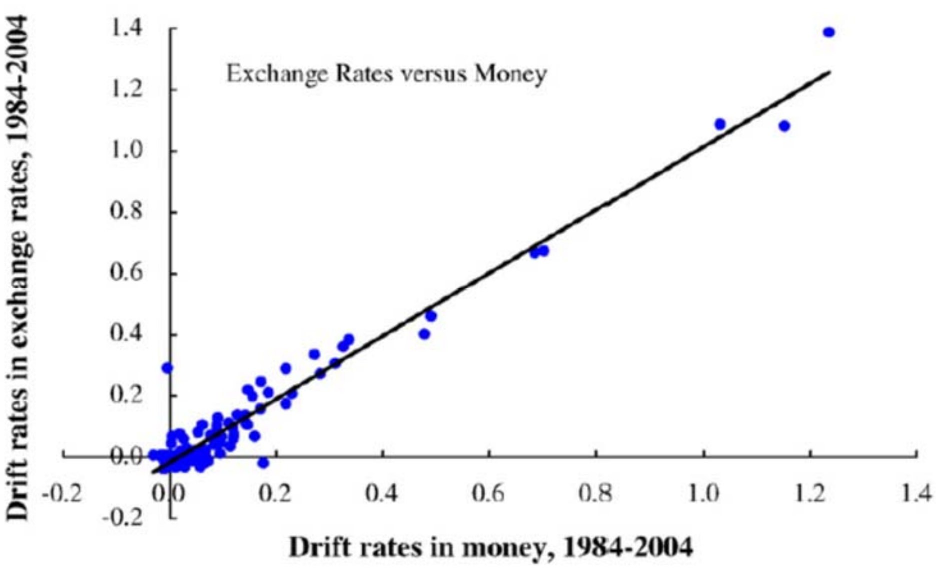



**Figure 17.3:** Twenty-year average growth rates in exchange rates and in monetary fundamentals, 1984–2004, for 94 countries. Source: Cerra and Saxena (2010).

The fact that the relationship holds in the long run, but not in the short run, suggests what might be wrong with the flexible-price monetary model: in the short run, prices might not be perfectly flexible.

*Identifying the Problem: Prices Are Not Perfectly Flexible*

A key building block of the model is purchasing power parity (PPP), which assumes that prices are equalized in common currency terms on an ongoing basis. However, in everyday observation we don't see firms adjusting prices minute by minute, or even necessarily month by month. So there's no obvious reason to believe that purchasing power parity actually holds, except perhaps *on average*.

The assumption of purchasing power parity is easy to test. If it does hold, then the exchange rate should follow closely the relative price level. Figure 17.4 displays two series, the U.S. dollar/euro exchange rate and the price level in the U.S. relative to that in the euro area, in log terms. (Price levels are measured using consumer price indexes, using baskets of goods that are not identical between U.S. and the euro area but function more or less as if they were).

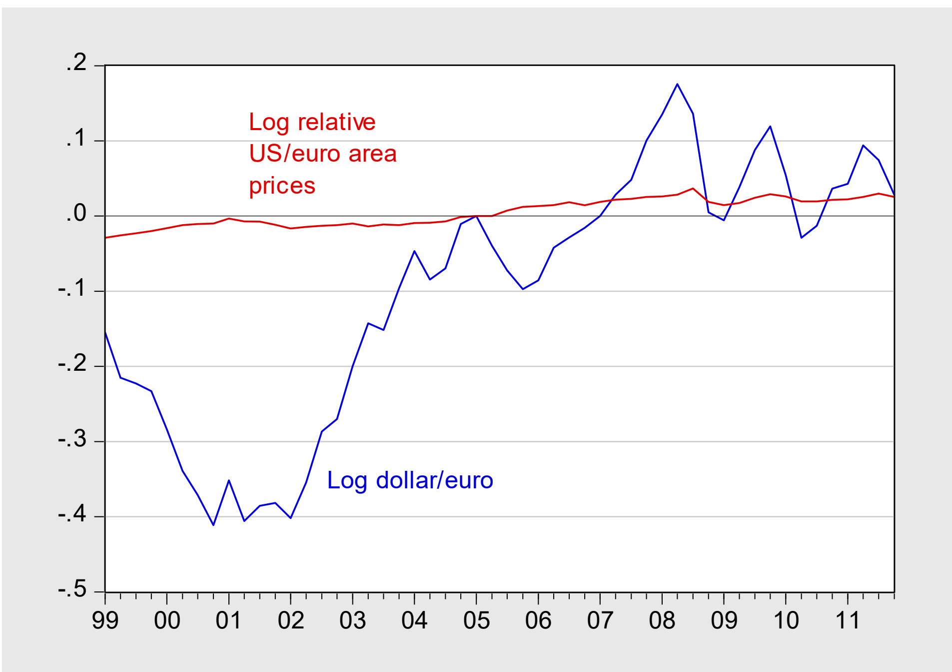



**Figure 17.4:** Log U.S. dollar/euro exchange (blue), and log U.S.-euro area relative price level (red), 2005Q1=0.

The figure highlights the fact that the two series do not move together, as they should if PPP held continuously. Rather, large and persistent deviations from PPP are evident. At the same time, one can see that the exchange rate doesn't seem to wander completely away from the relative price level over time, so there is some role for purchasing power parity.

Why does purchasing power parity fail to hold in the short term? One reason is the existence of transaction and transportation costs. Prices will tend toward parity if it is easy to buy in one place and sell in another. But if buying and selling involves auxiliary costs (government fees, for instance, or expenses associated with complying with regulations), or if the transportation of the goods is costly, then there's no reason for prices to be driven to equality. The same is true for tariffs and quotas that restrict international trade. These factors explain why there might be gaps in prices.

Those factors do not, however, explain why the price gaps vary over time. For that we need another explanation. We might speculate that the money demand equation isn't stable over time. Or maybe the central bank adjusts the money supply in response to other factors. Here, however, we will seek to explain the failure of purchasing power parity *and* the variability in price gaps by supposing that prices are not, after all, fully free to move period by period.

If firms or households don't adjust prices instantaneously as market conditions change, gaps between prices in one country and another country can open up. However, it doesn't make sense to argue that prices are fixed forever. A more realistic view is that prices are fixed today, but over time can move; in other words, prices are sticky but not stuck. Everyday experience suggests that sticky prices are prevalent, an impression confirmed by statistical analyses. For instance, empirical studies indicate that for the United States, the typical length of time the price of a consumer good stays unchanged is about eight months.[7]

**17.5 Exchange Rates and Sticky Prices**

One of the key assumptions of the model with flexible prices is that nominal interest rates vary primarily because of changes in the expected inflation rate.[8] One way to test the validity of this assumption is to examine how actual one-year interest rates and expected one-year inflation rates evolve over time. Figure 17.5 plots data for the United States. The interest rate is represented by the yield on one-year U.S. Treasuries. Expected inflation was determined by surveys of professional forecasters in the financial industry.

[7] "Typical" in this case means "median", and pertains to a sample analyzed over the 1998–2005 period. See Nakamura and Steinsson (2013).
8 Taken literally, the model says that interest rates differ between countries *only* because the corresponding expected inflation rates differ.

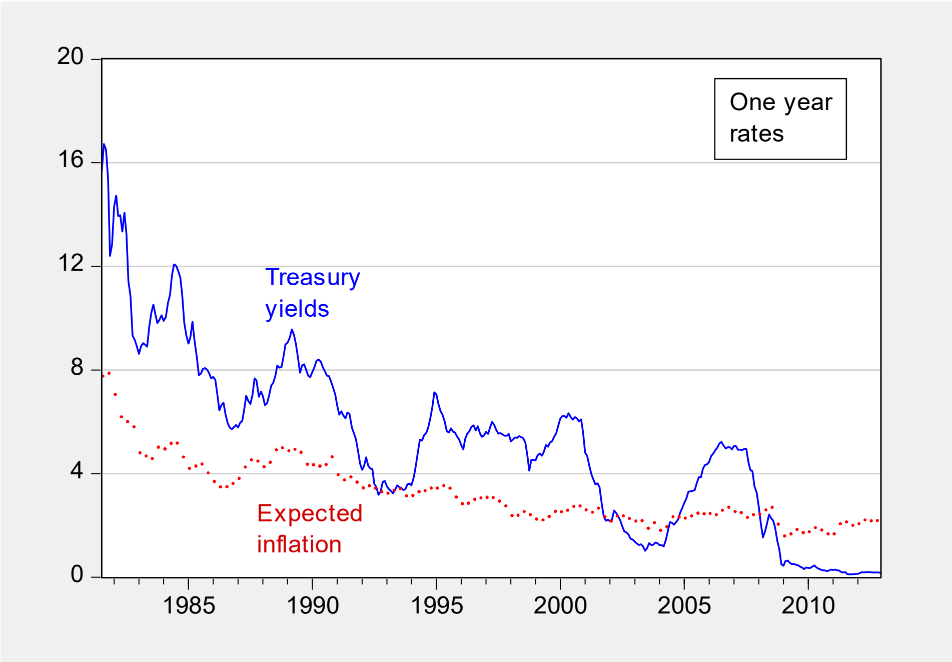



**Figure 17.5:** Yields on one-year U.S. Treasury bonds (constant maturity), and expected inflation from surveys (red). Source: St. Louis Fed for interest rates, Philadelphia Fed Survey of Professional Forecasters for expected inflation.

If prices were perfectly flexible, and the only shocks were monetary in nature, then the blue and red series should parallel each other closely. The fact that at best the curves display similar trends over a three-decade time span, with no similarity of behavior on a smaller time scale, suggests that the flexible price assumption is a poor one. Hence, it's not surprising that the flexible price monetary model fails so badly in predicting exchange rates.

We will now develop a more realistic model that drops the assumption of perfectly flexible prices, replacing it with an assumption of sticky prices in the short run. The result is a model where the exchange rate overshoots its long-run value in response to monetary shocks; this is sometimes called an **overshooting model** of the exchange rate.

*A More Realistic Model*

Let us assume that Equation (17.5) holds *in the long run*. Since in the long run, a difference in interest rates reflects a difference in inflation rates, we can replace $i_t - i_t^*$ with $\pi_t - \pi_t^*$. Then with tildes (˜) denoting the long term, Equation (17.4) becomes:

(17.12) $$\tilde{s}_t = (\tilde{m}_t - \tilde{m}_t^*) - \phi(\tilde{y}_t - \tilde{y}_t^*) + \lambda(\tilde{\pi}_t - \tilde{\pi}_t^*)$$

To get an expression for the *short*-run exchange rate, we assume that exchange rates revert back towards the long-run value at a rate proportional to the short-run deviation from the long run. This phenomenon is called overshooting. We must also factor in the difference in inflation rates, because the greater the difference, the faster one currency is losing value against the other, with everything else held constant. These considerations suggest the following description of the evolution of the exchange rate:

(17.13) $$\Delta s_{t+1} \equiv s_{t+1} - s_t = -\theta(s_t - \tilde{s}_t) + (\tilde{\pi}_t - \tilde{\pi}_t^*)$$

When the exchange rate is weaker than its long-run value ($s_t > \tilde{s}_t$), the exchange rate will go down, i.e., appreciate; and when the exchange rate is stronger than its long-run value, it will depreciate. The parameter $\theta$ is the **rate of reversion**. If $\theta = 0.5$, for example, then a 10% undervaluation induces a 5% exchange rate appreciation in the subsequent period, holding everything else constant.

We now make two assumptions: (1) that people's *expectations* about exchange rates match Equation (17.13), and (2) that each of the fundamental variables (money, income, inflation rate) follows a **random walk**, meaning that the present value of variable *X* is always the best estimate of *X*'s long-run average value. Then, as detailed in the Appendix, we can use Equations (17.12) and (17.13) to obtain an equation for the exchange rate that is applicable in the short term:

(17.14) $$s_t = (m_t - m_t^*) - \varphi(y_t - y_t^*) - \left(\frac{1}{\theta}\right)(i_t - i_t^*) + \left(\lambda + \frac{1}{\theta}\right)(\pi_t - \pi_t^*)$$

Since the nominal interest rate minus inflation equals the real interest rate, $r_t \equiv i_t - \pi_t$, we could also write Equation (17.14) as:

(17.15) $$s_t = (m_t - m_t^*) - \varphi(y_t - y_t^*) - \left(\frac{1}{\theta}\right)(r_t - r_t^*) + \lambda(\pi_t - \pi_t^*)$$

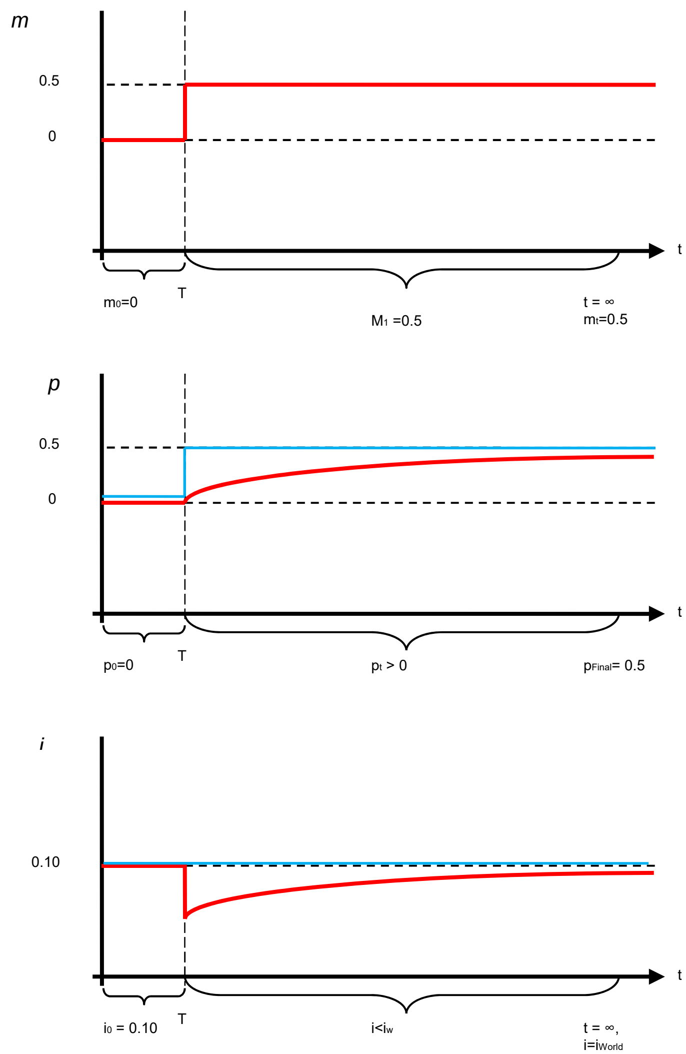
As in the previous model, the current exchange rate depends positively on current money stocks and inflation rates, and negatively on income levels and interest rates. The key difference – that a higher nominal interest rate (holding inflation constant) means a stronger currency – is driven by the fact that interest rates and inflation rates now don't move in tandem.[9] Since the real interest rate shows up in Equation (17.15), this model is sometimes called the **real interest differential** model. It is also called the Dornbusch-Frankel model.[10]

It's easiest to explain the workings of the model using an example. Assume for simplicity that the foreign country's variables are held fixed. Then Figure 17.6 shows the evolution of log money ($m$), log price level ($p$), the interest rate ($i$), and the log exchange rate ($s$) over time, when the money supply increases abruptly by 50% at time $T$.

---

[9] A common error in using this model is to reason as follows: higher real interest rates in the U.S. induce an inflow of foreign capital. This causes a greater demand for U.S. dollars, thereby appreciating the currency. This interpretation cannot literally be correct since, in this model, the current account and the financial account are both zero. Recall also that uncovered interest parity always holds, so investors are always indifferent between holding U.S. versus foreign assets.

[10] See Dornbusch (1976) and Frankel (1979).



m
0.5
0
t
T
$m_0$=0
$M_1$ =0.5
t = ∞
$m_t$=0.5
p
0.5
0
t
T
$p_0$=0
$p_t$ > 0
$p_{Final}$= 0.5
i
0.10
t
T
$i_0$ = 0.10
$i<i_w$
t = ∞,
$i=i_{World}$

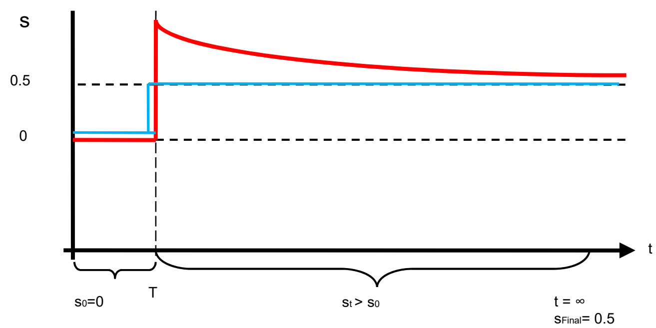



**Figure 17.6:** Evolution of log money (*m*), log price level (*p*), interest rate (*i*) and log exchange rate (*s*) in a sticky price model (red lines) and a flexible price model (blue lines).

To understand how the graphs are generated, consider first the sticky-price case, represented by the red lines. When the money supply increases, then *with prices fixed*, real money balances increase by 50%. That in turn means that domestic interest rates fall, while foreign rates stay constant. If the exchange rate immediately depreciated to its long run value, i.e., 50% higher, then future expected depreciation would be 0, and uncovered interest parity could not hold. Hence, it must be that the exchange rate depreciates *above* the long run value of the exchange rate, such that in the long run it is expected to *appreciate* over the long run so as to satisfy uncovered interest parity.

Now let's compare what happens if we repeat the experiment but prices are perfectly flexible (the light blue lines). When the money supply increases, the price level immediately rises by 50%, as well, so that real money balances remain unchanged. Moreover, since prices are perfectly flexible, purchasing power parity holds, and the exchange rate depreciates by exactly 50%. Note that an immediate jump in the exchange rate to its long-run value is entirely consistent with uncovered interest parity, since the domestic interest rate equals the foreign one.

One way to think of the contrasting results is that when prices are perfectly flexible, a shock to the system – in this case a monetary shock – results in proportionate movements in the related nominal variables. When one of the variables is not free to move – such as the price level – then the other variables have to do a disproportionate share of the adjustment. In this case, the real interest rate moves, and the exchange rate overshoots its long-run value.

## 17.6 Empirical Evidence for the Sticky Price Model

Numerous studies have attempted to evaluate the usefulness of the monetary model of the exchange rate. The translation from theory to empirical work is difficult, in part because the specification requires that the long-run values of money and income, which we do not observe, be included in the regression equation. To the extent that the actually observed money and output variables deviate from the long run, the model shouldn't do particularly well.

And in fact, in the short run, for month-to-month fluctuations in the exchange rate, the monetary model does not fit the data very well. In the long run, the model works somewhat better. Alquist and Chinn (2008) examined quarterly data for the United States, Canada, Japan, the UK, and the euro area from 1975 to 2005. Narrow money (M1) was used for the money variable, with the exception of the UK, where M4 is used; and inflation was calculated using consumer price indices.

The model is estimated using a statistical procedure that isolates the long-run relationship between the variables.

| | EUR | GBP | CAD | JPY |
|---|---|---|---|---|
| Money | −0.154 | −0.224 | 0.029 | 0.422 |
| | (0.263) | (0.192) | (0.058) | (0.395) |
| Output | −1.035 | −2.696* | −2.938*** | 1.604 |
| | (0.899) | (1.567) | (0.512) | (1.181) |
| Interest rates | −1.602 | −0.351 | −2.558* | −7.713 |
| | (1.495) | (1.441) | (1.419) | (2.393) |
| Inflation | 9.942** | 1.314 | 3.523*** | 3.080 |
| | (4.317) | (1.314) | (1.181) | (6.000) |
| Adj. $R$-sq. | 0.56 | 0.20 | 0.59 | 0.59 |
| Sample | 81Q4-05Q4 | 75Q4-05Q4 | 75Q2-05Q4 | 80Q4-05Q2 |
| $T$ | 95 | 119 | 121 | 99 |

*Notes*: Point estimates from DOLS(2,2). Newey-West HAC standard errors in parentheses. *, **, *** Indicate statistical significance at the 10%, 5%, 1% level.

**Table 17.1:** Estimates of the Sticky Price Monetary Model of the Exchange Rate

For all exchange rates of the dollar against the other currencies, interest and inflation rates point in the right direction – that is, higher interest rates appreciate the dollar, while higher inflation rates depreciate the dollar. Higher relative income also tends to appreciate the currency. On the other hand, money stocks don't seem to have a robust impact on the exchange rate. This might be due to the fact that the money demand equations are, contrary to the assumptions in the model, not very stable.

**Box 17.1: Can we predict exchange rates?**

There is ample evidence that movements in exchange rates can be statistically explained by movements in money supplies, incomes, and interest and inflation rates. However, it's an open question whether there is a way to forecast exchange rates in the future at economically meaningful horizons, like a quarter or a year.

Over thirty years ago, two economists, Richard Meese and Kenneth Rogoff (1983), demonstrated that even when one assumed knowledge about the actually realized values of the theoretically important variables, it was extremely difficult to predict the future movement of the exchange rate. In fact, it seemed that the best prediction (the one that minimized the variance of the prediction errors) was provided by the assumption that the exchange rate followed a random walk – meaning the best predictor of the future exchange rate was today's exchange rate.

There is actually good reason to think that if one *didn't* know anything about money supplies, incomes and any other macroeconomic variables tomorrow, the best guess of tomorrow's exchange rate would be today's. That's because the current value of the exchange rate incorporates current best-estimate expectations about all future fundamentals, so that there's no future movement still remaining to be inferred from the currently available data, aside from a relatively small interest differential component.

However, it should be the case that, if one knew the money supply, income, interest and inflation rates a year from now, and had a reliable knowledge of the parameters linking these variables and the exchange rate, then the exchange rate *could* be predicted.

Meese and Rogoff showed that neither the flexible price nor the sticky price monetary model, nor a model augmenting the sticky price model with cumulated trade balances, out-predicted a no-change forecast. Why did they obtain this finding? One explanation is that in general, the parameters of the models are very imprecisely estimated.

Subsequent studies failed to robustly overturn this finding, at least at horizons of up to a year. Mark (1995) and Chinn and Meese (1995) found some evidence that at horizons of up to four years, these types of models could out-predict a random walk. In the most recent comprehensive analysis, extending up to 2015, researchers found that some models, such as interest rate parity and purchasing power parity, do well relative to a random walk at horizons of a year to five years (Cheung et al., 2018). In the end, the fundamentals do seem to matter, but it is difficult to tease out the effects except at long horizons. At short horizons, other factors seem to dominate.

## 17.7 Real Models of the Real Exchange Rate

As explained in Ch. 12, the real exchange rate is the inflation-adjusted rate of exchange. The previous model focuses on how monetary factors influence the value of a currency in nominal terms. In particular, in the long run exchange rates primarily track with how much money has been printed up in one country relative to another, as in the dollar/euro exchange rate. But particularly for some exchange rates involving economies of drastically different levels of income, real factors seem to take on a larger role. That requires we dispense with purchasing power parity, even in the long run.

This point is easiest to see when examining the real exchange rate. Using the notation from earlier, define the real exchange rate as:

(17.16) $$\log(q_t) \equiv s_t - p_t + p_t^*$$

Again, the real exchange rate is the inflation-adjusted exchange rate. Alternatively, it's the rate at which one would give up bundles of home goods for a unit bundle of the foreign goods.

Purchasing power parity (as expressed in Equation 17.2) implies that the real exchange rate is a constant, namely 1 (the log of which is zero). Figure 17.7 displays the (log) real exchange rate of the Japanese yen against the U.S. dollar.

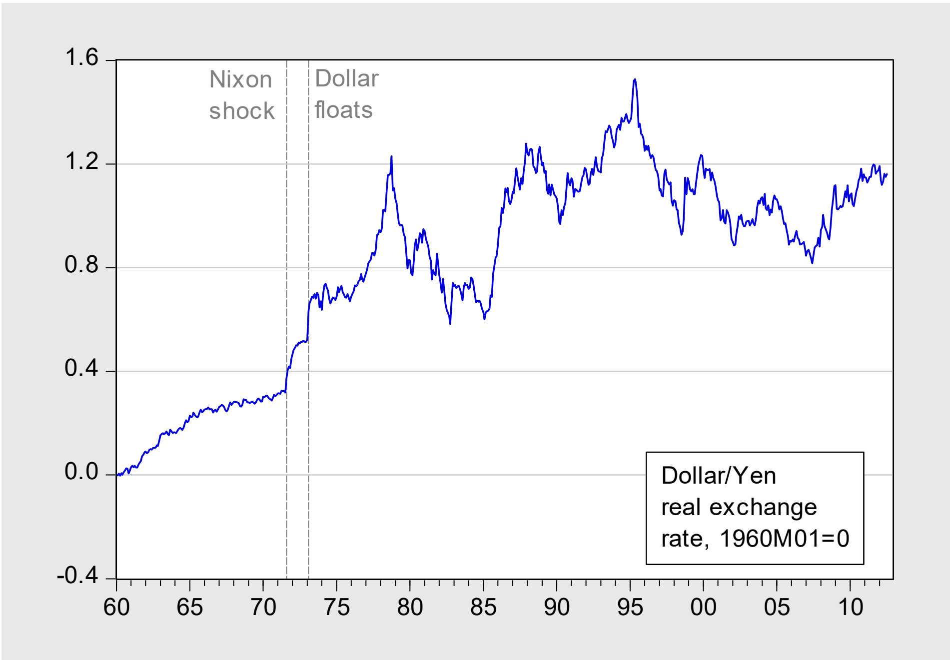



**Figure 17.7:** Log real U.S. dollar/Japanese yen exchange rate, 1960M01–2012M08, calculated using CPIs. An upward movement denotes a real appreciation of the Japanese currency.

While Japan today is at roughly the same per capita income level as the United States, back in 1960 this was not the case. From then up to about 1990, the dollar/yen exchange rate – rather than reverting to a constant average value –trended upward. That means that over several decades, the yen was gaining greater and greater strength against the U.S. dollar. How could this occur? Purchasing power parity is assumed to hold when people can arbitrage goods across borders, thereby forcing the equalization of prices of individual goods. However, not everything is traded. Services, in particular, have long been considered nontradable. (Haircuts are hard to export.)

Suppose, then, that the (log) price level is a weighted average of prices of **nontradable goods** (including services) and **tradable goods**.

(17.17) $$p_t = \alpha p_t^N + (1-\alpha) p_t^T$$

where the *N* and *T* superscripts denote nontraded and traded goods, respectively. Assume the foreign country has the same structure. Making the appropriate substitutions into Equation (17.16), rearranging, and using $\hat{p}$ to denote $p^N - p^T$, the (log) relative price of nontradable goods in terms of tradable ones, we obtain:

(17.18) $\log(q_t) = \log(q_t^T) - \alpha(\hat{p}_t - \hat{p}_t^*)$, where $\log(q_t^T) = s_t - p_t^T + p_t^{T*}$

So the real exchange rate can differ from zero if it is nonzero for tradable goods, or if the relative price of nontradable goods versus tradable goods differs across countries. In order to focus on the long-term determinants of the trend in the real exchange rate, let's assume that $\log(q^T)$ is zero. That's equivalent to stating that purchasing power parity holds for the goods that are tradable.

The consequence of letting purchasing power parity pin down the tradable goods' prices is to make the real exchange rate depend negatively on the relative price of nontradable goods, in the home country compared to the foreign one. For instance, the faster the relative price of nontradable goods in South Korea rises, the faster the Korean won appreciates in real terms.

These effects should show up in cases where relative prices change a lot; one instance of this would be the East Asian countries during the period of rapid growth in that region, up through the 1990s. Figure 17.8 shows the change in real rates plotted against the change in relative prices over the 1972–1992 period. We expect a negative relationship, the way the variables are defined.

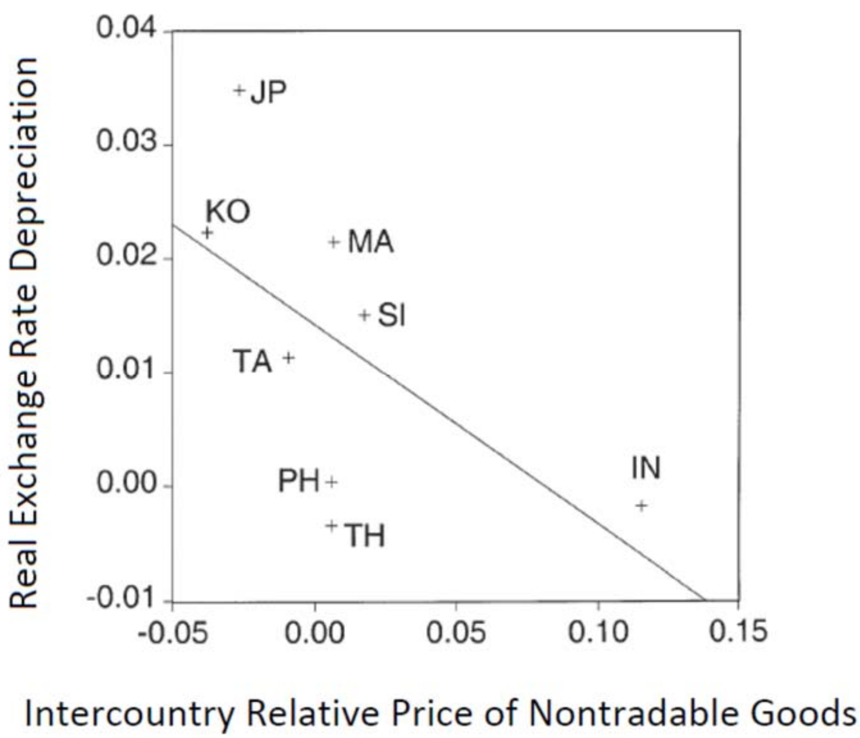


**Figure 17.8:** Average annual change in real exchange rate against the U.S. dollar versus average annual change in the relative price of nontradable to traded goods, 1972–1992. Source: Chinn (2000).

One reason the relative price of nontradable goods might move is productivity. Consider the relative price of haircuts and mobile phones: rapid productivity growth in mobile phone production means that haircuts become relatively more expensive (at least in terms of mobile phones). Moreover, since mobile phones are traded internationally, the price of mobile phones is tied down. Hence, over time, the more rapid the productivity growth in the (traded) mobile phone sector, the faster the rise in the price of haircuts, and the faster the rise in the total price level. That means that the higher tradable-good productivity, the lower the real exchange rate (i.e., the stronger the currency is in real terms).

Figure 17.9 presents this relationship for the same East Asian countries, with the change in real exchange rates plotted against the change in relative productivity ratios. Again, we expect to see a negative relationship, given the definitions of the variables.

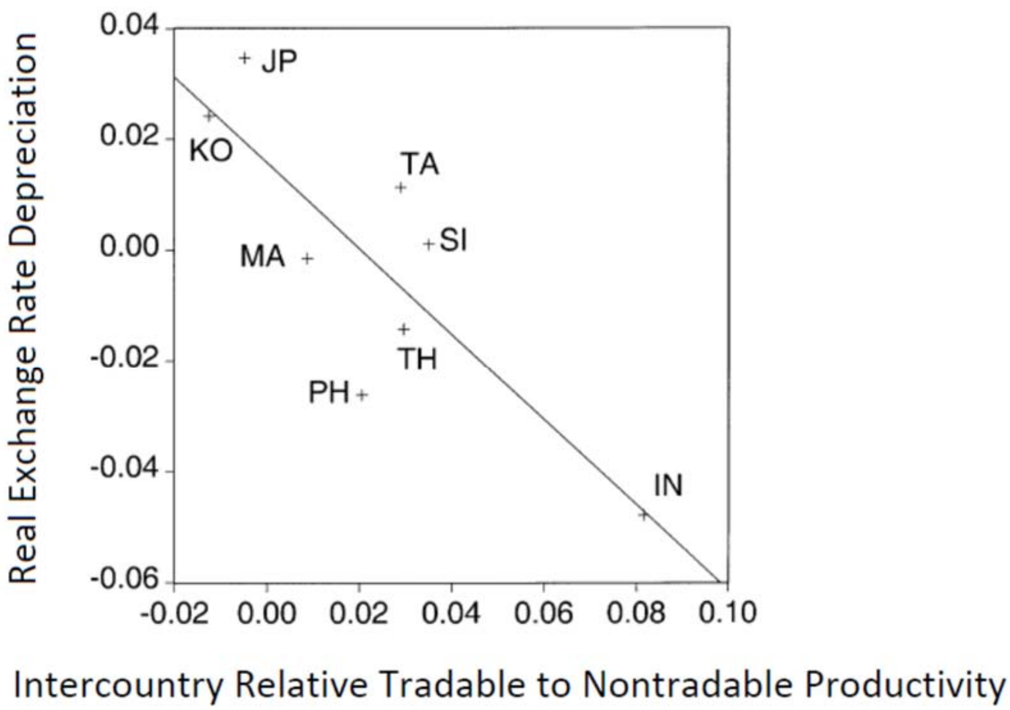



**Figure 17.9:** Average annual change in real exchange rate against the U.S. dollar versus average annual

change in the relative productivity of traded to nontraded goods, 1972–1992. Source: Chinn (2000).

The negative relationship is consistent with the view that faster productivity growth in the manufacturing sector of East Asian countries (roughly, the tradable goods sector) as compared to that in the United States has been a key driver in the appreciation of those currencies against the U.S. dollar. This phenomenon, relating productivity trends to real exchange rates, is known as the **Balassa-Samuelson effect**.[11] [12]

The fact that higher income countries (with higher productivity in the tradable sectors) have stronger currencies is one of the most robust findings in the literature.

**Box 17.2: Tales from the Big Mac**

In our earlier discussion of purchasing power parity, we compared the dollar price of an American Big Mac to the dollar price of a euro-area Big Mac; the difference was only about 2%. However, it turns out that in general, price differences are much wider. Figure 17.9 is a scatterplot of the (log) relative dollar price of country's Big Mac (compared to an American Big Mac) against the relative per capita income. The United States is at (0, 0), since everything is compared to the U.S. If all Big Macs were equally priced across countries, then all the observations would lie along the horizontal straight line at 0.

[11] After Balassa (1964) and Samuelson (1964)

[12] In principle, anything that shifts the relative price of nontradables -- rising government spending or a changing preferences for services – will affect the real exchange rate.

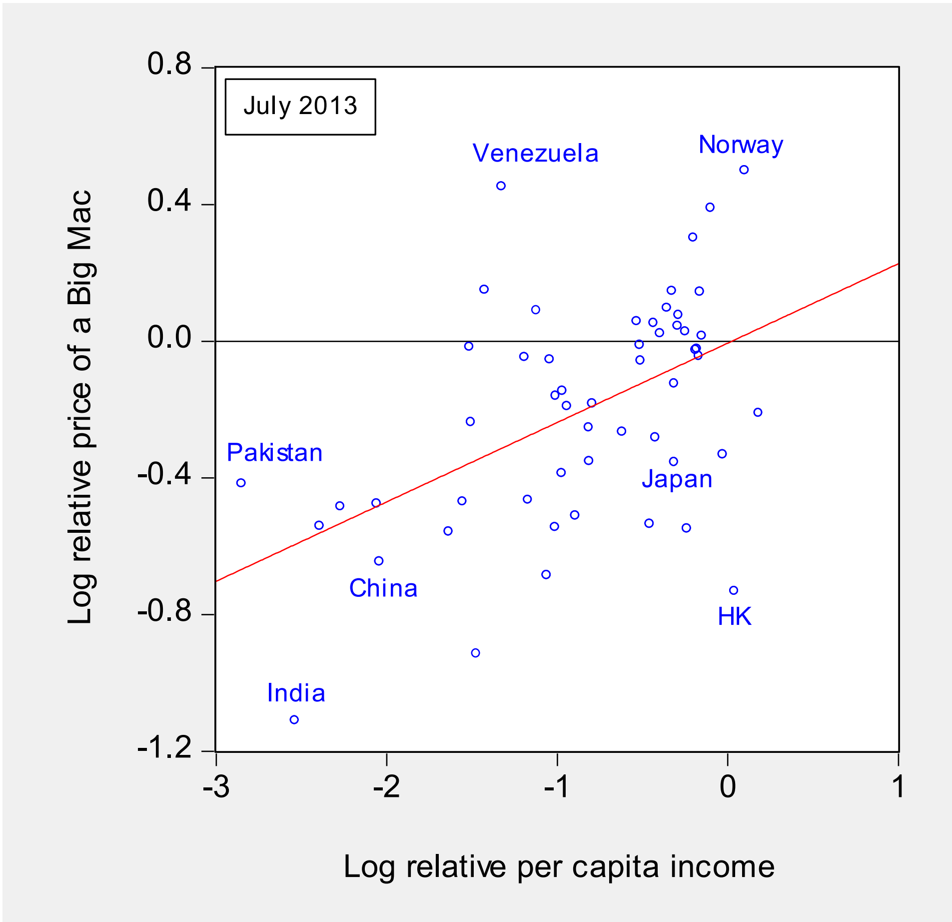



**Figure 17.10:** Log dollar price of a Big Mac in indicated country relative to that in the United States versus log per capita income relative to the United States (in PPP terms). The red line is a regression fit. Source*: The Economist* and IMF, *World Economic Outlook* database (April 2013).

Contrary to the predictions of purchasing power parity, not only is there substantial dispersion in the relative prices of Big Macs across countries, there also seems to be a pattern in the deviations from purchasing power parity. The higher per capita income is, relative to the U.S., the higher the price of a Big Mac. A regression using the 2013 data (the red line) indicates that for each percentage point increase in relative income, Big Mac prices go up a quarter of a percentage point. This is a manifestation of what is called the **Penn Effect.**[13] The same

[13] The pattern shows up in a data set compiled by economists at the University of Pennsylvania. The "Penn World

pattern shows up if one broadens the scope of observation to include years 1987 through 2013. In other words, the pattern is not a fluke.

Why doesn't arbitrage drive Big Mac prices together? And why do Big Mac prices rise with income?

There are several answers to the first question. One is the factor discussed in Section 17.5, namely sticky prices: firms do not adjust prices instantaneously. Another is that Big Macs, being highly perishable, are not tradable internationally, and so arbitrage pressure on prices is limited. (At the same time, some of the *components* of a Big Mac – flour, beef, tomatoes – are traded.)

Neither of these explanations addresses the second question: why does the long-term relationship between relative Big Mac prices and relative per capita income hold? Here, it matters that labor costs account for a relatively large share of the costs of production. Labor is essentially not traded across borders. Furthermore, wage rates in-high income countries are higher than those prevailing in low-income countries. So when next you travel to either South Asia or to Northern Europe, don't be surprised if the price of a Big Mac, converted into dollars by the exchange rate, differs from the dollar price you remember from your experience in the U.S.

One of the practical implications of this pattern is that it provides a concrete definition of undervaluation or overvaluation, i.e., **misalignment**. For instance, China, which has long been criticized for manipulating its currency to keep it undervalued, looks very guilty indeed, according to the PPP criterion – to the tune of something like 70%. But taking into account the Penn Effect, the undervaluation in 2013 was less than 20%.[14]

## 17.8 Conclusion

The nominal exchange rate is the relative price of currencies, so it is natural to think of the

Tables" contain consistent measures of price levels, calculated in principle using common baskets, as well as real income calculated using these measures of price levels. See Summers and Heston (1991).

[14] For a more extensive analysis of Chinese yuan misalignment, see Cheung, Chinn and Fujii (2009).

determinants as being the relative supplies and demands for money. The insight that the exchange rate is an asset price is useful, because it highlights the fact that expectations about the future will determine the price today. Partly because expectations fluctuate more than the underlying variables, exchange rates are more variable than the fundamentals (money, income).

In the flexible price monetary model, increases in the home money supply lead to depreciation of the home currency, while increases in income (which increases the demand for money) lead to appreciation. Higher interest rates are associated with a weaker currency. This is because under flexible prices, a higher interest rate is associated with a higher inflation rate, i.e., a depreciation of the currency against a bundle of real goods.

Under the more realistic assumption that prices are sticky in the short run, higher real interest rates are associated with an appreciated currency. This more realistic model relies upon the idea that in response to any monetary shock, the exchange rate overshoots its long-run value as the exchange rate has to take on a greater share of the role of adjustment, since prices are fixed in the very short run. Furthermore, this means the exchange rate reverts to the long-run value in response to any deviation.

Purchasing power parity – the proposition that prices of bundles of goods and services denominated in a common currency are equalized – underpins both models of the nominal exchange rate. Prices are equalized continuously in the flexible price model, and in the long run in the sticky price model.

In explaining longer-term movements in the real, or inflation-adjusted, exchange rate, the assumption of purchasing power parity is relaxed. It now only applies to traded goods, while the relative price of nontraded to traded goods then determines the price of nontraded goods. That relative price is driven by the relative levels of productivity in the two sectors. This means that over time, countries that experience more rapid productivity growth in the traded sector than the nontraded, compared to other countries, will have currencies that appreciate in real terms over time. This model provides an explanation for why the Japanese yen appreciated rapidly over the post-World War II period, up to 1990.

## CHAPTER REVIEW

### SUMMARY

1. Purchasing power parity is a condition wherein price levels expressed in a common currency are equalized.

2. Changes in expectations about the future values of the fundamentals will affect the exchange rate today, even when the fundamentals don't change today.

3. In a monetary model of exchange rates, increases in money supply depreciate the currency, while higher income (which increases demand for money) appreciates the currency.

4. When prices are perfectly flexible, higher interest rates are due to higher expected inflation rates; hence higher interest rates depreciate the currency.

5. When prices are sticky, a higher real interest differential appreciates the currency.

6. In the long run, purchasing power parity may not hold, if some goods are nontraded.

7. One determinant of the relative price of nontraded to traded goods prices is the productivity differential between the nontraded and traded sectors.

8. The Balassa-Samuelson effect is result of higher traded sector productivity resulting in stronger currencies.

9. The Penn effect is the long-term positive association between currency strength and per capita income.

**KEY CONCEPTS**

Balassa-Samuelson effect

Law of One Price

magnification effect

misalignment

monetary approach

monetary fundamentals

nontradable good

overshooting model

Penn effect

purchasing power parity

random walk

rate of reversion

real interest differential tradable good

**REVIEW QUESTIONS**

1 If purchasing power parity always holds, and the foreign price level suddenly rises by 2 percent, while the home price level stays constant, what must happen to the exchange rate?

2. In the monetary model, demand for money relative to the supply of money in the home country relative to the foreign determines the exchange rate.

3. The implication that a high interest rate – relative to that in the foreign country – results in a weaker currency is due to the approach of treating the exchange rate as a function of stocks of money in the two countries.

4. True and False. The expected pace at which the monetary fundamentals grow relative to the foreign country only determines the pace at the currency depreciates.

5. If prices are sticky, then will purchasing power parity hold at all times? If not, when?

6. Does purchasing power parity hold in the long run for all countries?

7. Are all goods tradable?

8. If haircut cutting technology starts improving faster than manufacturing technology (all relative to the foreign country), what will happen to the real exchange rate.

**EXERCISES**

**1.** Consider the flexible price monetary model.

a. Using Equation (17.7), show what happens if overnight the markets re-set their expectations of the dollar/euro exchange rate one year from now to be higher by 10%? What do you expect to happen to the dollar/euro exchange rate today, assuming nothing else changes? Assume $\lambda = 5$.

b. Using Equation (17.8), show what happens if overnight the expected monetary fundamentals for $t + 3$ are increased by 10% (and nothing else changes)? What happens to the exchange rate overnight? Assume $\lambda = 5$.

**2.** In the flexible price monetary model of exchange rates, where the semi-elasticity of money demand is 5, consider the following events.

a. If the money supply increases by 5% today, and in all future periods stays 5% higher than it was expected to be, what happens *quantitatively* to the nominal exchange rate and nominal interest rate today, and into the future?

b. Suppose the fundamentals are initially expected to grow by 0% per annum. Suppose the expected growth rate increases to 5%. Show graphically what happens to the exchange rate, if anything, the instant the expected growth rate changes?

**3.** In the sticky price monetary model of exchange rates,

a. Explain what happens if the monetary authority in U.S. decreases the money supply by 5 percent? In your answer, indicate the time paths of $M$, $P$, $M/P$, $r - r^*$, $s$. Use graphs.

b. Suppose $\theta$ is effectively infinite. Redo part a.

**4.** Suppose South Korean productivity growth in manufacturing exceeds that in services by 10%, but U.S. productivity in manufacturing and services are growing equally fast. Further suppose the share of nontraded goods (services here) is 60%. How fast should the Korean real exchange rate appreciate against the U.S. dollar, on average?

**5.** Using the "Trade, exchange rates, budget balances and interest rates" Table in the *Economist*, http://www.economist.com/, answer the following questions. (Be sure to specify which issue you use.)

a. Given the inflation rates over the past year, what should have been the rate of change in the U.S. dollar/euro exchange rate, if relative purchasing power parity (in growth rates) held?

b. Interpret the most recent *Economist* poll of the expected inflation rate for the current year as the expected change from December last year to December this year. What is the expected change in the U.S. dollar/euro over that period if relative PPP holds?

**6.** Download the latest available data from https://github.com/TheEconomist/big-mac-data. It contains data on Big Mac prices. Column D is the price in local currency, column E is the exchange rate expressed as local currency per USD, and column F is the local currency price expressed in USD. Column H is per capita GDP in US dollar terms (assume this is a good proxy for per capita GDP in PPP terms)

a. Calculate the percent misalignment (in log terms) for China, Venezuela, Switzerland, Argentina, using purchasing power parity, taking the U.S. as benchmark.

b. Calculate the percent misalignment (in log terms) for China, Venezuela, Switzerland, Argentina, using the Penn effect, taking the U.S. as benchmark. In order to estimate this, run a regression:

$$p_i = \alpha + \beta y_i + u_i$$

where $p_i$ is the log of the dollar price of a Big Mac in country $i$ divided the dollar price of a Big Mac in the U.S., and $y_i$ is the log of country $i$ per capita income divided by U.S. per capita income. The misalignments are then the residuals from the regression.

## WORKED EXERCISE

**1.** Consider the flexible price monetary model.

a. Using Equation (17.7), show what happens if overnight the markets re-set their expectations of the dollar/euro exchange rate one year from now to be higher by 10%? What do you expect to happen to the dollar/euro exchange rate today, assuming nothing else changes? Assume $\lambda = 5$.

Recall that the expression for the exchange rate is given by:

$$s_t = \left(\frac{1}{1+\lambda}\right)\sum_{\tau=0}^{\infty}\left(\frac{\lambda}{1+\lambda}\right)^{\tau} E_t\widetilde{M}_{t+\tau}$$

where $s_t$ is the log exchange rate, and $\widetilde{M}_t$ is the log fundamentals.

Assume to begin with that $E_t\widetilde{M}_{t+i} = 1$ for all $i$.

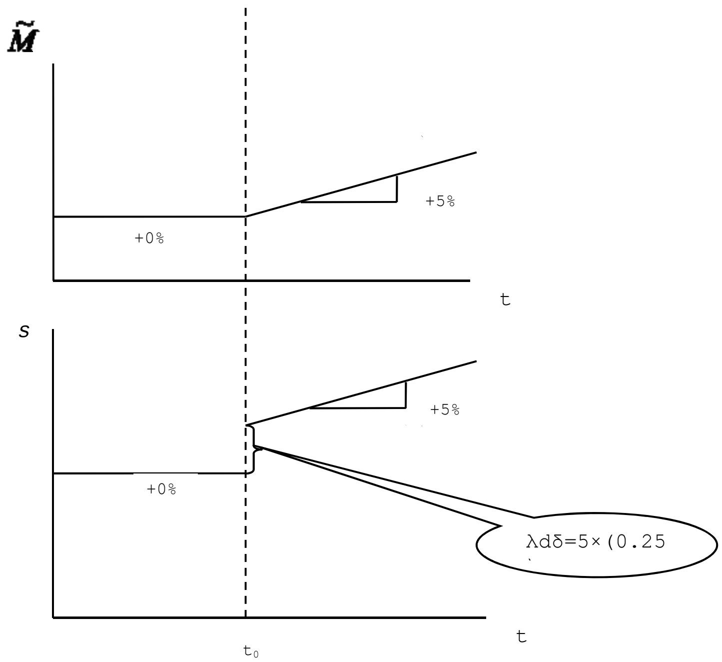
$$s_t = \left(\frac{1}{1+\lambda}\right)[1 + z + z^2 + z^3 + \ldots] \text{ where } \left(\frac{\lambda}{1+\lambda}\right) \equiv z$$

Since the term in the square brackets is equal to 1/(1 – z), then the above equation becomes:

$$s_t = \left(\frac{1}{1+\lambda}\right)\left[\frac{1}{1-z}\right] = \left(\frac{1}{1+\lambda}\right)\left[\frac{1}{1-\left(\frac{\lambda}{1+\lambda}\right)}\right] = \left(\frac{1}{1+\lambda}\right)(1+\lambda) = 1$$

So the exchange rate would be 1. Now increase all $E_t\widetilde{M}_{t+i} = 1.05$ . Then the current exchange rate would immediately jump higher by 5%.

b. Using Equation (17.8), show what happens if overnight the expected monetary fundamentals for $t + 3$ are increased by 10% (and nothing else changes)? What happens to the exchange rate overnight? Assume $\lambda = 5$.




## REFERENCES


Alquist, Ron and Menzie Chinn, "Conventional and Unconventional Approaches to Exchange Rate Modeling and Assessment," *International Journal of Finance and Economics* 13 (2008): 2–13.

Balassa, Bela, 1964, "The Purchasing Power Parity Doctrine: A Reappraisal," *Journal of Political Economy* 72: 584–596.

Cerra, Valerie and Sweta Chaman Saxena, "The monetary model strikes back: Evidence from the world," *Journal of International Economics* 81(2) (2010): 184–196.

Cheung, Yin-Wong, Menzie Chinn and Eiji Fujii, 2009, "Pitfalls in Measuring Exchange Rate Misalignment: The Yuan and Other Currencies," *Open Economies Review* 20(2): 183–206.

Cheung, Yin-Wong, Menzie D. Chinn, Antonio Garcia Pascual, and Yi Zhang, 2018, "Exchange rate prediction redux: new models, new data, new currencies*," Journal of International Money and Finance* (2018).Chinn, Menzie, "The Usual Suspects? Productivity and Demand Shocks and Asia-Pacific Real Exchange Rates," *Review of International Economics* 8(1) (February 2000): 20–43.

Dornbusch, Rudiger, 1976, "Expectations and Exchange Rate Dynamics," *Journal of Political Economy* 84(6): 1161–1176.

Frankel, Jeffrey A., 1979, "On the Mark: A Theory of Floating Exchange Rates based on Real Interest Differentials," *American Economic Review* 69(4): 610–622.

Hanke, Steve H., and Alex KF Kwok, 2009, "On the measurement of Zimbabwe's hyperinflation," *Cato Journal* 29: 353.

Mark, Nelson C., 1995, "Exchange Rates and Fundamentals: Evidence on Long-horizon Predictability," *The American Economic Review* 85(1): 201–218.

Meese, Richard A., and Kenneth Rogoff, 1983, "Empirical Exchange Rate Models of the Seventies: Do They Fit Out of Sample?" *Journal of International Economics* 14(1–2): 3–24.

Nakamura, Emi and Jon Steinsson, "Price Rigidity: Microeconomic Evidence and Macroeconomic Implications," *NBER Working Paper* No. 18705 (January).

Samuelson, Paul, 1964, "Theoretical Notes on Trade Problems," *Review of Economics and Statistics* 46: 145–154.

Summers, Robert, and Alan Heston, 1991, "The Penn World Table (Mark 5): an expanded set of international comparisons, 1950–1988," *The Quarterly Journal of Economics* 106(2): 327–368.

**Appendix**

To obtain Equation (17.14), we assume that the flexible-price monetary model holds in the long run:

(17.12) $$\tilde{s}_t = (\widetilde{m}_t - \widetilde{m}_t^*) - \phi(\tilde{y}_t - \tilde{y}_t^*) + \lambda(\tilde{\pi}_t - \tilde{\pi}_t^*)$$

We also assume the overshoot description of the short-term evolution of the exchange rate:

(17.13) $$\Delta s_{t+1} \equiv s_{t+1} - s_t = -\theta(s_t - \tilde{s}_t) + (\tilde{\pi}_t - \tilde{\pi}_t^*)$$

If, further, we assume rational expectations, so that people's beliefs about future exchange rates conform to Equation (17.11), then we can replace $s_{t+1}$ with $s_{t+1}^e$:

(17.A1) $$s_{t+1}^e - s_t \equiv -\theta(s_t - \tilde{s}_t) + (\tilde{\pi}_t - \tilde{\pi}_t^*)$$

We use the uncovered interest parity condition, $i_t - i_t^* = s_{t+1}^e - s_t$, to substitute on the left-hand side:

(17.A2) $$i_t - i_t^* = -\theta(s_t - \tilde{s}_t) + (\tilde{\pi}_t - \tilde{\pi}_t^*)$$

Solving for the exchange rate,

(17.A3) $$s_t = \tilde{s}_t - \left(\frac{1}{\theta}\right)[(i_t - \tilde{\pi}_t) - (i_t^* - \tilde{\pi}_t^*)]$$

Substituting the right side of Equation (17.10) in for $\widetilde{s_t}$,

(17.A4)
$$s_t = (\widetilde{m}_t - \widetilde{m}_t^*) - \varphi(\tilde{y}_t - \tilde{y}_t^*) + \lambda(\tilde{\pi}_t - \tilde{\pi}_t^*) - \left(\frac{1}{\theta}\right)[(i_t - \tilde{\pi}_t) - (i_t^* - \tilde{\pi}_t^*)]$$

We can eliminate the tildes if we assume random-walk behavior for *m*, *y*, and *π*, so that their present actual values are the best estimates of their long-term average values. Thus,

(17.A5)

$$s_t = (m_t - m_t^*) - \varphi(y_t - y_t^*) + \lambda(\pi_t - \pi_t^*) - \left(\frac{1}{\theta}\right)[(i_t - \pi_t) - (i_t^* - \pi_t^*)]$$

Combining like terms gives the desired result:

(17.14) $$s_t = (m_t - m_t^*) - \varphi(y_t - y_t^*) - \left(\frac{1}{\theta}\right)(i_t - i_t^*) + \left(\lambda + \frac{1}{\theta}\right)(\pi_t - \pi_t^*)$$