DORNBUSCH'S OVERSHOOTING MODEL: A REVIEW

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Dornbusch's influential Overshooting Model aims to explain why floating exchange rates have such a high variance. Christoph Walsh provides an extremely well researched account of the model in detail, while examining the empirical evidence for uncovered interest rate parity and purchasing power parity.

Introduction

Dornbusch's (1976) overshooting model was path-breaking, used not only to describe exchange rate overshooting but also the 'Dutch disease', exchange rate regime choice and commodity price volatility. Dornbusch's model was highly influential because, at the time of writing, the world had only recently switched from the Bretton Woods system to flexible exchange rates and very little was understood of them and their volatility. In a study on graduate courses in international finance, Dornbusch's article was the only article to make it on to more than half of the reading lists – and it made it on to every one (Rogoff, 2002)!

The first section of this essay will describe Dornbusch's model in detail. The second section will then give empirical evidence on the two main assumptions of the Dornbusch model: UIP and long-run PPP, and will review the findings for and against the Dornbusch model in general.

The Model

Dornbusch's model makes the following assumptions:

Uncovered interest-rate parity (UIP) states that the interest rate differential is equal to the expected change in the spot rate: $i_t - i_t^* = E_t\left[\Delta s_{t+1}\right]$, *where* i_t *and* i_t**are the domestic and foreign interest rates at time t respectively and* $E_t[\Delta s_{t+1}]$ *is the expected change in the logarithm of the exchange rate*[1]. The model assumes that UIP holds at all times.

Note that in the following a rise in S_t is denoted as a depreciation of the exchange and a fall in S_t is an appreciation.

1 Referenced with permission.

UIP assumes that capital is perfectly mobile, investors are risk neutral and domestic and foreign assets are perfect substitutes. The model assumes that the capital market adjusts instantaneously to shocks and that investors have rational expectations (Arnold, 2009).

Absolute purchasing power parity (PPP) states that a basket of goods, when expressed in a common currency, should have the same cost across countries. PPP states that the real exchange rate, defined by $Q_t = S_t P_t^*/P_t$ is equal to unity, *where S_t is the spot rate and P_t and P_t^* are the domestic and foreign price levels respectively at time t.* Setting $Q_t = 1$ gives: $P_t = SP_t^*$. The price levels, expressed in a common currency, are equal (Pilbeam, 2006).

The model assumes that deviations from PPP are permitted in the short run, but the exchange rate will return to PPP in the long run (Arnold, 2009). In the short run, the real exchange rate can rise which increases the competitiveness of the economy and increases net exports (Frankel, 1979).

The assumption of long-run PPP is made because prices are 'sticky' in the short run due to nominal and real rigidities as in Keynesian theory (Romer, 2006). A main feature of the model is that it allows a distinction between sluggishly-adjusting goods markets and hyperactive asset markets (Rogoff, 2002).

The money market is in equilibrium when real money supply equals real money demand where real money demand is a rising function of output and a falling function of the interest rate: $M_s^t/P_t = L(Y_t, i_t)$ (Arnold, 2009).

Output is given by the standard IS curve, which is rising in the real exchange rate and falling in the interest rate (Copeland, 2008).

The inflation rate is a function of the output gap, given by the Phillips curve: $\Delta P_{t+1} = \psi(y_t - \text{ybar})$ *where Δp_{t+1} is the change in the logarithm of the price level, y_t and ybar* are the logarithms of output and potential output respectively and ψ is a measure of the price flexibility in the economy (Copeland, 2008).

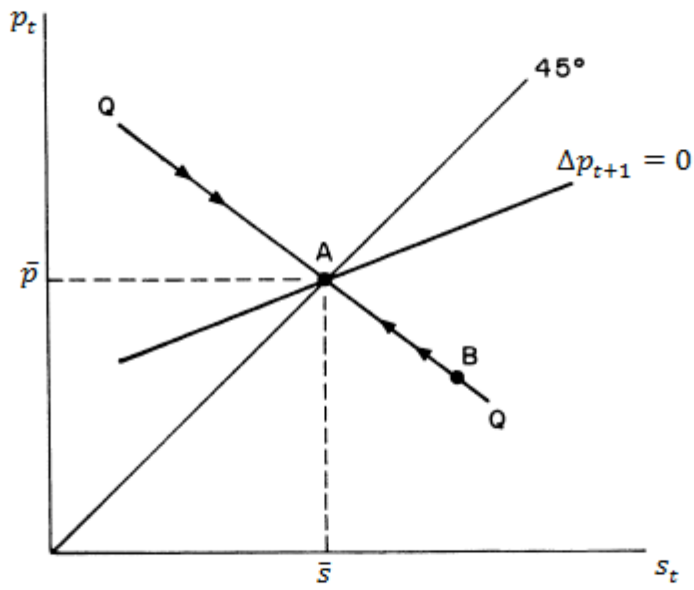
The economy under scrutiny is a small open economy so that it cannot affect foreign interest rates, prices and output.

The economy begins at a stationary state where:

(i) output is at potential,
(ii) PPP holds,
(iii) domestic and foreign interest rates are equal,
(iv) prices are constant, and
(v) the exchange rate is at its equilibrium level.

The stationary state, (Sbar, Pbar) is shown by point A in the Figure 1 below.

Figure 1



(Dornbusch, 1976)

The 45° line represents equilibrium PPP. Below the line, the economy is more competitive and net exports will rise. Above the line, the opposite is true.

The $\Delta p_{t+1} = 0$ line is the goods market when output is at potential. Below the line output is above potential and there is an upward pressure on prices (Pilbeam, 2006).

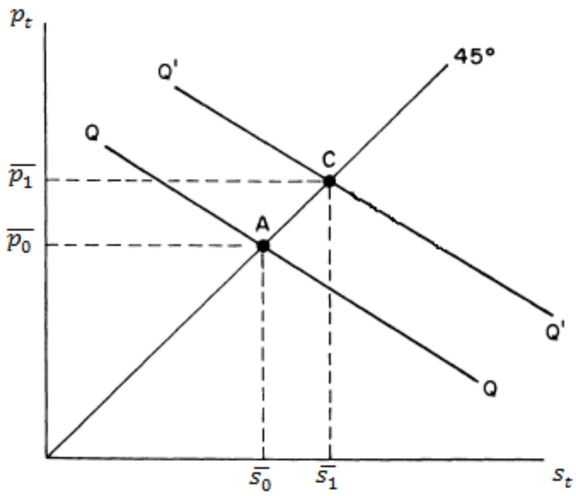
The QQ schedule combines money market equilibrium and UIP. At point A, the money market is clear, UIP holds and the domestic and foreign interest rates are equal. As the money market clears instantly and UIP holds at all times, the economy must be on the QQ schedule at all times. Point A is the model's stationary state (Dornbusch, 1976).

The model analyses the dynamics of the economy after an unanticipated rise in the money supply. It is convenient to first analyse what will happen in the long run after the change in money supply before studying the short-run dynamics.

The Long Run

By the quantity theory of money, a 1% rise in the money supply leads to a 1% rise in the price level. All else constant, a 1% rise in the price level must be matched by a 1% depreciation in the exchange rate to maintain PPP. This is as in the monetary model (Rosenberg, 1996). The rise in the money supply is given by a shift of the QQ schedule to Q'Q'. The new stationary state, is given by point C in Figure 2.

Figure 2

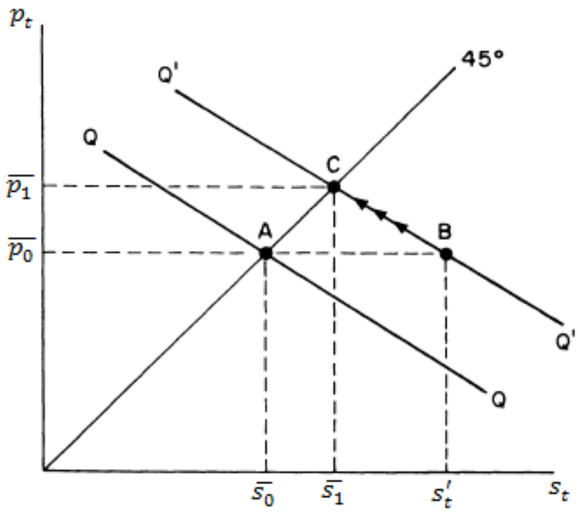


(Dornbusch, 1976)

The Short Run

After the increase in money supply, the money market is in disequilibrium. The interest rate falls by the liquidity effect to increase money demand. As $i_t < i_t$* foreign assets have become more attractive to investors. By UIP, individuals will only invest in domestic assets if they expect an appreciation in the exchange rate. But in the long run, as shown above, the exchange rate must depreciate overall. The exchange rate must therefore depreciate so much after the shock that it 'overshoots' its long-run equilibrium level and appreciate thereafter. The exchange rate jumps to point B in Figure 3.

Figure 3

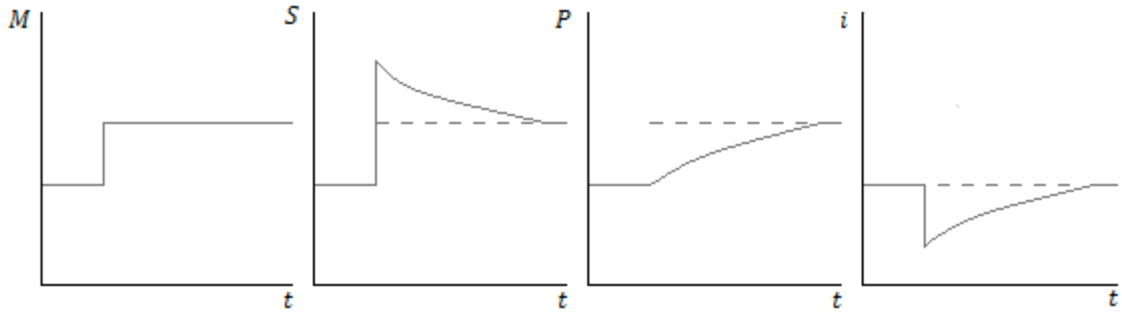


(Dornbusch, 1976)

Because of a rise in the real exchange rate and a fall in the interest rate, output is above potential. By the Phillip's curve, this gives an upward pressure on prices. The gradual appreciation of the exchange rate and inflation will lower the economy's competitiveness until it reaches the new stationary state C in Figure 3. Also, the fall in real money balances (due to the rising price level) will raise the interest rate back to its original level of $i_t = i_t*$ so there are no more expected changes in the exchange rate (Copeland, 2008; Dornbusch, 1976).

The time paths of the money supply, the exchange rate, the price level and the domestic interest rate are shown below in Figure 4.

Figure 4



The extent of the overshoot depends on the interest-sensitivity of the demand for money and how sensitive the market is about over-valuations and under-valuations of the currency (Dornbusch, 1976; Copeland 2008).

Wilson (1979) analyses the case where the money supply shock is anticipated, rather than unanticipated in Dornbusch (1976). He demonstrates that the announcement or expectation of an expansionary policy alone will cause the exchange rate to jump – even before the policy is implemented.

Empirical Evidence

Evidence on UIP: Fama's beta coefficient, β, describes the relationship between the percentage change in the spot rate and the one period lagged value of the interest rate differential between two countries (Davis, Miller and Prodan, 2009): $\Delta S_t = \beta(i_{t-1} - i^*_{t-1})$

Using OLS, β would be expected to equal plus unity, which would be consistent with UIP. However, empirical tests usually generate negative β coefficients. Froot and Thaler (1990) found that in over 75 published estimates, the average value was -0.88. Some estimates were positive but not one was equal to or greater than plus unity. This is called the *UIP puzzle*. These findings undermine the credibility of the Dornbusch model.

Fama (1984) suggests that there may be an omitted variable in the equation. If this is so, because of omitted variable bias, β will be biased away from plus unity. The omitted variable could be exchange rate prediction errors or a risk premium. UIP assumes risk-neutrality when in fact investors are generally risk averse and demand a risk premium.

UIP is tied to foreign exchange (FX) speculation in the carry trade. It is suggested that either the volume of carry trade is insufficient to generate UIP or that the risk premium associated with carry trade is very large. Excess returns from the carry trade are found to range from 5% to 6.5% (Davis, Miller and Prodan, 2009). Scholl and Uhlig (2008) measured the Sharpe ratio for speculating on violations of UIP and found that it lay between 1 and 1.5, showing large excess returns in the carry trade. Other suggestions are that there are significant transaction costs and shortages of liquidity in the carry trade which can lead to deviations from UIP. The puzzle may also exist due to central bank reaction functions, which create a simultaneous equation bias when estimating β (Davis, Miller and Prodan, 2009).

Evidence on PPP

Views on PPP have changed over time. Before the breakdown of Bretton Woods, economists clung to PPP's existence (Isard, 1995). In the first phase of research on PPP in the 1970s and 1980s, the emerging consensus was that the real exchange rate followed a random walk, even in the long run, thus denying the existence of PPP. Over the past decade however, more advanced econometric methods have given new findings on PPP (Copeland, 2008). The main consensus now is that long-run PPP has some validity and holds better than in the short run (Sarno and Taylor, 2002). For example, Lothian (1997) used panel data of 23 OECD countries over 1974-91 and found that, although there were large and prolonged deviations from PPP in the short run, he couldn't reject it over the long run of 3 to 6 years. This supports the assumption of PPP in the Dornbusch model.

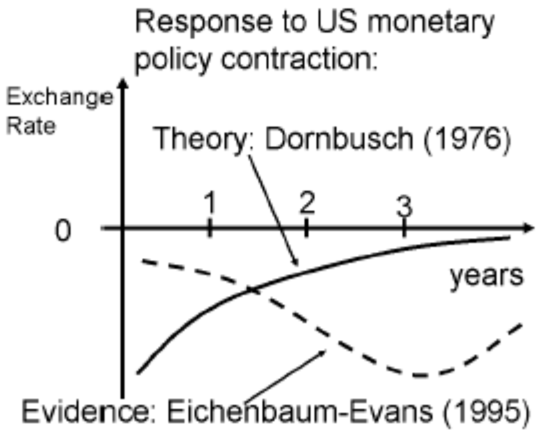
However, much of the other evidence on PPP is disenchanting. The *PPP puzzle* is that the real exchange rate does not equal unity across countries (Rogoff, 1996). Rogoff (1996) explains this by noting that exchange rates are highly volatile and the prices of goods are rigid. A deviation of the real exchange rate from unity has a half-life of 3-5 years. For example, if the real exchange rate jumped from 1 to 1.5, it would take 3-5 years for it to return to 1.25. Rogoff (1996) identifies the frictions in the goods market as transport costs, information costs, tariffs and the lack of labour mobility. Other reasons identified for the poor performance of PPP are imperfect competition, statistical problems in measurement, productivity differentials and home bias in trade (Arnold, 2009; Obstfeld and Rogoff, 2000; Pilbeam, 2006).

Evidence on the Dornbusch Model

Eichenbaum and Evans (1995) find that in studying the US economy in the period 1974-1990 with a value at risk (VAR) based identification scheme, contractionary monetary policy shocks are followed by a sharp rise in interest rates and lead to persistent, significant appreciations in the nominal and real exchange rate. The maximal effect of the shocks was not contemporaneous – the dollar continued to appreciate for a substantial period of time. This is inconsistent with the Dornbusch model which predicts that the exchange rate jumps instantaneously. This is called the *delayed overshooting puzzle*. They also found significant and persistent deviations from UIP: the returns on higher US interest rates were magnified by the future expected appreciations in the dollar.

Figure 5 below shows the differences in the time path of the exchange rate in Dornbusch's overshooting theory and evidence found by Eichenbaum and Evans (1995) which shows 'delayed overshooting'.

Figure 5



(Scholl and Uhlig, 2008)

Heinlein and Krolzig (2010) studied the *delayed overshooting puzzle* in the $/£ exchange rate using VAR over 1972-2009. They found strong evidence of delayed overshooting and a violation of UIP as a result of excess returns due to delayed overshooting. Exchange rate jumps after monetary shocks are only significant at 10% and, with 95% certainty, the jumps are not large enough for UIP to hold.

Scholl and Uhlig (2008) also investigated the *delayed overshooting puzzle* for the non-US G-7 countries over 1977-2001. They use a VAR procedure, imposing sign restrictions on the impulse responses for key monetary variables, for example, by assuming contractionary monetary policy shocks do not lead to decreases in domestic short-term interest rates. This narrowed down the range of possible shocks considerably. They find that after a monetary contraction, there is a persistent appreciation for periods of up to three years, thus finding robust evidence of delayed overshooting.

Bjørnland (2009) criticises the findings of Scholl and Uhlig (2008). He argues that they disregard the strong contemporaneous interaction between monetary policy and exchange rate movements and notes that they place zero restrictions on them. He finds that, after imposing a long-run neutrality restriction on the real exchange rate (long-run PPP), the puzzle disappears. The maximal impact of overshooting occurs in the first two quarters and his findings are also consistent with UIP. He made a study on four small open economies: Australia, Canada, New Zealand and Sweden over the period 1983-2004. He only used data from periods with less volatility and shocks and where the economy was open.

Pippenger[1] (2009) finds that evidence of overshooting in the literature inspired by Eichenbaum and Evans (1995), such as Scholl and Uhlig (2008), is flawed. Eichenbaum and Evans (1995) did not claim to find 'delayed overshooting', as is widely interpreted. Rather, their impulse response functions suggest a gradual response to monetary shocks or 'undershooting'. The problem with the impulse response functions in the literature is that they describe impulse responses to 'innovations' in a variable rather than the variable itself. His findings are that since in the absence of intervention, exchange rates are essentially martingales (which is consistent with efficient FX markets), it does not seem appropriate to interpret the impulse response functions in the literature as clear evidence of overshooting.

Voss and Willard (2009) studied the US and Australia with a structural VAR model over the period 1984-2007. They examined the behaviour of the Australian exchange rate with monetary policy. They find that Australian monetary policy innovations give rise to an exchange rate response as expected under the Dornbusch model; the exchange rate changed immediately and slowly returned to its equilibrium level. They also did not observe significant deviations from UIP during the adjustment. They found, however, that changes in the US interest rate have no significant effect on the exchange rate and significant deviations from UIP were found. This is because Australian interest rates moved in tandem with US interest rates, perhaps because Australia is a small open economy while the US is not.

Frenkel (1976) examined the determinants of the exchange rate during the German hyperinflation of 1922-1923. The disturbances during this period were clearly monetary and dominate any other disturbances, thus it is possible to examine the effect of monetary variables in virtually complete isolation. He regressed the rate of change of the exchange rate against current and lagged values of the rates of change of the money supply. He found the elasticity of the exchange rate with respect to the money supply exceeded unity (1.57); this magnification effect of money on the exchange rate is consistent with overshooting. However, that the model fits in an environment of

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hyperinflation does not imply it will fit in an environment of stable prices. In a hyperinflation, the liquidity effect tends to break down and the Fisher effect dominates, even in the very short run.

Meese and Rogoff (1983) found that a random walk model performs as well as any estimated exchange rate model. The Dornbusch model was one of the models tested. They made out-of-sample forecasts with OLS over one-month, three-month, six-month and twelve-month periods for various currency pairs, using GLS, instrumental variables and lag specifications where appropriate. Rolling regressions were used to update the parameters each period. They compared the models using root mean squared error (RMSE). None of the models achieved a significantly lower RMSE than the random walk model at any horizon, even though forecasts were based on actual realised values of explanatory variables. Different estimations using first differences, GLS, corrections for serial correlation or different proxies for money supply and expected inflation didn't give significantly better results. They give possible reasons for the poor out-of-sample fit as sampling errors, stochastic movements in the true underlying parameters, misspecifications, OVB, or possible non-linearities.

Meese and Rogoff (1988) found that the hypothesis of 'real shocks' in technology like those in real business cycle theory are more consistent in their findings in explaining exchange rate volatility than monetary shocks as in the Dornbusch model.

Conclusion

While Dornbusch's model is highly elegant (Rogoff, 2002) the empirical evidence on the model is mixed. While there is some evidence of long-run PPP, UIP is rejected by most academics. Academics' empirical results on the model range from overshooting, delayed overshooting, undershooting to no overshooting whatsoever. So while being a highly influential model, it does not serve to give accurate forecasts of exchange rate movements.

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