Open Economy Macroeconomics, Aalto University SB, Spring ~~2017~~ 2019

Sticky Prices: The Dornbusch Model

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~~08.03.2017~~
13.03.2019

The failure of the monetary model

- The simple monetary model is incapable of explaining basic facts on international prices
  - PPP is the critical assumption
- Observed exchange rate volatility far greater than the simple model implies
- The Mundell-Fleming model, by assuming fixed or sticky prices, is relevant for the very shortest horizons
- Dornbusch's model, introduced in 1976, is a hybrid
  - short-run price stickiness $\longrightarrow$ Keynesian features
  - long-run characteristics like in the monetary model
- Key idea: differential adjustment speed in goods and financial markets
  - goods markets: slow
  - financial markets: fast

The overshooting model

- Implication: the burden of short-run adjustment falls on financial markets which **overreact** to different shocks, monetary shocks in particular
  - financial markets **overshoot** relative to long-run equilibrium
- Why? Price level initially fixed, a change in the *nominal* money stock is a change in the *real* money stock
  - an instantaneous change in the money demand has to result
  - only possible, if the interest rate changes appropriately, if, in particular, output is assumed fixed
- In the short-run, monetary policy changes have what is nowadays known as the *liquidity effect*
- Change in interest rates only temporary and the price level will start its delayed response
  - real money stock will starts to revert itself back to the original level driving interest rates, aggregate demand and the real exchange rate back to their original level

The overshooting model

- Hence, over the long-run all real variables have reverted back to their original values
  - a flavour from the monetary model!
- Change in the nominal exchange rate in the long-run equilibrium reflects the proportionate change in the nominal money supply
- We will next outline the overshooting model, with two conventions
  - focus on a small open economy $\longleftarrow$ takes intl prices and quantities as given, ie. does not affect them
  - comparative statics: we will start from an initial equilibrium position and consider what happens to the *level* of the exchange rate once we change the *level* of the money supply

The overshooting model: assumptions

- We need the following assumptions

1. Aggregate demand is determined by the standard IS-LM mechanism/model
2. Financial markets adjust instantaneously. In particular, investors are risk neutral, so that UIRP holds at all times

- Hence, perfect capital mobility ensures that expected depreciation/appreciation is just enough to offset any interest rate differential between the domestic and foreign economy

$$r - r^f = \Delta s^e$$

- But: how are expectations actually determined?
  - suppose there is a long-run equilibrium real exchange rate $\overline{Q}$ (and nominal exchange rate $\overline{S}$), which determined by the domestic money stock, national income and interest rates relative to those of the rest of the world (ROW), ie. by the monetary model

The overshooting model: assumptions

- Dornbusch model: Q in equilibrium only in the long-run, deviations in the short-run

- Dornbusch assumes that the expected rate of depreciation of the domestic currency $\frac{S^e - S}{S}$ is proportional to the percentage deviation of the actual exchange rate from its long-run equilibrium value $\overline{S}$, $\frac{\overline{S} - S}{S}$
- We can formalize this idea by saying that there is a positive parameter Θ such that

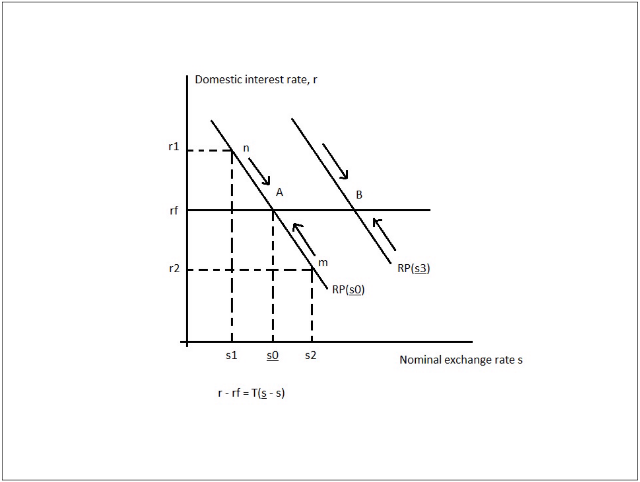
$$\frac{S^e - S}{S} = \Theta \left(\frac{\overline{S} - S}{S} \right)$$

- Since $\frac{X - Y}{Y} \approx \ln(1 + \frac{X - Y}{Y}) = \ln(X) - \ln(Y) = x - y$, we can rewrite the above as

$$\Delta s^e = \Theta \left(\overline{s} - s \right)$$

- We can represent this relationship graphically in the next figure (slope $-\Theta$)

The force of the UIP



Overshooting: adjustment

- Initially the economy is in point **A** with an exchange rate of $\underline{s0}$ and nominal interest rate at rf
- If the domestic interest rate falls to $r2$, continuous validity of the UIRP implies that the domestic currency is expected to appreciate
- Given Dornbusch's model for exchange rate expectations, this means that the value of the domestic currency (euro) is currently below its equilibrium value, ie. $S > \overline{S}$, so as to generate the expectation of a future euro appreciation
- Euro will appreciate towards its long run value as long as it is currently below the equilibrium value
- The arrows in the figure indicate the direction of adjustment that the exchange rate takes once off its long-run equilibrium
- The same analysis holds for any long-run equilibrium value of the domestic currency, eg. point **B**
- Note that the UIRP holds at any point along the **RP** line in the figure!

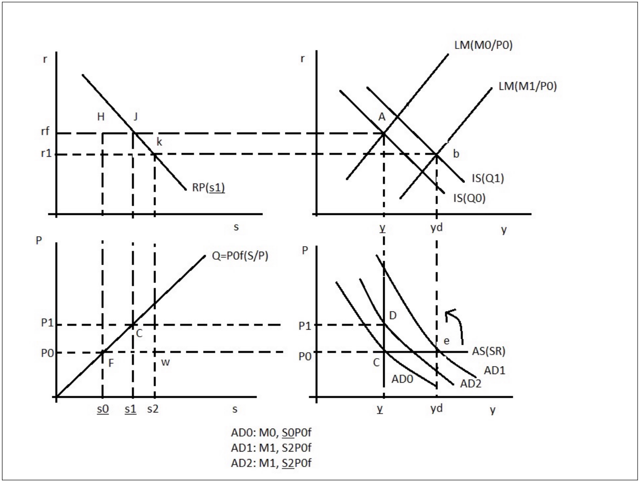
Goods market

- Deviations from the equilibrium exchange rate result from the following assumption

3. The price level is sticky. That is aggregate supply curve is flat in the immediate impact phase, increasingly steep in the adjustment phase and, ultimately, vertical in the long-run equilibrium

- In the long-run the exchange rate is at its equilibrium level, ie. the market clearing real value, given the domestic and foreign price levels
- In the short-run, the price level is fixed, so shocks move the nominal exchange rate and, hence, the real exchange rate
  - current account surpluses and deficits will follow
- With the passage of time and without any further shocks, the economy moves back to its long-run real exchange rate as a result of movements in both the nominal exchange rate and the price level
- Let us look at the next figure to see what the Dornbusch model implies

Overshooting in graphics



Long-run equilibrium

- In the figure:
  - top rhs figure is the IS-LM diagram, showing the determination of aggregate demand
  - top lhs figure is the RP diagram (initial S at $\underline{s0}$, the corresponding UIRP line not drawn)
  - bottom rhs figure AD-AS curves, AS for both long-run and short-run (AS(SR))
  - bottom lhs figure shows the PPP line and deviations from the PPP level
- **Long-run equilibrium:**
  - aggregate demand is equal to aggregate supply: no upward or downward pressure on the price level
  - domestic and foreign interest rates are equal: static exchange rate, no expected change
  - the real exchange rate is at its long-run level: no imbalances in the current account
  - satisfied at points A, C, F, H in the figure

Monetary expansion

- Suppose ECB decides to increase the domestic money supply from $M0$ to $M1$
- Long-run effects as in the monetary model: vertical long-run AS curve means that the price level has to increase as much as the money supply leaving the real money stock unchanged
  - for fixed government expenditure, the IS-curve will not shift if the real exchange rate returns back to its original level
- Short-run effects:
  - LM curves shifts down and to the right giving rise, at fixed real income, to an excess supply of domestic money
  - domestic interest would have to fall (to $r1$) to bring about the absorption of the temporarily higher real money stock (*liquidity effect)*
  - lower domestic interest rate, ie. negative interest rate differential induce expectations of a stronger domestic currency
    - domestic currecy depreciates immediately to generate these expectations
    - S immediately jumps to $s2$

Monetary expansion

- domestic and foreign price level fixed in the short-run, hence the real exchange rate weakens to $Q1$, boosting net exports and domestic demand $\rightarrow$ IS curve shifts up and to the right (point b)
- this increase in demand represents, given the flat short-run AS curve, also an increase in output produced
- with a given interest rate at $r1$ the temporary equilibrium is at point k in the top lhs figure
- subsequent adjustment takes place along the RP curve

- **But note that the short-run exchange rate S at $s2$ is above the long-run equilibrium level of $\underline{s1}$**
  - this is the essence of the Dornbusch model: after the monetary expansion, the domestic currency weakens more than its new long-run equilibrium value, ie. it overshoots its long-run equilibrium level

What is important?

- The extent of the overshoot depends on two factors:
  - *interest rate elasticity of money demand*; our formalism is

$$\frac{M}{P} = ky - lr$$
$$\frac{dr}{dy} = \frac{k}{l}$$

    so that a fall in the interest elasticity of money demand, l, will make the LM curve steeper and the greater will the fall in the interest rate have to be from any given increase in the real money stock
  - *the slope of the RP curve*; the flatter it is the more the exchange rate must overshoot its long-run equilibrium, for any given change in the interes rate
    - the slope of the RP line is determined by the expectations parameter Θ

$$r - r^f = \Theta\left(\bar{s} - s\right)$$
$$\frac{\partial r}{\partial s} = -\Theta$$

      so lower Θ implies larger overshooting

What is important?

- The intuition for the last result is that when Θ is small, a larger gap between the current exchange rate and the corresponding long-run level is required to generate any given interest rate differential
- If Θ falls to zero no interest rate differential would be possible, because no matter how large the gap between current and long-run equilibrium exchange rate, no expected currency appreciation would be generated by the gap
- Note that along the adjustment path to the long-run equilibrium in the Dornbusch model, rising interest rates coincides with an appreciating domestic currency, an implication often observed in actual data
- However, it should be noted that it is wrong to conclude from this that the rising domestic interest rate *causes* the domestic exchange rate to appreciate; rather, both phenomena result from the same cause, namely expansionary domestic monetary policy and the concomitant, albeit temporary, undervaluation of the domestic currency

Formal model

- Dornbusch's overshooting model can be represented formally as follows

$$
\begin{aligned}
r - r^f &= \Delta s^e \quad \text{(UIRP)} \\
\Delta s^e &= \Theta\left(\bar{s} - s\right) \quad \text{(S expectations)} \\
m - p &= k\bar{y} - lr \quad \text{(MM equilibrium)} \\
y^d &= h(s - p) = h(q), \;\; q = s - p \quad \text{(AD)} \\
\dot{p} &= \pi\left(y^d - \bar{y}\right) \quad \text{(Inflation adjustment)}
\end{aligned}
$$

Formal model

- where $\overline{y}$ is constant and

$$\dot{p} = \frac{d \ln p}{dt} \quad \text{(inflation rate)}$$

- Note that we have set the foreign price level to unity, $P^f = 1$, so that the log of it $\ln P^f = \ln 1 = 0$
- Note also that inflation responds to *excess demand* $y^d - \overline{y}$: inflation rate will increase if aggregate demand exceed aggregate long-run output
- This system can be reduced to two equations:

$$\begin{aligned} p &= \underbrace{m - k\overline{y} + lr^f}_{L} + l\Theta\left(\overline{s} - s\right) \\ &= L - l\Theta\left(s - \overline{s}\right) \\ \dot{p} &= \pi\left[h(s-p) - \overline{y}\right] \end{aligned}$$

that is one equation for the price level and another for the rate of inflation

Formal model: long-run equilibrium

- **Long-run equilibrium:** $y^d - \overline{y} = 0$, so the price level is stable, ie. rate of inflation is zero $\dot{p} = 0$
- Hence, from the inflation adjustment equation we have

$$h(\overline{s} - \overline{p}) - \overline{y} = 0 \Longleftrightarrow \overline{s} - \overline{p} = \overline{q} = \frac{\overline{y}}{h}$$

- There is strong implication here, reflecting the classical monetary aspects of the Dornbusch model: *in the long-run, only the (growth of the) capacity output will affect the real exchange rate; any change in the nominal exchange rate S is matched by a change in the price level*
- The expected rate of depreciation Δs^e is in the long-run zero, since S is in equilibrium; hence

$$\overline{p} = L = m - k\overline{y} + lr^f$$

hence in the long-run equilibrium the price level is equal to the ratio of the money stock to the level of demand when it is at its long-run level or when the domestic and foreign interest rates are equal

Formal model: long-run equilibrium

- Finally, the long-run equilbrium for the nominal exchange rate can be obtained by combining the two last equations

$$\bar{s} = \left(h^{-1} - k\right)\bar{y} + m + lr^{f}$$

- Now, all of our previous analysis is vindicated by the last two equations: an increase in the domestic money stock pushes up the long-run values of the domestic price level and exchange rate in the same proportion and hence leaves the real exchange rate and, by implication, aggregate output untouched
- **Short-run dynamics (disequilibrium)**: inflation adjustment can now, given the long-run solution, written conveniently as

$$\dot{p} = \pi h(q - \bar{q})$$

so that the larger deviations of the real exchange rate from its long-run equilibrium level will generate higher rates of inflation

Formal model: short-run dynamics (disequilibrium)

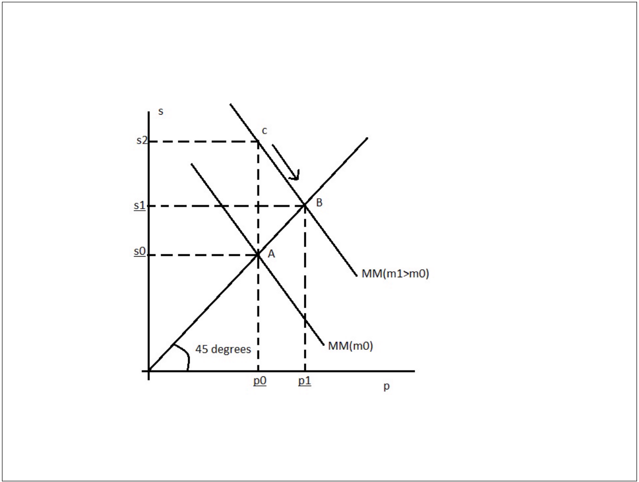
- Money market equilibrium implies, on the other hand, that deviations of the price level from its long-run level are given by

$$p - \overline{p} = -l\Theta \left(s - \overline{s} \right) \qquad \text{(SRMM)}$$

(Note! In Copelands book, ch 7 p. 207 the sign is not correct)

- This is a necessary condition for the *short-run* equilibrium in the money market
- Hence, the system adjust so as to preserve this relationship at all times, which means that the economy lies somewhere along a downward sloping line in the (p, s) -space (with slope $-\frac{1}{l\Theta}$)
- See next figure, where we have drawn the long-run condition $\dot{p} = 0$ together with (SRMM)

Formal model: Graphics



Formal model: Graphics

- Economy starts at $(\underline{p0}, \underline{s0})$, where the money supply is $m0$
- Money supply increases to $m1$: MM curve shifts out and to the right $(MM\,(m0)$ to $MM(m1))$
- Price level fixed, nominal exchange rate jumps from $\underline{s0}$ to $s2$
- Post jump convergence **along** the $MM(m1)$ curve from point C towards point B:
  - new long-run equilibrium $(\underline{p1}, \underline{s1})$: that is the change in the price level equals the change in the nominal exchange rate $dp = ds$ $(d = \Delta)$
- Short-run overshooting: size $s2 - \underline{s1}$
- Now, **perfect foresight** means expectations are fullfilled at any point in time: hence expected values equal realized values,ie

$$\begin{aligned} \Delta s^e &= \Delta s = \dot{s} \\ \Delta p^e &= \Delta p = \dot{p} \end{aligned}$$

Formal model: Perfect foresight

- We have

$$\begin{aligned} \dot{p} &= \pi h(q - \overline{q}) \\ &= \pi h(s - p - \overline{s} + \overline{p}) \\ &= \pi h(s - \overline{s} - (p - \overline{p})) \\ &= \pi h(1 + l\Theta)(s - \overline{s}) \end{aligned}$$

- On the other hand, money market equilibrium implies

$$\begin{aligned} p &= L - l\Theta\left(s - \overline{s}\right), \text{ ie} \\ \dot{p} &= -l\Theta\dot{s} = l\Theta^2\left(s - \overline{s}\right) \end{aligned}$$

Formal model: Perfect foresight

- So, along the perfect foresight path these two expressions for the inflation rate has to be consistent with each other: this can happen only if the the expectations parameter Θ satisfies

$$
\begin{aligned}
l\Theta^2 &= \pi h(1 + l\Theta) \iff \\
\Theta &= \pi h \left[1 + \left(\frac{1}{l\Theta} \right) \right]
\end{aligned}
$$

- There's nothing magical about this particular parameter value or nothing particularly illuminating in computing this value:
  - what may be interesting is to note that the model as presented includes a special case where the market's apparently rule of thumb (of forming expectations) is self-fulfilling, so that its anticipations always turn out to be correct in the short- as well as in the long-run (perfect foresight = **rational expectations)**
- **How do we prove that overshooting takes place?** Take the semi-reduced solution to the price level

$$p = L - l\Theta \left(s - \bar{s} \right)$$

Formal model: Overshooting

- In the long run: $dm = d\bar{s}$ and, importantly, at the time of the money supply changes, the price level is fixed, ie. $dp = 0$

$$
\begin{aligned}
0 &= (1 + l\Theta)dm - l\Theta ds \iff \\
ds|_{dp=0} &= \left[1 + \left(\frac{1}{l\Theta}\right)\right] dm > dm
\end{aligned}
$$

- So that the nominal exchange rate indeed overshoots its long-run equilibrium level
- **What about empirical testing of the overshooting hypothesis?**
- The Dornbusch model is very difficult to test
  - permanent increases in the money supply
  - expectations formation
  - lags in the response of the exchange rate to money supply changes
  - etc
- Instead, use the approach proposed by Jeffrey Frankel: it is based on real interest rate differentials

Empirical testing: Frankel approach

- The starting point of the Frankel approach is a small addition to the Dornbusch expectations mechanisms: denote by a tilde above the variable x, $\widetilde{x}$, the ratio of domestic x to foreign x^f. so that

$$\Delta s^e = \Theta\left(\bar{s} - s\right) + \Delta\widetilde{p}^e$$

  that is the difference between expected domestic and foreign inflation rates enters foreign exchange rate expectations
- Frankel extension amounts to a generalization of the Dornbusch mechanism to accommodate long-run inflation
- UIRP now gives

$$\begin{aligned} \widetilde{r} &= \Theta\left(\bar{s} - s\right) + \Delta\widetilde{p}^e \text{ or} \\ \bar{s} &= s + \frac{1}{\Theta}\left(\widetilde{r} - \Delta\widetilde{p}^e\right) \end{aligned}$$

- Next, follow Dornbusch in assuming that the monetary model only determines the (long-run) equilibrium, not the actual exchange rate:

$$\bar{s} = \widetilde{m} - k\widetilde{y} + l\Delta\widetilde{p}^e$$

Empirical testing: Frankel approach

- The above is a familiar formulation, apart from the last term
- If PPP does not hold, real exchange rates have to diverge: under UIRP real interest rates have to diverge too
- To get an estimable equation combine the above two equations

$$s = \widetilde{m} - k\widetilde{y} + l\Delta\widetilde{p}^e - \frac{1}{\Theta}\left(\widetilde{r} - \Delta\widetilde{p}^e\right)$$

  which clearly shows the role of played by the real interest rate differential $\left(\widetilde{r} - \Delta\widetilde{p}^e\right)$
- If we can find a measure of inflation expectations, we can test the last equation
- Note that as a special case the above equation includes the basic monetary model: if Θ increases without bound (ie $s = \overline{s}$ at all times), then the coefficient on the real interest rate will be zero
- Frankel's evidence suggests that this equations works in the 1970's (for DM/$ exchange rate)
- Since 1980's in particular, the model fails on exchange rate data