

V. The Speed of adjustment of Endogenous Variables and Overshooting

The second section of Chapter 11 of Dornbusch (1980) draws on Dornbusch (1976) "Expectations and Exchange Rate Dynamics", *Journal of Political Economy*, vol. 84, no.6, pp. 1161-76, and is an extremely important contribution to open macroeconomic theory. Professor Dornbusch explained the overshooting of exchange rates as something that happened because exchange rates adjusted more quickly than the price of goods. Here we start with an intuitive explanation of Professor Dornbusch's analysis and then show the basic logic using a very simple model. Then we go on to outline Professor Dornbusch's analysis.

An overburdened endogenous variable overshoots

One important thing to understand about overshooting is that it could happen with variables other than exchange rates. Anytime there are endogenous variables that adjust with differing speed, the variable with the higher speed of adjustment could overshoot.

In macroeconomic theory, there can only be two types of speed: fast and slow. This is because variables in economics are ordinal, as opposed to cardinal. We can say that one amount is bigger than the other, but not by how much.

So the most we can have are two, when it comes to the speed of adjustment. There can be only two types of endogenous variable, when they are divided according to the speed with which they adjust. One type adjusts quickly, and immediately changes after an exogenous shock. The other type adjusts slowly. In the short-run, the latter type of endogenous variable does not respond to exogenous shocks and is therefore exogenous. Only with time does this type of endogenous variable begin to adjust. Before that begins, in the short-run, the entire burden of adjustment falls on the endogenous variable that adjusts quickly.

Adjusting is a task given to endogenous variables. The objective is to recover the state of equilibrium. The role of endogenous variables is to adjust in such a way that the economy reaches a new equilibrium, once it is thrown out of the initial equilibrium by an exogenous event. If the equilibrium is stable, the economy will indeed reach a new equilibrium (or return to the original equilibrium in some cases).

If one of the endogenous variables refuses to budge for a while, the other endogenous variable must do all of the adjusting. This adjustment will be larger than the adjustment required when both variables adjust. And that is what overshooting is.

Imagine you and your friend are given a task, and your friend happens to be lazy. He or she will work, but only after a while. In contrast, you are the type of person who begins

the work immediately. In the short-run, until your friend starts doing the job, you will be doing all the work. And the effort you have to make in the short-run is more than is necessary to reach the final goal, after your friend has joined in and made the necessary effort.

The Essence

The essence of the explanation provided by Professor Dornbusch can be shown in a simple framework. The gist of the overshooting story is as follows. Start with the LM equation in a small country:

$$M/P = L(r, Y)$$

and assume that:

- (1) P is slow to adjust and is given in the short-run
- (2) $r = r^* + \mu$, where $\mu \equiv (\bar{e} - e)/e$ and \bar{e} is the long-run equilibrium level of e
- (3) Y is exogenous, or the structure of the model is such that Y is determined in another equation (such as the IS equation).

The second assumption states that the interest rate parity condition holds, with a non-static expectation regarding exchange rate depreciation. Professor Dornbusch uses rational expectations, which enables the economy to get on the path that takes it to the new long-run equilibrium. But in terms of overshooting, what is important is that μ is a function of an endogenous e . This renders r also endogenous, even in a small country with perfect capital substitutability.

With respect to the third assumption regarding Y , Professor Dornbusch treats Y as exogenous in the first part of the analysis, and then relaxes this assumption. When Y is exogenous, obviously it is fixed in the LM equation. When Y is endogenous, the short-run Y is determined from the IS equation, and is also fixed in the LM equation. The LM equation determines r , and the interest rate parity condition determines e . Hence, in either case, Y is already fixed by the time we come to the LM equilibrium.

This is all we need, in order to have overshooting of the exchange rate after an exogenous change in M . When M is increased, the LM equilibrium is disturbed, there is an oversupply of money. Something must adjust to recover equilibrium. P does not respond, neither does Y . So the burden of adjustment befalls to r , where r is a function of r^* and μ . r^* is exogenous to this small country, but μ is endogenous and is a function of e . Therefore, a change in r translates directly into a change in e . All the burden of adjustment is carried by e until P begins to respond, and e

overshoots in the short-run. As we will see below, the amount of overshooting is smaller when Y is endogenous, compared to when Y is exogenous. This is consistent with the logic of sharing the burden of adjustment; if another endogenous variable is there to take on some of the task, less will be carried by e .

The relationship between r , μ and e in the IRPC with rational expectations

Before moving on to outline Professor Dornbusch's analysis, it may be helpful to discuss how to judge the responses of μ and e to a given change in r in the IRPC with rational expectations. This can sometimes be confusing.

Take the case when, as in the simple story of exchange rate overshooting above, the money supply increases and r drops below the level equal to $r^* + \mu$. r^* is exogenous, so only μ can adjust to recover the IRPC. Specifically, μ must decline, making the right-hand side smaller and equal to the new, lower level of r . Since $\mu \equiv (\bar{e} - e)/e$, a lower μ means a higher e , given the long-run value of e, \bar{e} . This says that a decline in the

domestic rate of interest gives rise to an exchange rate depreciation (a higher e) today, and an expectation of exchange rate appreciation (or a lower rate of depreciation).

Some might wonder how people could expect the exchange rate to appreciate after a decline in the domestic interest rate. In order to avoid this type of confusion, it helps to keep in mind that people expect the economy to return to the state of long-run equilibrium, albeit a new one, after an exogenous change. They expect the exchange rate e to reach its new long-run equilibrium value \bar{e} , in the long-run.

The economy is initially in long-run equilibrium, as well as a corresponding short-run equilibrium. Then, there is an exogenous shock, such as a monetary expansion. The economy is thrown out of the initial long-run equilibrium, yet during the adjustment process towards the new long-run equilibrium, remains in short-run equilibrium. There is one short-run equilibrium corresponding to each level of the dynamic variable. In the present case, this dynamic variable is P . After the monetary expansion, the rate of interest falls and the exchange rate depreciates in the short-run. Assuming rational expectations, people in this model can calculate the new long-run equilibrium value \bar{e} , and know that it is lower (more appreciated) than the short-run value e . In other words, people know that the exchange rate overshoots (depreciates too much) in the short-run. Hence, they expect the exchange rate to eventually appreciate to the new long-run value.

We can tell this story using the IRPC equation. At initial equilibrium, $r = r^* + \mu$. Furthermore, $\mu=0$ at initial equilibrium, because the exchange rate e is at its initial long-run equilibrium value \bar{e} . When the money supply is increased, we have a new long-run value

of e (and a new long-run value of P). This is because all nominal values change at the same rate, in the same direction, in the long-run. But because P is sluggish, it takes time for the economy to reach the new long-run equilibrium. In the short-run, both P and \bar{e} are exogenous and fixed. After the money supply increase, r goes down and becomes lower than r^* ; $r < r^*$. The exchange rate e depreciates and rises to a higher level. A higher e means a lower μ , given \bar{e} . μ changes from zero to a negative value and the IRPC equality is maintained; $r = r^* + \mu$ where $\mu < 0$. A negative μ means an expectation of exchange rate appreciation. The appreciation actually takes place during the economy's adjustment through time, towards the new long-run equilibrium. When the economy reaches the new long-run equilibrium, e is equal to the new \bar{e} and $\mu=0$, $r = r^*$ again.

Now let us look at how the exchange rate overshoots (depreciates too much) in the short-run, then appreciates to its new long-run equilibrium value, in Professor Dornbusch's analysis.

The Analysis

The model used by Professor Dornbusch is a small country dynamic model, with P as the slowly adjusting dynamic variable. e and r are the endogenous variables that adjust quickly. In the short-run, P is given and only the change in P (differential of P with respect to time; $\dot{P} \equiv dP/dt$) is endogenous, along with e and r .

The economy is always in short-run equilibrium, while it reaches long-run equilibrium through time. With time, P begins to respond to the discrepancy between the aggregate supply fixed at the full employment level and the actual aggregate demand. At the new long-run equilibrium, P stops adjusting.

Fixed Y

In the first part of the analysis with a fixed Y , there is no IS equilibrium condition. The model comprises the interest rate parity condition (IRPC) with rational expectations regarding exchange rate depreciation, the LM equation and the equation showing the dynamic adjustment of P (the \dot{P} equation).

The endogenous variables are r, e, \dot{P} in the short-run, r, e, P in the long-run. The exogenous variables are $P, \bar{e}, \bar{P}, \bar{Y}$ (long-run equilibrium values of e, P, Y), h, g in the short-run, \bar{Y}, h, g in the long-run. h is money supply. The independent equations are the IRPC, LM and the \dot{P} equation in the short-run, the IRPC, LM and the $\dot{P} = 0$ condition in the long-run.

By definition, all nominal variables change at the same rate in the long-run. Therefore, both e and P change at the same rate as h at the initial long-run equilibrium and the

final long-run equilibrium. In contrast, in the short-run, P does not change and e changes at a larger rate than the long-run changes in e, P and h . In other words, e overshoots in the short-run.

Professor Dornbusch shows this using his figure on the (e, P) plane. By substituting r from the IRPC into the LM, we can derive an equation simultaneously representing the LM equilibrium and the IRPC with rational expectations. This equation is a function only of e and P , and represents the short-run equilibrium of the economy. We then derive the long-run version of this equation, and subtract the long-run version from the short-run version. This gives us an equation showing the relationship between $(e - \bar{e})$ and $(P - \bar{P})$. The equation indicates the relationship that must hold between the short-run e and P if short-run equilibrium is maintained, given the long-run values \bar{e}, \bar{P} . It is represented as a downward sloping line AA on the (e, P) plane. The economy is always in short-run equilibrium, so the economy is constantly on this line.

There is a fixed long-run full employment level of Y (\bar{Y}), and P responds to the discrepancy between \bar{Y} and short-run aggregate demand. That is the dynamics of P . Aggregate demand comprises government spending, the current account, investment and consumption. But consumption does not change because it is a function of Y and Y is fixed at \bar{Y} . Investment is a function of r , and by substituting r from the LM equation and using the relationships that hold at long-run equilibrium, the dynamics of P is turned into a function of only e and P . The economy is in long-run equilibrium when P stops moving ($\dot{P} = 0$). The $\dot{P} = 0$ line is upward sloping on the (e, P) plane, and the economy gets on this line only when it is in long-run equilibrium. During the process of adjustment to long-run equilibrium, $\dot{P} \neq 0$. At the initial and final equilibrium points, the economy is in short-run and long-run equilibria at the same time, and the AA and $\dot{P} = 0$ intersect with each other.

After an increase in the money supply, the AA line shifts immediately to the new long-run position. Each AA line is drawn for a particular set of long-run values \bar{e}, \bar{P} . So immediately after the money supply increase, there are new long-run values \bar{e}, \bar{P} and the AA line shifts accordingly. The $\dot{P} = 0$ line also shifts. The economy does not immediately attain these long-run values however, because P adjusts slowly. The economy immediately moves to a point on the new AA line, but not to the final long-run equilibrium. Only e adjusts in the short-run and overshoots its new long-run value, while P remains at the initial level. In other words, the economy is in short-run equilibrium but not in long-run equilibrium at this stage.

With time, P adjusts, and the economy moves along this new AA line towards the new long-run equilibrium position. The change in e at the new long-run equilibrium is

smaller than the short-run change in e . Professor Dornbusch shows how the speed of adjustment to the new long-run equilibrium is larger, the smaller the response of money demand to r , the larger the response of aggregate demand to r and the larger the response of aggregate demand to P .

Endogenous Y

In the second part of the analysis when Y becomes endogenous, the IS equation is introduced. The short-run equilibrium level of Y is demand-determined in the IS equation. In the short-run, producers produce as much Y as is demanded and the goods market reaches equilibrium. This short-run equilibrium level of Y is not (necessarily) the same as the long-run full employment level \bar{Y} . And P adjusts to the discrepancy between this short-run equilibrium level of Y and the long-run full-employment level \bar{Y} . That is the dynamic adjustment of P (the \dot{P} equation).

The endogenous variables are r, e, Y, \dot{P} in the short-run, r, e, Y, P in the long-run. The exogenous variables are $P, \bar{e}, \bar{P}, \bar{Y}, h, g$ in the short-run, \bar{Y}, h, g in the long-run. Y is endogenous in the long-run, but \bar{Y} is fixed. Through the adjustment of P , Y converges to the fixed long-run value \bar{Y} in the long-run. The independent equations are the IRPC, LM, IS and the \dot{P} equation in the short-run, the IRPC, LM, IS and the $\dot{P} = 0$ condition in the long-run.

Again, e overshoots in the short-run. The endogeneity of Y does not change this. Professor Dornbusch shows the overshooting using his figure on the (Y, P) plane. First he derives the long-run version of the IS equation and subtracts that from the short-run version. This gives us $(Y - \bar{Y})$ as a function of $(e - \bar{e})$, $(P - \bar{P})$ and $(r - r^*)$. He substitutes out $(r - r^*)$ from this equation using the IRPC. Then he derives $(e - \bar{e})$ as a function of $(Y - \bar{Y})$ and $(P - \bar{P})$ by subtracting the short-run LM from the long-run LM, and uses that to substitute out $(e - \bar{e})$. We then have $(Y - \bar{Y})$ as a function of $(P - \bar{P})$. This is Professor Dornbusch's YY line on the (Y, P) plane, representing the short-run equilibrium combinations of P and Y , given the long-run values \bar{P} and \bar{Y} .

The dynamics of P is independent of P itself, so the $\dot{P} = 0$ line is vertical at \bar{Y} on this plane. After a monetary expansion, the YY line shifts immediately to a location corresponding to the new long-run equilibrium values of P and Y . But since P is fixed in the short-run, Y overshoots to an over-employment level. It may be less intuitive to think of a real variable like Y overshooting, but in this model the only variable that is assumed to adjust slowly is P . Y is assumed to adjust just as quickly as e , and as Y overshoots, e also overshoots in the short-run.

Comparing the amount of overshooting

As was done by Professor Dornbusch in the version with a fixed Y , we can calculate the amount of overshooting of e . Instead of substituting out $(e - \bar{e})$, we can substitute out $(Y - \bar{Y})$ from the relationships between $(e - \bar{e})$, $(Y - \bar{Y})$ and $(P - \bar{P})$ derived from the IS, IRPC and LM. The resulting equation turns out to be

$$e = \bar{e} - \frac{1 - \delta\phi}{\delta\phi + \sigma\theta\phi + \theta\lambda}(P - \bar{P})$$

Differentiate this e with respect to h , and use $d\bar{e} = d\bar{P} = dh$ for long-run values. In the long-run, $dP = d\bar{P}$ and $d\bar{e}/dh = 1$. But in the short-run, $dP = 0$ and we have

$$\frac{de}{dh} = 1 + \frac{1 - \delta\phi}{\delta\phi + \sigma\theta\phi + \theta\lambda}$$

where the second term on the right-hand side shows the amount of overshooting. Contrast this with Professor Dornbusch's equation (17),

$$\frac{de}{dh} = 1 + \frac{1}{\theta\lambda}$$

and we can confirm that the amount of overshooting is larger when Y is fixed, compared to when Y is endogenous in the short-run.