Christiano
362, Winter 2006

Lecture #10: Making Y Endogenous in Short Run, and Integrating Short and Long Run

Up to now, we have assumed that Y is exogenous in the short and the long run. We will continue to maintain this assumption for the long run. However, for our purposes this assumption is a bad one for the short run. First, there is a widespread consensus that monetary disturbances do affect output in the short run. For example, in the late 1960s there was growing concern about the rise in inflation. In late 1969 that concern became very intense and the Fed adopted a very tight monetary policy. When the economy slipped into recession in 1970 everyone took it for granted that that was due to tight monetary policy. Another example comes from the early 1980s, when the Fed again became very concerned about inflation and switched to a tight monetary policy. The severe recession experienced at the time is assumed to be a consequence of this policy. So, our assumption that output is exogenous with respect to monetary policy in the short run seems to fly in the face of the evidence. There's more reason to endogenize output in our short run model. A key concern in this course is with the determination of interest rates and exchange rates. We have seen that the nature of the output response to a monetary disturbances affects how interest rates and exchange rates respond to those disturbances. This can happen for two reasons. One is that movements in output induce movements in money demand. Another is that the perceived riskiness of the economy may depend on the level of output. Movements in perceived risk can have important effects on asset markets. We continue to suppose that in the long run output is determined by the size of the population, the level of education, the amount of physical capital, etc. All the evidence on this suggests that this is a sensible assumption.

1. The Model in Short Run and Long Run.

   The three equations of our model are:

$$\begin{aligned}
(1)\ \text{UIP} &: \quad R = R^f + \frac{E^e - E}{E}. \\
(2)\ \text{Money Market} &: \quad \frac{M}{P} = L(R, Y). \\
(3)\ \text{Goods Market Equilibrium} &: \quad Y = D,
\end{aligned}$$

   where D is aggregate demand:

$$D = C(Y - T) + I + G + CA(q, Y - T).$$

The definition of the real exchange rate, the price of foreign versus domestic goods, is:

$$q = \frac{EP^*}{P}.$$

In the short run, the endogenous variables are Y, E, R, and their values are determined by (1)-(3). The exogenous variables from the point of view of the short-run model are E^e, P, M, R^f, I, G, T, P^*. The short run disequilibrium dynamics specify that Y increases (slowly) whenever $D > Y$, and decreases slowly whenever $D < Y$. Also, E rises quickly whenever the left side of (1) is less than the right, and E falls shaprly whenever the left side of (1) is greater than the right. This is a complete specification of the 'short run model'.

In the long run, the variables to be determined by (1)-(3) are P, E, R and the exogenous variables are P, M, R^f, I, G, T, P^*. The disequilibrium dynamics for the long run are that P rises whenever short run equilibrium output exceeds the level of output associated with full employment. The price level, P falls whenever the level of output associated with full employment exceeds the short run equilibrium level of output. This is a complete specification of the 'long run model'.

We study the effects on the economy of a *shock*, a change in the values of one or more of the exogenous variables. We always suppose that the shock occurs when the economy is in a long-run equilibrium, with output at its full employment equilibrium. This may at first seem a little strange. One might suppose that governments primarily think about increasing the money supply when output is below its full employment level. Yet, we focus on increases in the money supply that occur when output is *equal* to its full employment level. The reason we proceed as we do is for convenience only. It is easy to confirm that the basic conclusions of the analysis, the pattern of responses of the economy to a shock, are not much affected by the condition of the economy at the time that the shock occurs.

When we investigate the long and short-term effects of a shock, we work with both the Short Run model and the Long Run model. Even if we are exclusively interested in the short run impact of a shock, we must first work out its effect on the long run, since otherwise we don't know what value to assign E^e when working with the short run model. The value of E^e used in the short run model is the equilibrium value of the exchange rate determined by the short run model.[1]

A diagram illustrating the structure of our analysis of the impact of a shock is displayed in Figure 1. Suppose the shock is a permanent

[1] This is why E^e is exogenous with respect to the short run model. It is not determined by this model. It is determined by the long run model.

one, so that it has an effect on the long-run. To figure out the impact on the short run, you have to first determine the impact on the future exchange rate using the long-run model. That future exchange rate is E^e in the short run model. Thus, a shock impacts on the short run via an indirect channel and a direct channel. The indirect channel operates by way of the shock's impact on the expectation of the future exchange rate, E^e, (see down arrow) and the direct channel through the places where the shock appears explicitly in the equations of the short-run model.

So, as the diagram suggests, we work out the economic effects of a shock by working 'backward' through time. First, solve the long run model to get E^e. Then, we solve the short run model.

2. Solving the Model.

   Studying the effects of changes in the exogenous variables will be referred to as *experiments*.

   The short run version of the model has three equilibrium relationships to determine the three unknowns, Y, E, R. We will solve it and do experiments in it by collapsing the three relationships into two, and then putting the two into one graph which has E on the vertical axis and Y on the horizontal axis. In the two relationships, one is the set of E, Y combinations that clear the goods market, i.e., where $Y = D$. The other is the set of E, Y combinations that clear the asset market, i.e., where the money demand and UIP relations are satisfied.

   (a) Goods Market. This is the combinations of (E, Y), where total planned spending equals total output. In class, this was derived graphically. An algebraic derivation is obtained by substituting out for q in the goods market clearing condition:

   $$Y = C(Y - T) + I + G + CA(\frac{EP^*}{P}, Y - T).$$

   Note that higher values of E require higher equilibrium values of Y. That is, the DD curve has a positive slope.

   (b) Asset Market. The asset markets are composed of the money market (money demand relation) and the international financial market (UIP). The E, Y combinations where the asset markets are in equilibrium is called the AA curve. It is a negatively sloped curve. That's because at a high level of income, money demand is high, requiring a high rate of interest to clear the money market. But, at a high domestic interest rate you need a low value of E to assure UIP. If US dollar assets are paying a high return, then you need a greater depreciation (smaller appreciation) of the US dollar to make domestic and foreign assets look the same (remember, E^e is held fixed here, so a low E means a high $E^e - E$). You should understand how the AA curve shifts with E^e, P, R^*, M. How does an increase in money demand shift the AA curve?

For example, to see how the AA curve shifts with a rise in M, pick a particular point on the horizontal axis in the E, Y graph, a particular value of Y. Then ask, what has to happen to E to restore equilibrium in the asset markets after a rise in M? Other variables, like E^e, that determine the location of AA must be held fixed to know how M shifts AA. So, suppose M rises with Y, holding E^e fixed. Equilibrium in the money market requires a fall in the rate of interest. Then, UIP requires a rise in E. This is because an appreciation (or smaller depreciation) of the US currency is needed to compensate investors for the low US returns. It is important to emphasize that this logic is not designed to tell us directly what will happen with an increase in M. The logic has the more limited algebraic purpose of telling us what happens to the location of the AA curve with a rise in M. What will actually happen depends on the interaction of the AA and DD curves, something we turn to next.

(c) Putting AA and DD together. Consider various points in the E versus Y graph: points above the AA and DD curve; points above AA but below DD; point below AA and above DD; points below both. Understand what the situation of the economy is at each of these points. Convince yourself that there is just one overall equilibrium, the one where the two curves cross. Points above DD are points were there is excess demand for goods, and we assume that in such a situation, output has a tendency to rise (slowly). Points below are the opposite. Points above AA are points were there is a strong demand for the domestic currency, driving E down (instantly); points below are the opposite and drive E up. We assume E always jumps instantly to the A curve, but Y is slower to get to the DD curve. The *disequilibrium dynamics* of a model refer to the assumptions made about what happens when a market is out of equilibrium. Thus, our assumption about disequilibrium dynamics is that the exchange rate, E, moves instantly to clear the asset markets and Y moves slowly to clear the goods market. Given what we know about these markets, this seems like a reasonable assumption.

3. In what follows, we first analyze the effect of a temporary shock to the stock of money. The fact that the money shock is temporary simplifies the analysis because we don't have to worry about the long run. After

that, we proceed to analyze the case of a permanent jump in the stock of money.

Experiment #1: Temporary increase in M. This has no impact in the long run, and in particular it has no impact on the future exchange rate, E^e, from the perspective of the short run model. The first step is to figure out how the AA curve and DD curves shift. From the earlier discussion, we know that the AA curve shifts up. What about the DD curve? Well, M does not appear in that curve, and so it does not move at all.
So, the AA curve shifts up. This means that the point the economy was at initially is no longer an equilibrium point: the asset market is out of equilibium. Given our assumptions about disequilibrium dynamics, the exchange rate now shoots up to restore equilibrium in the asset markets. Now, however, the goods market is out of equilibrium. The depreciation of the exchange rate puts us above the DD curve, which is a situation of excess demand for goods. The jump in E produces a real depreciation (q falls) which stimulates current account. Over time, the excess demand for goods results in a rise in output. This process continues until we reach a point of intersection between the new AA curve and the old DD curve. We end up with a depreciated exchange rate (which actually overshot a little to get to where it was going) and higher output.

Here are some notes on the analysis of the effect of a temporary jump in M. They approach the problem in two ways, which take a total of 8 steps. These steps break into two parts. The first 4 go through the 'math' of the analysis, the raw logic. Doing this makes sure you get the answer right. However, this line of approach also drains the 'blood and guts' out of the analysis. The last 4 steps then do the 'human' part of the analysis, the way it might be written up by a reporter writing about it in a magazine. It's the latter analysis that's really the interesting one. However, you need the first four steps as a kind of foundation, or scaffolding for your argument, to make sure it is logically sound.

Analysis of Jump in M:

(a) do the sheer algebra (in graphs). Increase M and note that because the change is temporary, E^e does not change.

(b) study the DD curve and, recognizing how it is constructed, note that M does not enter and so that curve does not shift.

(c) study the AA curve carefully and note that M appears in one of the equations that goes into it, the money market clearing condition. Discuss how an increase in M shifts the AA curve by building up explicitly from its impact on the UIP and money market relations.

(d) Shift the AA curve in the E, Y space, and note how what was an equilibrium is no longer. Implement the 'disequilibrium dynamics', and note the path they cause the economy to follow into the new equilibrium. You should jump up immediately in the vertical direction, and then slide down the new AA curve into the equilibrium.

(e) Redo the analysis as a journalist might, talking about the basic intuition along the way. The increase in the money supply creates an excess supply of real balances in the money market. This puts downward pressure on the domestic rate of interest. This makes the dollar look very unattractive because dollar returns have fallen relative to world returns, appropriately adjusted for anticipated exchange rate changes. This leads to an immediate depreciation in the value of the dollar (i.e., E jumps). This has the effect - for the given future value, E^e, of the exchange rate - of reducing the anticipated depreciation of the dollar. This makes US returns look as attractive as those in other currencies. You should think carefully about these observations, which lie at the heart of the UIP relation, which plays a very important role in this course.

(f) The depreciation of the dollar triggered by the events in the financial markets have spillover effects in the goods market. The depreciation of the exchange rate makes US goods look more attractive, and net exports rise, raising the demand for US goods (this is what the situation above the DD curve is all about). This creates pressure for output to rise, as retailers seek to replenish the inventories they see dropping due to the rise in demand.

(g) The rise in output triggered by events in the goods market increases the demand for money, raising the domestic interest rate from the low it fell to with the initial jump in M. This rise in the interest rate produces an appreciation of the currency, causing E to fall back somewhat from the high it jumped to initially (i.e., when output increased, the economy ends up above the AA curve a little and this causes a drop in E).

(h) The combination of rise in output in (f) and fall in E in (g) corresponds to the slide down the AA curve mentioned in (d).

4. Experiment #2. Now we analyze the effect of a permanent jump in the stock of money, as depicted in figure 2. We adopt the convenient assumption that the original long-run equilibrium is one in which $E^e = E$ and $R^f = R$ and P is constant, i.e., there is no inflation. Since q is constant in long run equilibrium, we implicitly also assumed the foreign inflation rate is zero. We also assume full employment output growth is zero, so that the zero domestic long run inflation rate corresponds

to a constant money stock. It is not necessary that we adopt all these assumptions about rates of growth. They simply make the graphs simpler, without really distorting the basic elements of the story. Indeed, much of the verbal analysis below will not make use of these zero growth rate assumptions.

The analysis is broken into four steps: (i) determine the long run equilibrium effect of the shock; (ii) determine which curves in the short run model shift and by how much; (iii) apply our assumed disequilibrium dynamics to see how the economy moves from the old equilibrium to the new short run equilibrium; (iv) determine how the economy passes from the short run to the long run.

(a) Long run effects. Suppose (we will verify that this was a good guess later) the nominal rate of interest, R, remains unchanged. From (2) we see that there is no change in the demand for real balances, so there cannot be any change in M/P in the long run, when there is a permanent change in the stock of money. Given the jump in M, it follows that P must jump by the same percent. Since everything but the variable, q, in (3) remains unchanged, it follows that q itself cannot change. That is, world demand and supply for domestically produced goods does not change with the change in M, so the relative prices of domestic versus foreign goods cannot change. For q to remain unchanged when P jumps requires that E jump by the same percent as P. Since the equations of the long-run model must hold at every date in the future, it follows that the jumps in E and P must occur at every date in the future. Recall that E^e in the long run context simply means a period beyond E.[2] With the exchange rate jumping by the same percent in each date, it follows that E^e jumps by that percent too. In particular, $(E^e - E)/E$ does not change with this experiment. By equation (1), it follows that R does not change either. This confirms the conjecture made at the start of this analysis. We conclude that the permanent jump in M induces a equiproportionate jump in E^e.

(b) Which curves shift and by how much. We now turn to the short-run analysis. We represent the short run model using the AA-DD

[2]Sometimes the date to which a variable applies is denoted by a subscript, E_t. This is the exchange rate at date t. Then, $E_t^e = E_{t+1}$, or, more precisely, E_t^e is the expected value of E_{t+1}. Letting $t = 0$ denote the present, the short run, then $t = 1, 2, ...$ corresponds to the long run. Our finding is that E_t jumps by the same percent as the jump in the money supply in each of $t = 1, 2, 3, ...$. This obviously implies that E_t^e jumps by that percent in each of these dates too. In the short run context, E^e is E_1 and E is E_0.

curve framework. The first task is to figure out how the permanent jump in M affects the AA and DD curves. The jump in current M directly shifts the AA curve because it appears explicitly in one of the two equations that underlie it: the money market clearing condition. The jump in M has no direct effect on the DD curve.[3] The indirect effect of the jump in M also operates through the AA curve. That's because E^e only appears in that curve, in the UIP relation.

We can figure out algebraically what happens to the AA curve with the jump in M, like this. Recall that the AA curve describes the Y, E combinations where the financial markets are in equilibrium, i.e., where equations (1) and (2) are satisfied. The AA curve is what you get when you substitute out for R in (2) from (1):

$$\frac{M}{P} = L(R^f + \frac{E^e - E}{E}, Y),$$

or,

$$\frac{M}{P} = L(R^f + \frac{E^e}{E} - 1, Y).$$

From this expression, it is obvious that the AA curve is negatively sloped. A rise in E drives the first argument of L down, which raises L and requires a rise in Y to restore equality. From this expression it may perhaps also be obvious to some that the AA curve shifts up with a rise in M and with a rise in E^e, for every given level of Y. But, for most, the more graphs-intensive approach to figuring this out that was pursued in class may be more accessible. Figure 3 graphs equations 1 and 2. Note how the increase in M to M' - holding E^e fixed and Y fixed too, at a value of Y_1 - produces a lower value of R and raises E to E_2. The rise in E^e induces an additional increase in E to E_3, by shifting the UIP curve in the left quadrant up. So, the direct effect of a jump in M shifts up E, and the indirect effect shifts it up some more, holding Y fixed at Y_1. This graphical information allows us to deduce the impact of a permanent jump in M on the AA curve. So see this, look at Figure 4, which displays Y_1, E_1, E_2 and E_3.

[3] This may at first seem suprising. 'Surely, if people have more money, they will want to buy more goods.' This is not the right way to think about a rise in M in our model. The type of increase in M that we consider is one brought about by an open market purchase of bonds by the central bank. This has the effect of changing the allocation of people's portfolios between money and bonds. So, the rise in M does not correspond to a rise in people's wealth. If it did, then we would expect it to affect desired planned spending. But, it does not.

(c) Evolution of Economy from Old Equilibrium to the New Short-Run Equilibrium. Our assumed disequilibrium dynamics allow us to deduce the path the economy will take from the old long-run equilibrium to the new short run equilibrium. Starting from the old equilibrium, the economy finds itself below the AA curve after the shock hits. We assume that in a situation like this, the exchange rate jumps instantaneously in a vertical direction to the AA curve. At this point the economy is above the DD curve. At points like this, Y rises slowly. This is because such points represents situations where there is excess aggregate demand for output. We assume that firms respond to this by expanding output. As the economy moves towards the right, it finds itself above the AA curve. This causes E to drop to the AA curve. In this way, the disequilibrium dynamics imply that the economy rides down the AA curve into the new short run equilibrium.

(d) Passage from Short Run to Long Run. In the long run, the price level will rise. The rise in the price level shifts both the AA and the DD curves to the left. (As an exercise, you should work out exactly how and why this happens.) Long run equilibrium is restored when the two curves intersect at a value of Y equal to where we started. Implicitly, we assumed that was the full employment level of output.

5. Informal analysis of experiment #2. The immediate impact of the monetary shock is on the financial markets. By making the domestic currency more plentiful, the nominal rate of interest is driven down. This creates an imbalance in international financial markets because it makes the return on domestic currency assets lower than what it is on foreign currency assets, after adjusting for anticipated exchange rate changes. Markets respond to this by selling the domestic currency and buying the foreign currency. This has the effect of depreciating the currency, i.e., driving E up. As E goes up there is a point where international financial markets become happy with their holdings of the domestic currency assets. Markets form expectations about where the exchange rate will end up eventually in response to the shock, and if the exchange rate rises above that, there is an expectation of an appreciation in the currency. If the expected appreciation in the currency is sufficiently strong, then the international financial markets will feel compensated for holding the now lower rate of return domestic currency assets. In fact, we expect no international financial flows to actually occur. We imagine that all traders will be trying to sell the domestic currency, and will find no buyers. What will happen is that E will shoot up enough so that traders lose interest in selling.

   These effects in the financial markets have a spillover impact on the goods markets. The depreciated exchange rate makes domestic goods relatively cheap compared with foreign goods (recall, P is fixed and the relative price of foreign and domestic goods is $P^f E/P$). So, demand for domestically produced goods goes up. Retailers see this when their inventories start dropping. We assume that they respond by hiring more workers. The expansion in output has secondary spillover effects back on the financial markets. It raises the domestic rate of interest and attenuates the rise in E. This process continues, the partial undoing of the initial overshooting in the exchange rate and the expansion in output, until the economy arrives at the new equilibrium.

With the higher level of output, eventually prices start to rise. This shifts the AA curve left as real money balances begin to erode. This raises the interest rate and leads to an appreciation of the currency, i.e., a fall in E. This fall in E, together with the rise in P, both have the effect of making domestic goods more expensive than foreign goods, reducing demand for domestic goods. In this way, we go through a period of appreciating exchange rate and fall in output as the economy moves to the long-run equilibrium. As noted above, in that equilibrium the only thing that happened is that prices (both P and E) jumped by the same percent as M.

6. Cases where the experiment described is of interest.

   (a) The US in the early 1980s. At this time, the Fed ran the above experiment in reverse, by raising the US rate of interest and triggering an appreciation of the dollar. They also produced a recession. The Fed's motive in adopting a tight money policy, was to stop inflation. A full analysis of this is beyond us at this point. But, the reasons why the dollar appreciated, interest rates rose and output fell are nicely captured by our model.

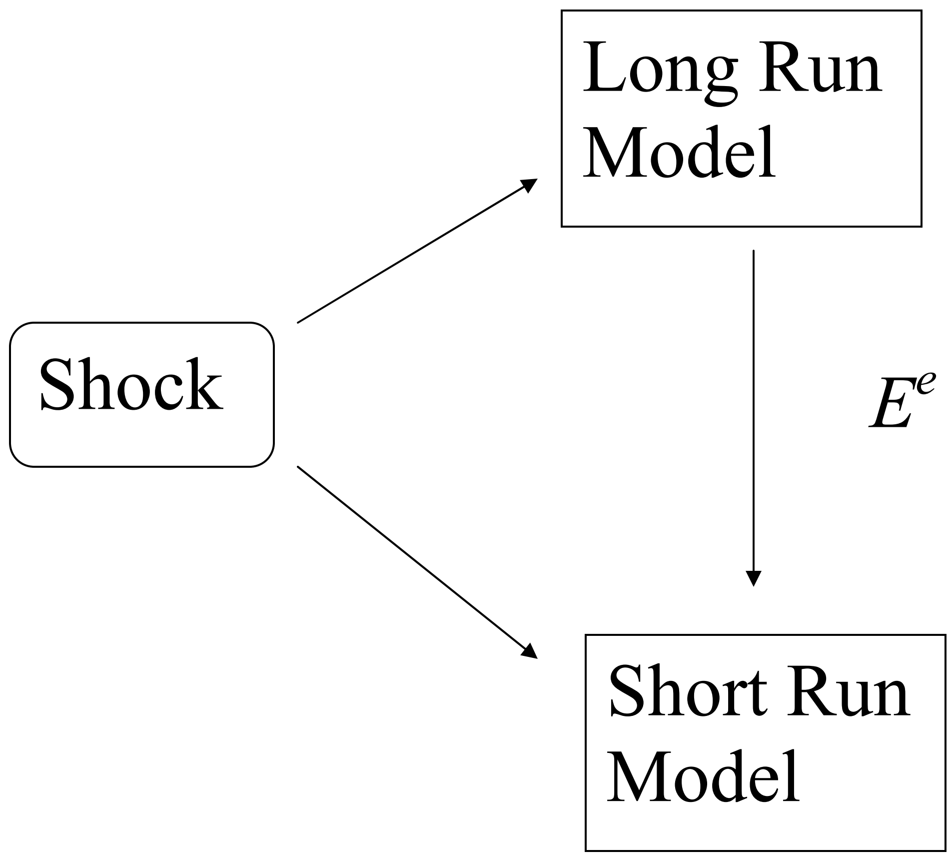
   (b) Japan right now. People want the Japanese government to depreciate the yen by adopting a loose money policy. Critics argue that this will not work. The key channel by which loose money results in a currency depreciation operates by way of a cut in the interest rate. The Japanese interest rate is already at its lower bound. Other critics assume that it is feasible for the Bank of Japan to depreciate the exchange rate. However, they argue that the resulting rise in Japanese output that would occur because of the increase in CA would irritate Japan's trading partners whose CA must of necessity fall.

   (c) Japan in the 1990s. The Bank of Japan drove the interest rate down continually during the 1990s, in the hope of stimulating the economy. The reasoning they had in the back of their minds is the one captured in our model. The policy was not effective. The interest rate is down to zero now, and output is still relatively weak. This suggests that the problems in Japan may be something deeper, something not amenable to monetary policy.

(d) The US since 2000. The US Fed drove interest rates down starting in the beginning of 2000, in order to stimulate the economy. Most think the Fed was successful at doing this, and that the reason US economic performance has been better than Europe's coming out of the 2001 recession is loose US monetary policy.

7. Useful exercise. Draw pictures of the evolution of the economy's variables in response to the permanent monetary shock.

Fig 1: Short Run Impact of a Shock that has a Long-Run Effect



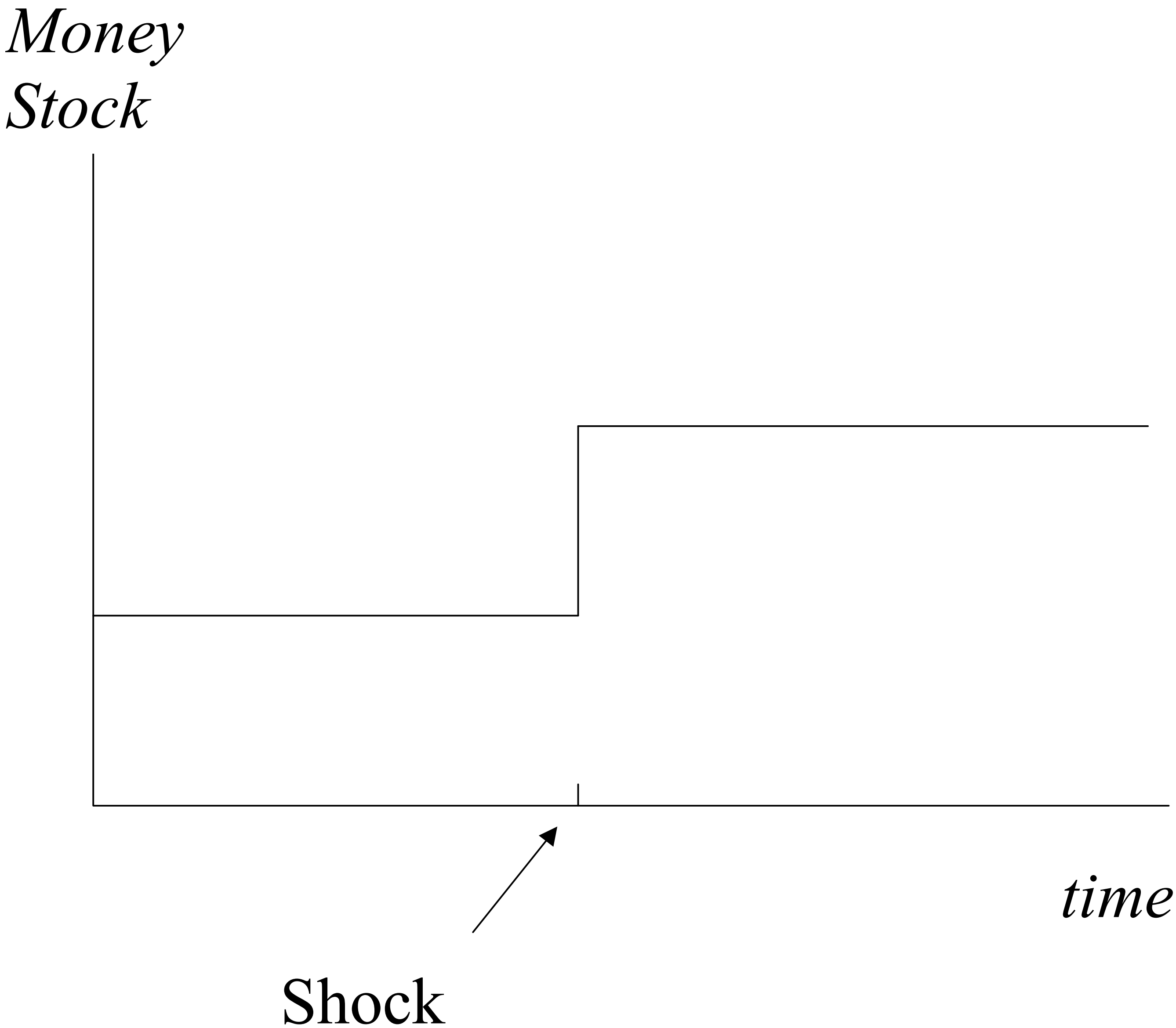


Figure 2: A Permanent Jump in the Stock of Money

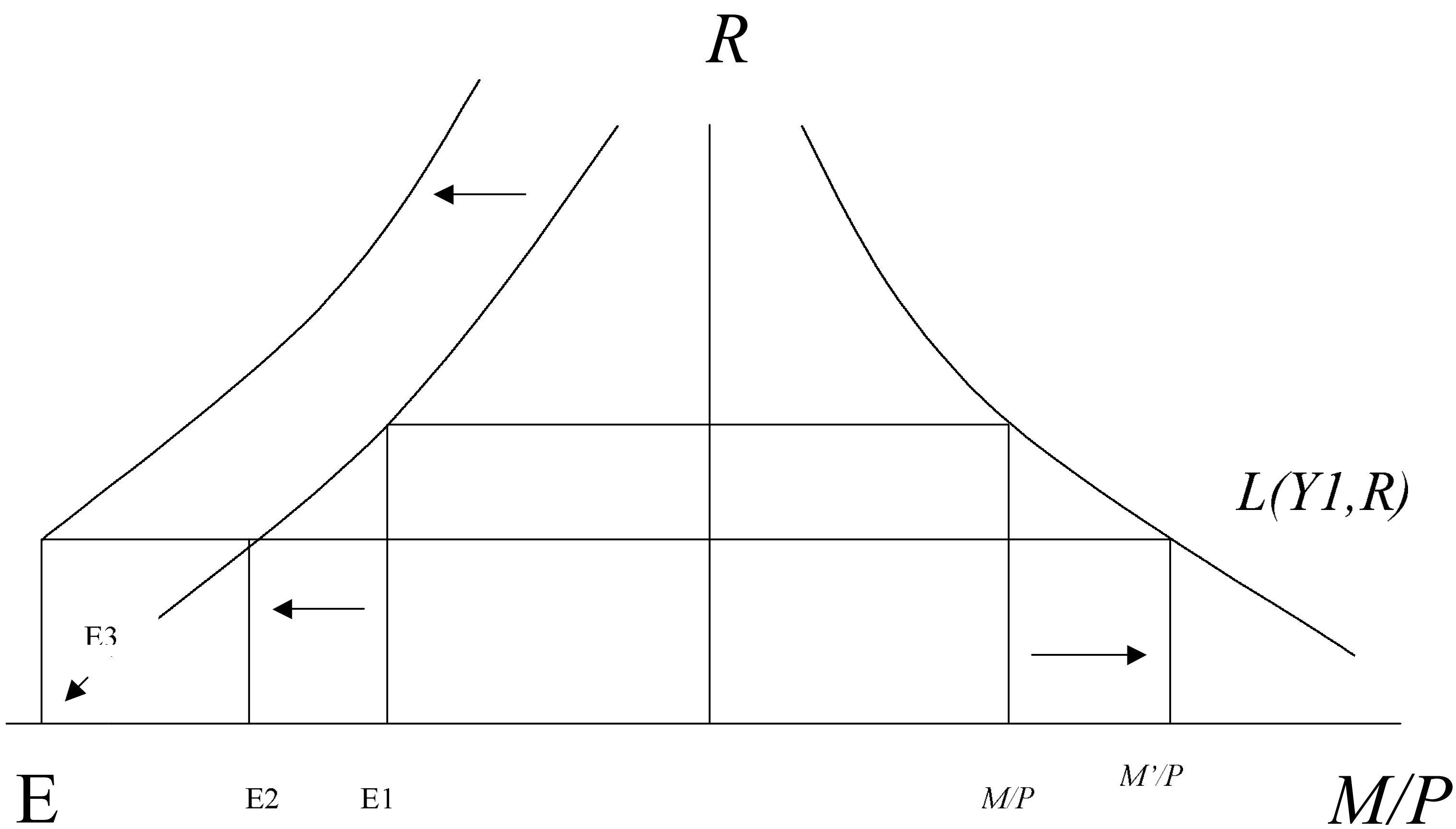


Figure 3: Impact of Jump in *M* and Jump in Expected Exchange Rate, in Financial Markets, for Given Level of *Y*

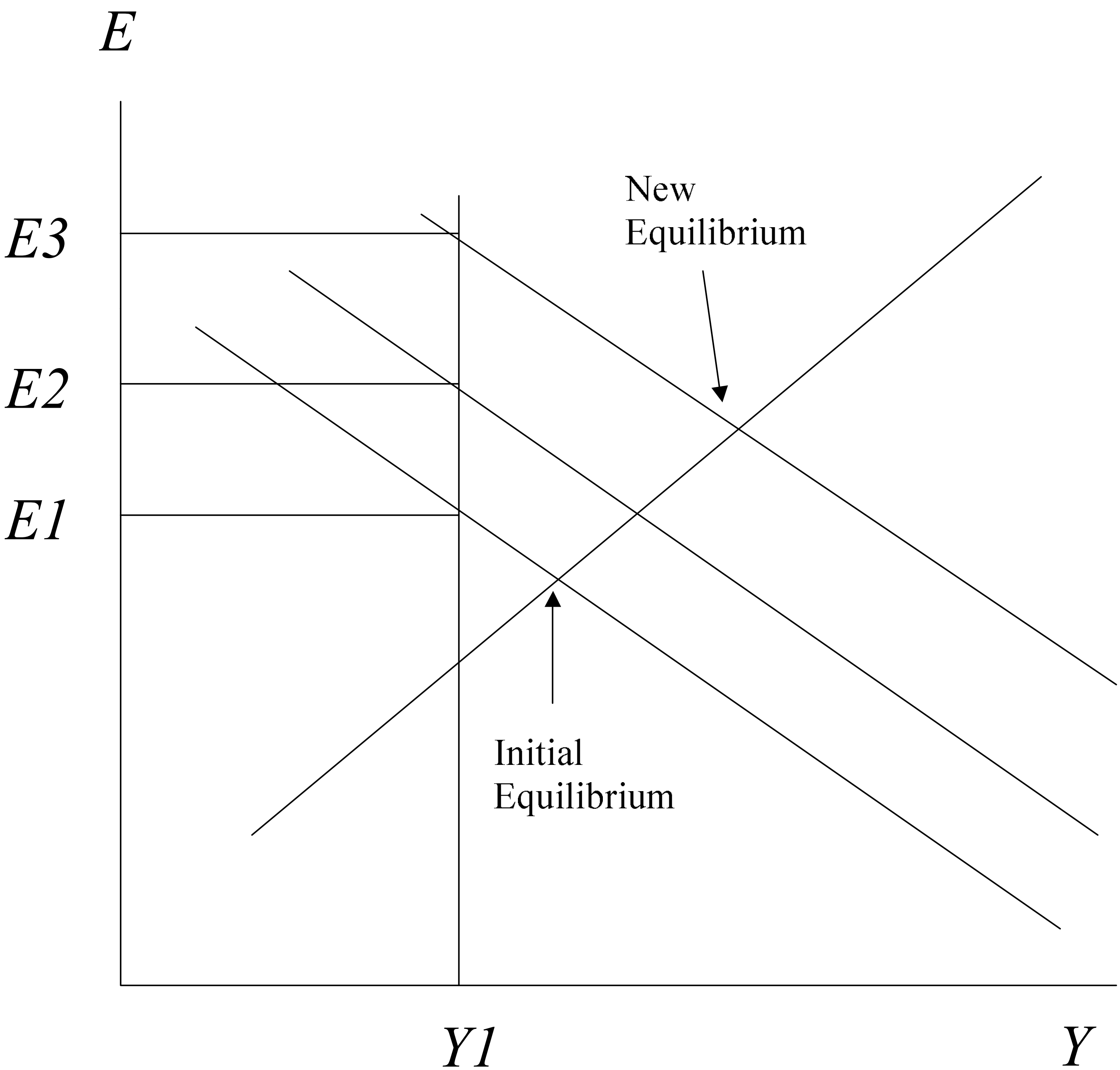


Figure 4: Analysis of Permanent Jump in M in the AA-DD Curve Framework