

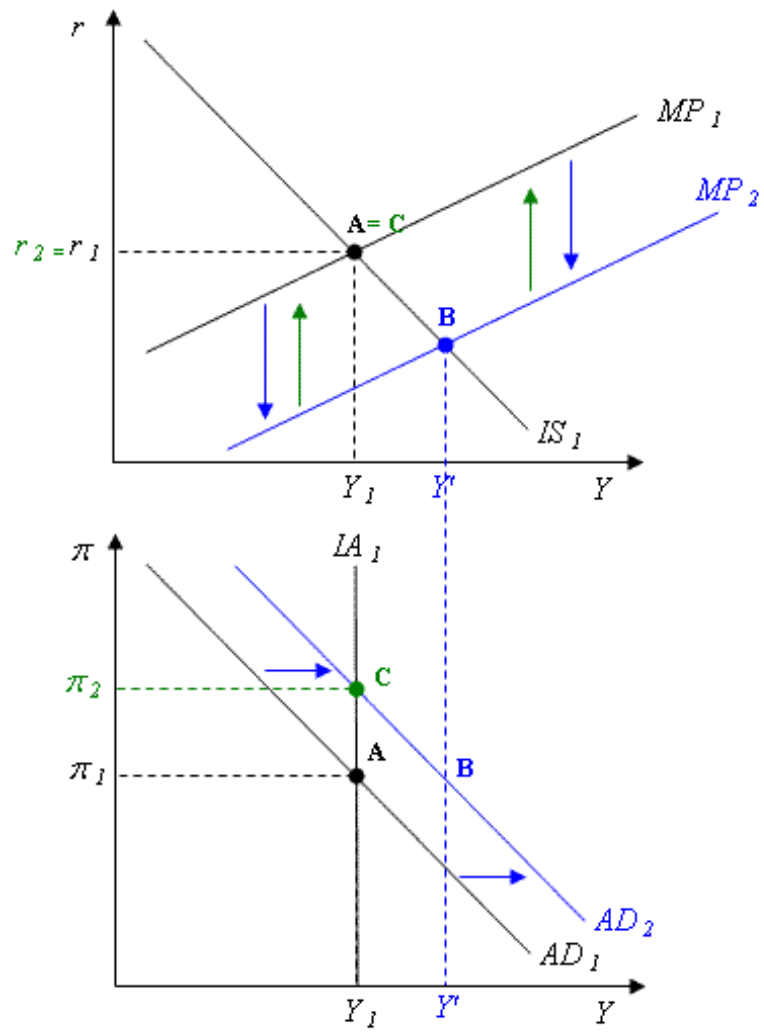
Chapter 6

Microeconomic Foundations of Incomplete Price Adjustment

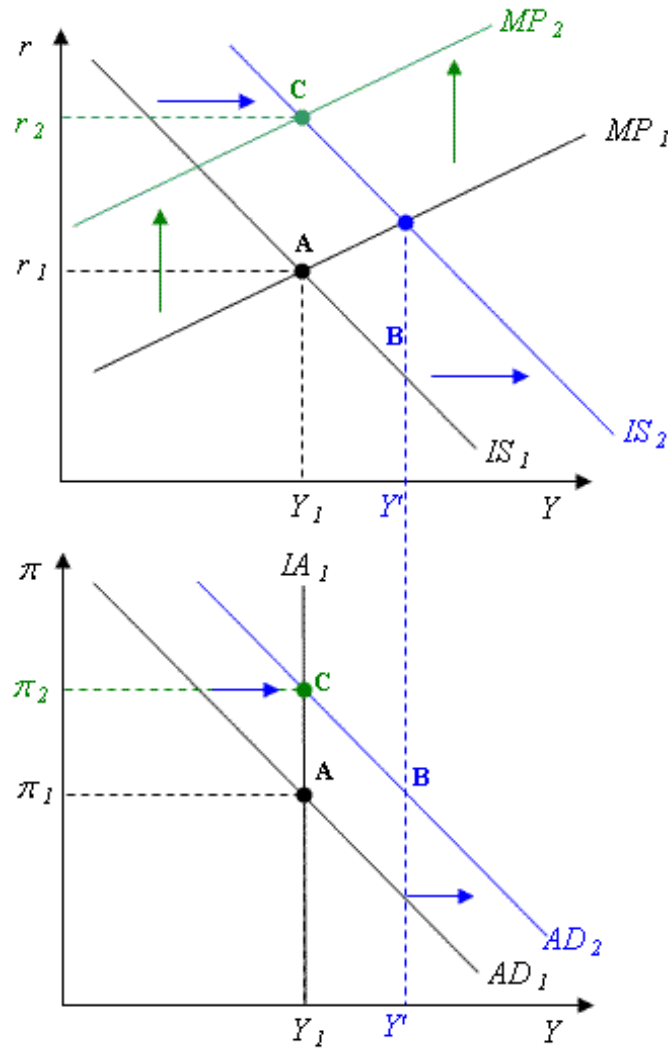
In Romer's IS/MP/IA model, we assume prices/inflation adjust imperfectly when output changes. Empirically, there is a negative relationship between unemployment and output in the short-run, according to an expectations-augmented Phillips Curve. Friedman (1968) and Phelps (1968). This implies a positive relationship between inflation and output. This chapter focuses on theories of why prices adjust imperfectly. Rather than simply *assuming* that wages/prices fail to adjust, these theories *demonstrate why* there is a positive relationship between prices and output in the short run, resulting from optimizing decisions by rational households and firms.

These theories serve as the foundation of modern analysis of economic fluctuations. Without a positive relationship between inflation and output in the short run, there is no role for monetary policy to affect real economic variables. In the IS/MP/IA model, this would mean assuming $\pi'_Y \rightarrow \infty$. We can see from the model that a vertical IA curve implies that shifts in IS/MP have no effect on output. Also, we can see that changes in fiscal policy can affect the composition of output (through affecting the real interest rate), but cannot affect the level of output. This is consistent with the classical dichotomy: changes in nominal variables (money supply, nominal interest rates, inflation) do not affect real variables (output, unemployment, real interest rates).

We can see this in the case studies below where the economy is initially at potential output, $Y_1 = \bar{Y}$. Assume that prices/inflation adjust perfectly to deviations in output from potential output, so that the IA curve is vertical. Now, consider a situation where the Federal Reserve tries to expand output by lowering interest rates. We see from the diagram below that money has no effect on real economic variables (real interest rate and output return to their initial values). This is known as money neutrality.



Now, consider the same scenario, except that the government attempts to boost output through a tax cut. We see from the diagram that this has no effect on output, but it does lead to an increase in the real interest rate. The tax cut therefore leads to an increase in consumption (because disposable income has increased) and a decrease in investment.



From the cases above, we can see that if there is some imperfection in price adjustment, there is a role for policy to affect real economic variables. Generally, if such a perfection does exist, then changes in aggregate demand affect output. The focus in this literature tends to be on monetary policy. There are several reasons for this. The most obvious one being that we know fiscal policy has

the ability to affect real economic variables through affecting the composition of output. Also, when we consider using policy in response to economic outcomes, monetary policy has the ability to respond quickly to economic conditions (relative to fiscal policy) because of institutional limitations (e.g., the federal budget process).

Another reason why these theories of incomplete price adjustment are important relates to the timing between short run and long run. The time between short run (when output can deviate from potential) and long run (when prices adjust and the economy returns to potential output/natural rate of unemployment) depends on your assumptions about the nature of incomplete price adjustment.

Part A The Lucas Imperfect-Information Model

This model relaxes the assumption of perfect information in the classical model. Perfectly competitive firms observe the prices of their individual products, but they do not observe the economy-wide price level. Therefore, when the producer observes a change in the price of her product, she does not know if this is a reflection of increased demand for her individual good, or simply a general increase in the economy-wide price level (associated with changes in aggregate demand). She must forecast the expected economy-wide price level and determine whether or not to change her individual production levels when she observes a change in her individual price.

The model presented in this chapter is based mainly on Lucas (1972) and less so on Lucas (1973, 1976).

6.1 The Case of Perfect Information

To understand how the Lucas model works, we will begin with developing a classical model with utility maximizing households who supply labor to profit-maximizing firms. All economic agents observe information perfectly, so that producers are able to distinguish between fluctuations in prices associated with individual demand versus aggregate demand. To simplify things, we focus on the behavior of a representative producer.¹

6.1.1 Producer Behavior (and Household Behavior)

A perfectly competitive firm produces output Q_i using labor supplied by the household, L_i :

$$Q_i = L_i$$

¹In the model, the "owner" of the firm is also the worker. That is, each household produces its own product by hiring itself.

The firm's profit maximization problem is:

$$\Pi = P_i Q_i - W_i L_i$$

where P_i is the price of the individual good produced by the aforementioned firm. and $Q_i = L_i$ because of the linear production function:

$$\Pi = P_i L_i - W_i L_i$$

The FOC for this problem is:

$$\frac{\partial \Pi}{\partial L_i} = 0 : W_i = P_i$$

Therefore, $W_i L_i = P_i Q_i$. That is, each household earns $P_i Q_i$ in nominal wages. The worker receives real income equal to $\frac{P_i Q_i}{P}$. The aggregate price level is denoted P — this represents the price of a market basket of goods produced in the economy. Therefore, we deflate the worker's wages by P to adjust for the purchasing power of wages earned.

Utility depends positively on consumption and negatively on labor (e.g., positively on leisure). We assume the following utility function:

$$U_i = C_i - \frac{1}{\gamma} L_i^\gamma$$

where C_i is (real) consumption purchased by the household. From this expression, we can see that as the household works more, she enjoys less leisure time, reducing her utility. The household maximizes utility subject to the budget constraint (note that $Q_i = L_i$ from the production function above):

$$\begin{aligned} & \max C_i - \frac{1}{\gamma} L_i^\gamma \\ \text{subject to } & C_i \leq \frac{P_i L_i}{P} \end{aligned}$$

This problem can be set up as a Lagrangian:

$$\mathcal{L} = C_i - \frac{1}{\gamma} L_i^\gamma + \lambda \left(\frac{P_i L_i}{P} - C_i \right)$$

The first order conditions are:

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial C_i} &= 0 : 1 - \lambda = 0 \\ \frac{\partial \mathcal{L}}{\partial L_i} &= 0 : -L_i^{\gamma-1} + \lambda \frac{P_i}{P} \end{aligned}$$

Combining these conditions we have:

$$\begin{aligned} L_i^{\gamma-1} &= \frac{P_i}{P} \\ L_i &= \left(\frac{P_i}{P} \right)^{\frac{1}{\gamma-1}} \end{aligned}$$

In log notation (with lower case letters indicating logs):

$$\begin{aligned}\log(L_i) &= \frac{1}{(\gamma - 1)} (\log(P_i) - \log(P)) \\ \ell_i &= \frac{1}{(\gamma - 1)} (p_i - p)\end{aligned}$$

We can see from this expression that the supply of labor from the household is a positive function of the relative price of his/her product. If the firm/household sees the price of his/her individual product is higher than the economy-wide price level, then it should increase production. It does so by increasing labor hours.

6.1.2 Demand

The demand for an individual good (in log form) q_i is expressed as:

$$q_i = y + z_i - \eta(p_i - p)$$

where y denotes the log of aggregate real income, z_i is an idiosyncratic shock to the demand for good i , and η is the elasticity of demand for each good.² We can see from this expression that if the price of this good is relatively low, $p_i < p$, then the demand for good i will exceed the average, $q_i > y$. If all goods are identical, then we can express aggregate real income y and aggregate prices p as:

$$\begin{aligned}y &= \bar{q}_i \\ p &= \bar{p}_i\end{aligned}$$

Aggregate demand is specified as:

$$y = m - p$$

where m denotes the log of money supply. However, it is easier to interpret this as any shock to aggregate demand. This expression is consistent with the quantity theory of money.³

6.1.3 Equilibrium

Note, the demand for good i is given above:

$$q_i = y + z_i - \eta(p_i - p)$$

²We assume $z_i \sim (0, \sigma_z^2)$.

³The quantity theory of money uses the equation of exchange $MV = PY$. In logs, this expression is $m + v = p + y$, or $y = m - p + v$. Since the quantity theory of money assumes that velocity is constant, it is dropped from the expression (it will not be a source of variation in aggregate demand).

The quantity supplied is given by the production side of the economy. We know that $q_i = \ell_i$ from the production function:

$$q_i = \ell_i = \frac{1}{(\gamma - 1)} (p_i - p)$$

The quantity of good i demanded must equal the quantity supplied:

$$y + z_i - \eta (p_i - p) = \frac{1}{(\gamma - 1)} (p_i - p)$$

Solving for p_i :

$$p_i = \frac{\gamma - 1}{1 + \eta\gamma - \eta} (y + z_i) + p$$

We can use this expression to find q_i for the individual producer. We can see that on the production side of the economy, it is the relative price of individual good i that matters for production.

6.2 New Classical Approach: The Case of Imperfect Information

Now, we assume that the producers are unable to observe the expression above - they only see p_i and are unable to distinguish between possible sources of a shock to their individual prices.

6.2.1 Producer Behavior

Here, when the firm chooses how much to produce, she has to forecast the relative price of her product, conditional on the information she observes (which is the individual price of her product):

$$q_i = \ell_i = \frac{1}{(\gamma - 1)} E[(p_i - p) | p_i]$$

Lucas assumes that the household has rational expectations. This means that rather than basing her forecast of $(p_i - p)$ on past values, she fully incorporates all available information (in this problem, this information is contained in p_i) into her forecast.

To determine how much the firm will produce, we need to find $E[(p_i - p) | p_i]$. This value depends on the underlying distributions of p and p_i . The firm observes p_i , $E(p_i | p_i) = p_i$:

$$q_i = \frac{1}{(\gamma - 1)} p_i - \frac{1}{(\gamma - 1)} E(p | p_i)$$

To see the implications of this model for the economy, see the Lucas Imperfect Information model supplement. In the end, we arrive at the following production choice for the individual producer (in the notation used by Romer):

$$q_i = \alpha\beta(p_i - p)$$

where $\alpha = \frac{1}{\gamma-1}$ and

$$\beta = \frac{\sigma_z^2}{\sigma_p^2 + \sigma_z^2}$$

The parameter β measures how much the producer responds to a change in her price. It is known as a signal-to-noise ratio. Notice that when the aggregate price level is unstable (σ_p^2 is large), β is small. That is, the producers are less responsive to changes in their individual prices because of the “noise” created by unstable aggregate prices. When σ_z^2 is large, β is large, so that most variation in the individual price is associated with idiosyncratic demand shocks.

In aggregate, production is:

$$y = \alpha\beta (p - E(p))$$

where $p = E(p)$ on average (e.g., in the long run), so that $y = 0$ in the long run. Notice, this can easily be modified to allow for some positive potential output, \bar{y} :

$$y = \bar{y} + \alpha\beta (p - E(p))$$

6.2.2 Equilibrium

Taking the expression for output and combining this with the aggregate demand equation:

$$\begin{aligned} p &= \frac{1}{1 + \alpha\beta} m + \frac{\alpha\beta}{1 + \alpha\beta} E(p) \\ y &= \frac{\alpha\beta}{1 + \alpha\beta} m - \frac{\alpha\beta}{1 + \alpha\beta} E(p) \end{aligned}$$

We can combine these expressions to show that $E(p) = E(m)$. Substituting this into the expressions above:

$$\begin{aligned} p &= E(m) + \frac{1}{1 + \alpha\beta} [m - E(m)] \\ y &= \frac{\alpha\beta}{1 + \alpha\beta} [m - E(m)] \end{aligned}$$

From these expressions, we see the key implications from the model. Only unanticipated changes in money supply (or unanticipated shocks to AD in general), affect real output. Anticipated changes in money only affect the price level.

6.3 New Classical Approach: Implications and Limitations

This section applies the model to the data to consider its implications for policy and potential limitations.

6.3.1 The Phillips Curve and the Lucas Critique

In the Lucas model, shocks to aggregate demand affect real output only when these shocks are unanticipated. To understand the time series implications of the model, we need to assume a distribution for the money supply. Romer suggests assuming that money supply follows a random walk with a drift:

$$m_t = \delta + m_{t-1} + u_t$$

where $u_t \stackrel{iid}{\sim} (0, \sigma_u^2)$. Taking the expectations of this expression (at time t) allows us to find $E(m)$:

$$\begin{aligned} E(m_t) &= E[\delta + m_{t-1} + u_t] \\ &= E(\delta) + E(m_{t-1}) + E(u_t) \\ &= \delta + m_{t-1} \end{aligned}$$

so that $m - E(m) = u$. Plugging this into the expressions for prices and output above we have:

$$\begin{aligned} p_t &= \delta + m_{t-1} + \frac{1}{1 + \alpha\beta} [u_t] \\ y_t &= \frac{\alpha\beta}{1 + \alpha\beta} u_t \end{aligned}$$

This highlights the key implication pointed out above. Shocks to aggregate demand affect real output *only* when they are unexpected. Notice that inflation $\pi_t = p_t - p_{t-1}$ (because the variables are defined in logs). Therefore, inflation is:

$$\begin{aligned} \pi_t &= \delta + m_{t-1} + \frac{1}{1 + \alpha\beta} [u_t] - \left\{ \delta + m_{t-2} + \frac{1}{1 + \alpha\beta} [u_{t-1}] \right\} \\ \pi_t &= m_{t-1} - m_{t-2} + \frac{1}{1 + \alpha\beta} (u_t - u_{t-1}) \\ \pi_t &= \delta + \frac{1}{1 + \alpha\beta} (u_t - u_{t-1}) \end{aligned}$$

When there is a positive shock to m_t , that is, $u_t > 0$, y_t and π_t increase according to the expressions above. Therefore, there is a positive relationship between inflation and output in the short run.

If there were an anticipated shock to money, then the price level would increase proportionately, leaving real output unaffected. In the context of the model, if the producers know that aggregate demand has increased, then they will not increase individual production. They won't be tricked into increasing production because they will know that the increase in their individual prices are a reflection of economy-wide inflation.

6.3.2 Stabilization Policy

Another important implication from the Lucas imperfect information model is that systematic changes in policy will not affect output. If the Federal Reserve or federal government respond to recessions in the same way, households and producers learn from this, and adjust their inflation forecasts accordingly. For example, if the Federal Reserve announces that it wants to lower the inflation rate, if this is credible, then households and producers will lower their inflation expectations, allowing for a “painless” disinflation. However, if the Fed tries this repeatedly, then agents learn that the announcements are not credible, reducing the effectiveness of policy to reduce inflation.

The general implication from the model is as follows: if the policy is a surprise, it is more likely to affect real economic variables.

6.3.3 International Evidence on Output-Inflation Trade-offs

Lucas (1973) examines the relationship between the variance in prices and variance of output. Empirically, he identifies the effect of an aggregate demand shock on real output using a two step process. First, he estimates the relationship between real output, y_t , and the change in the log of nominal output, x_t (plus some control variables):

$$y_t = \gamma + \delta t + \tau \Delta x_t + \rho y_{t-1}$$

He runs this time series regression for several countries. Then, taking the estimates τ_i for each country, he runs the following cross section regression:

$$\tau_i = \alpha + \beta \sigma_{\Delta x, i}$$

where $\sigma_{\Delta x, i}$ is the standard deviation of the change in the log of nominal GDP for country i . According to the Lucas imperfect information model, $\beta < 0$. This would mean that aggregate demand shocks have a relatively smaller effect on real output in countries where nominal GDP is less stable. The idea is that in these countries, the individual producers would be less responsive to changes in individual prices because of the noise created by unstable nominal variables.

This is related to the discussion of stabilization policy above. The more policymakers attempt to stabilize real output, the more volatile are nominal variables, and the less effective their policies become. This has led toward a general consensus, even among new Keynesians, that stabilization policy should NOT be used to “fine tune” a perceived recession. Stabilization policy should be used sparingly in response to large negative shocks to the economy.

6.3.4 Difficulties

There are two major weaknesses in the model. This model is actually a precursor to the RBC model we’ve already studied. The fluctuations in output come

entirely from changes in labor supply and production. Like the RBC model, in order to generate fluctuations in (the cyclical component of) output that are consistent with the data, we need to assume a high degree of labor supply elasticity. In order to generate large fluctuations in output, we need households to be very responsive to changes in wages.

The second problem is that it is difficult to believe that business cycles can be attributed to imperfect information. Producers can learn of changes in aggregate prices relatively quickly and adjust their output accordingly. This appears to be at odds with the generate the large and persistent changes in output observed in the data.