11   Aggregate Supply with Imperfect Information

Chapter 11 Contents

A.   Topics and Tools

This chapter and Romer's Section 6.9 examine Robert Lucas's imperfect information model, which sits at a major crossroads in the evolution of macroeconomic theory. The Lucas model represents macroeconomists' first voyage into mathematical modeling of a complete monetary-macroeconomic system based on well-specified microeconomic assumptions. It was also the first application of the concept of rational expectations in macroeconomics.

Despite its historical importance, the more extreme implications of the Lucas model have failed to survive the intense battery of empirical testing to which they have been subjected. Few economists still believe that anticipated changes in the

money supply are completely neutral or that prices adjust instantly to clear goods and labor markets. Nonetheless, the dynamic microfoundations approach to modeling the macroeconomy remains Lucas's legacy to the profession and dominates the way that modern macroeconomists do their work. Lucas was awarded the Nobel Prize in economics in 1995.

B. The Lucas Model in Historical Perspective

To understand the historical significance of the neoclassical imperfect information model, it is helpful to have some understanding of the state of macroeconomics as of 1970, when Lucas began publishing his path-breaking work. At that time, there were basically two schools of macroeconomic thought, the Keynesians and the monetarists. The intellectual battlefield on which they did combat was largely a Keynesian one: short-run analysis with a heavy emphasis on using monetary and fiscal policy for business-cycle stabilization.

Keynesian macroeconomics in the 1960s

The majority of the macroeconomics profession in the 1940s through the 1960s lined up as Keynesians. Their basic framework of analysis was the *IS/LM* model with a Phillips curve grafted on to predict inflation. Monetary neutrality was dismissed by this group as applying only to idealized models based on unrealistic classroom assumptions. The Keynesians were confident that money had real effects in the "real world." In terms of policy analysis, Keynesians of this period relied on the observed empirical regularity of the traditional Phillips curve to justify the existence of a tradeoff between high unemployment and high inflation. Reducing either inflation or unemployment was thought to lead inevitably to an increase in the other.

In the 1960s, the research agenda of the Keynesians was to estimate the basic structural functions of the Keynesian model with ever-greater precision. Empirical models of the consumption function, investment function, demand function for money, and Phillips curve formed the core of an ever-expanding set of larger and larger **macroeconometric forecasting models**. These models, which grew to as many as 3,000 equations and a like number of endogenous variables, were (and still are) used routinely to forecast future movements in the economy and to simulate the effects of government policies.

Keynesians generally advocated the active use of monetary and fiscal policy to combat business cycles. As soon as a recession began, the central bank was advised to expand the money supply more rapidly and lower interest rates to increase aggregate demand and stimulate the economy. Expansionary fiscal policy would take the form of higher government spending and/or lower taxes—fiscal stimulus.

It is worth noting that while traditional Keynesian analysis fell out of favor in the 1970s among academic economists, businesspeople and policymakers often still rely on Keynesian-style models to predict and understand short-run movements in the economy.

Monetarism

Dissenting from the Keynesian orthodoxy were the monetarists, led by Milton Friedman and his colleagues at the University of Chicago and elsewhere. The monetarists believed that money was neutral, at least in the long run, and that attempts to use monetary or fiscal policy to smooth the business cycle were likely to be ineffective (at best) or perhaps actually destabilizing.

While most monetarists did not deny that changes in the money supply could have non-neutral short-run effects, they believed that the effects of money on real variables were unpredictable and subject to long lags. They argued that it was so difficult to use monetary policy properly for stabilization that the central bank was just as likely to make business cycles worse as to make them better.

To see how this is possible, suppose that there is a two-year lag between a change in the money supply and its maximum effect on aggregate demand. This can happen because investment and consumer spending may respond very slowly to changes in interest rates. Once interest-sensitive spending changes, then the multiplier effect must further influence income-sensitive consumption before the full demand effect is felt. This process can be quite lengthy. Given these long lags, suppose that the central bank pursues monetary expansion starting at the trough of the business cycle. It is likely that the natural equilibrating forces of the labor and goods markets will have returned the economy at least part way to full employment by the time the increase in aggregate demand is fully felt two years later. The effect of this extra boost to demand may then be felt at a time when the economy is already producing near its capacity rather than in a depressed state. At full employment, the extra demand may simply fuel an inflationary boom.

In a typical scenario as painted by the monetarists, the monetary authority would respond during this policy-induced inflationary boom by slamming on the monetary brakes, which could trigger another recession. Such "stop-and-go" policies were believed by monetarists to be one of the main underlying causes of business cycles.

The monetarist policy prescription was to simply maintain monetary growth equal to the trend rate of growth of the real economy—typically about 3 percent. This would stabilize the long-run inflation rate near zero and avoid the dangers of mistimed cyclical policy actions.

The analytical framework of the Keynesian/monetarist debate

The debate between the 1960s Keynesians and monetarists was conducted on a very different level than the abstract mathematical theories we now study. The prime

issues of contention were empirical in nature. Disagreement tended to focus on such questions as the slope of the *LM* curve (monetarists thought it was steep, Keynesians flat), the slope of the *IS* curve (monetarists believed it to be flat, Keynesian argued it was steep), the length of lags in the effects of policies, and the relative social importance of unemployment and inflation.

The mode of analysis was almost entirely "top-down" in the style of Keynes himself. The starting point was observation of correlations among aggregate variables. These correlations were then expressed as aggregate economic relationships such as the consumption function or investment function and assembled into models. The models were then estimated using samples of macroeconomic data. Variables that could not be observed (such as expectations) were often ignored, since it might not occur to someone following this top-down approach that unobservable variables could be important.

Microeconomic theory was often neglected by macroeconomists. Few worried much about whether a particular form of a macro equation was consistent with utility maximization, profit maximization, or any particular market structure. As long as it worked empirically, a model was deemed satisfactory.

It would be an overstatement to say that there was *no* attention to the microeconomic underpinnings of macro theory in the 1950s and 1960s. Ando and Modigliani (1963) used utility functions in their derivation of the life-cycle consumption model, Robert Clower (1965) examined the microeconomic decisions of income-constrained households in justifying the Keynesian approach to consumption, and much of investment and money-demand theory was based on models in which profit was maximized and/or costs minimized. However, the emphasis in macroeconomics was clearly on empirical work and the ability to generate more accurate forecasts and policy simulations.

During the late 1960s, economists began to look more carefully at the microfoundations of the Phillips curve relationship. A major milestone was the publication of a collection of papers edited by Edmund Phelps (1970). The papers in the "Phelps volume" began to explore microeconomic models of the labor market and their implications for the existence and stability of the Phillips curve. Together with Milton Friedman's presidential address delivered to the American Economic Association in December of 1967 [Friedman (1968)], this work is often cited as marking the beginnings of a new approach to macroeconomic theory.

Rational expectations

One of the papers in the Phelps volume was a study by Lucas and Rapping (1969), which presented a dynamic model of labor supply in which households explicitly maximize expected lifetime utility. They found that in order to test this model, they needed to know about peoples' expectations of future values of wages and

prices. Although this Lucas research did not provide a new solution to the expectations problem, the search for a solution later led Lucas to the idea of *rational expectations*, which had been devised a decade earlier by John Muth.

The central idea of rational expectations is that individual agents are not consistently fooled by events that could be anticipated correctly by someone with knowledge of economic models. In other words, market participants (eventually) learn about the markets in which they participate. A rational expectation is the best prediction of the relevant economic model, based on the variables that agents can observe at the time the expectation is formed. Muth (1961) applied rational expectations to microeconomic markets such as those for agricultural goods. Markets for farm products require long production periods. Farmers must decide which crops to plant many months before they harvest and sell them. They must therefore act on expectations about future product prices when making production decisions.

The most common expectations assumptions in use before Lucas were *myopic* or *adaptive expectations*. Under myopic expectations, individuals simply assume that the future value of any variable will be the same as the current value. The adaptive-expectations hypothesis assumes that agents calculate expected future values as a function of current and past values. In both cases, price expectations are made mechanically based on current and/or recent past histories of prices, without considering the effect of any predictable changes in economic conditions or decisions.

In a farm-product context, myopic expectations can lead to irrational and predictable cyclical fluctuations in output and prices. Suppose that bad weather reduces the corn harvest in 2009, which leads to higher prices. Farmers with myopic expectations would assume that prices would remain high in 2010 and would plant lots of corn. Of course, unless the abnormal bad weather shock recurred, there would be more corn in 2010 and prices would be below normal. Extrapolating the low price into the future would cause farmers to lower corn production in 2011, raising the price again, and so on.[1]

These cycles would be detrimental to farmers because they would alternately over-plant and under-plant corn and repeatedly end up being disappointed by the market price at harvest time. Muth argued that it would be irrational for farmers to continue to form expectations myopically. They would have much to gain by figuring out how the economic model worked and applying that knowledge to forecasting.[2] Farmers who were able to forecast more effectively would make more money and could eventually drive less effective farmers out of the market, so all remaining

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[1] This model is often called the "cobweb" model because of the pattern of squares that are traced out on a supply-demand diagram as the model cycles between low and high prices.

[2] It is worth noting that the farmers need not do the economic forecasting themselves. They could simply monitor the forecasts of the U.S. Department of Agriculture or of any of many private forecasters.

producers would form rational expectations. This rational-expectations equilibrium would eliminate the price-output cycles of the naïve cobweb model.

Lucas applied rational expectations to forecasts of future inflation. Just as the farmers of the cobweb model were assumed by Muth to be capable of learning about the relationship between current prices and future production and prices, Lucas argued that producers and households would learn that monetary expansion leads to inflation. Even if not everyone in the economy has studied macroeconomics, forecasts by experts are published regularly in the media, allowing all economic agents to act on informed (and presumably "rational") forecasts.

Policy ineffectiveness

The combination of a well-specified microeconomic model of aggregate supply (which dove-tails with the expectations-augmented Phillips curve) with the assumption of rational expectations led Lucas to a shocking result. If monetary expansion raises people's inflationary expectations, then it should shift the Phillips curve upward rather than simply moving the economy along the Phillips curve to lower unemployment. In its most extreme form, Lucas's theory predicts that the change in expectations will completely neutralize the unemployment-reducing effect of monetary expansion, even in the short run.

The **policy-ineffectiveness proposition** was viewed by Keynesians as being outrageous and obviously counterfactual. Not only were they totally convinced that Lucas's conclusion must be wrong, many did not understand the complicated mathematics that led to it. Because the most unfamiliar aspect of Lucas's model was his assumption of rational expectations; his approach quickly became known as the "rational-expectations model." In retrospect, the assumption of rational expectations is only a small part of Lucas's model—other models with rational expectations have been shown to lead to opposite conclusions. In fact, it is the assumption of perfectly flexible wages and prices more than that of rational expectations that lies at the heart of Lucas's neutrality and policy-ineffectiveness results.

The fact that most of the models we have studied in this macroeconomics course begin with maximization of utility and/or profit and that they incorporate stochastic disturbance terms to allow the rigorous modeling of expectations serves as testimony to the impact that Lucas and his followers have had on macroeconomics. In his view, Keynesians got the wrong answer not simply because they made the wrong assumption about the slope of the *IS* or *LM* curve, but because they did not take the care needed to work out an alternative to the *IS*/*LM* framework that was consistent with reasonable behavior on the part of individual households and firms.

Lucas and macroeconomic modeling

Robert Lucas was very critical of the kind of econometrics-based macroeconomic models used for policy evaluation in the 1960s. Lucas (1976) presents an argument

known, after the title of the paper, as the "Lucas critique." According to this argument, well-specified economic models consist of two kinds of parameters.

Underlying structural parameters ("deep" parameters), such as the rate of time preference, the rate of risk aversion, and the parameters of production functions, are likely to be quite stable over time and would not change in response to different policies. These parameters determine the decision rules by which individuals respond to changes in actual and expected conditions.

The second set of parameters describes how people form expectations about future conditions. Unlike the deep parameters, this set depends crucially on the economic-policy regime. For example, people's expectations of future prices would be very different in a recession if they expected a strong countercyclical monetary policy than if they expected the Fed to maintain stable money growth.

Lucas argued persuasively that relationships such as *IS* and *LM* curves (and even consumption and investment demand functions) are complex combinations of deep and expectations parameters. Because the expectations parameters will be sensitive to policies and other conditions, these equations can *never* be counted on to remain stable as macroeconomic conditions change. This means that one could not count on the *IS/LM* model to predict the results of a change in monetary policy because the policy change itself might change the slopes and positions of all of the curves in complicated ways by affecting the embodied expectations parameters.

Since Lucas's work, most academic macroeconomic models have been based on carefully worked-out microeconomic assumptions. Microeconomics tells us that decision-making is nearly always dynamic, so modern micro-based macro models have tended to emphasize dynamics, which has required a careful specification of how expectations are formed. Since rational expectations collapse to perfect foresight unless there is uncertainty, these models usually include stochastic shocks. Great advances have been made following Lucas in the ability of macroeconomists to deal with dynamic stochastic models. Although the specific model in which Lucas embodied all these ideas (and that we are studying) is no longer very often used, it is an important benchmark in the development of modern macroeconomics.

C. Understanding Romer's Section 6.9

The basic idea

As we discussed when we studied the real-business-cycle model, a perfectly competitive economy with instantaneous price and wage adjustment and perfect information leads to the conclusion that the real economy is totally independent of monetary and nominal variables. (The money supply, nominal interest rate, price level,

and inflation rate did not even appear as variables in the RBC model.) Monetary policy is totally neutral; a change in money affects prices and other nominal variables but no real magnitudes. In order to explain the considerable evidence supporting short-run effects of monetary policy on real variables, we must introduce some kind of "imperfection" into the classical general-equilibrium framework.

The imperfection that Lucas examined was in the information that agents are assumed to possess. To make information imperfect, Lucas used a theoretical setting originated by Phelps (1970) that is often called the "island paradigm." In this setting, we can think of individuals as being randomly scattered over the many islands of a large archipelago. Each island has a local market and each individual on the island has perfect information about the current market-clearing price of the good on her own island. The individual is assumed to sell her output on the local island at the known local price, but to buy goods originating on all islands at an average price level that is not immediately known. The key information asymmetry in the model is that agents know the price of the goods that they sell, but not the price of the goods they will buy. The Phelpsian islands correspond to individual producers in Romer's model. Each producer knows what is happening to the price of her output, but not (immediately) what is happening to the prices of the goods she buys.

The production decision is based on the idea of intertemporal substitution in labor and leisure. (Recall the important role that this also plays in the RBC model.) Each agent would like to time her work effort to get the maximum possible consumption out of her work hours. To accomplish this, she wants to sacrifice leisure and produce a lot during periods when the price on her island is high (relative to the cost of the goods she purchases) and to enjoy more leisure and produce less during periods when the relative price of her output is lower. However, she must make her production decision before she knows the actual price that she must pay for consumption goods. Therefore, the production decision will depend on the relationship of the known local price to her *expectation* of the unknown average price across islands.

The central operational features of this model can be characterized simply as follows. Suppose that there is a general aggregate-demand shock to all industries, perhaps because the central bank expanded the money supply. Since there is higher (nominal) demand in each industry, each industry's equilibrium price rises. If the aggregate change is perfectly anticipated so that everyone recognizes that the price level has risen over the entire economy, then they perceive that the price of the goods they will buy has risen in equal proportion to the price they receive for their output. Because they see that relative prices have not changed, such well-informed agents will not change their level of output—the rise in the money supply is neutral.

However, if the aggregate change is unanticipated and an agent does not realize that the change in money is universal, she may mistakenly interpret the rise in *all*

prices as a rise in the *relative price of her own good*. In that case, she produces more, thinking (incorrectly) that her own price is higher than everyone else's. Agents would mistake a rise in the general, *nominal* price level for an increase in their individual *relative* prices. In this way, increases in the aggregate money supply would have non-neutral effects, even if markets clear and the price in each market is perfectly flexible.

The real effect of an aggregate monetary expansion in this model arises solely out of incorrect expectations or perceptions. Correctly expected changes in the money supply (where this confusion is absent) are neutral in Lucas's model, whereas unexpected changes (where confusion over nominal vs. relative prices leads to an output effect) are non-neutral.

Modeling considerations

Before we begin the formal analysis, it may be beneficial to step back and consider the fundamental characteristics that our model must have in order to represent the behavior we have described. First of all, if expectations are to be imperfect, there must be random shocks in the model that are not foreseen by agents. In this case a single random shock to money or aggregate demand is not enough. Each agent is assumed to observe the price of the good she produces before making any decisions during the period. If there is just one kind of random disturbance, then a clever agent (*i.e.*, one with rational expectations) will be able to figure out the magnitude of the shock by working backwards from her observation of the local price. For example, if the only random variable is an aggregate shock that affects prices in all markets symmetrically, then an agent observing the price in her market to be 10% higher than she expected can confidently infer that prices in all other markets are also 10% higher. There would be no confusion and the aggregate price shock would be neutral. Thus, a single aggregate random shock is not sufficient to produce the kind of confusion that leads to non-neutrality in the Lucas model.

In order to produce the partial-information setup that is required, there must be two kinds of shocks with the following properties: (1) both shocks must affect a producer's individual, nominal price (which is the observed variable on which the agent relies for information); and (2) the two shocks must lead to different responses by the agent *if she had perfect information*.

The shocks in the Lucas model are (1) aggregate monetary shocks, which affect the demand for each good symmetrically, and (2) good-specific (relative) shocks that affect the market for each good uniquely but average to zero across all goods. If an aggregate shock occurs and is correctly recognized as such, agents will not change their levels of production; they will recognize that the prices of the goods they buy have increased as much as the prices of the ones they sell, leaving the real tradeoff between work and goods unchanged. However, if a good-specific demand shock occurs (and is recognized correctly), then the rise in the good's nominal price is not ac-

companied by an increase in other prices, so the agent's relative price increases and she would like to raise her level of output. Output will respond to aggregate shocks only if some agents misinterpret them as relative-price shocks.

The problem for the agent is that all she sees is a rise in her good-specific, nominal price, which could be caused either by an aggregate shock or by a good-specific shock. She faces a ***signal-extraction problem*** in trying to infer from the change in a single information variable (her nominal price) which of two underlying random variables caused the change. Since she cannot know which shock changed the price in the current period, she will form an expectation based on the average prevalence of the two kinds of shocks. If good-specific local shocks are more prominent, then she will probably interpret price changes as changes in her relative price and change her output strongly. However, if aggregate shocks dominate in the general economy, then she is likely to interpret the price increase (whatever its actual cause) as general inflation and leave her level of production unchanged.

Romer's formalization of the Lucas model

There are several different ways of formalizing the basic model of imperfect information. Romer's approach is representative of the literature on such models and keeps the algebra pretty simple. The model is similar in most ways to the new Keynesian model of the earlier part of Chapter 6, but differs in some details. The model in Section 6.9 has perfect, rather than imperfect, competition. Households produce directly for the market using their own labor rather than selling their labor to firms that produce output. And, of course, the random shocks discussed above play a central role. The assumption of perfect competition means that even though each agent produces only one of many commodities, it is not the sole producer of that commodity. In fact, there are many producers of each commodity i, which means that each individual producer of i is a price taker. Thus, in contrast with the imperfect competition model we developed earlier, P_i is not a choice variable of the agent who produces good i.

We assume that there is no capital or saving/borrowing, so households consume their entire income each period, which allows us to examine the model period-by-period, without considering dynamic budget constraints or utility functions. Thus, the agent's consumption is her current dollar earnings from production divided by the dollar price of the goods she consumes. She produces Y_i and receives a price of P_i dollars per unit. Since she buys goods from all industries, her consumption costs P dollars per unit. Therefore, $C_i = P_i Y_i /P = (P_i /P) \ Y_i \ = (P_i /P) \ L_i$. Thus, the relative price P_i /P is the agent's "real wage"—the amount of consumption she gets per unit of additional work. As in the RBC model, the focus here is on the response to temporary changes in the real wage. However, Romer suppresses the potentially inter-

temporal nature of this response by assuming no saving. Instead, we just have the simpler static response of workers to higher wages.

The utility function given in equation (6.72) is also a simple one. It is linear in consumption, which corresponds to the case $\theta = 0$ in the CRRA function we used in the Ramsey growth model. By assuming away diminishing marginal utility of consumption, we are eliminating the motivation for consumption smoothing. We don't need a motivation for consumption smoothing because there is no saving in this model.

He retains the usual assumption of diminishing marginal utility of leisure (increasing marginal disutility of labor) because agents' positive response to their real wage depends on this assumption. The assumption that $\gamma > 1$ assures that the marginal disutility of work increases as the agent works more, and implies that the labor-supply curve slopes upward.

Given the utility function in (6.72), and given that the agent is one of many competitive producers of good i, the only choice variable in the equation is Y_i, the amount of output that a representative producer of good i should produce. Setting the derivative of the utility function with respect to Y_i equal to zero yields equations (6.73) and (6.74). The model turns out to be linear in the logs of variables, so we get (6.75) as the log of (6.74), denoting logs by lower-case letters.

The demand equation (6.76) for the ith good is the logarithmic version of equation (6.48) that we derived from consumer utility maximization in the earlier model. One thing has been added: the shock z_i that is the good-specific shock to the demand for good i. Equation (6.76) expresses the log of the demand for good i as the sum of three terms. The first term y is a measure of the log of "aggregate demand" relative to its normal level, which is the level of log-demand averaged across all the goods. As before, we will assume that aggregate demand depends on a demand variable M via $Y = M/P$, or in log form, $y = m - p$.

The second term in the demand function is the local demand shock, z_i. These shocks add up to their expected value of zero when they are aggregated across all goods. The final term involves the log of the relative price of good i: $p_i - p = \ln(P_i/P)$. The elasticity of demand with respect to price is again η.

The signal-extraction problem

Under our assumptions, agents must act based on imperfect information about P, the aggregate price level. They are assumed to observe P_i (the price of the good they produce) perfectly, but they must infer from this good-specific nominal price their expectation of the *relative* price P_i/P, which is what determines their desired amount of work and production.

Romer defines $r_i = p_i - p$ to be the log of the relative price of good i. From (6.75) and, under certainty equivalence, (6.81), this relative price determines the individu-

al's labor effort and production. There are two random variables in the model, m and z_i, which correspond to the aggregate-demand shock and the good-specific demand shock. The aggregate monetary shock has mean equal to $E[m]$ and variance V_m. The local (relative) shock has mean 0 and variance V_z. The two shocks are assumed to be independent of one another.

Given (6.81), the agent's problem is to calculate $E[r_i|p_i]$, the expectation of the relative price conditional on the observed local nominal price. To do this requires solving a signal-extraction problem. In particular, suppose that the price she observes for her good is different than the price she expected (before observing it). She must determine to what extent this is likely to be due to an increase in her relative price r_i rather than to an unexpected increase in the general price level p.

Methods of stochastic modeling tell us that the mathematical expectation of r_i in this case is given by Romer's equation (6.82).[3] Under rational expectations, we assume that agents act as though they have the information and ability necessary to form subjective expectations that correspond to mathematical expectations, so equation (6.82) can be substituted into (6.81) to get the individual's production function (6.83). This is then aggregated to get the "Lucas supply curve" (6.84).

The intuition of equation (6.82) may not seem obvious, but it is readily explained. The variable p_i is the "information variable" from which agents producing i attempt to infer aggregate and relative prices. From (6.80), the information variable p_i is the sum of the log of the aggregate price level p and the log of the relative price r_i. The shocks that drive demand in the local market are independent of the aggregate monetary shock, so these two components will be independent and the variance of the information variable p_i is the sum of the variances of p and r_i. Thus, the $V_r + V_p$ in the denominator is the total variance of the information variable, p_i. The ratio $V_r / (V_r + V_p)$ measures the share of the variation in the information variable that is due to relative-price variation. If relative prices contribute, say, two-thirds of the variation in p_i then the agent would attribute two-thirds of any change in p_i to relative prices. If p_i went up unexpectedly by 0.3, then she would guess that r_i went up by 0.2 and p by 0.1.

To clarify the intuition, we consider two polar cases where one kind of variation or the other dominates. Suppose that nearly all of the variation in the price of i is due to fluctuations in aggregate inflation. This will be the case if there was very little variation in relative prices, *i.e.*, if $V_r \rightarrow 0$, or if inflation is extremely variable, *i.e.*, if V_p becomes very large. In the first case, the numerator of the coefficient $V_r / (V_r + V_p)$

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[3] If you are interested in the mathematics of these kinds of problems, you might want to take a look at Sargent (1987). This is a graduate textbook that places more emphasis on the mathematical aspects of the analysis. In particular, Chapters X and XI discuss the analytical foundations of stochastic models such as this one.

approaches zero while the denominator approaches $V_p > 0$, so $V_r / (V_r + V_p) \to 0$. In the second case, the denominator becomes very large, so again $V_r /(V_r + V_p) \to 0$. That means that the agent's expected relative price is hardly affected at all by changes in the nominal local price. Intuitively, these cases correspond to situations where there is very little relative-price variation compared to the magnitude of aggregate fluctuations in prices. Thus, any observed change in the price of good i is likely to be attributed to inflation rather than to a relative-price change. Since agents with rational expectations recognize this, their supply curves will be inelastic—their levels of labor effort and output will not respond much to changes in prices.[4]

The opposite polar case is one in which aggregate inflation is very stable compared with relative prices. This is usually thought of as a case in which $V_p \to 0$. In this case, the ratio $V_r / (V_r + V_p) = 1$ and agents act as though *all* changes in their observed price were due to relative-price shocks. Their supply curves in this case are highly elastic, which means that if an aggregate shock does occur (though they are improbable if V_p is small) it will fool them almost completely and lead to a substantial response in labor effort and output.

This ratio is the basis for Lucas's famous empirical examination of his supply theory, which is discussed by Romer on pages 303 and 304. The theory predicts that aggregate-supply curves should be very inelastic in countries with highly variable inflation, such as many Latin American countries before 2000, and much more elastic in countries with more stable inflation such as the United States, Japan, and Germany. Lucas (1973) showed that changes in nominal GDP (which he used to proxy for the position of the aggregate demand curve) led to much larger changes in output during his sample period in stable-inflation countries than in countries with volatile inflation. This evidence is discussed in more detail in Chapter 13 of the coursebook.

Policy ineffectiveness

Solving for the model's equilibrium is straightforward once you understand the supply behavior that is implied by the Lucas supply curve. One implication of equations (6.89) and (6.90) deserves special emphasis. This is the ***policy-ineffectiveness proposition*** that generated great controversy among macroeconomists when it was

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[4] Since the agent cannot tell the difference between aggregate and relative shocks, the parameter $V_r / (V_r + V_p)$ describes her response to *either* kind of shock. Not only will she not respond to inflation shocks (which is good), but she won't respond to relative price shocks either (which is bad). This implies that the reduced responsiveness of agents' decisions to relative price changes in economies with high and variable inflation can hinder the functioning of the relative-price signals that are so important to efficient resource allocation. This is one reason why inflation (more specifically, unpredictable inflation) is undesirable.

originally proposed.[5] It implies that the effect on the economy of a change in the money supply or other shocks to aggregate demand is very different depending on whether or not it is correctly anticipated by the agents in the economy.

Changes in aggregate demand that are fully anticipated are completely neutral, increasing prices proportionally and not affecting real output at all. Only when an aggregate-demand change surprises agents do they respond by changing their labor effort and their output. This applies, in particular, to aggregate-demand changes arising out of monetary policy actions by the central bank. Two examples of monetary changes that could be correctly anticipated are (1) changes that are announced in advance by the central bank (and believed by the public) and (2) steady increases in the money supply over time that people eventually learn to expect, say, a steady increase of n percent per year.

However, the more controversial application is that agents with rational expectations should learn to anticipate countercyclical stabilization rules as well if the central bank uses them consistently. If the central bank expands the money supply every time the economy falls into a recession, then people will begin to expect higher money growth as soon as they see signs of a recession—countercyclical monetary-policy actions will be correctly anticipated. Since anticipated monetary policy has no effect on real output, the Lucas model implies that such monetary changes will not affect real variables and monetary policy is useless for stabilizing business cycles.

This conclusion was so radically at odds with the prevailing Keynesian view of monetary stabilization policy that it provoked a storm of response and a flood of empirical tests. A few of these tests are described in Coursebook Chapter 13.

D. Aggregate Supply and Demand and the Lucas Model

The Lucas model can easily be formulated in the language of aggregate supply and aggregate demand. Romer's equation (6.41) gives the aggregate-demand curve as $y = m - p$. For the purely classical model with perfect information, the aggregate-supply curve is vertical at the natural level of output. Under imperfect information, we derive the Lucas aggregate-supply curve in the short run to be Romer's equation (6.84): $y = b\,(p - E[p])$.

The model with no imperfect information translates very easily into *AS/AD* space. The *AS* curve is vertical at the natural level of output ($y = 0$, or $Y = 1$, in this case) and the *AD* curve is downward-sloping. Any change in aggregate demand is immediately perceived as such by agents, so affects only prices. In particular, an in-

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[5] The policy implications of the Lucas model are forcefully presented in Sargent and Wallace (1975).

crease in the money supply raises prices proportionally, so money is neutral in this model. Because most microeconomic rigidities (such as price stickiness or imperfect information) apply only in the short run, we often call this vertical AS curve the long-run aggregate-supply curve.

To see how the graphical analysis of the imperfect information case would work, suppose that everyone shares a common expectation m^e of m, so that the expected aggregate-demand curve is at $AD(m^e)$ in Figure 1. Based on this expected AD curve, the expected price would be set at $E[p|m^e]$, the level where the expected AD intersects the natural level of output.

The expected price level fixes the vertical position of the Lucas $SRAS$ curve, since y is its natural level of zero when price equals expected price. Thus, the $SRAS$ curve must be at the position shown by $SRAS(m^e)$ in Figure 1.

The random realization of actual m determines the actual position of the actual (as opposed to expected) aggregate-demand curve; it could be higher or lower than m^e. Figure 1 shows the case where actual m is $m_1 < m^e$. With aggregate demand lower than expected, prices end up below expectation, which fools producers into reducing their levels of output as they misperceive their lower nominal prices as lower relative prices. Price ends up at p_1 and output at y_1.
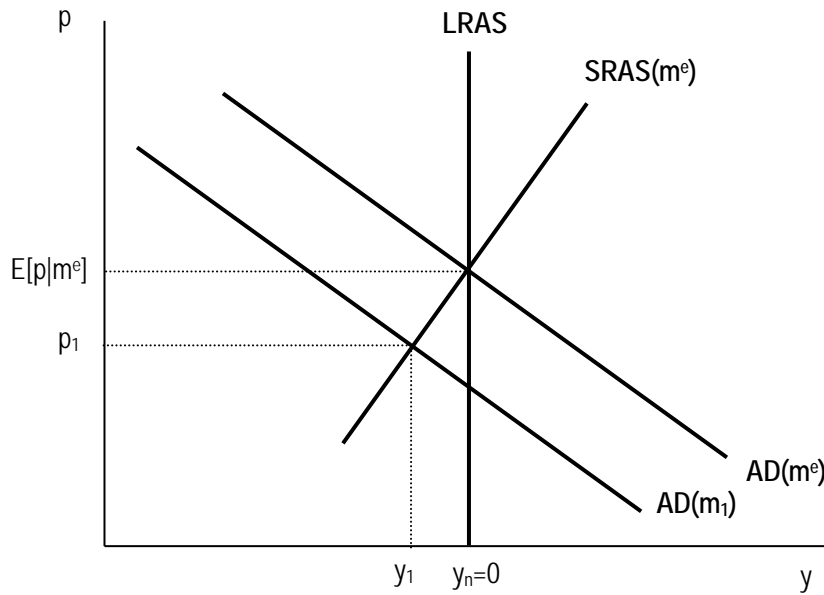
Figure 1. Lucas model in AS/AD

The reduction in output persists as long as people misperceive the aggregate price level. If the lower level of m is permanent, people eventually adjust their expectations

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down to m_1. When this happens, the *SRAS* curve shifts downward to intersect the $AD(m_1)$ curve at $y = 0$, returning the economy to full employment at a price level that falls in proportion to the decline in m.

E.   Works Cited in Text

Ando, Albert, and Franco Modigliani. 1963. The Life-Cycle Hypothesis of Saving: Aggregate Implications and Tests. *American Economic Review* 53 (1):55-84.

Clower, Robert. 1965. The Keynesian Counter-Revolution: A Theoretical Appraisal. In *The Theory of Interest Rates*, edited by F. Hahn and F. P. R. Brechling. London: Macmillan.

Friedman, Milton. 1968. The Role of Monetary Policy. *American Economic Review* 58 (1):1-17.

Lucas, Robert E., Jr. 1972. Expectations and the Neutrality of Money. *Journal of Economic Theory* 4 (2):103-124.

———. 1973. Some International Evidence on Output-Inflation Tradeoffs. *American Economic Review* 63 (3):326-334.

———. 1976. Econometric Policy Evaluation: A Critique. *Journal of Monetary Economics* 1 (2):19-46.

———. 1981. *Studies in Business-Cycle Theory*. Cambridge, Mass.: MIT Press.

Lucas, Robert E., Jr., and Leonard A. Rapping. 1969. Real Wages, Employment, and Inflation. *Journal of Political Economy* 77 (5):721-54.

Muth, John F. 1961. Rational Expectations and the Theory of Price Movements. *Econometrica* 29 (3):315-335.

Phelps, Edmund S. 1970. *Microeconomic Foundations of Employment and Inflation Theory*. New York: W.W. Norton.

Sargent, Thomas J. 1987. *Macroeconomic Theory*. Second ed. Boston: Academic Press.

Sargent, Thomas J., and Neil Wallace. 1975. 'Rational' Expectations, the Optimal Monetary Instrument, and the Optimal Money Supply Rule. *Journal of Political Economy* 83 (2):241-254.