The Role of Expectations in the FRB/US Macroeconomic Model

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In the past year, the staff of the Board of Governors of the Federal Reserve System began using a new macroeconomic model of the U.S. economy, referred to as the FRB/US model. This system of mathematical equations describing interactions among economic measures such as inflation, interest rates, and gross domestic product (GDP) is used in economic forecasting and the analysis of macroeconomic policy issues at the Board.

The FRB/US model replaces the MPS model, which, with periodic revisions, had been used at the Federal Reserve Board since the early 1970s.[1] A key feature of the new model is that expectations of future economic conditions are explicit in many of its equations. Because of the clear delineation of expectations, issues that would have been difficult or impossible to study with the MPS model can now be examined. For example, the new model can show how the anticipation of future events, such as a legislated reduction in future defense spending, may affect the economy today. Similarly, the FRB/US model can be used to examine the extent to which the consequences for inflation of a sharp increase in the price of oil depend on the course of monetary policy anticipated by the public.

EXPECTATIONS IN MACROECONOMIC MODELS

Expectations play an important role in the economic theories that underpin most macroeconomic models. Planning for the future is a central part of economic life. The need to make decisions about the type of car to buy, the amount of education to pursue, and the fraction of income to save forces households to think about which choices make the most sense not just for today but for years into the future. Similarly, business firms, in deciding where to locate factories and offices, what equipment to install, and what products to develop and produce, make decisions with consequences that may last many years. Individuals must make informed guesses about circumstances in the years ahead and then base decisions on these expectations. The approach to expectations taken in the FRB/US model is best understood in the context of a debate that has engaged macroeconomists for the past twenty-five years.

The Debate about Expectations

Economists have long recognized that expectations play a prominent role in economic decisionmaking and are a critical feature of macroeconomic models. However, they disagree about the basis on which individuals form expectations and thus about the way to model them. For example, the conventional view is that current consumption spending depends partly on how large or small consumers expect their future income to be. But economists are not in accord over exactly what information consumers take into account in forecasting future income.

The debate continues, partly because obtaining data on expectations is difficult. For example, surveys of expectations are limited to a few economic variables, such as inflation, and it is unclear whether the sur-

1. For further discussions of the FRB/US model, see Flint Brayton and Peter Tinsley, "A Guide to FRB/US: A Macroeconomic Model of the United States," Finance and Economics Discussion Series, 1996-42 (Board of Governors of the Federal Reserve System, 1996; available on the Board's web site at http://www.bog.frb.fed.us/pubs/feds/); Sharon Kozicki, Dave Reifschneider, and Peter Tinsley, "The Behavior of Long-Term Interest Rates in the FRB/US Model," *The Determinants of Long-Term Interest Rates and Exchange Rates and the Role of Expectations,* Bank for International Settlements Conference Papers, vol. 2 (Basle: Bank for International Settlements, 1996), pp. 215–51; and Flint Brayton, Andrew Levin, Ralph Tryon, and John C. Williams, "The Evolution of Macro Models at the Federal Reserve Board," *Carnegie–Rochester Conference Series on Public Policy,* forthcoming. The latter paper also discusses a new global macroeconomic model, known as FRB/MCM, now used by the staff of the Federal Reserve Board. See also Andrew Levin, "A Comparison of Alternative Monetary Policy Rules in the FRB Multi-Country Model," *The Determinants of Long-Term Interest Rates,* pp. 340–69. For a discussion of the MPS model, see Flint Brayton and Eileen Mauskopf, "The Federal Reserve Board MPS Quarterly Econometric Model of the U.S. Economy," *Economic Modelling*, vol. 3 (July 1985), pp. 170–292.

veys accurately measure the expectations that influence actual decisions. In some instances, expectations can be inferred from nonsurvey data. Expectations about future short-term interest rates, for example, can be inferred by comparing the yields on bonds of different maturities, given the assumption that a bond's yield depends on the sequence of short-term interest rates expected over its term to maturity, plus a term premium. However, this approach provides accurate measures of expectations only if this theory of the term structure of interest rates is itself correct and if term premiums can be reliably estimated.[2]

The lack of adequate data has meant that builders of macroeconomic models have had to specify a priori how individuals form expectations (see box ''Assumptions about the Ways in Which Expectations Are Formed''). Most models developed in the 1960s and 1970s, including MPS, incorporated the simplifying assumption that people form expectations *adaptively*. Under this assumption, for example, the expectation for inflation in the next year is based on the recent inflation trend. Similarly, expected interest rates depend on past interest rates.

Starting in the 1970s, a number of economists strongly criticized this treatment of expectations in macroeconomic models. Robert Lucas, in what has become known as the ''Lucas Critique,'' argued that analyzing alternative monetary and fiscal policies using these models is of questionable value because the adaptive approach fails to recognize that, in the real world, people are likely to modify their expectations as policies are changed.[3] According to Lucas and others, individuals have economic incentives to form accurate forecasts of future economic events, and such forecasts include the anticipated effects of the government's macroeconomic policies. If the Federal Reserve usually lowers interest rates during recessions, for example, then individuals facing the onset of a recession will base their forecasts of future interest rates on the systematic relationship between the cyclical state of the economy and interest rates.

Because of the criticism of adaptive expectations, the assumption of *rational expectations*, which had first been proposed in the early 1960s, gained favor among many macroeconomists.[4] In a given macroeconomic model, expectations of future events are rational if they are identical to the forecasts of that model. Because it posits that individuals make full use of all of the information embodied in the structure of a macroeconomic model, the rational expectations approach has become one benchmark for the estimation of unobserved expectations.

Cost–benefit analysis provides a useful perspective on this debate. In the view represented by models employing adaptive expectations, either the costs of

2. Similarly, the Treasury's recent issuance of bonds with returns indexed to the consumer price index (CPI) may help in the measurement of inflation expectations, which can be calculated by comparing the rate of interest on conventional bonds with the rate on indexed bonds. This approach, however, is subject to a number of potential problems. For a discussion, see Martin D.D. Evans, ''Index-Linked Debt and the Real Term Structure: New Estimates and Implications from the U.K. Bond Market,'' New York University, Solomon Center, Working Paper Series S-96-24 (March 1996).

3. Robert E. Lucas, ''Econometric Policy Evaluation: A Critique,'' *Carnegie–Rochester Conference Series on Public Policy,* vol. 1 (1976), pp. 19–46.

4. See John F. Muth, ''Rational Expectations and the Theory of Price Movements,'' *Econometrica,* vol. 29 (1961), pp. 315–35. The definition of rational expectations proposed by Muth (p. 316) includes the statement that ''the way [rational] expectations are formed depends specifically on the structure of the relevant system describing the economy.''

Assumptions about the Ways in Which Expectations Are Formed

Macroeconomic models have relied on several different assumptions about how individuals form expectations of future economic conditions:

Adaptive expectations depend only on past observations of the variable in question. Most econometric models developed in the 1960s and 1970s, including the MPS model, employed this assumption.

Rational, or model-consistent, expectations are identical to the forecasts produced by the macroeconomic model in which the expectations are used. This assumption has been used in many macroeconomic models developed in the past fifteen years and is one option for the formation of expectations used in FRB/US.

VAR expectations are identical to the forecasts of a small vector autoregression (VAR) model that includes equations for a few key economic measures (see box ''Types of Macroeconomic Models'' for a description of a VAR model). This is another option for expectations formation used in FRB/US.

Adaptive and VAR expectations may be rational if they are used in a macroeconomic model with a coinciding structure. For example, if actual inflation depends only on past inflation, then adaptive expectations of inflation will be rational.

sophisticated approaches to forming expectations are high, or the benefits from improved forecast accuracy are slight. Thus, individuals form their expectations of the future using simple rules of thumb or easily computed formulas, such as adaptive expectations. At the other extreme is the view underlying the rational expectations approach. In this case, collecting and analyzing information is assumed to have small costs and large benefits, and consequently individuals base expectations on sophisticated forecasting models that make use of all relevant data.

Between these extremes is the view that forecasting has both significant advantages and significant costs. Such a circumstance should lead households and firms to choose forecasting models that closely resemble their economic environment but fall short of a complete model of the economy in every detail.[5] In FRB/US, one of the options for expectations formation, referred to as *VAR expectations,* is motivated by this view.

Separation of Expectations from Actions in FRB/US

An important feature of the new model is the explicit separation of expectations regarding future events from delayed responses to these expectations. This separation does not exist in traditional structural macroeconomic models (see box ‘‘Types of Macroeconomic Models’’), partly because the expectations of firms and households are unobservable and partly because the structures of these models are not based on formal theories of optimal planning over time. Thus, traditional structural models cannot distinguish whether changes in activity are a function of altered expectations today or lagged responses to past plans. For example, they cannot determine whether a rise in business capital investment is attributable to revised expectations about sales or is part of a sequence of gradual capital acquisitions related to earlier investment plans.

FRB/US removes this ambiguity by explictly parsing observed dynamic behavior into movements that have been induced by changes in expectations and responses to expectations that have been delayed because of adjustment costs. This separation rests on two assumptions. One is that the unobserved expectations of firms and households can be adequately captured by forecasts of an explicit model of the economy. The second is that participants in the economy behave so as to achieve the highest possible expected welfare and profits over time. Although these assumptions are similar to those usually found

5. In recent years, the view that information about the economy is costly to obtain and analyze has spurred some economists to study how individuals' knowledge about the economy might increase over time as they observe their economic environment. Different approaches to learning are discussed in Thomas J. Sargent, *Bounded Rationality in Macroeconomics* (Clarendon, 1993).

Types of Macroeconomic Models

FRB/US is one of many macroeconomic models that have been developed over the past thirty years. Macroeconomic models are systems of equations that summarize the interactions among such economic variables as gross domestic product (GDP), inflation, and interest rates. These models can be grouped into several types:

Traditional structural models typically follow the Keynesian paradigm featuring sluggish adjustment of prices. These models usually assume that expectations are adaptive but subsume them in the general dynamic structure of specific equations in such a way that the contribution of expectations alone is not identified. The MPS and Multi-Country (MCM) models formerly used at the Federal Reserve Board are examples.

Rational expectations structural models explicitly incorporate expectations that are consistent with the model's structure. Examples include variants of the FRB/US and FRB/MCM models currently used at the Federal Reserve Board, Taylor's multi-country model, and the IMF's Multimod.[1]

Equilibrium business-cycle models assume that labor and goods markets are always in equilibrium and that expectations are rational. All equations are closely based on assumptions that households maximize their own welfare and firms maximize profits. Examples are models developed by Kydland and Prescott and by Christiano and Eichenbaum.[2]

Vector autoregression (VAR) models employ a small number of estimated equations to summarize the dynamic behavior of the entire macroeconomy, with few restrictions from economic theory beyond the choice of variables to include in the model. Sims is the original proponent of this type of model.[3]

1. John B. Taylor, *Macroeconomic Policy in a World Economy* (Norton, 1993); Paul Masson, Steven Symansky, Rick Haas, and Michael Dooley, ‘‘MULTIMOD: A Multi-Region Econometric Model,’’ *Staff Studies for the World Economic Outlook* (International Monetary Fund, 1988).
2. Finn Kydland and Edward C. Prescott, ‘‘Time to Build and Aggregate Fluctuations,’’ *Econometrica*, vol. 50 (1982), pp. 1345–70; Lawrence J. Christiano and Martin Eichenbaum, ‘‘Current Real-Business-Cycle Theories and Aggregate Labor-Market Fluctuations,’’ *American Economic Review,* vol. 82 (1992), pp. 430–50.
3. Christopher Sims, ‘‘Macroeconomics and Reality,’’ *Econometrica,* vol. 48 (1980), pp. 1–48.

in rational expectations macroeconomic models, the FRB/US model uses a more general description of frictions to more closely match the correlations in historical time-series data.

OPTIONS FOR EXPECTATIONS FORMATION IN FRB/US

The FRB/US model is designed so that alternative assumptions can be made about the *scope* of information that households and firms use in forming expectations and the *speed* with which they revise their expectations on the basis of new information. Because of the lack of detailed knowledge on how individuals actually form expectations, the grounds are weak for choosing one assumption over all others. The flexibility of FRB/US makes it possible to gauge the sensitivity of conclusions drawn from model simulations to alternative assumptions about the way expectations are formed.[6]

Scope of Information

Two alternative assumptions regarding the scope of information are used in the FRB/US model. One is that expectations are rational, or model-consistent. In this case, households and firms are assumed to have a detailed understanding of how the economy functions, and expectations are identical to the forecasts of the FRB/US model.

The other alternative is that expectations are based on a less elaborate understanding of the economy, as represented by a small forecasting model containing only a few important macroeconomic variables. Because the form of the forecasting model is similar to that of a vector autoregression (VAR), such expectations are called VAR expectations. The VAR approach in the FRB/US model assumes that households and firms form expectations primarily on the basis of their knowledge of the historical interactions among three variables: the federal funds rate, the cyclical state of the economy, and the rate of inflation (see box ''The Forecasting Model for VAR Expectations'').

The FRB/US model can also be simulated under the assumption that the scope of information used in forming expectations is greater for some participants in the economy than for others. For instance, the expectations of investors in financial markets may be based on more detailed information and more sophisticated forecasting models than are those of households—a difference that can be approximated by making the expectations of investors model-consistent and those of households VAR.

Speed of Expectations Revision

Another dimension of expectations formation is the speed with which households' and firms' views of the economy respond to changes in the economic environment. Of particular importance in analyzing the effects of monetary and fiscal policy actions is how quickly the public recognizes that a deliberate change in policy has occurred or will occur sometime in the future.

In some instances, households and firms may recognize that a shift in policy has occurred only after some time has elapsed. FRB/US allows for the gradual adjustment of expectations about some key long-run conditions to changes in policy objectives so as to mimic the process of learning. For example, under either VAR or model-consistent expectations, a shift in monetary policy intended to reduce inflation can be simulated using alternative assumptions about how quickly the change in policy is recognized by the public. If recognition is assumed to be slow, expectations about long-run inflation are specified to adjust slowly. Conversely, rapid recognition is associated with fast adjustment of inflation expectations.

In other instances, a policy action—or the likelihood of the action—may be recognized in advance. For example, movements in bond yields have at times been attributed to revised expectations of future government fiscal actions.[7] Under model-consistent expectations, anticipation of future policy changes or of other events can be introduced simply by including knowledge of the event in the information that firms and households use when forecasting. In the case of VAR expectations, advance recognition, if appropriate, is introduced by specifying that expectations of both long-run inflation and interest rates respond before the event.

6. The legitimacy of shifting among alternative specifications of expectations formation rests on the assumption that the coefficients in the equations of FRB/US are unaffected by such changes in specification.

7. For a discussion of such effects during 1993, see Council of Economic Advisers, *Economic Report of the President* (February 1994), pp. 78–87.

The Forecasting Model for VAR Expectations

VAR expectations in FRB/US are the forecasts of a model that has at its core a set of three equations—one each for the federal funds rate, inflation, and the output gap. The equations contain an identical set of explanatory variables consisting of the first lagged value of the deviation of each variable from its expected long-run value and three lagged values of the first difference of each core variable. Coefficient estimates indicate that the system of core equations is stable, meaning that forecasts of outcomes far into the future converge to the measures of long-run expectations observed on the date they are formed. Long-run expectations for inflation are taken from survey data, and those for the federal funds rate from forward interest rates. The long-run expectation of the output gap is assumed to be zero. In the equations in this box, each set of weights ($w_{j,i}, j = 1, 2 \ldots 9$) sums to one.

(1) $$\Delta r_t = .03(\pi - \pi^e_\infty)_{t-1} + .12\,(\tilde{x} - 0)_{t-1} - .05\,(r - r^e_\infty)_{t-1} + .33 \sum_{i=1}^{3} w_{1,i}\Delta\pi_{t-i} + .22 \sum_{i=1}^{3} w_{2,i}\Delta\tilde{x}_{t-i} - .27 \sum_{i=1}^{3} w_{3,i}\Delta r_{t-i}.$$

(2) $$\Delta\pi_t = .17(\pi - \pi^e_\infty)_{t-1} + .13\,(\tilde{x} - 0)_{t-1} - .01\,(r - r^e_\infty)_{t-1} - .27 \sum_{i=1}^{3} w_{4,i}\Delta\pi_{t-i} - .17 \sum_{i=1}^{3} w_{5,i}\Delta\tilde{x}_{t-i} + .02 \sum_{i=1}^{3} w_{6,i}\Delta r_{t-i}.$$

(3) $$\Delta\tilde{x}_t = .02(\pi - \pi^e_\infty)_{t-1} - .04(\tilde{x} - 0)_{t-1} - .21(r - r^e_\infty)_{t-1} + .09 \sum_{i=1}^{3} w_{7,i}\Delta\pi_{t-i} + .19 \sum_{i=1}^{3} w_{8,i}\Delta\tilde{x}_{t-i} + .08 \sum_{i=1}^{3} w_{9,i}\Delta r_{t-i}.$$

The variables are defined as follows:

r = federal funds rate

π = inflation rate of chain-weight price index for personal consumption expenditures

$\tilde{x}$ = percentage gap between actual and potential output

π^e_∞ = expected long-run rate of inflation

r^e_∞ = expected long-run value of the federal funds rate.

The set of equations is able to generate expectations of the values of the three core variables at any future date. (Forecasts of π^e_∞ and r^e_∞ equal their most recent observed value.) For each additional variable for which an expectation appears in FRB/US, an auxiliary equation, which expresses the variable as a function of its own past values and of the set of explanatory variables appearing in the core equations, is added to the forecasting model.

Expectations in Individual Decisionmaking

In the FRB/US model, expectations about future economic conditions influence current prices and activity by means of two distinct channels. Through the first channel, *asset valuation,* today's price of an asset is linked to the expected earnings stream of the asset and the expected rate of return on alternative assets. Thus, in the model, current bond and stock prices are determined by the present discounted value of expected coupon and dividend payments. Through the second channel, *adjustment dynamics,* expectations play a role in reducing the costs of economic frictions. Households, in maximizing their welfare, and firms, in maximizing their profits, face various frictions in pursuing their goals, such as costs associated with adjusting the rate of household purchases of durable goods or the rate of business investment in capital equipment. In FRB/US, small changes in activity, made over several periods, are generally less costly than the same cumulative change made in a single period. As a result, anticipation of relevant future conditions benefits households and firms. The more accurately they forecast future events, the less frequently they must make large revisions to their economic plans and, consequently, the lower are their adjustment costs.

Asset Valuation

Tying the current price of an asset to its expected future earnings is a common way of modeling bond and equity prices and is not unique to FRB/US. The price of a bond equals the flow of payments (coupons plus principal repayment) that will accrue to the owner of the bond discounted by the opportunity cost of holding the bond. Because an alternative to holding a bond is holding a sequence of short-lived assets, the opportunity cost can be represented, in part, by the set of short-term interest rates expected to prevail over the bond's term to maturity. Thus, the bond's yield depends on expected future short-term interest rates, plus a term premium to compensate for the difference in risk exposure from holding the bond instead of the sequence of short-term assets (see box ''Equation for the Ten-Year Treasury Bond Yield'').

Similarly, the value of corporate equity depends on the present discounted value of the expected dividend stream accruing to the owner of the equity. In FRB/US, the opportunity cost of holding equity is proportional to the corporate bond rate adjusted for expected inflation. Thus, expectations about future dividends, future inflation, and future short-term interest rates, as captured by the corporate bond rate, determine the current price of equity.

FRB/US also applies the link between the current value of an asset and its expected earnings stream to the valuation of human capital, where the flow of earnings is that expected by an individual over his or her lifetime. The need to have a measure of the value of human capital arises from a theory of consumption in which households base current spending not on current income but on the expected average of income over their remaining lifetime. Households borrow and lend in banking and capital markets to adjust for discrepancies between actual income and average expected income. In FRB/US, the value of human capital is defined as the present discounted value of expected future wage income net of taxes and inclusive of transfer payments.

Equation for the Ten-Year Treasury Bond Yield

According to the expectations theory of the term structure, the current yield on ten-year Treasury bonds equals a weighted average of the values of the federal funds rate expected over the forty-quarter term of the bond, plus a term premium,

$$r10_t = E_t\{\sum_{i=0}^{39} w_i r_{t+i}\} + \mu_t,$$

where $E_t\{.\}$ denotes forecasts based on information available during the current quarter and the weights, w_i, sum to one. In the FRB/US model, the term premium,

$$\mu_t = .46 - .79E_t\{\sum_{i=0}^{39} w_i \tilde{x}_{t+i}\},$$

equals a constant, a cyclical component that varies inversely with the expected gap between actual and potential output, and an unexplained residual (not shown).

The variables are defined as follows:

$r10$ = yield on ten-year Treasury bonds

r = federal funds rate

μ = term premium

$\tilde{x}$ = percentage gap between actual and potential output.

Adjustment Dynamics

The need for expectations in areas of decisionmaking other than asset valuation is determined by the strength of frictions or constraints on dynamic adjustments. As discussed below, slower responses require longer lead times as provided by forecasts of more distant events.

In the nonfinancial sectors of FRB/US, decisions by households and firms rest on forecasts of equilibrium goals that would be selected in the absence of frictions but, because of costs in adjusting activities, are only gradually achieved. Consequently, the economy generally is characterized by disequilibrium, with firms and households behaving optimally but being constrained from immediate movement to equilibrium. Indeed, apart from the expectations required for asset valuation, the condition of gradual adjustments to equilibrium is the main reason that firms and households need to look ahead.

Displacements from equilibrium levels of activity are in many cases due to unexpected events, such as differences between anticipated and actual household income or between expected and realized business sales. The restoration of equilibrium is subject to planning lags, contractual requirements, and other frictions that inhibit full adjustment to equilibrium within a quarter. The extent of frictions varies by activity, so the speed at which equilibrium is restored varies across activities and sectors.

Diagram 1 illustrates differences in behavior due to differences in the extent of friction constraints on dynamic adjustment. Typically, a household purchase of a staple commodity is not subject to significant adjustment costs. The decision to purchase such a staple—milk—is depicted in the diagram, in which the horizontal axis denotes time; t denotes ''today,'' the current period; and line y^* denotes the equilibrium amount of milk consumption for each period. The equilibrium amount of milk consumption is assumed to grow over time as the expected number or age of children in the household increases. The amount of milk carried over from the past, y_a, is below the equilibrium amount needed for today's consumption, y_b. In this example, frictions are not a significant constraint on dynamic adjustment because milk is readily available at a nearby store. Thus, the decision to purchase additional milk is followed by an action that restores the amount of milk on hand to the equilibrium level, y_b. In the absence of significant frictions, forecasts of future requirements for milk are unnecessary because the household can quickly adjust the stock of milk to the equilibrium level required in each subsequent period.

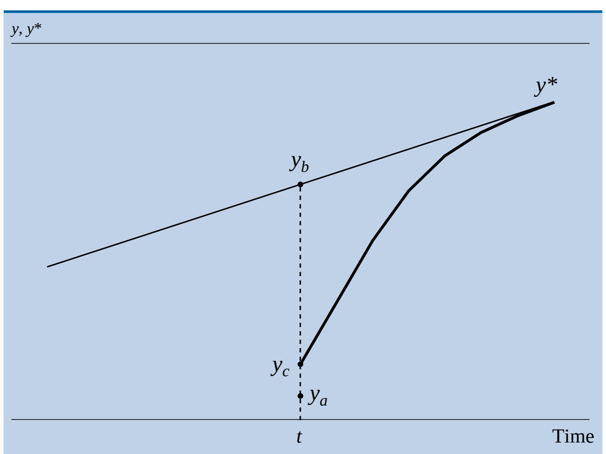
The diagram also depicts a situation in which forward-looking expectations are necessary because of the presence of significant frictions—for example, the purchase by a firm of new capital equipment. Because the firm expects to increase its output, the path of equilibrium purchases, y^*, rises over time. In this example, y_a represents yesterday's level of equipment investment, which is assumed to be below the equilibrium level, y_b, that is consistent with demand and cost conditions today. In contrast to the earlier example, only a fraction of the gap between the previous level of investment, y_a, and the current equilibrium level, y_b, will be eliminated in the current period, t. Delays in adjusting investment may be due not only to the need to collect and assimilate information on customer needs and supplier costs but also to lags in developing engineering and management specifications for the new equipment. The firm may select a slower delivery schedule if equipment producers charge more for early delivery. Finally, additional delays may occur because of the time needed for the installation of the new equipment and the training of operators.

Confronted by these constraints on adjustment, the firm decides on a program of gradual adjustment to equilibrium. Based on the average speed of quarterly adjustment for equipment investment estimated from historical data, the firm moves the current level of equipment investment to y_c, which is about 15 percent closer to the equilibrium, y_b, than the level of investment in the previous period, y_a. In each subsequent period the firm reduces the distance between the actual and equilibrium rates of investment about 15 percent, as shown by the line curving from y_c to the equilibrium path y^*.

Although diagram 1 is useful in illustrating the difference between rapid adjustment to equilibrium in the absence of frictions and gradual adjustment to equilibrium when frictions are present, it does not directly indicate the way in which expectations of future goals influence dynamic adjustments under frictions. That is, diagram 1 provides an external observer's view of different adjustment speeds resulting from differences in the importance of frictions in specific economic activities, but it does not reveal the nature of the decisionmaking process used by firms and households.[8] As indicated in the box ''Optimizing Actions When Change Is Costly,'' an optimal action today reflects plans for adjustment formulated in earlier periods and revised plans for the future based on current information. Thus, in the case of business capital investment, decisions in the current period are based on a weighted average of equilibrium values for past periods and expected equilibrium values for future periods.

Diagram 2 presents the intertemporal planning perspective of a profit-maximizing firm for which frictions are important constraints on actions. The vertical line indicates the decisionmaker's location in

1. Adjustments to equilibrium



8. The forward-planning aspect of decisionmaking is absent in the partial adjustment equations frequently used in traditional structural models to represent the dynamic behavior depicted in diagram 1. In such equations, action in the current period is related to the distance that remains between today's equilibrium and yesterday's action: $y_t = y_{t-1} + \lambda(y_t^* - y_{t-1})$, where y_t denotes today's action and y_t^* is today's equilibrium value.

Optimizing Actions When Change Is Costly

Firms and households in FRB/US balance the expected costs of deviating from equilibrium against the costs of changing their actions. Expected future costs are discounted so that those in distant periods have a smaller influence on current actions than do those in near-term periods. The optimization of tradeoffs between the costs of current and future actions is represented in FRB/US by the assumption that individuals minimize the following weighted sum of expected current and future costs:

$$E_{t-1}\{\sum_{i=0}^{\infty} B^i[c_0(y_{t+i} - y^*_{t+i})^2 + c_1(\Delta y_{t+i})^2$$

$$+ c_2(\Delta^2 y_{t+i})^2 + c_3(\Delta^3 y_{t+i})^2 + \ldots]\},$$

where $E_{t-1}\{.\}$ is a forecast of future costs based on information available at the end of the previous period, $t-1$, and B is a discount factor between zero and one. The first squared term in the summation is the cost of deviating from equilibrium in period $t+i$, where c_0 is the unit cost associated with squared deviations from equilibrium, y_{t+i} is the planned activity, and y^*_{t+i} is the associated equilibrium.

The remaining terms in the cost function define the expected costs of frictions associated with changes in actions. Δ is a mathematical shorthand to represent the one-period change in a variable, such as $\Delta y_t \equiv (y_t - y_{t-1})$, and $\Delta^2 y_t \equiv \Delta(y_t - y_{t-1}) \equiv ((y_t - y_{t-1}) - (y_{t-1} - y_{t-2}))$. Many macroeconomic models assume that the principal source of friction in observed behavior is represented by the term $c_1(\Delta y_{t+i})^2$, where c_1 is the unit cost of changing the *level* of activity. A more generalized description of frictions is permitted in FRB/US, with c_2 representing the unit cost of changing the *growth rate* of actions, c_3 representing the unit cost of changing the *rate of acceleration*, and so on.

The decision rule that minimizes this weighted sum of expected costs can be represented as the following:[1]

$$\Delta y_t = a_0(y^*_{t-1} - y_{t-1}) + \sum_{j=1}^{m-1} a_j \Delta y_{t-j} + E_{t-1}\{\sum_{i=0}^{\infty} f_i \Delta y^*_{t+i}\}.$$

Optimal adjustment of activity in the current period, Δy_t, depends on three components: (1) the deviation of last period's activity from its equilibrium level, $y^*_{t-1} - y_{t-1}$; (2) past changes in the levels of activity, Δy_{t-j} (these lagged terms are not present if firms or households minimize only the costs associated with changing the level of activity); and (3) a weighted forecast of future changes in equilibrium levels, Δy^*_{t+i} (the forecast weights, f_i, are functions of the discount factor, B, and the cost parameters, $c_0, c_1, c_2, \ldots$).

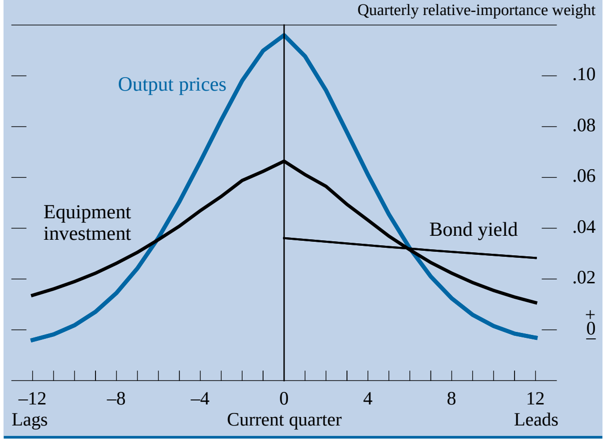
The optimal level of activity, y_t, defined by this decision rule can be expressed equivalently as a two-sided moving average in past and future equilibrium values:

$$y_t = E_{t-1}\{\sum_{i=-\infty}^{\infty} w_i y^*_{t+i}\},$$

where the w_i weights, indicating the relative importance for current decisions of past and future equilibrium values, sum to one. The estimated relative-importance weights for selected activities in FRB/US are plotted in diagram 2.

1. See Peter A. Tinsley, "Fitting Both Data and Theories: Polynomial Adjustment Costs and Error Correction Decision Rules," Finance and Economics Discussion Series, 93-21 (Board of Governors of the Federal Reserve System, 1993).

2. Relative importance of past and future equilibrium values in current decisions



time. Future quarters over the firm's planning period appear to the right of the vertical line, and past quarters to the left. The three curves show the relative-importance weights used in planning for different economic activities and are based on the dynamic responses estimated for these activities in the FRB/US model.

The curve labeled "Equipment investment" depicts the relative-importance weights of past and expected future events in determining investment in capital equipment. Although in principle firms plan over an infinite future, the effective length of the planning period is determined by the extent of the frictions associated with the firm's actions. The relative-importance weights for only the past three years and future three years are plotted because the weights for more distant quarters are close to zero. In the case of equipment investment, the initial twelve quarters of the planning period (to the right of the vertical line) account for about 90 percent of the relative-importance weights over the infinite planning period. Equilibrium levels further in the future are less important to current investment than are those in the nearer term because more-distant needs can be satisfied by equipment purchases in future quarters.

A summary measure of the effective average length of the forward planning period is the *mean lead* determined by the relative-importance weights.[9] Because frictions play a large role in dynamic adjustments for capital equipment, the mean lead for equipment investment is relatively lengthy—approximately six quarters.

Weights for past quarters (to the left of the vertical line) indicate the relative importance of past equilibrium levels for current decisions. The relative-importance weights for past planning periods also approach zero for distant quarters because older plans have been completed by past actions. In a construction similar to that used to define the mean lead, relative-importance weights for past quarters can be used to estimate the *mean lag* response. This construction is useful as a measure of the average speed at which firms respond to unexpected shocks because, by definition, firms cannot respond in advance to unforseen events. In the FRB/US model, the mean lag for responses involving equipment investment is about seven quarters.

Lead and lag responses for activities less affected by frictions in FRB/US also appear in diagram 2. One is the adjustment of output prices by firms to better reflect current and anticipated demand and cost conditions. In the FRB/US model, the prices of most goods and services are "sticky," or slow to adjust to equilibrium. This behavior contrasts with that of models based on classical theories, in which the prices of goods and services are as flexible as those in financial markets. The curve labeled "Output prices" illustrates the relative importance firms assign to past and future equilibrium values in deciding the current price of business output. Because the frictions for pricing are smaller than those for equipment investment, the equilibrium values in periods close to the current quarter are assigned higher weights, and periods further from the current quarter are assigned lower weights. Consequently, the mean lead for pricing is markedly shorter—about three quarters.

Diagram 2 also illustrates the one-sided format of relative-importance weights used in asset valuations. Because frictions are of negligible importance in financial markets, asset valuations are only forward-looking, and the bond yield is determined by forecasts of the federal funds rate over the maturity of the bond. For a ten-year Treasury coupon bond (the example plotted in diagram 2), the relative-importance weights of expected future funds rates decline over the ten-year planning period. Consequently, the associated mean lead is about four years.

Overview of the Equations in FRB/US

The FRB/US model takes into account decisions in three sectors: (1) the household sector, where households make choices about spending, saving, and entering or leaving the workforce; (2) the private business sector, where firms make investment, employment, pricing, production, and financial plans; and (3) the public sector, where local, state, and federal governments (including the Federal Reserve) set monetary and fiscal policies.[10] FRB/US models the behavior of these sectors in the aggregate, but some equations do allow for differences among households or among firms. For example, because small businesses have less ready access to capital markets than large corporations have and must rely more heavily on internal funds to finance capital investment, the equation for investment in business equipment allows the amount of investment to depend, in part, on firms' cash flow.

About half of the approximately fifty behavioral equations in the model—estimated from thirty years of historical data—use explicit measures of expectations. Of this half, the adjustment-dynamics framework is used for the equations for consumption of nondurable goods and services; spending on consumer durables of two types; investment in residential structures, producers' durable equipment, and manufacturing and trade inventories; aggregate labor hours; the price level and rate of hourly labor

9. The mean lead is calculated by multiplying the sequential number of each quarter in the forward planning period by the corresponding relative-importance weight:

$$\sum_{i=0}^{\infty} w_i i / \sum_{i=0}^{\infty} w_i,$$

where $w_i i$ is the relative-importance weight for the i^{th} quarter in the planning period.

10. Decisions made by financial intermediaries such as banks are not modeled directly, but instead are captured by equations that link rates on consumer and business loans and home mortgages to those on comparable government securities.

compensation; and dividends. The asset valuation approach is used for the equations for the yields on three types of bonds; the market value of corporate equities; and the exchange rate. The other behavioral equations—including those for exports, imports, employment, labor supply, investment in nonresidential construction, and the stock of inventories outside of manufacturing and trade—are estimated using traditional specifications without explicit expectations.

Household Sector

In the model, households maximize their welfare, which is measured by the present discounted value of expected utility derived from the consumption of nondurable goods and services.[11] Households are assumed to prefer a smooth pattern of consumption over time and therefore base their spending on estimates of permanent income—defined to be proportional to the sum of human capital and other wealth—rather than on current income alone. By doing so, a household is able to maintain a relatively stable standard of living over its lifetime even if its income fluctuates substantially. This model of consumption is commonly referred to as the ''life-cycle'' model.[12]

The equation for consumption of nondurable goods and services follows the life-cycle model by allowing aggregate consumption spending to depend on the distribution of income and assets across the population (see box ''Consumption of Nondurable Goods and Services''). For example, the life-cycle model predicts that the marginal propensity to consume—the increase in spending associated with a dollar increase in income or assets—is higher for retirees than for young workers, who are assumed to be saving for their retirement and their children's education. Thus, the consumption equation incorporates an estimated higher marginal propensity to consume out of social security benefits (as well as other transfer income) than out of after-tax labor income. Consequently, a shift of resources from workers to retirees in the form of equal increases in payroll taxes and social security benefits is predicted to raise total spending on consumer goods and to reduce saving.

The standard life-cycle approach is modified for FRB/US in three important ways. First, in evaluating lifetime income, households discount their expected future income at a rate estimated to be 25 percent per year. Such a high rate of discount reflects the significant degree of uncertainty that households attach to their future earnings. Given this rate, expected after-tax wage and transfer income over the next five years makes up about three-fourths of human capital.[13] Second, consumption adjusts to permanent income only gradually (in accordance with the adjustment-cost approach described earlier). The frictions that slow adjustment are relatively small, however, and spending therefore adjusts to the level warranted by permanent income at an estimated rate of 20 percent per quarter. Finally, an estimated 10 percent of total consumption is accounted for by a group of households that spend on the basis of current rather than permanent income, perhaps because their access to credit is limited.[14]

Besides choosing how much to consume, households also decide how much to spend on housing, motor vehicles, and other consumer durable goods. Because housing and durable goods last for many years, purchases of these items are modeled as capital investments, where the cost depends in part on the inflation-adjusted interest rate on consumer loans or home mortgages. As with the consumption of nondurable goods and services, the equations for purchases of motor vehicles, other durable goods, and housing reflect households' gradual adjustment to equilibrium.

Income that households do not spend on goods and services is assumed to be invested in various financial assets, including Treasury and corporate securities. Households are assumed to be risk averse, and the equations for returns on long-term bonds and stocks

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11. In the FRB/US model, the measure of consumption of nondurable goods and services includes the flow of services from durable goods and therefore differs from the data published under the same name in the national income and product accounts.

12. The life-cycle model was introduced in the 1950s by Franco Modigliani and Richard Brumberg. It is described in A. Ando and F. Modigliani, ''The Life-Cycle Hypothesis of Saving: Aggregate Implications and Tests,'' *American Economic Review*, vol. 53 (1963), pp. 55–84.

13. The idea that income may be discounted at a rate well in excess of the market rate of interest was originally proposed by Milton Friedman in his description of the permanent income model of consumption. See Friedman, ''Windfalls, the Horizon, and Related Concepts in the Permanent Income Hypothesis,'' in Carl Christ and others, eds., *Measurement in Economics* (Stanford University Press, 1963), pp. 3–28.

14. For a number of reasons, including the presence of credit-constrained households, Ricardian Equivalence—the independence of private consumption and the level of government debt—does not hold in the FRB/US model. For example, a temporary reduction in current income taxes funded through the issuance of bonds redeemed over thirty years leads to a short-run increase in consumption in FRB/US.

Consumption of Nondurable Goods and Services

The equilibrium level of consumption depends on current values of stock market and other property wealth and on the present discounted value of expected future income. Income is divided into labor, transfer, and property components, where labor income is represented by total income less the sum of transfer and property income. Expectations of future income are discounted at the rate of 7 percent per quarter. The equilibrium level of consumption also varies procyclically, as represented by the positive coefficient on the output gap, X_{gap}. The adjustment equation for consumption indicates that optimal dynamic planning determines about 90 percent of consumption but that about 10 percent (the coefficient on $\Delta \log Y_{h,t}$) of consumption moves with current income, possibly because of liquidity constraints.

(1)
$$\log C_t^* = .8307\, E_t\{\log[(1-.93)(\sum_{i=0}^{\infty} .93^i Y_{h,t+i})]\}$$
$$+ .0584 E_t\{\log[(1-.93)(\sum_{i=0}^{\infty} .93^i Y_{ht,t+i})]\}$$
$$- .0656 E_t\{\log[(1-.93)(\sum_{i=0}^{\infty} .93^i Y_{hp,t+i})]\}$$
$$+ .0325 \log W_{ps,t} + .144 \log W_{po,t}$$
$$+ .00801\, X_{gap,t} - .262.$$

(2)
$$\Delta \log C_t = .000554 + .154(\log C_{t-1}^* - \log C_{t-1})$$
$$+ .208\, \Delta \log C_{t-1}$$
$$+ (1-.0995) E_{t-1}\{\sum_{i=0}^{\infty} f_i\, \Delta \log C_{t+i}^*\}$$
$$+ .0995\, \Delta \log Y_{h,t}$$
$$- (.0995 * .208)\, \Delta \log Y_{h,t-1}.$$
$$\Sigma f_i = .74.$$

Definitions

C = Consumption of nondurable goods and services (including service flow from the stock of durables), billions of chained (1992) dollars.

E_t = Expectational operator, using information available at time t.

W_{po} = Household property wealth excluding stock market assets, divided by price index for C.

W_{ps} = Household stock market wealth, divided by price index for C.

X_{gap} = Percentage deviation between real GDP and its potential level.

Y_h = After-tax total household income, divided by price index for C.

Y_{hp} = After-tax household property income, divided by price index for C.

Y_{ht} = Household transfer income, divided by price index for C.

$*$ = Equilibrium value.

include term and risk premiums that compensate households for the risks they bear in holding them. Through the process of arbitrage, asset prices are assumed to adjust rapidly, and risk-adjusted returns are equalized across assets.

Finally, the decision to participate in the workforce is modeled in a relatively simple way that captures the time trends in participation over the past thirty years and the tendency for the participation rate to rise during periods of high employment. The aggregate supply of labor is assumed not to respond to the wage rate or to taxes.

Business Sector

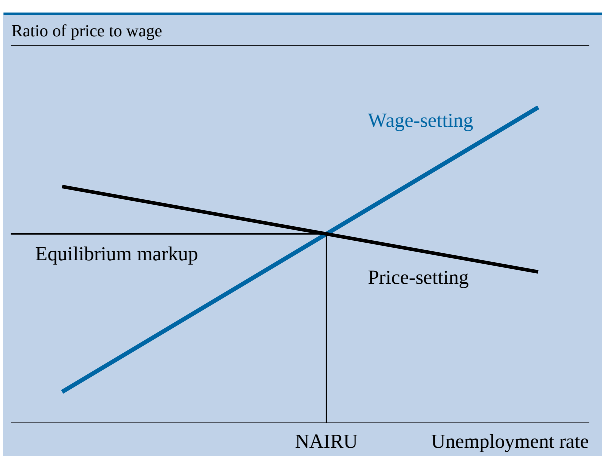
In the model, firms maximize the present discounted value of expected profits. They set prices for their products, negotiate wages and benefits with their employees, and decide how much to invest in buildings and equipment, how much inventory to hold, and how many workers to employ and the length of the workweek. They also select the amount of profits paid out as dividends. Expectations enter these equations because of the need for planning that arises from adjustment costs.

In FRB/US, most firms sell their products in markets characterized by imperfect competition; that is, a firm sets the prices of goods it sells as a markup over costs of production (see box ‘‘Prices and Wages’’). Abstracting from frictions that impede price adjustment, the profit-maximizing price markup varies inversely with the degree of slack in the economy as measured by the unemployment rate. This relationship is illustrated by the downward-sloping line in diagram 3. In the model, firms are inhibited by the reactions of their customers and competitors from changing their prices too rapidly in response to changes in costs or demand. Prices adjust to their equilibrium level at a rate estimated to be 25 percent per quarter.

The equation for the rate of hourly labor compensation, as measured by the employment cost index, is based implicitly on a model of bargaining over the real wage. Because wages are typically based on explicit and implicit multiperiod contracts, they are less flexible than prices: Wages adjust to their equilibrium level at a rate estimated to be only 10 percent per quarter. Abstracting from such frictions, the ability of workers to bargain for a high real wage depends on their relative bargaining power, which declines during periods of high unemployment. In diagram 3, this relationship is represented by the upward-sloping line, which relates the inverse of the real wage (the price markup) to the unemployment rate.

In equilibrium, price inflation equals the growth rate of unit costs, and the price markup over wages chosen by firms equals the inverse of the real wage resulting from the bargaining process. This equilibrium in wage- and price-setting is shown by the intersection of the two lines in diagram 3. This intersection determines a unique equilibrium unemployment rate consistent with profit-maximizing behavior of firms and the bargaining ability of workers.[15] Because the equilibrium unemployment rate does not depend on the rate of inflation, it is the same as the nonaccelerating inflation rate of unemployment (NAIRU). Because of short-run frictions, the labor market is often not in equilibrium. When it is not in equilibrium, wage and price inflation will tend to rise when unemployment is below the NAIRU and to fall when unemployment is above the NAIRU. But inflation can also change for other reasons, such as a movement in energy or import prices.

3. Price and wage equilibrium



Equilibrium production costs depend on the profit-maximizing mix of capital, labor, and energy used in production, and the mix, in turn, depends on the after-tax cost of capital relative to the prices of other factor inputs. The cost of capital increases as the inflation-adjusted yield on bonds rises and decreases as the price of shares in the stock market rises. Equilibrium labor productivity, or output per unit of labor input, is determined by two factors—long-run trends, assumed to be exogenous, and the equilibrium capital and energy intensity of production.

In the FRB/US model, a firm meets the demand for its goods and services given the price it has set by adjusting production and by building up or drawing down inventory stocks. A firm can alter its level of production by adjusting the number of labor hours hired and by installing new equipment. In the model, the responses of employment and investment depend on the relative costs of labor and capital and on the frictions that slow the adjustment of labor hours and capital.

Because of the costs of adjusting total hours, including the costs of hiring and training new workers and of paying shift and overtime premiums, most firms (covering an estimated two-thirds of private-sector employment) are modeled as adjusting labor input to its equilibrium level at a rate estimated to be about 15 percent per quarter, thus smoothing labor input over the business cycle. The remaining firms (covering one-third of private-sector employment) adjust hours immediately when demand changes by laying off or recalling workers or by using temporary help.

Rapidly altering the rate of equipment investment to its equilibrium level is costly for firms, so their

15. Several theories of wage and price determination yield an equilibrium unemployment rate like that in FRB/US. These theories include labor market search, union wage bargaining, efficiency wages, and insider–outsider interests in employment and compensation. N. Gregory Mankiw and David Romer, eds., *New Keynesian Economics* (MIT Press, 1991), contains examples of such models.

Prices and Wages

Prices. The main price variable in the FRB/US model, P_{xp}, is a domestic absorption (private domestic final sales plus exports, net of indirect taxes) price index. The equilibrium price, P^*_{xp}, is a weighted average of the equilibrium price for private output, P^*_{xg}, and the price of output from other sectors less inventory change, P_{oth}, and is inversely related to the rate of unemployment, L_{urda}. The equilibrium private output price—based on a three-factor Cobb–Douglas production technology—is a markup over minimized cost. The dynamic equation for P_{xp} follows the framework for gradual adjustment described in the text and is constrained to be consistent with a vertical long-run Phillips curve; that is, the coefficients on lagged and future inflation sum to one. The equation also contains terms that allow for the more rapid adjustment of the prices of energy-intensive products, such as retail gasoline, relative to that of the prices of other goods.

(1) $\log P^*_{xp} = \log((P^*_{xg}X_g + P_{oth}X_{oth})/X_p) - .003L_{urda} + .019.$

(2) $\log P^*_{xg} = .280 + .980 \log(P_l/L_{prdgt}) + .020 \log P_{ceng}.$

(3)
$$\Delta \log P_{xp,\,t} = .001 + .101(\log P^*_{xp} - \log P_{xp})_{t-1} + \sum_{i=1}^{2} w_i \Delta \log P_{xp,\,t-i} + E_{t-1}\{\sum_{i=0}^{\infty} f_i \Delta \log P^*_{xp,\,t+i}\} + .271\omega_{e,\,t-2}\Delta \log P_{cengr,\,t-1} - .047\omega_{e,\,t-3}\Delta \log P_{cengr,\,t-2}.$$

$\Sigma w_i = .566.$ $\Sigma f_i = .434.$

Wages. The equilibrium nominal wage (compensation per hour) is based on the same relationship that underlies the equilibrium private output price, P^*_{xg}, with an additional term reflecting the negative effect of the unemployment rate on the equilibrium wage. As in the case of the dynamic price equation, the wage equation follows the gradual adjustment framework and is constrained to be consistent with a vertical long-run Phillips curve. Three additional terms—a dummy for wage and price controls, D_{wpc}, the rate of growth of employer social insurance taxes, ΔS_{tax}, and the rate of increase of the real minimum wage, $\Delta \log P_{lminr}$—capture the rapid pass-through of changes in these variables to actual wages.

(4)
$$\log P_l^* = .068 + \log L_{prdgt} + 1.020 \log P_{xg} - .020 \log P_{ceng} - .011L_{urda}.$$

(5)
$$\Delta \log P_{l,\,t} = -.009 + .030(\log P_l^* - \log P_l)_{t-1} + \sum_{i=1}^{3} w_i \Delta \log P_{l,\,t-i} + E_{t-1}\{\sum_{i=0}^{\infty} f_i \Delta \log P^*_{l,\,t+i}\} - .009D_{wpc,\,t} + 1.400\,\Delta S_{tax,\,t} + .023\,\Delta \log P_{lminr,\,t}.$$

$\Sigma w_i = .709.$ $\Sigma f_i = .291.$

Definitions

D_{wpc} = Dummy for Nixon wage–price controls.

E_{t-1} = Expectational operator, using information available at the end of the previous quarter, $t - 1$.

L_{prdgt} = Trend labor productivity.

L_{urda} = Demographically adjusted unemployment rate.

P_{ceng} = Price index for crude energy consumption.

P_{cengr} = Price for crude energy consumption relative to price of nonfarm business output.

P_l = Compensation per hour in nonfarm business.

P_{lminr} = Minimum wage, deflated by hourly labor compensation.

P_{oth} = Price index for X_{oth}.

P_{xg} = Price index for X_g.

P_{xp} = Price index for X_p.

S_{tax} = Employer social insurance premiums, deflated by total labor compensation.

X_g = Nonfarm, nonhousing business output plus oil imports (net of indirect business taxes).

X_{oth} = Output of housing, farm, household, and institutional sectors plus government output (net of employee compensation) plus non-petroleum imports less inventory investment.

X_p = Private domestic final sales (net of sales taxes and other indirect taxes) plus exports.

ω_e = Energy share of output.

$*$ = Equilibrium value.

adjustment to changes in expected output or in the costs of capital, labor, and energy proceeds relatively slowly, at a rate estimated to be 15 percent per quarter in the FRB/US model. In addition, for a group of firms (accounting for about 20 percent of investment), profit-maximizing investment plans are constrained by their limited access to external sources of funds. For these firms, investment is determined by available cash flow.

Government Sector

In the FRB/US model, the government influences macroeconomic conditions through three activities: monetary policy carried out by the Federal Reserve, fiscal policy carried out by the federal government, and the spending and tax actions of state and local governments.

Monetary policy is characterized by an equation for the level of the federal funds rate. In model simulations, policymakers are assumed to set the federal funds rate to stabilize the rate of inflation at some target level and to hold aggregate demand near the level consistent with full employment. The key characteristics of such a policy are the rate of inflation that policymakers hope to achieve over time—the inflation target—and the sensitivity of the federal funds rate to deviations of actual inflation from this objective and to deviations of the level of economic activity from its potential.

The activities of the federal government are summarized by a group of equations that describe the setting of tax rates (on personal and corporate incomes, payrolls, and the sales value of some goods) and the level of spending (on employee compensation, investment, other purchases of goods and services, transfer payments, net subsidies to government enterprises, and grants to state and local governments). Federal debt (the accumulation of deficits over time) is financed through the issuance of Treasury bills and bonds. A similar set of equations describes the aggregate tax and spending policies of state and local governments.

EXPECTATIONS IN ACTION: MODEL SIMULATIONS

So far the discussion has focused on the way in which expectations affect the decisions of firms and households. Now it turns to the interactions of these sectors of the economy and, through model simulations, explores the role of expectations in the behavior of aggregate production, employment, and inflation. Specifically, the FRB/US model is used to predict how the overall economy would respond to two hypothetical events—a tightening in fiscal policy achieved through a permanent reduction in defense spending and an increase in the price of oil.

In the analysis of the first scenario, a critical factor is the speed with which the public recognizes that a change in the economic environment has occurred or will occur. The model can be simulated with several possibilities, including gradual learning about the change after it has occurred, recognition of the change at the time it occurs, and anticipation of the change before it occurs. All three possibilities are relevant for fiscal policy, so the analysis of the cutback in defense spending focuses on the sensitivity of the model's predictions to changes in recognition speed.

For the second scenario, the recognition problem does not concern oil prices per se (these are readily observable) but instead the anticipated response of monetary policy to the rise in oil prices. Specifically, the public might think that a change in policy has occurred when none actually has. The macroeconomic implications of such a possibility is the focus of this analysis.

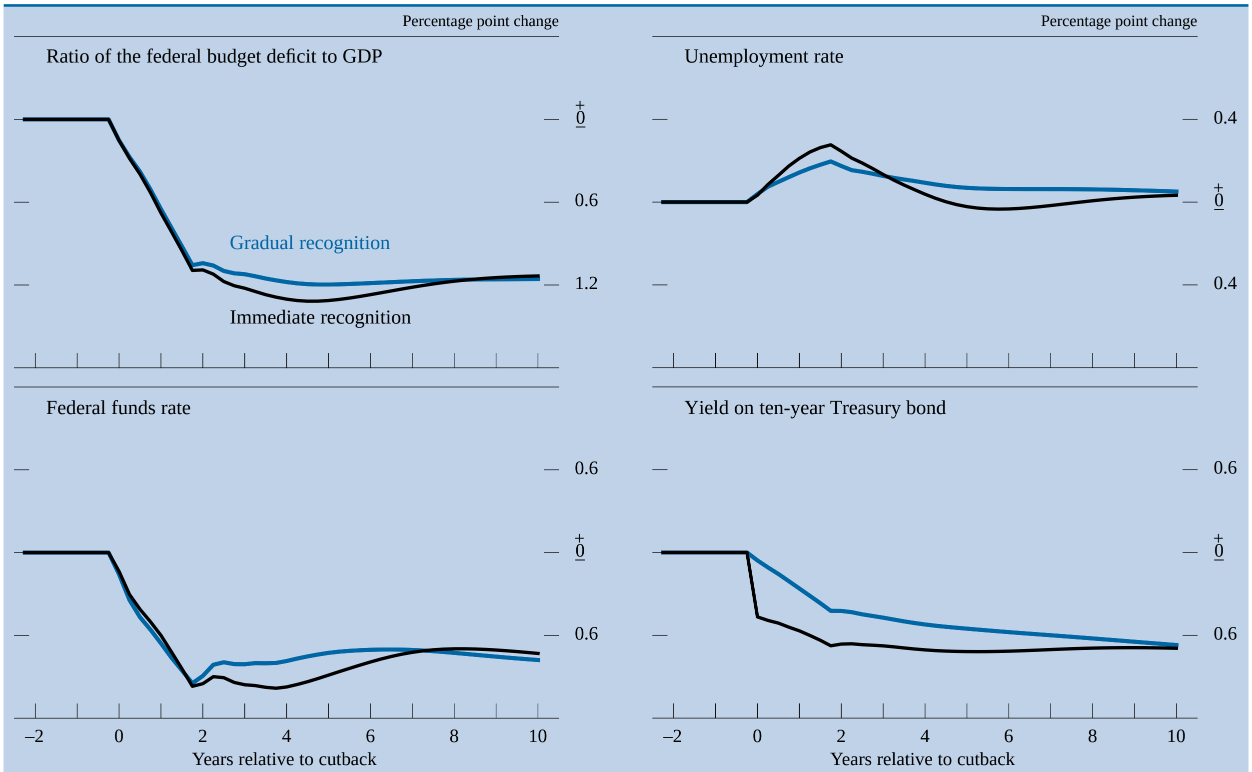
To simulate the effects of these events, a baseline forecast of economic activity is generated given a set of assumptions for fiscal and monetary policy, foreign economic conditions, oil prices, and so forth. Then the model is run again under the assumption that one of these factors—government spending or the price of oil—changes. A comparison of the baseline and simulation forecasts indicates the way the economy would react to such an event (according to the FRB/US model).

Simulation of economic events permits the tracing of the dynamic responses of households and firms to changes in the economic environment. It shows how adjustment costs give rise to macroeconomic disequilibrium—transitory deviations of aggregate demand from the economy's full-employment level of production. Such disequilibrium explains, for example, why many policies that may be beneficial in the long run, such as a reduction in federal borrowing or a return to price stability, often carry with them short-run costs in the form of reduced income and higher unemployment.

Tightening of Fiscal Policy

In the first hypothetical event, the Congress passes legislation that reduces annual defense expenditures

4. Simulated consequences of a cutback in defense spending when recognition of the change is immediate or gradual



Note. Both simulations are based on VAR expectations.

relative to baseline by ½ percent of GDP in the first year of the program and 1 percent in the second year. The annual reduction in non-interest outlays, expressed as a percentage of GDP, remains at this level thereafter.[16] The improvement in the overall budget balance is assumed to be a similar percentage of GDP; taxes are adjusted to offset interest savings generated by a reduction in federal borrowing. Monetary policy makers are assumed to act to stabilize the economy by gradually lowering the federal funds rate whenever the level of real activity is below its potential and inflation is less than the targeted rate; when the opposite is true, they raise the funds rate.[17]

Effects under Immediate and Gradual Recognition

The macroeconomic effects of the tightening of fiscal policy, under the assumption that households and firms have VAR expectations, are summarized in diagram 4. Results are shown for two different characterizations of the speed with which the public recognizes the extent of the change in policy: (1) The public at the start of the program recognizes the full implications of the policy change for the long-run value of the real federal funds rate, and (2) the public only gradually revises its estimate of the equilibrium real funds rate, on the basis of observed changes in actual rates of inflation and interest. In both cases, the public's beliefs about the long-run rate of inflation (in other words, about the inflation goals of monetary policy makers) are unaffected by the change in fiscal policy.

Under either assumption about the speed of recognition, the cuts in defense spending weaken aggregate demand—first by decreasing the sales of defense contractors and then by decreasing sales in other sectors that supply goods and services to the defense industry and its workers. The initial effect is magnified as firms reduce employment and household spending responds to the loss in current income. Firms and households project (more or less correctly) that the initial decline in the level of aggregate sales, employment, and income will persist for a few years. Accordingly, firms cut back on their capital spending

16. Such cuts would be only half as great as the actual decline in defense spending since the end of the cold war: Expenditures have fallen from about 5½ percent of GDP in 1989–91 to about 3½ percent today.

17. The speed at which policy responds to changes in real activity and inflation is based on an equation for the funds rate estimated over 1980–95.

and further reduce their demand for labor; households moderate their spending on consumer goods and housing. Under these conditions, unemployment rises.

The initial increase in unemployment is smaller if the public fails to recognize immediately the size and persistence of the change in fiscal policy; in this situation, households and firms underestimate the full contractionary effect of the cuts and see less need to reduce their spending. In contrast, even though immediate recognition magnifies the short-run consequences of the policy change, it nonetheless hastens the return to equilibrium because in this situation firms and households understand a key fact about the economy as represented by FRB/US: A permanent decline in the federal budget deficit, by raising the economy's aggregate rate of saving, lowers the long-term real funds rate consistent with full employment.[18] Therefore, with monetary policy directed toward keeping the rate of inflation unchanged, the public forecasts that the nominal federal funds rate will quickly fall to a lower level and remain there permanently. This view leads to a drop in bond yields immediately upon enactment of the cuts in defense spending.[19] By contrast, when recognition is gradual, bond yields decline more slowly because firms and households only sluggishly revise their estimate of the long-run level of the federal funds rate.

Whether the public reacts quickly or slowly, competitive forces in financial markets ensure that the decline in bond yields is accompanied by falling mortgage rates, rising stock prices, and a depreciating dollar. These changes in wealth and borrowing conditions spur consumer spending and domestic capital formation and increase the net foreign demand for U.S. goods. Eventually, the stimulus from favorable financial conditions fully offsets the contractionary effect of the cuts in defense spending, and unemployment returns to its baseline level. This return takes five years if recognition is immediate and considerably longer if the public only gradually revises its notions of the long-term state of the economy.

18. In FRB/US, inflation stability is achieved only if the unemployment rate equals the NAIRU or, equivalently, only if aggregate demand equals the potential level of output. The real interest rate that achieves this equality is the equilibrium real rate. Because aggregate demand is positively related to government spending and negatively related to the real interest rate, a permanent decline in government spending must, if equilibrium is to be restored, be offset by a permanent decline in the real interest rate.

19. The initial decline in long-term interest rates is smaller than the eventual fall, primarily because the term premiums demanded by investors increase with the slowdown in economic activity. Once the level of activity returns to normal, term premiums return to baseline values.

Effects of Prior Recognition

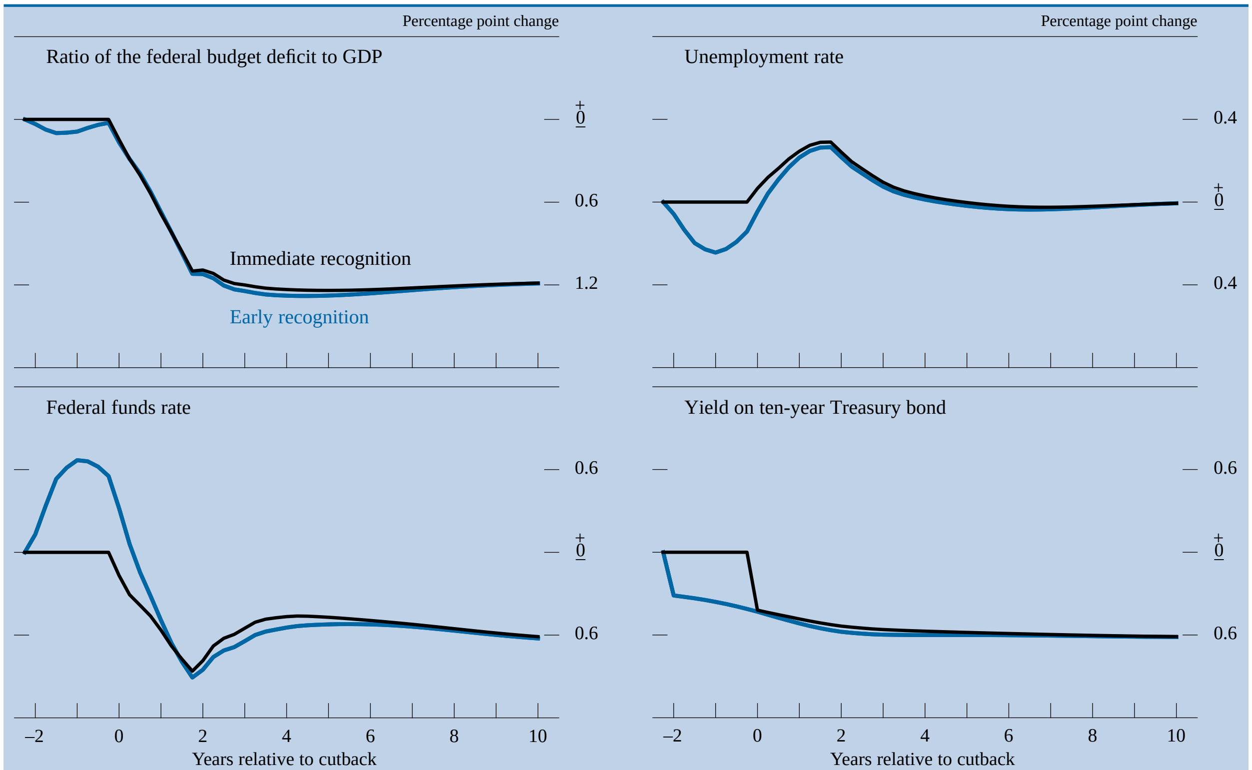
In the preceding simulations, the public either recognizes the economic implications of the spending cut as soon as it is implemented or learns about them as time passes. The public might, however, anticipate the policy change before its actual implementation. Such prior recognition could arise when the Congress passes legislation containing provisions that take effect at a later date. Prior recognition could also occur when a prolonged period of discussion within and outside the government has preceded the passage of legislation (as, for example, the public debate over the likely size of future cuts in defense spending that began immediately after the fall of the Berlin Wall, well before an actual reduction in spending).

If firms and households recognize a policy change before its enactment, they can begin to adjust early. Diagram 5 shows the response of the economy to the cuts in defense spending discussed earlier under two assumptions: (1) the public recognizes the full change in policy when the initial cuts are first enacted and (2) the public anticipates the change two years before it occurs. In both cases, households and firms are assumed to have model-consistent expectations.[20]

As can be seen, prior recognition causes the economy to strengthen in advance of the spending cuts. The source of this early pickup in activity is the public's knowledge that the coming change in fiscal policy is associated with a lower federal funds rate in the long run. As a result of this expectation, bond yields fall two years before the spending cuts take place. The stimulus from this reduction in borrowing costs—combined with the effects of higher stock prices and a lower foreign exchange value of the dollar—initially increases aggregate demand, particularly in the areas of investment goods and net exports. As a result, the unemployment rate falls before the change in policy, and in response, the federal funds rate rises. However, once the spending cuts are imple-

20. Comparison of the black lines in diagrams 4 and 5 shows that altering the *scope* of the public's knowledge about the economy has little effect on the predicted macroeconomic consequences of the change in fiscal policy: For this hypothetical event, what matters is not whether the public has VAR (diagram 4) or model-consistent (diagram 5) expectations, but the speed at which they recognize that a change has occurred. For other scenarios (such as that of the oil price shock), however, altering the scope of the public's knowledge does significantly affect the model's predictions.

5. Simulated consequences of a cutback in defense spending when policy change is recognized before or immediately upon enactment



NOTE: Both simulations are based on model-consistent expections.

mented, the rise in aggregate demand is reversed, and the pattern of economic activity is roughly the same as if the change had not been recognized in advance.

Rise in Oil Prices

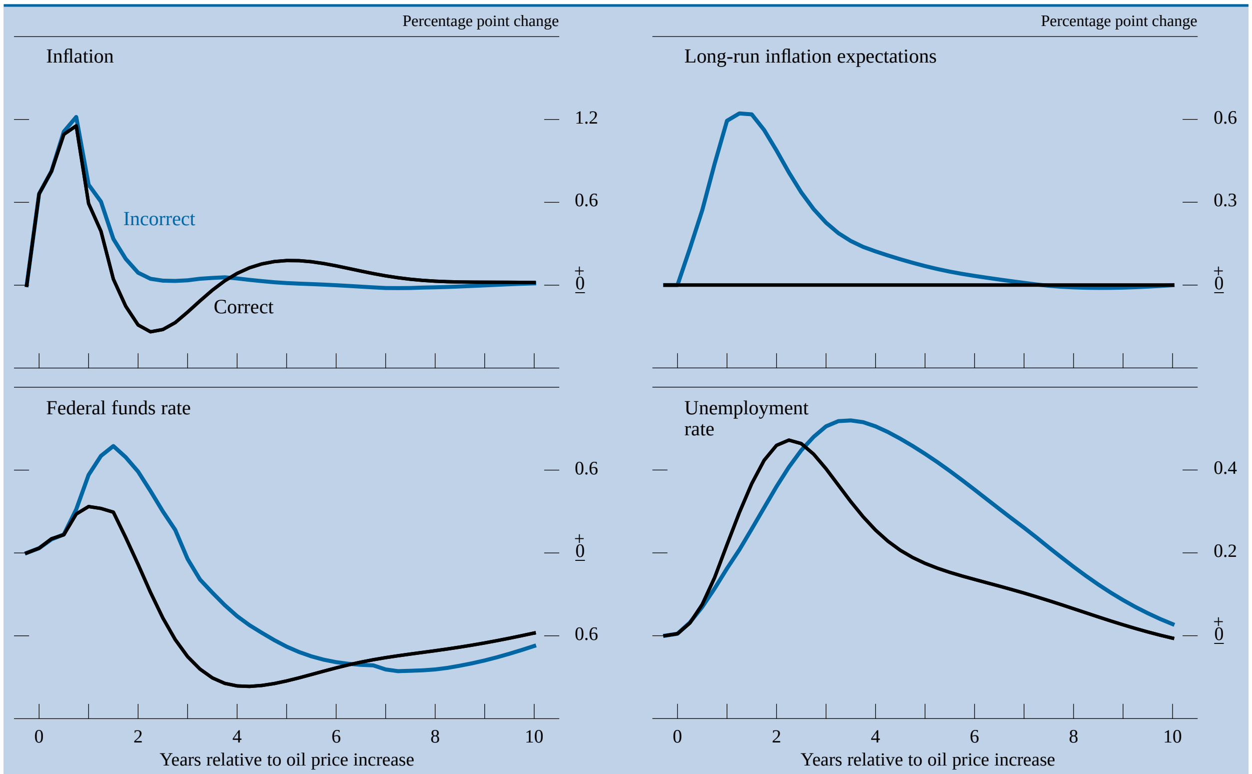
In the simulations involving a cut in defense spending, households and firms face the problem of discerning the long-run objectives of fiscal policy. In one case they recognize the complete details of the program immediately upon enactment; in others they either learn about the change over time or anticipate it in advance. In gauging the likely effects of their actions, policymakers must accept that any of these reactions is possible and that policy actions can influence but not wholly control the public's speed of recognition (or any other aspect of the public's beliefs).

Conceivably, there are circumstances in which the public may come to perceive a change in policy when none has occurred. Such a situation might arise, for example, in the context of a large increase in the price of oil, like the ones that occurred during the middle and late 1970s. Consider a simulation in which oil prices double over the course of a year and remain at this higher level for several years thereafter.[21] This situation is illustrated in diagram 6, under the assumption that firms and households have VAR expectations. As can be seen, such an energy shock would produce a large initial spike in consumer price inflation.

In one situation (curve labeled "Correct" in diagram), the initial rise in inflation is assumed to have no effect on the public's beliefs concerning the goals of monetary policy; the public has confidence in the government's commitment to restoring the baseline rate of inflation and does not change its expectations regarding inflation in the long run. In an alternative situation (curve labeled "Incorrect"), the public, seeing that inflation has risen, modifies its views about

21. A price increase of this magnitude would be considerably smaller than the 250 percent rise in 1973–74 but about the same size as that in 1979–80.

6. Simulated consequences of higher oil prices when public perceptions of monetary policy are correct or incorrect



NOTE. Both simulations are based on VAR expectations.

the long-run target for inflation, even though the goals of policy have not changed. Under such circumstances the price spike leads to expectations of a signficant increase in long-run inflation. Only after policymakers prove their commitment to a noninflationary path and achieve a reduction in the actual rate of inflation—a process that takes several years—do expectations of long-run inflation return to baseline.

The rise in oil prices affects households and firms in similar ways under the two assumptions about expectations. For example, in both cases higher oil prices feed directly into higher prices for gasoline, heating oil, and other sources of energy. The higher energy bill puts pressure on firms' profit margins, and thus on prices, while workers demand higher wages as the cost of living rises. Because wages adjust more slowly than prices, the real wage falls and depresses the demand for consumer goods. Consumption spending is further restrained by the increase in the share of aggregate income flowing overseas to pay for imported oil. Under these circumstances, unemployment rises.

The resultant weakness in aggregate spending is only transitory. Because the goal of monetary policy is to stabilize the economy, the federal funds rate initially rises in response to the original spike in inflation but later falls below baseline as inflation moderates and unemployment rises. With inflation close to baseline after three years, the implied reduction in the real interest rate is sufficient to eventually offset the contractionary effects of higher oil prices.

The cost of bringing inflation down to its original level is greater, in terms of the cumulative increase in unemployment, if the public thinks that the target rate of inflation has risen. This extra cost arises because the public's misperception of policy leads it to make two forecasting errors: (1) an overstatement of the future rate of growth of unit labor costs (the wage rate adjusted for productivity growth) and (2) an understatement of the average future level of unemployment. The first error is a direct consequence of the policy misperception, because equilibrium in FRB/US requires that the rate of growth of unit labor costs must equal the target rate of inflation in the long run. The second error results from the mistaken belief that monetary policy makers will allow inflation to remain permanently higher instead of bringing it back to baseline by restraining aggregate demand. Because the actual rate of inflation depends on the expected growth of unit labor costs and the future level of unemployment (as well as on lagged inflation), the two forecasting errors exacerbate the inflation problem created by higher oil prices. To offset this additional source of inflationary pressure, the stance of monetary policy must be tighter on average. The need for this tighter stance does not disappear until the policy misperception is corrected through an actual reduction in inflation.

CONCLUSION

These simulations provide a glimpse of the key role that expectations play in the new macroeconomic model of the U.S. economy used at the Federal Reserve Board and the ways in which they affect predictions of the economy's response to disturbances in aggregate supply and demand. As noted earlier, economists do not agree on the appropriate treatment of expectations in macroeconomic models. Thus, the FRB/US model was designed to be flexible with respect to the formation of expectations. A subject of ongoing research is the way in which firms and households modify their method of forming expectations in light of new evidence—that is, how they learn about the structure of the changing economic environment. The FRB/US model provides a framework for analyzing this and other issues. □