Working Paper Series

The New Neoclassical Synthesis and the Role of Monetary Policy

WP 98-05

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June 1997

Abstract

Macroeconomics is moving toward a New Neoclassical Synthesis, which like the synthesis of the 1960s melds Classical with Keynesian ideas. This paper describes the key features of the new synthesis and its implications for the role of monetary policy. We find that the New Neoclassical Synthesis rationalizes an activist monetary policy which is a simple system of inflation targets. Under this "neutral" monetary policy, real quantities evolve as suggested in the literature on real business cycles. Going beyond broad principles, we use the new synthesis to address several operational aspects of inflation targeting. These include its practicality, the response to oil shocks, the choice of price index, the design of a mandate, and the tactics of interest rate policy.

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1. Introduction

It is common for macroeconomics to be portrayed as a field in intellectual disarray, with major and persistent disagreements about methodology and substance between competing camps of researchers. One frequently discussed measure of disarray is the distance between the flexible price models of the new classical macroeconomics and real-business-cycle (RBC) analysis, in which monetary policy is essentially unimportant for real activity, and the sticky-price models of the New Keynesian economics, in which monetary policy is viewed as central to the evolution of real activity. For policymakers and the economists that advise them, this perceived intellectual disarray makes it difficult to employ recent and ongoing developments in macroeconomics.

The intellectual currents of the last ten years are, however, subject to a very different interpretation: macroeconomics is moving toward a *New Neoclassical Synthesis*. In the 1960s, the original synthesis involved a commitment to three—sometimes conflicting—principles: a desire to provide practical macroeconomics policy advice, a belief that short-run price stickiness was at the root of economic fluctuations, and a commitment to modeling macroeconomic behavior using the same optimization approach commonly employed in microeconomics.

The New Neoclassical Synthesis inherits the spirit of the old, in that it combines Keynesian and classical elements. Methodologically, the new synthesis involves the systematic application of intertemporal optimization and rational expectations as stressed by Robert Lucas. In the synthesis, these ideas are applied to the pricing and output decisions at the heart of Keynesian models, new and old, as well as to the consumption, investment, and factor supply decisions that are at the heart of classical and RBC models. Moreover, the new synthesis also embodies the insights of monetarists, like Milton Friedman and Karl Brunner, regarding the theory and practice of monetary policy.

Thus, there are new dynamic microeconomic foundations for macroeconomics. These common methodological ideas are implemented in models that range from the flexible, small models of academic research to the new rational-expectations policy model of the Federal Reserve Board. The New Neoclassical Synthesis (NNS) suggests a set of major conclusions about the role of monetary policy. First, NNS models suggest that monetary policy actions can have an important effect on real economic activity, persisting over several years time, due to gradual adjustment of individual prices and the general price level. Second, even in settings with costly price adjustment, the models suggest little long-run trade-off between inflation and real activity. Third, the models suggest significant gains from eliminating inflation, which stem from increased transactions efficiency and reduced relative price distortions. Fourth, the models imply that credibility plays an important role in understanding the effects of monetary policy. These four ideas are consistent with the public statements of central bankers from a wide range of countries.

In addition to the general points, NNS models allow the analysis of alternative monetary policy rules within a rational-expectations setting. It is in this role that they can inform—rather than confirm—the priors of central bankers. The credibility of monetary policy appears intuitively to require a simple and transparent rule. But which one? We use the NNS approach to develop a set of principles and practical guidelines for *neutral* monetary policy, defined as that which supports output at its potential level in an environment of stable prices. The new synthesis suggests that such a monetary policy involves stabilizing the average markup of price over marginal cost. In turn, this implies a monetary policy regime of inflation targets, which vary relatively little through time. Although price stability has been long suggested as a primary objective for monetary policy, a number of major questions have arisen about its desirability in practice. We confront a range of implementation issues, including the response to commodity price shocks, the long and variable lags between monetary policy and the price level, the potential policy trade-off between price and output variability, and the use of a short-term interest rate as the policy instrument.

The organization of our discussion is as follows. In Section 2, we describe the general approach of the original neoclassical synthesis as it was articulated by Paul Samuelson. In Section 3, we review why the original neoclassical synthesis was never fully accepted by monetarists, even at the height of its influence in the 1960s, and then was more fundamentally challenged by the rational-expectations revolution. We then turn to more recent work in macroeconomics covering RBC models in Section 4, and New Keynesian economics in Section 5.

The NNS is introduced and described in Section 6. We analyze the effect of monetary policy within the new synthesis using two complementary approaches. First, we employ the standard Keynesian method that views monetary policy as affecting real aggregate demand. Second, we use an RBC-style alternative which views variations in the average markup as a source of variations in aggregate supply; these markup variations are analogous to the effects of tax shocks in RBC models. We use the insights of the previous sections to develop principles for monetary policy in Section 7 and practical guidelines for monetary policy in Section 8. Section 9 is a summary and conclusion.

2. The Neoclassical Synthesis

As popularized by Paul Samuelson,[1] the neoclassical synthesis was advertized as an engine of analysis which offered a Keynesian view of the determination of national income—business cycles arising from changes in aggregate demand because of wage and price stickiness—and neoclassical principles to guide microeconomic analysis. In our discussion of the neoclassical synthesis, we consider three major issues: the nature of the monetary transmission mechanism, the interaction of inflation and real activity, and the role of monetary policy.

2.1. THE MONETARY TRANSMISSION MECHANISM

The basic macroeconomic framework of the neoclassical synthesis was the IS-LM model. The neoclassical synthesis generated a number of advances in the 1950s and 1960s to make this framework more consistent with individual choice and to incorporate the dynamic elements that were so evidently necessary for econometric modelling of macroeconomic time series. Theoretical work rationalized the demand for money as arising from individual choice at the margin, leading to a microeconomic explanation of the interest rate and scale variables in the monetary sector. The synthesis stimulated advances in the theory of consumption and investment based on individual choice over time. Econometric work on money demand and investment developed dynamic partial adjustment specifications.

These new elements were introduced into large-scale models of the macroeconomy. Our discussion focuses on the Federal Reserve System's MPS model, which was developed because "no existing model has as its major purpose the quantification of monetary policy and its effects on the economy," as de Leeuw and Gramlich (1968, p. 11) reported. The MPS model initially included the core elements of the IS-LM framework: a financial block, an investment block, and a consumption-inventory block. The structure of production possibilities and the nature of wage-price dynamics were viewed as important, but secondary in the early stage of model development. Relative to other then-existing models, the

[1] An early description of the neoclassical synthesis is found in the 1955 edition of Samuelson's *Economics,* and the mature synthesis is discussed in the 1967 edition (Samuelson, 1967).

MPS model suggested larger effects of monetary policy because it incorporated a significant effect of long-term interest rates on investment and its estimated lags in the demand for money suggested much faster adjustment than in earlier models.

In its fully developed form, circa 1972, the MPS model incorporated several structural features that are worth stressing. It was designed to have long-run properties like that of the consensus growth model of Robert Solow, including the specification of an aggregate production function implying a constant labor share of national income in the face of trend productivity growth. As explained in Ando (1974), however, the MPS model had a short-run production function which linked output to labor input roughly one for one, as a result of variations in the utilization of capital. The empirical motivation for this feature is displayed in Figure 1: over the course of business cycles, total man-hours and output display similar amplitude, with measured capacity utilization strongly procyclical. For the most part, these cyclical variations in total hours arise largely from variations in employment rather than hours per worker.[2]

2.2. INFLATION AND REAL ACTIVITY

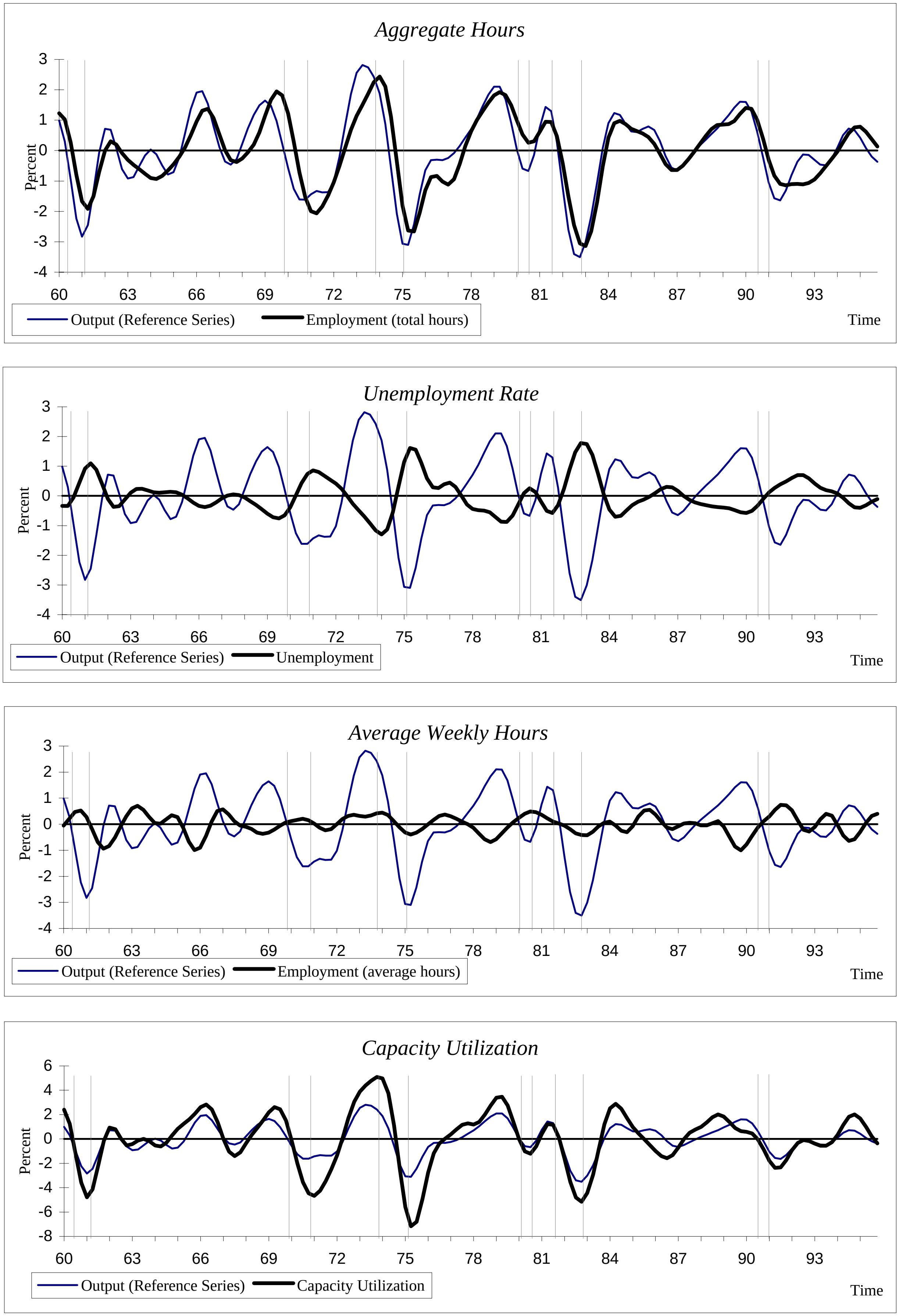
In the early years of the neoclassical synthesis, macroeconometric models were constructed and practical policy analysis was undertaken assuming that nominal wages and prices evolved independently from real activity and its determinants. In fact, in the 1950s, there was relatively little variability in inflation. By the mid-1960s this premise could no longer be maintained—inflation became a serious policy concern and it was plain to see that inflation was related to developments in the economy.[3]

The Phillips curve thus became a central part of macroeconomic modeling and policy analysis. Macroeconomic models were closed with wage and price sectors that indicated major trade-offs between the rate of inflation and the level

[2] In each panel of Figure 1, output is the lighter solid line. The data are filtered to isolate periodic components between 6 quarters and 24 quarters in duration

[3] de Menil and Enzler (1972) report "the first large econometric models of the 1940s and 1950s had relatively little to do with wages and prices. As late as 1960, one of the major U.S. models did not have wage or price equations. In the late 1950s, the authors of another model reported that for all practical purposess price and wage movements were independent of real variables in their model. However, postwar experience has focused attention more and more on the problem of inflation and has shown that there are crucial links between real variables and prices and wages that imply a tradeoff between real output and employment on the one hand and inflation on the other."

Figure 1: Hours, Employment, and Utilization



of real activity. The MPS model specified that the price level was determined by a markup of price over marginal cost, with the nominal wage rate being a central determinant of cost. In addition, the MPS model made the markup depend on the extent of utilization and allowed the price level to gradually adjust toward marginal cost (Ando 1974, pp. 544 and 552). The MPS version of the Phillips curve specified that the rate of wage inflation depended on the unemployment rate and the lagged rate of change of nominal prices. With these three assumptions taken together, as in de Menil and Enzler (1972), the MPS model suggested that the effect of reducing the long-run rate of inflation from 5% to 0% was an increase in the unemployment rate from 3.5% to 7%.

The nature of the trade-off between inflation and unemployment became central to macroeconomic policy, as well as to macroeconomic modeling. Policy advisors worried about a wage-price spiral and were concerned that inflation could develop a momentum of its own, as appeared to be the case in the recession of 1957-58 (Okun et al., 1969, p. 96; Okun, 1970, p. 8). By the standards of later years, the outcomes for inflation and unemployment were relatively favorable in the 1950s and 1960s. The Phillips correlation held up remarkably well throughout the 1960s.[4] Yet economic advisors operating within the synthesis tradition were pessimistic about the prospects for taming inflation.

2.3. THE ROLE OF MONETARY POLICY

The practitioners of the neoclassical synthesis saw a need for activist aggregate demand management. Given the degree of short-run price level stickiness built into the neoclassical synthesis, monetary policy was recognized to have potentially powerful effects. Yet, in practice, policy advisors working within the synthesis viewed monetary policy as playing a permissive role in supporting fiscal policy initiatives. Moreover, economists regarded the effect of market rates on interest-sensitive components of aggregate demand as less important than direct credit effects (Okun et al., 1969, pp. 85-92). They thought monetary policy worked primarily by affecting the availability of financial intermediary credit, with particular importance attached to the effect on spreads between market rates and then-regulated deposit rates. Accordingly, there was a reluctance to let the burden of stabilization policy fall on monetary policy, since it worked by a distortion

[4]See Tobin's (1972, p. 48) discussion of the cruel dilemma.

of sorts.[5]

In spite of a reluctance to use it, practitioners of the neoclassical synthesis recognized that monetary policy could control inflation. Okun's (1970, p. 8) view was representative: "the basic cure for inflation is to remove or offset its cause: cut aggregate demand by fiscal or monetary policy sufficiently so that money spending will no longer exceed the value of goods." James Tobin could say of the 1966 tightening of monetary policy to fight sharply rising inflation that "the burden of restraint fell almost wholly on the Fed which acted vigorously and courageously."[6]

Thus, monetary policy in the neoclassical synthesis was regarded as a powerful instrument, but one ill-suited to controlling inflation or to undertaking stabilization policy. While monetary policy could control inflation in theory, the practical view was that inflation was mainly governed by psychological factors and momentum, so that monetary policy could have only a very gradual effect. Since monetary policy created distortions across sectors, fiscal policy was better suited for controlling the business cycle.

3. Monetarism and Rational Expectations

When it emerged in the 1960s, monetarism seemed to threaten the neoclassical synthesis. Partly, this was because monetarists portrayed themselves as intellectual descendants of the pre-Keynesian quantity theory of money, as articulated by Irving Fisher and others. Partly, it was because monetarists questioned so much of synthesis doctrine, e.g., the effectiveness of fiscal policy and the structural stability of the Phillips curve. In the 1970s and 1980s, many monetarist insights were to be incorporated into the broad-based synthesis, and for good reason: monetarism was a set of principles for practical policy advice, it was committed to neoclassical reasoning, and it too identified the source of business cycles in short-run price-level stickiness.[7] However, at the same time, Lucas's critique of macroeconometric policy and the subsequent introduction of rational expectations into macroeconomics led to a broader questioning of the neoclassical synthesis.

[5] One particular concern was that changing credit availability would create instability in those sectors most dependent on financial intermediaries: small businesses and individuals.

[6] Tobin (1974, p. 35).

[7] See, for instance, Friedman (1970).

The quantity theory—the heart of monetarism—suggested organizing monetary analysis in terms of the supply of nominal money and the demand for real money balances. This focus had implications for the monetary transmission mechanism, for the linkage between inflation and real activity, and for the role of monetary policy.

3.1. THE MONETARY TRANSMISSION MECHANISM

The basic monetarist framework was the quantity equation, which we introduce using notation that we carry throughout the paper. According to the quantity theory, nominal income (Y_t) is the result of the stock of money (M_t) and its velocity (v_t):

$$\log Y_t = \log M_t + \log v_t. \tag{3.1}$$

Monetarists made the quantity theory operational by taking money as autonomous.[8] Monetarists also constructed an econometric model on the basis of their analytical framework. The St. Louis model of Anderson and Jordan (1968) was simply the quantity equation in a distributed-lag context, with a flexible specification introduced to capture the dynamic adjustment of money demand and money supply.

The monetarist view of the transmission mechanism was sharply at odds with the neoclassical synthesis, which tended to view the main channels of transmission as working through credit availability and secondly through the effect of long-term interest rates on investment. Monetarists regarded both of those channels as secondary. They focused on money rather than credit channels.

Following Irving Fisher, monetarists recognized that nominal interest rates contained a real component and a premium for expected inflation. Like other lags, those in expectation formation were taken to be long and variable. As a practical matter, though, monetarists regarded most of the variation in long-term rates as reflecting inflation premia, giving long rates a relatively minor role in the transmission of monetary policy to real activity.

3.2. INFLATION AND REAL ACTIVITY

Monetarists also differed in their view of the linkage between inflation and real activity. For the most part, monetarists acknowledged that they had no reliable

[8] Fully operational monetarist analysis also required assumptions about velocity. In some contexts velocity was assumed constant, in others, autonomous. More sophisticated analyses made velocity a function of a small set of macro variables.

theory to predict the short-run division of nominal income growth between the price level (P_t) and real output (y_t)—they had no *short-run price equation.* In various ways, they interpreted the apparent short-run nonneutrality of money as the result of price-level stickiness. But they observed that the effect of monetary policy actions on the economy was long and variable. They tended to attribute that variability to differences in the degree to which policy actions were expected, because expectations determined the degree to which prices and wages would adjust to neutralize an injection of money.

These expectational considerations were made explicit by Friedman (1968), who described how incomplete adjustment of expectations could lead wages and prices to respond sluggishly to changes in money. At the same time, Friedman suggested that sustained inflation should not affect real activity in the long-run, defined as a situation in which expectations were correct, since output would then be determined by real forces.[9] Friedman's suggestions were well timed. As shown in Figure 2, inflation increased sharply in the 1970s with little accompanying expansion of real activity.[10]

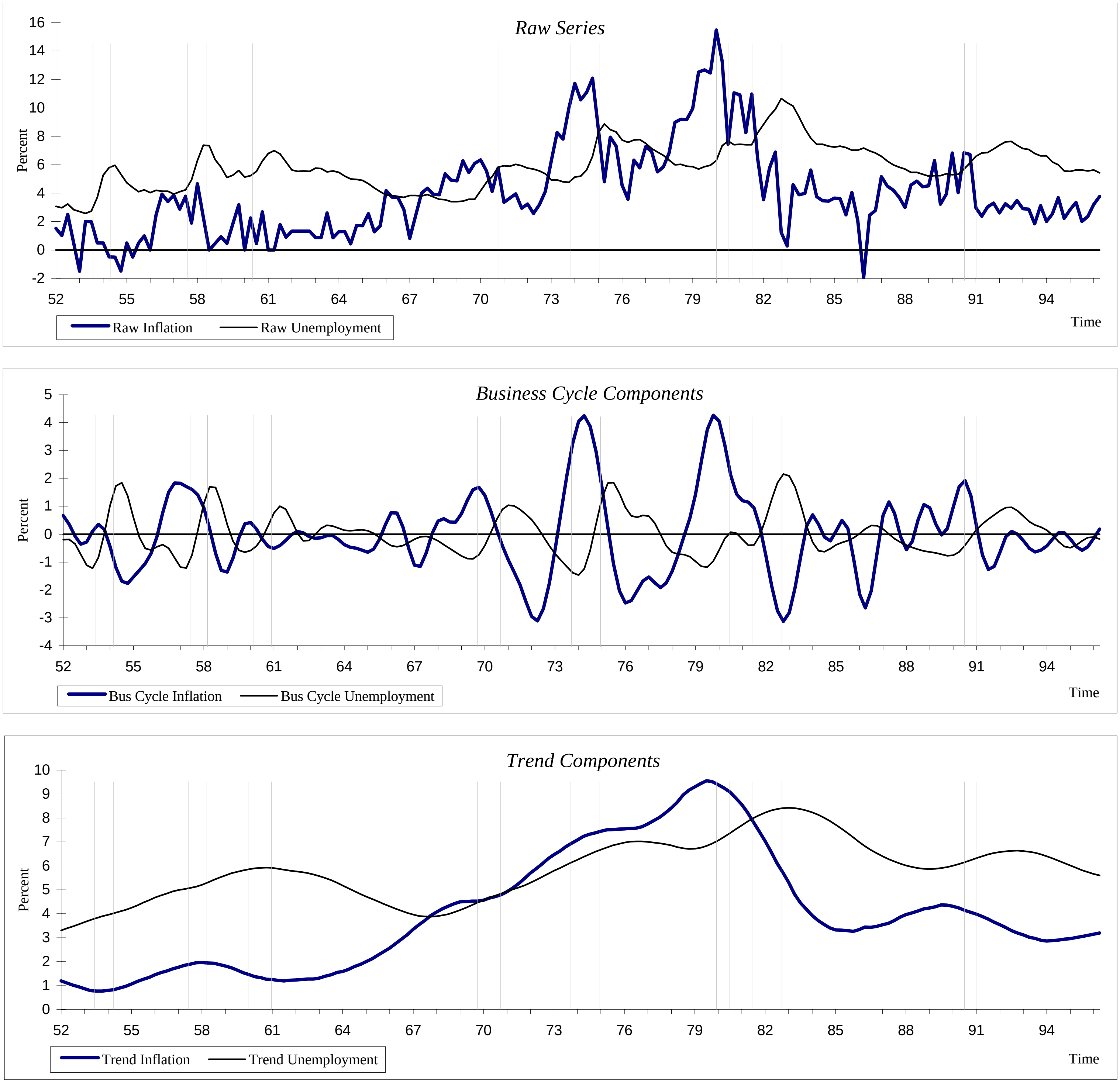
3.3. THE ROLE OF MONETARY POLICY

Monetarists saw a dramatically different role for monetary policy as well. Distrustful of discretionary and activist monetary policy, they sought to formulate simple fixed rules for policy. With Friedman and Schwartz's (1963) interpretation of the Great Depression in mind, they believed that the monetary authority should avoid major monetary shocks to the macroeconomy, suggesting a rule in which the quantity of money grew at a constant rate sufficient to accommodate trend productivity growth (Friedman 1960). After arguing that sustained inflation

[9]The builders of the St. Louis model sought to develop a price equation along these lines (see Anderson and Carlson,1972), which incorporated the simultaneous determination of price and output and a long-term interest rate as a measure of expected inflation.

[10]Figure 2 displays U.S. inflation (the dark line) and unemployment (the light line), with NBER turning points plotted as vertical dashed lines. Unemployment and inflation moved inversely together during all major postwar recessions. Business-cycle components of inflation and unemployment are negatively correlated in a stable manner over the postwar period. However, low-frequency *trend* components of inflation and unemployment (cycles with periodicity greater than three years) bear relatively little relationship to each other and virtually none to NBER business-cycle episodes. Not shown, the high-frequency *irregular* components of inflation and unemployment are also essentially unrelated, with inflation having much more volatility at high frequencies than unemployment.

Figure 2: Inflation and Unemployment



has little effect on real activity, Friedman (1969) described a long-run monetary regime that involved sustained deflation, making the nominal interest rate zero and thereby providing for an optimal quantity of money.

In practice, there were also important differences in the suggested role of monetary policy over the business cycle. While the policy advisors of the neoclassical synthesis sought to have the Federal Reserve maintain unchanged interest rates as fiscal policy was varied, monetarists thought interest-rate smoothing contributed to fluctuations in real economic activity by making the money stock vary procyclically.

3.4. RATIONAL EXPECTATIONS

As was the case with monetarism, the introduction of rational expectations into macroeconomics in the early 1970s at first seemed incompatible with the neoclassical synthesis. This was particularly ironic in that John Muth motivated his rational expectations hypothesis by suggesting that individuals form expectations optimally, which is a natural extension of the neoclassical principle that the economy is inhabited by rational, maximizing agents.

The early new classical models, such as that of Sargent and Wallace (1975), incorporated Friedman's view that perceived variations in money led simply to changes in prices, with only misperceived monetary changes having real effects.[11] Coupled with rational expectations, this strong neutrality mechanism led to very specific and controversial statements about the role of monetary policy. First, as in the monetarist analysis, the central bank should avoid creating monetary shocks. Second, a wide class of monetary rules led to the same fluctuations in real activity, since real effects of perceived variations in money would be neutralized by price-level movements.

3.5. CREDIBILITY

Even though the policy-ineffectiveness result was fragile, other far-reaching implications carry over to most modern macroeconomic models, including the sticky-price framework that we discuss below. Rational-expectations reasoning teaches that the effect of a given shock cannot be calculated without understanding its persistence or the extent to which it was expected and prepared for in advance.

[11] McCallum (1980) discusses the robustness of the policy neutrality proposition.

This point, delivered forcefully in Lucas (1976), revolutionized policy analysis, implying that one cannot predict the effect of a policy action at a point in time without taking account of the nature of the policy regime from which it comes.

Sargent (1986) tied these ideas explicitly to the nature of the inflation process: "inflation only *seems* to have a momentum of its own. It is actually the long-term government policy of persistently running large deficits and creating money at high rates that imparts the momentum to the inflation rate."[12] Reviewing a series of historical episodes in which countries tried to reduce high inflation rates, he argued that the costs of disinflation—foregone output—were much smaller if the government's commitment to disinflation was credible than if it was not. Yet, ironically, the new classical macroeconomic model assigned little importance to credibility. In that model, the future intentions of the central bank are very important for the evolution of the price level, because they affect expected inflation, but they are of limited relevance for real activity so long as they are accurately perceived. Consequently, while many central banks viewed credibility as important, they were reluctant to use the new classical macroeconomic model for analysis of monetary policy issues.

4. Real Business Cycles

Although rational expectations were introduced into macroeconomics to study the links between real and nominal variables, its implications were more systematically worked out within the real-business-cycle research program. The strong monetary neutrality built into RBC models has precluded their widespread use in macroeconomic policy analysis to date. But we see RBC logic as a central part of the New Neoclassical Synthesis. One reason is that the RBC program constructs models in which the alternative policies can be compared on the basis of measures of the utility benefits or costs, rather than on the basis of ad hoc objectives. Another is that the RBC framework allows for the analysis of policy and other shocks in the dynamic-stochastic context of a fully specified system, as called for by rational-expectations reasoning. The RBC program integrates and clarifies the intertemporal substitution that is at the heart of macroeconomics—involving consumption, investment, and labor-supply behavior—and in so doing it clarifies the determinants of the real rate of interest. Finally, RBC models pro-

[12] Sargent (1986, p.41).

vide insights into the nature of cyclical nonneutralities in NNS models and also describe macroeconomic outcomes under neutral monetary policy.

4.1. THE CORE ELEMENTS OF RBC MODELS

The RBC approach employs real general equilibrium models to study macroeconomic phenomena. One key element is the intertemporal optimization approach to consumption and labor supply. Another is the similar intertemporal analysis of investment and labor demand, arising from the profit-maximizing decisions of firms. Plans of households and firms are then combined into a general equilibrium, in which quantities and prices are simultaneously determined.

4.2. PRODUCTIVITY SHOCKS

The RBC program focused macroeconomists on the procylicality of the measured productivity of factor inputs. In the hands of Prescott (1986) and Plosser (1989), the basic RBC model was seen to be capable of generating business cycles that resembled those of the U.S. and other economies when it was driven by Solow residuals. For the purpose of defining these residuals and for discussing other issues below, we write the production function as constant returns to scale in labor (n) and capital (k), shifting through time as a result of productivity shocks (a):

$$y_t = a_t F(n_t, k_t). \tag{4.1}$$

In the RBC model, productivity shocks have two sets of effects on output. One is that they mechanically raise or lower output as stressed by Solow in his famous decomposition,

$$\frac{dy_t}{y_t} = (s_n \frac{dn_t}{n_t} + s_k \frac{dk_t}{k_t}) + \frac{da_t}{a_t}, \tag{4.2}$$

where s_k and s_n are the factor shares of labor and capital.. However, productivity shocks also exert effects on macroeconomic activity because they affect marginal product (factor demand) schedules. These marginal (substitution) influences interact with the smoothing motivation built into households' preferences to govern the dynamic response of the economy. A temporary rise in current productivity, for example, makes it more valuable for households to work (to cut back on leisure) and to invest (to postpone current consumption). Within the RBC model, these mechanisms explain, for example, the procylicality of labor input and the high-amplitude response of investment. The RBC approach forces a researcher to explain the response of the macroeconomy in terms of substitution and wealth effects on households.

A major question about the RBC approach has been the measurement of productivity shocks, particularly whether the Solow method mismeasures factor inputs. Subsequent research has focused on variable capital utilization as one source of mismeasurement: recent work by Burnside, Eichenbaum, and Rebelo (1995) cuts down the variability of the Solow residual so substantially that an adherent of the RBC approach may worry that there is little left in the way of productivity shocks.

4.3. RATIONALIZING HIGH SUPPLY ELASTICITIES

By focusing attention on the supply side, RBC modelers provoked many questions, one of the most basic being: are the high-amplitude labor supply variations assumed in RBC models counterfactual? Early RBC models assumed that aggregate labor supply varied solely by an individual worker (the representative agent) changing the number of hours worked. This mechanism is arguably inconsistent with microeconomic evidence on labor supply.

Yet, over the course of the business cycle there are large changes in work effort. As illustrated by comparison of panels (a) and (c) of Figure 1, these mostly arise from changes in the number of employed individuals, rather than in the number of hours worked by each individual. Important modifications of the basic RBC framework have modeled such movements into and out of the work force, yielding extremely high aggregate labor supply elasticities while maintaining small micro elasticities. Other recent studies feature variable capital utilization, with a supply of capital services that is highly sensitive to changes in factor prices so that utilization is strongly procyclical.[13] Overall, the modern RBC approach describes a macroeconomy that is highly sensitive to real shocks. Hall (1991) points out that many approaches to business cycles require a "high-substitution" economy like that constructed by RBC researchers.

[13] Cho and Cooley (1994) show how heterogeneity of fixed costs of going to work can lead to large work-force adjustments and small hours adjustments. These labor supply and capacity utilization developments are reviewed in King and Rebelo (1997).

4.4. MONEY IN RBC MODELS

Early in the RBC research program, a monetary sector was added to explore the types of business-cycle correlations between money and output that could emerge if productivity shocks were the main driving factor (King and Plosser, 1984). At a later stage of research, the effects of the inflation tax were explored (Cooley and Hansen, 1989). From this research and other work over the last decade, a number of conclusions have emerged that are broadly shared by macroeconomists. First, endogenous variations in money supply arising from the joint actions of private banks and the monetary authority at least partly explain the business-cycle correlation of money and output. Second, while versions of RBC models supplemented with a monetary sector can in principle explain the correlation of money and output, they do less well at explaining the cyclical variation in real and nominal interest rates (Sims, 1992), suggesting that there is more to the cycle than real productivity shocks that cause sympathetic variations in money. Third, the predicted consequences of cyclical variations in expected inflation are quantitatively small within flexible-price models, if money demand is modeled via cash in advance or with an explicit transactions technology. That is, for business-cycle purposes, an RBC model with an explicit monetary mechanism works a lot like an RBC model with a money demand function just tacked on after a real general equilibrium analysis.

4.5. ANALYSIS OF SUSTAINED INFLATION

Studies of the costs of steady inflation conducted under the RBC rubric have led to a revised understanding of the benefits that may be obtained from lowering inflation. A basic reference in this area is Lucas (1993), who calculates that the welfare cost of a 7% inflation may be about 1% of output using a variant of the shopping-time model of money demand. Since Lucas's transactions technology has no satiation level of cash balances, most of his estimated gains from lowering inflation to the Friedman (1969) level arise as a result of deflation. However, estimating the parameters of a shopping-time model with annual U.S. data over 1915-1992, Wolman (1996) concludes that the U.S. experience appears more consistent with a transactions technology with a satiation level of cash balances. This alternative money demand model provides roughly the same total gain from lowering inflation, but locates most of it between the 7% inflation level and zero inflation.

4.6. FISCAL POLICY AND FISCAL SHOCKS IN AN RBC SETTING

Another important topic of RBC analysis has been the study of fiscal policy and fiscal disturbances in real general equilibrium. In the RBC model, changes in tax rates have a powerful effect on real activity. In particular, variations in a comprehensive income or sales tax affect the after-tax real factor returns to labor and capital, inducing substitutions between goods and across time that influence the quantities of work effort and investment chosen by a representative agent. For example, the after-tax real wage is

$$w_t = (1 - \tau_t) a_t \frac{\partial F(n_t, k_t)}{\partial n_t}, \tag{4.3}$$

where τ_t is the tax rate at date t and w_t is the real wage rate at t. Thus, from the standpoint of the marginal return to work, the tax works just like a productivity shock. Accordingly, changes in comprehensive income taxes exert a high-octane influence on the RBC model.

RBC studies of actual U.S. fiscal shocks, like that of McGrattan (1994), come to an ironic conclusion. Changes in tax rates have powerful effects on macroeconomic activity, but since the variation in measured U.S. capital and income tax rates at business-cycle frequencies is small, these shocks do not contribute much to overall business-cycle variability. However, we see below that changes in markups can be interpreted as taxes of a potentially cyclically volatile form.

5. New Keynesian Economics

The New Keynesian approach to macroeconomics evolved in response to the monetarist controversy and to fundamental questions raised by Lucas's critique, and in order to provide an alternative to the competitive flexible-price framework of RBC analysis. Our discussion of this wide-ranging research program will be divided into three parts. We first review early work by Gordon (1982) and Taylor (1980). We then discuss more recent New Keynesian microeconomic foundations, which highlight monopolistic competition and costly price adjustment. Finally, we focus on optimizing price adjustment in a dynamic setting.

5.1. FIRST-GENERATION NEW KEYNESIAN MODELS

In first generation of New Keynesian models, Gordon (1982) and Taylor (1980) modernized the specification of the wage-price block to incorporate monetarist and rational expectations insights.

5.1.1. Gordon's Price Equation

On the empirical side, Gordon (1982) estimated price dynamics using a monetarist *proximate exogeneity* of nominal aggregate demand. Abstaining from separate consideration of nominal wages because he viewed their dynamics as essentially identical to those of prices, Gordon estimated price equations of the form

$$\pi_t = \lambda(L)\pi_{t-1} + G(\log Y_t - \log Y_{t-1}) + ps_t + \eta_t, \tag{5.1}$$

where $\pi_t = \log P_t - \log P_{t-1}$ is the rate of inflation, $\lambda(L)$ is a polynomial in the lag operator, $\log Y_t - \log Y_{t-1}$ is nominal income growth, ps_t captures the effects of observable price shocks and η_t is an error term.

Gordon interpreted the $\lambda(L)$ coefficients as indicating how the price level gradually adjusts toward a long-run level required by nominal income and a "natural rate" level of real activity. There were three main findings of Gordon's investigation: First, there was a numerically small value of G in the price equation. Estimating quarterly price equations over nearly a century of data and several subsamples, Gordon found slope coefficients in the range of $G = 0.10$, indicating a small impact effect of output on prices equal to $G/(1+G) = 0.09$.[14] Second, lags were estimated to be very important in the price equation: the mean lag between output and prices was more than a year. Gordon interpreted this as evidence for gradual adjustment of the price level to changes in nominal expenditure.

However, Gordon also found remarkable changes in his estimates when the ninety years of data was split into three or more subperiods. Within the early subsample running from 1892 to 1929, there were major shifts in the effects of nominal income during the war period 1915-1922. In particular, the estimated coefficient on nominal income rose substantially, with a big difference arising between expected nominal income growth ($G = 0.47$) and unexpected nominal income growth ($G = 0.25$). Measures of supply shocks—notably energy and commodity prices—became increasingly important in the post-World War II sample

[14] The impact effect is interpreted using identity $\log Y_t - \log Y_{t-1} = \log P_t - \log P_{t-1} + (\log y_t - \log y_{t-1})$.

period. Finally, the sum of coefficients on lagged inflation, $\lambda(1)$, rose substantially from 0.4 during 1892-1929 to more than 1 during 1954-1980.

5.1.2. Taylor's Rational-Expectations Approach to Wage Setting

The most hardy of the first generation of New Keynesian rational-expectations macroeconomic models is that of Taylor (1980). In modern terminology, Taylor's vision was that the firm and its workers set a fixed wage over the life of a J-period contract. Wage bargains were assumed to be staggered through time with $\frac{1}{J}$th of the contracts set each period. The simplest mathematical representation of Taylor's wage-setting mechanism is as follows.[15] The nominal wage rate set at date t, $\log W_t^*$, depends on the average price level expected over the contract $(\frac{1}{J})\sum_{j=0}^{J-1} E_t \log P_{t+j}$; on the average labor-market tightness (incorporated as $(\frac{h}{J})\sum_{j=0}^{J-1} E_t e_{t+j}$, where e_t is the labor-market tightness at date t and h governs the wage response to this tightness); and on a wage shock (ν_t):

$$\log W_t^* = \frac{1}{J}\sum_{j=0}^{J-1} E_t \log P_{t+j} + \frac{h}{J}\sum_{j=0}^{J-1} E_t e_{t+j} + \nu_t. \tag{5.2}$$

Taylor (1980) adopted a very simple macroeconomic model to focus on the consequences of this wage-setting behavior. First, Taylor specified that the price level was a simple average of wages, motivated by reference to a monopolist with constant marginal cost selecting a fixed markup,

$$\log P_t = \frac{1}{J}\sum_{j=0}^{J-1} \log W_{t-j}^*. \tag{5.3}$$

Second, like Gordon (1982), Taylor made the monetarist assumption that nominal expenditure was determined by a quantity equation. Third, Taylor assumed that

[15] Taylor (1980) assumed that current wages depended on past and future wages:

$$\log W_t^* = \sum_{j=0}^{J-1} b_j \log W_{t-j}^* + \sum_{j=0}^{J-1} b_j E_t \log W_{t+j}^* + \frac{h}{J}\sum_{j=0}^{J-1} E_t e_{t+j} + \nu_t.$$

with the contract weights being $b_j = (\frac{1}{(1-J)})(1-(\frac{j}{J}))$. This is a reduced form obtained by substituting the text equation (5.3) into (5.2).

labor-market tightness directly related to output: $e_t = g_1 \log y_t$. Fourth, Taylor assumed an activist money stock rule for monetary policy, specifically that

$$\log M_t = g_2 \log P_t. \tag{5.4}$$

As with the earlier New Classical rational-expectations models, Taylor's rational-expectations model required specification of the monetary authority's behavior. Rather than taking the monetary authority to be a source of business-cycle impulses, he viewed it as adjusting the money stock to the price level with a response coefficient g_2.

5.1.3. Business-Cycle and Policy Implications of Taylor's Framework

There are were four implications of the Taylor framework. First, Taylor produced a "humped-shaped" pattern of cyclical output (unemployment) dynamics in response to wage shocks ν_t, which Taylor suggested was a measure of success, because a number of empirical researchers had estimated time-series models which implied such profiles. Second, Taylor demonstrated that the policy rule mattered for the evolution of real activity. Third, Taylor highlighted a new monetary policy trade-off between the variability of output and the variability of inflation within his model, even with the maintained assumption that there was no long-run trade-off between the rate of inflation and the level of output. If velocity shocks were small, for example, then a central bank could largely eliminate real variability by accommodating price-level movements (g_2 close to one), but this would require greater variability in the price level. Fourth, he showed that rational expectations mattered a great deal—for the response of the economy to shocks and for the design of monetary policy rules—by contrasting his results with those based on extrapolative expectations.

Importantly, sticky-wage and sticky-price rational-expectations models like Taylor's also explained the main findings of Gordon, at least in broad form. Lags of nominal wages and prices were important state variables in these models, reflecting gradual adjustment to real and nominal shocks. Moreover the effects of proximately exogenous variations in nominal income depended in a central manner on how persistent these were expected to be, since (5.2) indicated that price expectations played a major role in wage setting.

Taken together with his subsequent work on larger macroeconometric models incorporating gradual price adjustment, Taylor's theoretical model had a major intellectual impact. Yet, at the same time, there was an uneasiness about the staggered wage models of Taylor. In the United States, in particular, only a small portion of the labor force was subject to explicit multiperiod contracts. Further, the microeconomic underpinnings of the wage-setting process were sketchy.[16]

5.2. SECOND-GENERATION NEW KEYNESIAN MODELS

In the next stage of research, New Keynesian economists shifted the location of nominal stickiness from wages to prices.[17] In this new work, price-setting firms were explicitly modeled as monopolistic competitors. The imperfect-competition framework was used to explain the real output effect of money when prices were subject to costs of adjustment, to develop various amplification mechanisms, and to highlight the potential social costs of business cycles.

5.2.1. Explicit Monopolistic Competition Models

During the 1980s, implications of monopolistic competition were explored in a wide range of fields, including economic growth, international trade and finance, and macroeconomics. In each case, imperfect competition held the promise of understanding issues that were puzzling from the perspective of competitive theory. In macroeconomics, monopolistic competition was important for analyzing how firms set prices. In the standard competitive setting, firms take market prices as given and adjust quantity in response to variations in prices and costs. By contrast, in Blanchard and Kiyotaki (1987) and Rotemberg (1987), firms are monopolistic competitors and set prices in order to maximize profit. These studies take consumption to be an aggregate of a continuum of differentiated products, $c_t = [\int_0^1 c_t(z)^{1-\frac{1}{\varepsilon}} dz]^{\frac{(\varepsilon-1)}{\varepsilon}}$. An individual firm producing the product z faces the constant elasticity demand

$$c_t(z) = c_t(\frac{P_t(z)}{P_t})^{-\varepsilon}, \tag{5.5}$$

[16] See Barro (1977).

[17] These New Keynesian developments are encapsulated in Mankiw and Romer (1991) and surveyed in Mankiw (1990), Romer (1993) and Rotemberg (1987). In part, New Keynesian economists sought to avoid theoretical criticisms of wage contracting models. In part, they thought that price stickiness seemed pervasive and sticky-price models more consistent with the somewhat procyclical real wages found in the data (Mankiw, 1990).

which is shifted by the aggregate price level and the level of aggregate consumption demand. Investment and government purchases could be viewed similarly as aggregates of differentiated products, leading to a version of (5.5) that replaced c_t with an aggregate demand measure. The implied form of the (perfect) price index associated with aggregate expenditure is

$$P_t = (\int_0^1 P_t(z)^{1-\varepsilon} dz)^{\frac{1}{(1-\varepsilon)}}. \tag{5.6}$$

Accordingly, with a nominal marginal cost of Ψ_t, an optimizing firm would set its price at a constant markup over marginal cost, $P_t(z) = [\frac{\varepsilon}{(\varepsilon-1)}]\Psi_t$, with the markup being given by the conventional formula. Thus, monopolistic competition rationalizes a firm setting a price and setting it at a level greater than marginal cost. Imperfect competition does not, by itself, rationalize nominal stickiness.

5.2.2. Incorporation of Nominal Stickiness

At the microeconomic level, stickiness of nominal prices is a feature of our everyday life. Thus, if we are developing "micro foundations for macroeconomics," it is important to have models that can explain these observed pricing practices. The most direct explanation is that small real costs of changing nominal prices—menu costs—account for sticky prices. It is an open question as to whether small menu costs can lead to sustained stickiness of the prices of individual goods, particularly in a situation of positive inflation. For the most part, in the New Keynesian modeling approach, the discrete and occasional adjustment of individual prices is simply a feature of the environment, rationalized in more or less elaborate ways. In this paper, as in that literature, we focus less on why individual prices might be set in advance and more on the implications that discrete and occasional individual price adjustment has for the behavior of the aggregate price level and real economic activity.

5.2.3. The Causes and Consequences of Monetary Business Cycles

New Keynesian economists also have stressed that imperfect competition is important for the effect of money on output if there is nominal price stickiness. To see the power of this argument, think about the perfect-competition case. If demand rises, but price remains the same, the firm will not respond, routing its potential customers elsewhere. By contrast, if its price is fixed at a level that exceeds marginal cost, then it *is* desirable for an individual firm to expand its output if its demand rises. The easy case is if marginal cost is unrelated to the firm's output, for then it will absorb all of the demand variation without suffering a decline in its markup. Even if marginal cost rises with output, either at the level of the firm or in general equilibrium, then it will continue to be profitable to satisfy demand so long as price exceeds marginal cost. In response to a general economic expansion—a rise in c_t in (5.5) above—it is plausible that marginal cost increases because firms must pay higher real wages to secure the labor input to produce additional output. Accordingly, New Keynesians highlight the importance of procyclical movements in real wages and marginal cost.

As a related matter, New Keynesian analysis also suggests a new set of conclusions for welfare analysis of the business cycle. With monopolistic competition, market power of firms means that there is too low a level of employment and output on average. The New Keynesian analysis thus provides a coherent account of the temptation to expand the economy present in the literature on time-inconsistent monetary policies (Barro and Gordon, 1983).[18] Further, monetary policymakers should not be indifferent about short-run changes in employment that arise from changes in money when prices are sticky. Notably, a decrease in employment and output that results from a contractionary monetary policy lowers the welfare of the representative individual by increasing monopoly distortions.

5.2.4. The Origins and Implications of Monopolistic Competition

There are a range of economic mechanisms, of course, that are consistent with monopolistic competition. To us, the most plausible is that firms face important fixed costs, including general overhead costs. These suggest modifying the production function to

$$y_t = a_t[F(n_t, k_t) - \Phi], \tag{5.7}$$

where Φ is a measure of fixed costs, which plausibly are assumed to display the same factor intensity requirements and technical shifts which govern final output.With such a production function, the representative firm has constant marginal cost (at given factor prices) and diminishing average cost.

[18] Ireland (1996b) provides a fully articulated model of how imperfect competition and sticky prices lead to excessive inflation when the monetary authority is unable to commit its future actions.

Hall (1988) demonstrates that the modified Solow decomposition is

$$\frac{dy_t}{y_t} = (1+\phi)(s_n\frac{dn_t}{n_t} + s_k\frac{dk_t}{k_t}) + \frac{da_t}{a_t}, \tag{5.8}$$

where s_n and s_k are total cost shares and ϕ is the ratio of overhead to variable cost. This decomposition highlights the consequences of overhead costs. First, the standard Solow residual varies with the business cycle even if there are no productivity shocks. Second, there is an amplification mechanism, so that a one-percent change in labor changes output by $(1+\phi)s_n$ percent change in output.

The New Keynesian approach allows for a wide range of assumptions about the nature and extent of imperfect competition. If there are no pure monopoly profits, then the markup of price over marginal cost must simply cover overhead costs, i.e., we must have $\mu = 1+\phi$ on average, which we assume throughout our discussion. In various quantitative exercises below, it will also be necessary for us to take a stand on the value of the steady-state markup. Compared to some other recent studies, we take a relatively small value, $\mu = 1.1$, which corresponds to a ten percent "net" markup and a demand elasticity of about 11.[19] We do this for two reasons. First, it is broadly consistent with observed markups in the construction and automobile service industries, i.e., markups in the range of 7% to 15% in contracts and bills of sale. Second, it is consistent with the detailed empirical studies of Basu and Fernald (1997).

5.3. DYNAMIC PRICE-SETTING MODELS

Models of price dynamics based on fixed real costs of changing nominal costs were first developed in the early 1970s. In these models, firms choose the timing and magnitude of their price adjustments in response to the state of the economy, including the average rate of inflation and the stage of the business cycle. This *state-dependent* approach to pricing is attractive from a microeconomic perspective because (1) individual firms are observed to discretely adjust their prices at infrequent intervals of apparently stochastic length, and (2) firms are more likely to adjust price when there are large shocks to their markets or sustained inflation. However, it has proved difficult to introduce this form of price adjustment into complete macroeconomic models. Caplin and Leahy (1991) indicated that the consequences could be major, but also that many simplifications were necessary to

[19] Using $\mu = \frac{\varepsilon}{(\varepsilon-1)}$ as in the text above, $\mu = 1.1$ corresponds to $\varepsilon = 11$.

characterize the imperfectly competitive equilibrium with costly price adjustment including extreme restrictions on the rules of the central bank, on the behavior of consumers, and the nature of money demand. Thus, while state-dependent pricing is natural, existing models have been ill suited for empirical analysis or examination of alternative monetary policy rules. For this reason, the emphasis in New Keynesian literature has been on *time-dependent* price adjustment rules which specify that firms have exogenous opportunities for price adjustment.

5.3.1. An Intertemporal Approach to Price Setting

Following Calvo (1983), we consider how a rational firm would select its price today given that it will have to keep it fixed for an interval of stochastic length. To operationalize this idea, we use notation and structure from a recent study of time and state-dependent pricing.[20] As in the imperfect-competition model above, we can posit a large number of firms—technically a continuum of firms—and suppose that a fraction ω_{jt} last adjusted their price j periods ago, for $j = 0, 1, ...J - 1$. Accordingly, the date-t conditional probability of the next adjustment at date $t + j$ is $\omega_{j,t+j}/\omega_{0t}$. When the demand elasticity is assumed constant, so that $y_t(z) = (\frac{P_t(z)}{P_t})^{-\varepsilon} d_t$ with P_t being the perfect price index and d_t an aggregate demand construct, then the optimal price is restricted by

$$P_t^* = \frac{\varepsilon}{\varepsilon - 1} \frac{E_t \sum_{j=0}^{J-1} \beta^j (\frac{\Lambda_{t+j}}{\Lambda_t}) \omega_{j,t+j} (\Psi_{t+j} P_{t+j}^{\varepsilon} d_{t+j})}{E_t \sum_{j=0}^{J-1} \beta^j (\frac{\Lambda_{t+j}}{\Lambda_t}) \omega_{j,t+j} (P_{t+j}^{\varepsilon} d_{t+j})}. \tag{5.9}$$

where Ψ_{t+j} is nominal marginal cost at $t + j$ and $\beta^j \frac{\Lambda_{t+j}}{\Lambda_t}$ is the discount factor for date-$t + j$ contingent cash flows.[21] The general price adjustment rule (5.9)

[20] Dotsey, King, and Wolman (1996). The approach there is a generalization of the Calvo's (1983) approach to price setting.

[21] Although we will focus on time-dependent pricing in our discussion below, there is some recent work that has sought to make the timing of price adjustment endogenous within a framework like that just discussed (Dotsey, King, and Wolman, 1996). There are three general implications of this line of research. First, the adjustment probabilities $\omega_{j,t+j}/\omega_{0,t}$ vary through time with the state variables of the model, but we still obtain (5.9). Moreover, the approximation (5.10) is robust to state dependence, so long as the inflation rate is close to zero. Second, the model must allow for time variations in the resources used in price adjustment. However, since the levels of these resources are assumed to be small in most New Keynesian models, the direct resource effects of these are are likely to be minor. Third, there are time-varying fractions of the firms which last adjusted their prices $j = 1, 2, ..., J$ periods ago.

derives from an equating of marginal revenue and marginal cost in a dynamic setting and has a convenient approximate form that we use below.[22] In particular, when the inflation rate is close to zero, then $\log P_t^*$ is approximately $\log(\frac{\varepsilon}{(1-\varepsilon)}) + [\frac{1}{\sum_{h=0}^{J-1}\beta^h\omega_h}]\sum_{j=0}^{J-1}\beta^j\omega_j E_t \log \Psi_{t+j}$. That is, the price is a discounted distributed lead of expected nominal marginal cost, with the weights related to the frequency distribution of price adjustment dates. Equivalently, denoting real marginal cost as ψ_t and using three identities ($\log \Psi_t = \log P_t + \log \psi_t$, $\log \psi_t = -\log \mu_t$ and $\log \mu = \log(\frac{\varepsilon}{(1-\varepsilon)})$), we can express the optimal price as

$$\log P_t^* \approx \frac{1}{\sum_{h=0}^{J-1}\beta^j\omega_h}[\sum_{j=0}^{J-1}\beta^j\omega_j(E_t \log P_{t+j} + \log(\psi_{t+j}/\psi))], \qquad (5.10)$$

i.e., as a depending on the future path of the price level and on the deviation of real marginal cost from its steady-state level.

5.3.2. The Price Level

To complete the dynamic pricing model, we need an equation that aggregates prices across firms into the general price level. With all firms that adjust at date t choosing P_t^*, the perfect price aggregator is

$$P_t = (\sum_{j=0}^{J-1}\omega_{jt}(P_{t-j}^*)^{1-\varepsilon})^{\frac{1}{(1-\varepsilon)}}, \qquad (5.11)$$

so that the price level depends on pricing decisions and adjustment patterns. If variation in the adjustment patterns is small over the business cycle—as in time dependent models or some state-dependent models—and the inflation rate is low, then there is a comparable approximation,

$$\log(P_t) \approx \sum_{j=0}^{J-1}\omega_j \log P_{t-j}^*, \qquad (5.12)$$

which we can pair with (5.10). These two equations (5.10) and (5.12) are a convenient representation of the central "price block" of the NNS models that we describe in the next section.

[22] These approximations are derived in Dotsey, King, and Wolman (1996).

5.3.3. Comparison with Taylor's Dynamic System

Based on intertemporal optimization and three simplifications (low inflation, constant elasticity of demand, and small variations in adjustment patterns), we have obtained a pair of loglinear equations (5.10) and (5.12) describing price dynamics. These broadly resemble the forward-looking wage-setting and backward-looking price-level equations used by Taylor, but with additional flexibility in the distributed lead and lag mechanisms because of the use of a stochastic adjustment model.

There is, however, one notable omission: there are no price shocks in our pair of behavioral expressions. This is a common outcome in economic modeling: optimization theory leads one to view shocks as arising from more primitive events which affect economic decision makers. As we shall see, our optimization approach allows for many types of events that are typically described as price shocks [as, for example, the commodity price variations included by Gordon (1982) in his empirical specification]. However, these exert an influence on prices through marginal cost, rather than directly, according to the theory developed in the next section.

6. The New Synthesis: Description and Mechanics

The New Neoclassical Synthesis is defined by two central elements. Building on new classical macroeconomics and RBC analysis, it incorporates intertemporal optimization and rational expectations into dynamic macroeconomic models. Building on New Keynesian economics, it incorporates imperfect competition and costly price adjustment. Like the RBC program, it seeks to develop quantitative models of economic fluctuations.

The NNS is currently displayed in three distinct modelling scales. First, there are small analytical models that can be used to study a range of theoretical and empirical issues while retaining sufficient tractability that they can be solved by hand. Second, there are medium-scale macroeconomic models analogous to those developed by RBC researchers that are being used to address a wide range of positive and normative issues.[23] Third, there is the new FRB/US large-scale model of the American economy developed over the last few years, which is now the principal model employed for policy evaluation by the Federal Reserve Board.[24]

[23] A recent partial survey is contained in Nelson (1997).

[24] Brayton *et al.* (1996) provide a description of the new FRB-US model, which incorpo-

We call the new style of macroeconomics research the New Neoclassical Synthesis because it inherits the spirit of the old synthesis discussed in Section 2. NNS models offer policy advice based on the idea that price stickiness implies that aggregate demand is a key determinant of real economic activity in the short run. NNS models imply that monetary policy exerts a powerful influence on real activity. This has both positive and normative implications. From a positive point of view, the central conclusion is that economic fluctuations cannot be interpreted or understood independently of monetary policy. This is true notwithstanding the fact that the RBC model at the core of the NNS assigns a potentially large role to productivity, fiscal policy, or relative price shocks. From a normative perspective the NNS says that aggregate demand must be managed by monetary policy in order to deliver efficient macroeconomic outcomes. In other words, the NNS creates an urgent demand for monetary policy advice.

The New Neoclassical Synthesis also supplies that advice. The combination of rational forward-looking price setting, monopolistic competition, and RBC components in the NNS provides guidance for monetary policy based on the following reasoning. First of all, stationary monetary policy must respect the RBC determinants of real economic activity on average over time. That is, even though output may be demand-determined on a period-by-period basis in the NNS, output must be supply-determined on average. Second, the NNS locates the transmission of monetary policy to real activity in its influence on the ratio of the average firm's price to marginal cost of production, which we call the average markup. A monetary policy action which raises aggregate demand raises marginal cost and lowers the average markup. This lower average markup sustains the increase in output and employment, because it works like a tax reduction in an RBC setting. Third, there is little long-run trade-off between inflation and real activity at low inflation rates. Illustrating this point, we show within a Tayloresque version of optimal pricing—one in which the typical firm adjusts its price once per year—that the steady-state markup tax is minimized by monetary policy that pursues near–zero inflation. Thus, the recommendation is that monetary policy should stabilize the path of the price level in order to keep output at its potential. This policy is

rates rational expectations and dynamic specifications into consumption, investment, prices, and wages. The new model displays no long-run trade-off between inflation and real activity. Expectations are central to the dynamic consequences of monetary and fiscal actions. While the FRB-US model does not rely as completely on intertemporal optimization as some smaller academic models and contains a different process of wage determination, it nevertheless shares many other central structural features of the NNS approach.

"activist" in that the authority must manage aggregate demand to accomodate any supply-side disturbances to output.

The power of the new synthesis lies in the complementarity of its New Keynesian and RBC components, which are compatible because of their shared reliance on microeconomics. The New Synthesis allows knowledge gained from New Keynesian and RBC studies to be brought to bear on business-cycle and monetary policy questions in a single coherent model. In doing so, the new synthesis strengthens our understanding of economic fluctuations. This and subsequent sections elaborate on the key features and implications of the NNS models. The balance of this section covers some preliminaries—the basic mechanics of markups, the average markup as a tax on economic activity, relative prices as productivity shocks, and the power and limiations of monetary policy. NNS principles and practical guidelines for monetary policy are developed in Sections 7 and 8 respectively.

6.1. HOW MONETARY POLICY AFFECTS THE REAL ECONOMY

In the new synthesis, monetary policy has effects which resemble those of productivity and fiscal shocks, producing substitution and wealth effects on the economy as in RBC models. Variations in the average markup charged by firms affect marginal returns to factors in a way that is similar to productivity shocks or changes in comprehensive taxes; changes in relative prices across firms work like the level effects of productivity shocks or changes in government purchases.

6.1.1. Marginal and Average Markups

Two measures of the markup play a major role in models of the NNS.[25] As suggested above, the *average markup* of price over marginal cost plays a prominent role in the transmission of monetary policy. At any point in time, though, only a subset of firms are adjusting prices and setting a new markup level, which we call the *marginal markup*.[26]

Formally, the *marginal* markup is the ratio of price to marginal cost for firms

[25] Rotemberg and Woodford (1991) provide a survey of alternative theories of markup determination and some suggestive empirical evidence concerning its cyclical behavior.

[26] The terminology of average and marginal markup is used in a simpler model with Calvo-style price setting by King and Wolman (1996).

that are adjusting their price in period t, i.e.,

$$\mu_t^* = \frac{P_t^*}{\Psi_t}. \tag{6.1}$$

We know from Section 5 that P_t^* depends on the expectations that adjusting firms have about future economic conditions, including the price level and marginal cost. The average markup is the ratio of price to marginal cost for the average firm in the economy (the ratio of the price level to marginal cost), [27]

$$\mu_t = \frac{P_t}{\Psi_t}. \tag{6.2}$$

For analyzing the determination of real economic activity within period t, it is the *average* markup that is central. From this standpoint, it is important to stress that the average markup is just the reciprocal of real marginal cost,

$$\psi_t \equiv \frac{\Psi_t}{P_t} = \frac{1}{\mu_t}. \tag{6.3}$$

Thus, procyclical variation of real marginal cost—which many economists find realistic—directly implies a countercyclical average markup.

The average and marginal markups can move very differently from each other in response to shocks. In response to sustained increases in nominal aggregate demand, for example, the markup falls for firms not adjusting price, but the higher inflation motivates adjusting firms to choose a higher markup. Thus the short-run effect of a sustained increase in demand is that the marginal markup rises and the average markup falls. We will return to this point in Section 7.

6.1.2. The Average Markup as a Distorting Tax

Firms produce output with capital and labor services. Since they are monopolistically competitive, their factor demands are based on cost minimization at a demand-determined output level. A necessary condition for cost minimization is that the value marginal product of every factor is equated to its rental price. Using Ψ_t to denote nominal marginal cost as above and letting W_t be the nominal wage rate, the efficiency condition for labor is $W_t = \Psi_t a_t \frac{\partial F(n_t,k_t)}{\partial n_t}$, and there is a

[27] Capital is assumed to be perfectly mobile among firms, so the marginal cost is the same for all firms in equilibrium.

comparable condition for capital services. Dividing each side of this expression by the price level, the real wage is equated to real marginal cost times the marginal product of labor.

$$w_t = \psi_t a_t \frac{\partial F(n_t, k_t)}{\partial n_t} = \frac{1}{\mu_t} a_t \frac{\partial F(n_t, k_t)}{\partial n_t}, \tag{6.4}$$

where the last equality follows directly from fact that the average markup and real marginal cost are reciprocals. Again, a similar equality of real factor prices and real value marginal products holds for capital services.

Thus, variations in the average markup work just like a comprehensive tax which a firm must pay on factor inputs. In the case of labor demand, for example, the average markup drives a wedge between the real wage and the marginal product of labor, just as the tax wedge did in (4.3). A higher markup raises the implicit tax on labor and capital.

6.1.3. Relative Price Dispersion as a Productivity Shift

In addition to the average markup, there is a second important source of distortions inherent in NNS models. Since some individual prices are sticky, changes in the general price level bring about changes in relative prices. This dispersion of relative prices results in a misallocation of aggregate output across alternative uses of final goods. To exposit this misallocation, we define aggregate output as the simple sum[28]

$$y_t = \int_0^1 y_t(z) dz$$

Suppose further, as in (5.5) above, that demand is given by the constant-elasticity specification, $y_t(z) = [\frac{P_t(z)}{P_t}]^{-\varepsilon} d_t$, with d_t being the level of benefit derived in final (consumption or investment) use. Then the distribution of relative prices influences the extent of end-use benefit from final output:

$$d_t = \frac{y_t}{\int_0^1 [\frac{P_t(z)}{P_t}]^{-\varepsilon} dz}.$$

The normative consequences of variations in this composite measure of relative prices are analogous to those of a total-factor-augmenting productivity shock.

[28]This definition is consistent with our discussion above and draws on Yun's (1996) work, which shows that it is consistent with competitive factor markets and demand-determined output.

6.2. THE TRANSMISSION MECHANISM

The New Neoclassical Synthesis provides two complementary ways of thinking about the transmission of monetary policy actions to real economic activity, which we view as the aggregate demand and markup tax approaches.

6.2.1. Aggregate Demand

From a traditional perspective, changes in the quantity of money alter aggregate demand, which calls forth changes in aggregate supply. When NNS models are interpreted in this manner—taking real aggregate demand as determined by monetary policy—the results are sensible at each point in time. Yet, this interpretation is incomplete for two reasons: the price level may respond to monetary policy within the period, and the focus is shifted away from real marginal cost, which is an important element of NNS models.[29]

6.2.2. The Markup Tax

An alternative view of the monetary transmission mechanism is suggested by the idea that the markup can be interpreted as a tax and, in particular, as a change in a generalized output (sales) tax that affects the rewards to capital and labor. From an RBC perspective the influence of monetary policy on economic activity can be analyzed using the relatively well-understood effects of comprehensive tax changes on macroeconomic activity, which we reviewed in Section 4 above. This view places movements in the average markup and real marginal cost at the center of the mechanism by which monetary policy influences real economic activity. It is similarly incomplete, however, in that it does not incorporate the influence of the price level on the average markup, nor does it recognize the role of real marginal cost in the evolution of prices. Yet, the average markup remains a useful summary statistic for monetary transmission.

[29] The evolution of real marginal cost over time is central to dynamic pricing models. Generally, changes in real marginal cost are $\frac{d\psi_t}{\psi_t} = (s_n \frac{dw_t}{w_t} + s_k \frac{dz_t}{z_t}) - \frac{da_t}{a_t}$, where z is the rental price of capital. Thus, small responses of wages and rental prices to changes in output, as suggested by the U.S. aggregate data and built into RBC models, imply small responses of marginal cost. More specifically, it is necessary to look behind the preceding cost decomposition to factor-market equilibrium to determine the responsiveness of marginal cost and to gain a more complete understanding of the evolution of real activity and the price level over time.

6.3. THE POWER AND LIMITATIONS OF MONETARY POLICY

Like its namesake predecessor, the New Neoclassical Synthesis views monetary policy as having the potential to exert a major influence on economic activity, though within clearly defined limits. Moreover, that influence can likewise be understood to operate via distortions, albeit different ones than identified in the original synthesis of the 1960s.

6.3.1. What Monetary Policy Can Do

To illustrate the power of monetary policy, it is useful to study the simplest possible price-setting model, one with two-period staggered price-setting. In this setting, it might be supposed that monetary policy has limited power for influencing real activity because pricing decisions are made just one period in advance, but we will see that monetary policy is still very powerful. In the two-period setting with $\omega_0 = \omega_1 = \frac{1}{2}$, the approximate equation for the price level (5.12) is $\log P_t = \frac{1}{2}(\log P_t^* + \log P_{t-1}^*)$. The forward-looking price-setting equation(5.10) is

$$\log P_t^* = \frac{1}{1+\beta}[\log P_t + \log(\psi_t/\psi) + \beta E_t P_{t+1} + \beta \log E_t(\psi_{t+1}/\psi)]$$

Combining the equations in this two-period price block, we can express the price level as

$$\log P_t = \log P_{t-1}^* + \log(\psi_t/\psi) + 2\sum_{j=1}^{\infty} \beta^j \log E_t(\psi_{t+j}/\psi). \tag{6.5}$$

This rational-expectations solution for the price level displays two important features that carry over to longer-horizon pricing models. First, the price level is partly predetermined by prices set in the past. Second, prices set by currently adjusting firms depend on current and future real marginal cost. In fact, the price level depends on an infinite distributed lead of expected real marginal cost even though each firm must keep its price fixed for only two periods. Expectations of future real marginal cost matter for current pricing because each firm knows that it will keep its price fixed for some period of time. Moreover, each firm cares about what prices will be next period in setting its price today, and so it cares what prices firms will set next period, and so on into the future.

In order to think about the evolution of the price level and output in this simple NNS model we need to understand the behavior of real marginal cost.

To do so, recall once more that real marginal cost is just the reciprocal of the average markup, so we can write $\log(\mu_t/\mu) = -\log(\psi_t/\psi)$. The RBC analysis above indicated that variations in the markup tax can exert a powerful inverse effect on employment and output. Such effects can be complex in a fully dynamic RBC setting, but for heuristic purposes consider the simple inverse relationship

$$\log(\mu_t/\mu) = -\varphi(\log y_t - \log \overline{y}_t), \tag{6.6}$$

where $\overline{y}_t$ is the flexible price level of output, i.e., that obtained in a noncompetitive RBC model with a constant markup μ. Since real marginal cost is, in turn, given by $\log(\psi_t/\psi) = \varphi(\log y_t - \log \overline{y}_t)$, the parameter φ is the elasticity of real marginal cost with respect to an "output gap."

Now suppose that monetary equilibrium is given by a quantity equation such as (3.1): $\log M_t = \log P_t + \log y_t - \log v_t$, where v_t is the velocity process. Substituting for the price level and output in the quantity equation with the price level and markup expressions, we arrive at an expression relating the money stock to current and expected future markups:

$$\begin{aligned}\log(M_t) \;&=\; \log(P^*_{t-1}) + \log \overline{y}_t + \log(v_t) \\ &\quad -\frac{1+\varphi}{\varphi}\log(\mu_t/\mu) - 2\sum_{j=1}^{\infty}\beta^j \log E_t(\mu_{t+j}/\mu).\end{aligned} \tag{6.7}$$

Thus as long as the monetary authority follows a policy that supports a determinate distributed lead of expected markups (a relatively weak condition), the preceding expression indicates that it can choose the money stock to produce an arbitrary pattern of small variations in the average markup over time. The monetary authority would have similar leverage over the path of the markup, real marginal cost, and output in more general NNS models as well.

One way to summarize this power is that the monetary authority can choose an arbitrary stationary stochastic process for the markup tax relative to a mean μ.[30] However, the monetary authority can produce variations in the average markup only by accepting the implications for prices and money. In particular, markup stabilization and price-level stabilization are intimately related in NNS models, a point we shall return to when we discuss the role of monetary policy.

[30] When we state the power of monetary policy this way, it is important to remember that we are considering the sorts of small variations implicit in the loglinearizations (5.10) and (5.12), respecting the requirement that all firms have price at least as great as marginal cost.

6.3.2. What Monetary Policy Cannot Do

However, the analogy to taxation is incomplete. Although the monetary authority can choose how the markup tax moves through time, there is little that it can do to affect the steady state-level of the markup, because the NNS incorporates forward-looking price setting. As we discuss in the next section, at low inflation rates the level of the steady-state markup is nearly invariant to the inflation rate and so is essentially determined by the extent of monopoly power in the private sector. In addition, there are some restrictions across the short run and long run, as in any rational-expectations model. The more persistent the monetary authority's planned movements in the markup tax, the larger are their inflationary consequences.

7. Guiding Principles for Monetary Policy

The New Neoclassical Synthesis makes the strong recommendation that a central bank should target near-zero inflation. In this section we spell out the principles underlying this prescription. For concreteness and simplicity, we work within the time-dependent price-setting model developed above. The principles are sufficiently general, however, that they will guide monetary policy in other NNS models as well. The role of monetary policy in the new synthesis derives from two sources. First, the underlying microeconomic structure suggests that it is desirable to stabilize the average markup, avoiding a source of time-varying distortions to the macroeconomy. Second, forward-looking price-setting behavior makes it feasible to design simple policies that will accomplish this stabilization.

7.1. THE OPTIMAL RATE OF INFLATION

What are the implications of the new synthesis for the optimal rate of inflation? While a complete analysis of this topic is beyond the scope of the present study, we can identify several key features that are important. First, the rate of inflation affects the distribution of relative prices in any model with price stickiness, which in turn has effects on the end-use value of output that we described above. These are minimized when there is zero inflation. Second, the average markup depends on the rate of inflation: in the example that we study further below, the average markup is minimized at a rate of inflation that is near zero. Third, if resources are expended adjusting prices, then these are minimized at zero inflation. Hence, on these three grounds, the incorporation of imperfect competition and price stickiness leads to the suggestion that a rate of inflation close to zero is desirable.

However, Friedman (1969) earlier argued that it was desirable to have expected deflation, so that the short-term nominal interest rate was zero. Thus, a complete analysis of the optimal rate of inflation must balance the monetary benefits from disinflation with the distortion costs associated with deflation.

7.1.1. Effects on Markups[31]

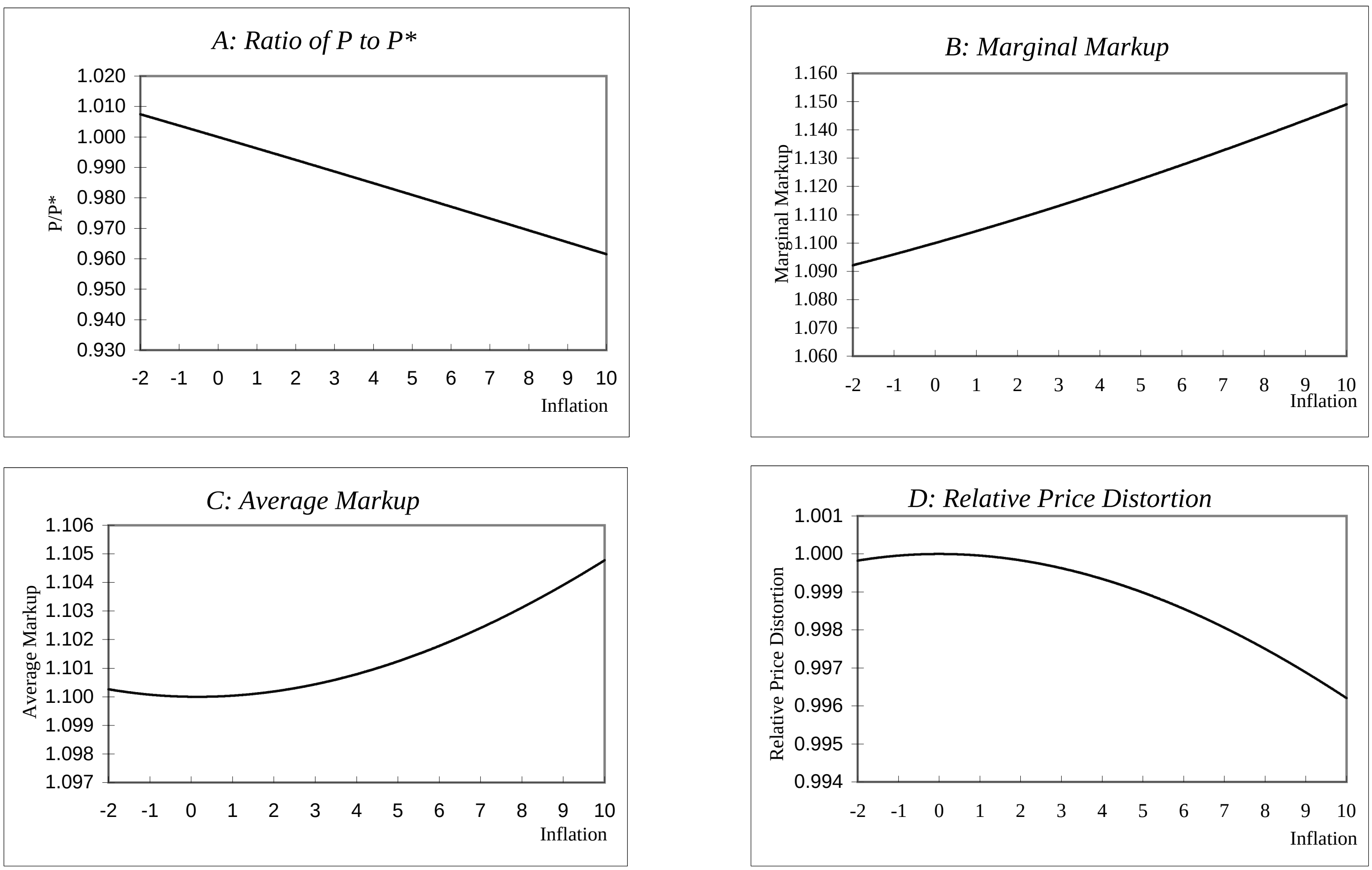
Early Keynesian analyses recognized that steady inflation would erode the market power of firms, suggesting benefits to sustained inflation. However, dynamic models of price setting suggest at best a small positive inflation rate on these grounds. Moreover, these models of price setting also suggest that larger rates of inflation will raise, rather than lower, average markups because of expected inflation effects. We use Figure 3 to display the main ingredients of this conclusion. First, in any model with sticky prices, positive inflation does mechanically erode the relative prices of firms which are not adjusting or, equivalently, there will be higher relative prices for those firms that are adjusting. To provide an idea of the quantitative importance of this channel, panel A shows the effect of inflation on P/P^* with a demand elasticity of 11 and the 4-quarter staggering of price adjustment suggested by some of Taylor's work ($\omega_j = 0.25$ for $j = 0, 1, 2, 3$). A 10% annual inflation rate lowers P/P^* by about 4%. Second, confronted with a situation of higher steady-state inflation, a rational price-setting firm has an incentive to raise its marginal markup. Using the same parameter values as above, panel B shows that a 10% inflation rate causes $\mu^* = P^*/\Psi$ to increase to 1.15 from the zero inflation level $\frac{\varepsilon}{(\varepsilon-1)} = 1.10$. Thus, firms raise the marginal markup substantially in response to anticipated inflation.

The average markup embodies both the inflation-erosion and expected-inflation effects, since it is simply the product $\mu = (\frac{P^*}{\Psi})(\frac{P}{P^*})$.[32] Accordingly, panel C dis-

[31] The discussion in this section draws heavily on King and Wolman (1996), who analyze the link between inflation and the average markup in a Calvo-style model of price setting.

[32] It is possible to show analytically that inflation has a negative effect on average markups near zero inflation: $\frac{d\mu}{d\pi}|_{\pi=0} = \mu(\frac{\sum_{j=0}^{J-1} j\beta^j\omega_j}{\sum_{j=0}^{J-1} \beta^j\omega_j} - \frac{\sum_{j=0}^{J-1} j\omega_j}{\sum_{j=0}^{J-1} \omega_j}) < 0$. Thus, a case can be made for reducing monopolistic competition distortions via a positive inflation rate within the NNS approach. This derivation is related to those of Benabou and Konieczny (1994) in a very different setup. Goodfriend (1997) makes a similar case for positive inflation in a model in which there is a "zone

Figure 3: THE EFFECTS OF STEADY-STATE INFLATION



plays the combined effect of inflation on the average markup, yielding three results of interest. First, the smallest value of the average markup occurs at a positive inflation rate, but this rate is not very different from zero. Second, the effect of inflation on the markup is positive at higher inflation rates. Third, the overall effect of inflation on the average markup is very small quantitatively near zero inflation. However, larger inflations actually raise rather than lower the average markup: increasing the inflation rate to 10% per year from zero produces an increase in μ from $\frac{\varepsilon}{(\varepsilon-1)} = 1.10$ to 1.1044. Thus, with small inflations or deflations, the monetary authority cannot influence the average markup by very much in the NNS model.

7.1.2. Relative-Price Distortions from Inflation

If there is no inflation in the steady state, then all relative prices will be one and the end-use value of output will be maximized. Further, small changes in relative prices near this initial point will have no effect on the ratio $\frac{d_t}{y_t}$, so that there will be no productivity effect of small business cycles or small rates of inflation or deflation. However, using a demand elasticity of $\varepsilon = 11$ and 4-quarter staggering of prices as above, we calculate that a 10% annual inflation rate will lower the end-use value of output by 0.4% and more generally display the relationship between inflation and relative-price distortions in panel D of Figure 3.[33] Thus, the NNS framework indicates a quantitatively important direct social cost of sustained inflation arising from relative price distortions.

Taking these findings concerning the average markup and the size of relative-price distortions together with the observation from Section 4 that there are relatively small gains from reducing inflation from zero to the Friedman rule, the NNS model recommends that the monetary authority target a near-zero rate of inflation. Since the productivity effects of relative-price distortions are minor near zero inflation, in what follows we focus solely on movements in the average markup in considering the response of the macroeconomy to various shocks.

of indeterminacy" for the average markup.

[33] That is, it will lower the ratio $\frac{d_t}{y_t}$ from the zero inflation level of unity to 0.996.

7.2. MONETARY POLICY AND THE BUSINESS CYCLE

How should monetary policy vary over the course of the business cycle? We argue the objective of the monetary authority should be to produce a constant path for the average markup or, equivalently, for real marginal cost. While markup constancy is an ad hoc objective, it is attractive to us for three related reasons. First, it brings about the same response of the real economy to various shocks as would arise if all prices were perfectly flexible. Second, it corresponds to tax smoothing as recommended in the public-finance literature.[34] Finally, it is consistent with the traditional suggested focus of monetary policy, which is to eliminate gaps between actual output and a time-varying level of potential (capacity) output.

Our recommendation amounts to a *neutral* monetary policy in the sense that it keeps the average markup at its steady-state level and makes the NNS model behave like a noncompetitive RBC economy. Neutral monetary policy accommodates shocks that would alter the equilibrium levels of output and employment with flexible prices, such as changes in productivity, fiscal policy, and international relative price changes, and some that would not, such as money demand shifts.

7.2.1. Neutral Monetary Policy and Price Dynamics

NNS price dynamics involve forward-looking and backward-looking components, as discussed in the previous section. To a first approximation [as in (5.10)], an adjusting firm sets its price at

$$\log P_t^* = \frac{1}{\sum_{h=0}^{J-1} \beta^j \omega_h} [\sum_{j=0}^{J-1} \beta^j \omega_j (E_t \log P_{t+j} + \log(\psi_{t+j}/\psi))]$$

To a first approximation [as in (5.12)], the price level is $\log P_t = \sum_{j=0}^{J-1} \omega_j \log P_{t-j}^*$.

Under the neutral-monetary policy requirement, real marginal cost is constant now and in all future dates, so that price setting depends only on the expected future path of the price level. Accordingly, the two dynamic equations imply an expectational difference equation that can be solved to determine the price level

[34] Existing analyses of dynamically optimal taxation in a stochastic general equilibrium setting are supportive of this assumption. Notably, in an economy with elastic supply of labor and capital services, Zhu (1995) shows that there is little variation in tax rates on either factor. Ireland (1996a) is an important start on studying optimal monetary policy in environments with imperfect competition and sticky prices that draws on the optimal-taxation approach.

and inflation implications of neutral monetary policy. It is possible to produce a general mathematical solution to this difference equation, but instead, we look at several special cases of this solution to provide an intuitive understanding of the implications of neutral monetary policy.

7.2.2. The Desirability of a Constant Price Level

The benchmark result is that a constant price level is a neutral monetary policy. That is, if we set $\log P_t^* = \log P_t = \log \overline{P}$ at all dates in the price equations ((5.10) and (5.12)), then a present value of real marginal cost must be expected to be zero at all dates, $0 = E_t \sum_{j=0}^{J-1} \frac{\beta^j \omega_j}{(\sum_{h=0}^{J-1} \beta^h \omega_h)} \log(\psi_{t+j}/\psi)$, which can only be satisfied by a constant level of real marginal cost.[35] There are two equivalent ways of stating this conclusion. Directly, a monetary authority committed to targeting a growth path for the price level must do so by maintaining constant real marginal cost or equivalently a constant average markup. Alternatively, one can say that a monetary authority committed to neutral policy must target a constant inflation rate.

7.2.3. The Money-Supply Process Supporting Neutral Outcomes

Under neutral monetary policy, output behaves according to a monopolistically competitive real business cycle with a constant markup μ in the face of shocks to technology, fiscal policy, and international relative prices. Neutral policy eliminates output gaps, making $y_t = \overline{y}_t$ at all dates.

Under a neutral policy, the monetary authority accommodates variations in money demand to insure that excesses or shortages of money do not create aggregate demand disturbances. To work out the implications for money supply, suppose that the price-level path under neutral policy is given by $\log \overline{P}_t = \log \overline{P}_{t-1} + \pi$, where $\log \overline{P}_t$ is the log of the price level and π is the trend rate of inflation. Since inflation is constant, variations in the real (r) and nominal (R) interest rate are identical ($R_t = \overline{r}_t + \pi$). Then, if money demand is $\log M_t = \log P_t - m_y \log y_t - m_R R_t - v_t$, the money stock must be:

$$\log M_t = \log \overline{P}_t - m_y \log \overline{y}_t + m_R(\overline{r}_t + \pi) - \log v_t. \qquad (7.1)$$

[35] More generally, any price-level path with a constant inflation rate at all dates also stabilizes the markup. This conclusion is obtained by similar reasoning and more algebra, together with setting $\beta = 1$.

That is: the monetary authority should accommodate movements in output and interest rates obtaining in the RBC model, and velocity shocks, too.

7.2.4. Initial Conditions and Inflation Transitions

The optimal pricing equations readily allow for a characterization of neutral monetary policy under more general conditions. Two decades ago, Edmund Phelps and Guillermo Calvo studied the disinflation problem in a basic fixed-wage model with a mathematical structure similar to (5.10) and (5.12).[36] Two key features of neutral monetary policy carry over to the economics of disinflation. First, the average markup must be constant through time, which amounts to requiring that the price adjustment decision depend only on the expected future path of the price level: $\log P_t^* = E_t \sum_{j=0}^{J-1} (\frac{\beta^j \omega_j}{\sum_{h=0}^{J-1} \beta^h \omega_h}) \log P_{t+j}$. Second, the path of the price level is just a function of the price adjustment decisions made at various dates: $\log P_t = \sum_{j=0}^{J-1} \omega_j \log P_{t-j}^*$. When we solve the resulting expectational difference equation assuming that the steady-state inflation rate is zero, the "stable" solution is of the form

$$\log P_t^* - \log P_{t-1}^* = \sum_{j=1}^{J-2} \sigma_j (\log P_{t-j}^* - \log P_{t-j-1}^*), \qquad (7.2)$$

where the coefficients σ_j are functions of the parameters ω_j and β. That is, there is a unique path of price adjustments which must occur if there is to be a constant average markup.

There are a number of implications of this Phelps-Calvo neutral disinflation formula. First, neutral monetary policy could equivalently be stated as a rule for the growth rate of newly set prices, $\pi_t^* = \log P_t^* - \log P_{t-1}^*$. Second, given that we have determined the growth rate π_t^* necessary for a neutral monetary policy, we can use the price level equation (5.12) to determine the neutral transition path for the measured rate of inflation, $\pi_t = \log P_t - \log P_{t-1} = \sum_{j=0}^{J-1} \omega_j \pi_{t-j}^*$.

In Section 7.1 above we used a 4-quarter Taylor model to get an idea of the quantitative sensitivity of the average markup to inflation in a steady state. In

[36]The results are reported in Phelps (1978), which contains an appendix coauthored with Calvo. The appendix to this working paper contains our derivation of the neutral monetary policy under the more general conditions necessary for the various scenarios discussed in the text. We thank Olivier Blanchard and Julio Rotemberg for alerting us to this reference.

that model, it turns out that a neutral transition to $\pi = 0$ takes the form

$$\pi_t^* = -0.43\pi_{t-1}^* - 0.12\pi_{t-2}^* \qquad (7.3)$$

That is, when we begin in an inflationary steady state with a quarterly rate of inflation of, say, 2.5% (so that the annual inflation rate is initially 10%), then there must be a price decrease on the part of adjusting firms equal to $-(0.42 + 0.12) * 0.025 = -0.01375$ in the impact period of a neutral disinflation. This price decline is necessary to stabilize the average markup given the past price rises built into the system, i.e., the initial conditions $\pi_{t-1}^* = \pi_{t-2}^* = 0.025$. With this aggressive policy action, the actual inflation rate, $\pi_t = \frac{1}{4}(\pi_t^* + \pi_{t-1}^* + \pi_{t-2}^* + \pi_{t-3}^*)$ drops from 2.5% to about 1.5% in the impact period of the policy and subsequently declines quickly to zero over the course of one year.[37]

7.2.5. Imperfect Control of the Price Level

We can also operationalize neutral monetary policy when the monetary authority has imperfect control of the price level. In such a setting, the monetary authority cannot achieve perfect control of the markup tax, but can keep it from varying in expected value. That is, its policy rule can make $(\frac{1}{\sum_{h=0}^{J-1}\beta^h\omega_h})E_{t-1}\sum_{j=0}^{J-1}\beta^j\omega_j \log(\mu_{t+j}/\mu) = 0$. The preceding results then apply to the expected component of monetary policy, with an additional *price adjustment shock* introduced into the analysis. That is, with imperfect control of the price level, neutral monetary policy takes the form

$$\pi_t^* = \sum_{j=1}^{J-2}\sigma_j\pi_{t-j}^* + \xi_t, \qquad (7.4)$$

where $\xi_t = \log P_t^* - E_{t-1}\log P_t^*$. Thus, the central bank accommodates some portion of price-level targeting errors, as in Taylor's analysis.

7.2.6. Comparison of Inflation Targets and Price Level Rules

Many central banks pursue inflation targets which allow for *base drift* in the price level. In our setting, a return to a fixed-price-level path is undesirable, since it

[37] The precise form of price stickiness is important for the details of neutral disinflation. With two-period staggered price-setting as in section 6.3, neutral monetary policy with a zero inflation target implies $\pi_t^* = 0$ for all periods after the disinflation begins, so that the path of the price level is $\log P = \log P^* = \log P_{t-1}^*$. The inflation rate in the first period of the policy is accordingly $\pi = \frac{1}{2}(0.025)$ as one-half of the agents catch up to the others at $\log P_{t-1}^*$.

requires variations in the average markup.

We can use the preceding analysis to quantify how much base drift is desirable in the setup with 4-quarter staggered price setting given in (7.3). Suppose that incomplete information leads to a targeting error, $\xi_t > 0$, which the monetary authority learns of at the end of the current period. How much of the forecasting error in the price level should be reversed eventually?[38] In the current setup (7.3), the desirable long-run effect on the price level is simply

$$\frac{\xi_t}{1-\sum_{j=1}^{J-1}\sigma_j} = \frac{\xi_t}{1-(-0.43-0.12)} \approx 0.6\ \xi_t$$

Thus, the monetary authority allows about six-tenths of a price forecasting error to feed through into the general price level in the long-run.

8. THE PRACTICE OF MONETARY POLICY

While price stability has long been suggested as a primary objective for monetary policy, a number of questions have arisen about its practical desirability and feasibility. This section takes up four major concerns using the approach of the New Neoclassical Synthesis. First, the effects of oil and other commodity price shocks have been long discussed by Keynesian economists as a reason for not stabilizing the price level. Second, Milton Friedman and other monetarists have questioned the desirability of inflation targeting on the basis of their reading of monetary history and the long and variable lags in the link between money and prices. Third, New Keynesians such as John Taylor have suggested the existence of important trade-offs between output and inflation variability. Fourth, central bankers routinely worry about the tactics of using their preferred policy instrument, a short-term interest rate. In addressing these issues below, we illustrate how the new Synthesis can guide the practice of monetary policy.

8.1. AN OIL SHOCK IN THE NEW SYNTHESIS MODEL

Oil shocks pose a difficult problem for monetary policy because they can create inflation and unemployment at the same time. This problem, however, makes oil

[38]We calculate the effect of such a forecasting error on the long-run price level under the rule $\pi_t^* = \sum_{j=1}^{J-1}\sigma_j\pi_{t-j}^* + \xi_t$ using the same approach employed in the literature on stochastic trends, since π_t^* follows an autoregressive process under the optimal policy.

shocks particularly instructive for illustrating the mechanics of the NNS framework and its prescriptive power for monetary policy. The analysis also highlights the complementarity of RBC and Keynesian reasoning that is inherited by NNS models.

It is natural to think of an oil shock as a restriction in the supply of oil available for use in the production of final goods. Firms produce output by combining (after overhead) capital and labor services with oil. Since firms are monopolistically competitive, output is demand-determined. For any level of final demand, optimal factor demands require the marginal cost of producing output for a firm to be the same for an increase in any of the three factors of production. By analogy to (6.4), measured in units of the final-good aggregate, optimal use of energy requires that

$$\psi_t a_t \frac{\partial F}{\partial q_t^e} = p_t^e,$$

where q_t^e is the quantity of energy (oil) input and p_t^e is the real price of oil. This gives us two independent marginal conditions for the three factors, plus the production function itself that relates the three factor uses to the demand-determined level of output. A firm chooses optimal factor uses taking factor prices as given. In general equilibrium, factor prices adjust to clear the factor markets, and by influencing the markup, factor-price adjustments also help clear the final-goods market.

Since the price level is sticky, output is governed by aggregate demand in the short run. Thus, we need to take a stand on how aggregate demand will behave in order to say how the system responds to the oil shock. For illustrative purposes our strategy is to ask what aggregate demand policy should do, and to assume that monetary policy supports that level of aggregate demand.

We benchmark the optimal policy response with RBC reasoning. By construction, the standard competitive RBC model would respond efficiently to the oil shock. For our purposes, the key feature of the competitive RBC model is that firms price output at the marginal cost of production. The gross markup is always 1 in the standard RBC model. A necessary condition for the NNS model to respond efficiently is that it also maintain a constant markup. Thus, the NNS recommends that monetary policy should aim to stabilize the markup against the oil shock, not accomodating any of the oil price rise in higher inflation.

With neutral monetary policy in place, we can ask how the NNS model would respond to the oil shock. At the initial level of factor inputs, output, and price, the rise in the price of oil raises nominal marginal cost and hence cuts the markup. In order for monetary policy to restore the markup to its initial level, policy must depress aggregate demand and cut employment. From the Keynesian perspective, such a recommendation sounds like adding insult to injury—causing employment to fall just when materials costs are high. Yet, RBC reasoning says that the economy should produce less when the marginal cost of production is temporarily high. That reasoning also suggests that the extent of the proper cut in demand depends on the expected persistence of the oil shock. A shock expected to be temporary has little wealth effect on labor supply and consumption demand. It mainly raises the opportunity cost of current work relative to leisure and of current leisure relative to future leisure. Thus, monetary policy should act to cut aggregate demand temporarily to reflect these opportunity costs. The temporary fall in current income in this case would cause agents to bid up real interest rates as they attempt to borrow to smooth consumption. Importantly, real interest rates must rise to support neutral monetary policy.

An oil shock expected to be highly persistent, on the other hand, would act like a persistent negative productivity shock, creating a large negative wealth effect that would offset the substitution effect on labor supply. Relatively little decline in employment might be called for in this case. But it would be appropriate for monetary policy to bring about a cut in consumption commensurate with the decline in productivity due to the lack of availability of oil. The willingness to cut consumption as incomes decline might produce little upward pressure on the real interest rate. In fact, when one takes account of the adverse effects on investment and the capital stock that might accompany what amounts to a highly persistent negative shock to productivity, there would likely be downward pressure on real interest rates.

To sum up, one might reasonably ask why, in practice, oil shocks have been inflationary? First, to the extent that oil products are produced in competitive markets and purchased directly by consumers, the increase in the price of oil gets directly into the price level without being intermediated by goods-producing firms in the sticky-price sector of the economy. To stabilize the price level against these direct price shocks would require pursuing aggregate demand policy restrictive enough to push demand and employment down in the sticky-price sector, thus increasing the markup there. NNS reasoning does not recommend increasing the markup in the sticky-price sector to stabilize the overall price level. Policy should be accommodative of such direct price shocks, especially since they are relative-price shocks whose effect on inflation is temporary. Second, and equally important, central banks can be reluctant to let real interest rates rise sharply, especially when a cost shock is hurting the economy. The inflationary consequences of oil price shocks have probably been exacerbated by central-bank attempts to smooth nominal interest rates with overly expansionary money growth.

8.2. IS INFLATION TARGETING PRACTICAL?

Monetary economists have long thought that price level stability has much to recommend it as the primary goal for monetary policy, and recently a number of central banks have adopted explicit inflation targets as a guide for policy.[39] It has been less clear, however, that inflation targets could play a useful role as an immediate policy objective and a criterion for performance. Using the NNS, we review practical arguments that have been advanced against inflation targeting by Friedman (1960) and others. We argue that these objections are unduly pessimistic when one recognizes the role of sticky prices and central-bank credibility in price setting.

8.2.1. Interpreting Historical Experience

Friedman's view is based in large part on his work on the monetary history of the United States with Anna Schwartz, in which they found lags in the effect of monetary policy to be long and variable, ranging between half a year to over two years. Reasoning on the basis of the historical data, Friedman observed that "the price level... could be an effective guide only if it were possible to predict, first, the nonmonetary effects on the price level for a considerable period of time in the future, and second, the length of time it will take in each particular instance for monetary actions to have their effect...." He concluded that "...the link between price changes and monetary changes over short periods is too loose and too imperfectly known to make price level stability an objective and reasonably unambiguous guide to policy."[40]

Friedman's inference about the advisability of inflation targeting seems too pessimistic. In the first place, none of the data from U.S. monetary history were drawn from a policy regime guided by the purposeful pursuit of price stability.

[39] See Haldane (1995) and Leiderman and Svensson (1995).
[40] Friedman (1960, pp. 87-88).

The gold standard prior to World War I was one in which trend inflation was small by today's standards. But the U.S. had no central bank, and money growth was heavily influenced by banking panics on a number of occasions, and by gold flows governed by the balance of payments and the happenstance of new discoveries and mining techniques. As a consequence, short-run price-level variability was quite significant at times during the period.[41]

After the founding of Federal Reserve there was inflation during World War I followed by a sharp deflation after the war; then prices stabilized in the 1920s, and the price level fell by around one-third from 1929 to 1933. The World War II inflation was not reversed subsequently, and instead the nation entered a period in which the price level more than tripled in the three decades following the Korean War.

NNS models imply that the linkages between prices and output depend sensitively on the monetary regime. Since U.S. monetary history has been a succession of very different monetary regimes, the NNS would predict just the kind of apparent instability in the effect of money found by Friedman and Schwartz. Robert Gordon's findings, mentioned in Section 5.1, of radically different empirical price equations across different sample periods, are a manifestation of the same kind of regime-dependent instability.

8.2.2. The Role of Credibility

If inferences from historical data can be misleading, we can make some conjectures about low-inflation targeting in the NNS model based on the role of central-bank credibility in the price-setting process. According to (5.10), for instance, costly price setting implies that firms care about a distributed lead of the price level and real marginal cost in setting today's price. When an inflation-targeting regime is perfectly credible, fixed distributed leads of both prices and real marginal cost (the reciprical markup) anchor current price-setting behavior.[42] Add to that some staggering of price setting, and the presumption is that credibility for low inflation is apt to be self-enforcing to a large extent, because in such an environment, firms will think less about inflation and be less nervous about it. This confidence would be reinforced further by a legislative mandate making low inflation a priority for

[41] Friedman and Schwartz (1963) and Meltzer and Robinson (1989).

[42] Ball (1995) contrasts credible and incredible disinflations in settings with forward-looking price setting.

monetary policy.

The main question for a central bank committed to low inflation is how "forgiving" price setters are likely to be of policy mistakes. Mistakes will inevitably occur due to imperfect information about the economy. But such mistakes would have little effect if caught in time, precisely because of the sluggishness in price setting. Of course, a central bank that allowed mistakes to cumulate for some reason, so that inflation began to move significantly higher, could turn the distributed lead in the price equation from a stabilizing anchor into a source of destabilizing inflation scares.[43]

Inflation scares are easy to understand from the perspective of the new synthesis. A central bank has an incentive to cheat on its commitment to price stability in the NNS model because a monetary policy action can reduce the markup distortion and increase employment. Chari, Kehoe and Prescott (1989), for instance, might argue that a central bank without a precommitment technology could not sustain a low-inflation equilibrium at all. At a minimum, their argument suggests that the incentive to cheat makes price setters hypersensitive to policy mistakes in a way that makes a low-inflation equilibrium extremely fragile.

It seems to us that NNS reasoning coupled with recent monetary policy developments weakens considerably the force of such a point. We think that central banks such as the Federal Reserve today largely internalize the long-run costs of cheating. As a result of the Volcker Fed's taking responsibility for inflation in the late 1970s and successfully bringing it down, the Fed is now widely held to be responsible for inflation.[44] Moreover, the low-inflation experience since then has demonstrated clearly the long-run benefits of price stability. Hence, we believe that the temptation for the Fed to cheat on its low-inflation commitment is much weaker than in the past.

[43] Goodfriend (1993) documents a number of inflation scares in the 1979-92 period and shows how they created problems for monetary policy.

[44] The Fed did not explicitly assert its responsibility for inflation in the initial October 1979 announcements of its disinflationary policy. However, by emphasizing the role played by money growth in the inflation process, and by announcing a change in operating procedures to control money, in effect, the Fed implicitly acknowledged its responsibility for inflation. Today, central banks are widely understood by the public to be responsible for inflation.

8.3. INFLATION AND OUTPUT VARIABILITY

Although his staggered-overlapping-contract model exhibits no long-run trade-off in the level of inflation and the level of output, Taylor (1980) showed that it does imply a trade-off between the variance of output and the variance of inflation. On this basis, Taylor argued that business cycles can be reduced only by accepting increased variability of inflation.

Since NNS models embody the kind of price-setting behavior assumed by Taylor, the question arises whether such models also present policymakers with a difficult choice between inflation and output variability. The question is of more than academic interest, since it bears on one of the most important issues in central banking today: the design of a legislative mandate for monetary policy. Most experts agree that some form of clear mandate would improve the effectiveness of policy by tying down inflation expectations and increasing central-bank accountability. The new synthesis supports such reasoning. But there is no agreement on whether a trade-off exists and if it does, on how to allow for it in a mandate.

8.3.1. Is There a Trade-off?

Recall our principle that monetary policy in NNS models should aim to keep the markup constant at the low level consistent with near-zero inflation. Thus, monetary policy should offset shocks to aggregate demand. Such policy actions would not only keep output at potential but stabilize prices as well. On the other hand, monetary policy should accommodate productivity shocks, taking into account any associated effects on labor supply and the capital stock. Otherwise, an output gap would open that would cause the markup to vary. There is no trade-off in either of these cases— policy should stabilize both the markup and prices in response to demand or productivity shocks. Even for an oil shock, society clearly faces no trade-off if oil is an intermediate input. We saw above that the best outcome is to maintain price stability and to reduce demand in response to the decline in productivity.

What about a NNS model with a flexible-price goods-producing sector alongside the sticky-price monopolistically competitive sector, in which shocks could impact inflation directly? Clearly, such a modification would not change the conclusion with respect to aggregate demand or productivity shocks, since these should still be offset or accommodated, respectively.

The added price flexibility, however, complicates the response to an oil shock, because the restriction in the supply of oil causes the oil price to rise relative to other prices. If policy were to depress aggregate demand just enough to maintain stable prices in the sticky-price sector, oil-intensive product prices in the flexible-price sector would still rise. The central bank could reduce aggregate demand enough to prevent the overall price level (flexible plus sticky prices) from rising, but then it would raise the markup and create an output gap in the sticky-price sector.

Thus, policy would appear to face a trade-off between inflation and output variability with respect to relative-price shocks. But even here, NNS reasoning provides a way out. Practically speaking, the New Synthesis suggests that a central bank should aim to stabilize an index of sticky prices alone, a *core* price index. This view accords well with the Keynesian emphasis on a core rather than an overall cost-of-living index, and the monetarist recommendation to stabilize a long-run price index and ignore such relative price movements as oil price shocks. When we define the measure of prices that a central bank should stabilize as a core index of sticky prices, we once again find that there is no policy trade-off between inflation and output variability.

8.3.2. The Design of a Legislative Mandate for Monetary Policy

What, then, are the implications of the new synthesis for the design of a legislative mandate for monetary policy? First, there is no policy trade-off between inflation and output variability if the targeted measure of inflation is a core price index of goods produced by monopolistically competitive firms. Second, a central bank should seek to keep output at its potential by targeting the minimum markup consistent with near-zero core inflation. Third, according to the analysis in Section 7.2, a central bank should partially accommodate core-price-level targeting mistakes in order to keep output at its potential.

8.4. TACTICAL POLICY IMPLEMENTATION

The new synthesis suggests that a central bank must pursue an activist policy to target inflation. There are great difficulties in implementing an activist policy rule, many of them well known and long debated among monetary economists and central bankers, some of which were addressed above. Our purpose in this section is to make a few additional points suggested by the new synthesis for thinking about the practical implementation of policy.

8.4.1. Interest-Rate Policy

Central banks invariably use a short-term interest rate as their monetary policy instrument. The new synthesis says that central bankers should manage a low-inflation targeting regime by making the short-term nominal rate mimic the real short rate that would be ground out by a well-specified RBC model with a low, constant markup. RBC reasoning is indispensable for thinking about how much and in what direction the real rate should be moved in response to a shock. For instance, even the direction of the appropriate real-rate response to a productivity shock depends on the expected duration of the shock, as we saw above when we discussed the oil shock.

As another example of the value of RBC reasoning, consider this. Recently, a possible pickup in productivity growth has been cited as a reason why the Federal Reserve need not raise short-term real interest rates to maintain low inflation. In fact, the standard RBC component of the NNS model suggests, at a minimum, that real rates would have to rise one for one with an increase in trend productivity growth, e.g., a 50-basis-point increase in the growth rate would be matched by a 50-basis-point increase in real interest rates.[45] Importantly, rates would have to rise even if the economy were otherwise operating at a noninflationary potential level of GDP.

Generally speaking, central-bank management of the short-term real interest rate is difficult for the following reason. Although the current output gap may move relatively closely and monotonically with the current markup in NNS models, the real interest rate and the markup are not closely related. Real interest rates rise and fall in response to various shocks in the RBC model, even though there is no markup at all. The real interest rate adjusts to equate saving and investment. At any point in time, the current real rate (and also the expected future sequence of real rates) needed to support a constant markup, will depend in a complex way on the nature and magnitude of current shocks hitting the economy and their expected duration.

[45] This is the case across steady states when utility is logarithmic. Rates would have to rise even more if consumption is less substitutable intertemporally than logarithmic utility suggests. Moreover, this calculation does not allow for the transitory upward pressure on real rates due to an accompanying investment boom.

8.4.2. Inflation Indicators

NNS reasoning suggests that familiar indicators of rising inflation will be less effective in a fully credible low-inflation-targeting regime. For instance, rapid inventory stock building and lengthening delivery lags warned of inflation in the past. From the perspective of NNS models, precautionary or speculative stock-building was rational precisely because monetary policy would fail to restrain aggregate demand before it pressed against capacity and raised expected real marginal cost sufficiently to cause firms to pursue inflationary price increases. In such circumstances, rising inflation expectations would rationally be incorporated into long-term interest rates as well, and bond rates could also warn of future inflation.

In contrast, if a central bank consistently controlled inflation, firms would be less likely to build up inventories or place precautionary advance orders when the economy neared full employment. Expected inflation would not raise bond rates. Bond rates would rise in cyclical expansions only because they embodied increases in future short-term real interest rates expected to be brought about by the central bank. In a fully credible low-inflation-targeting regime, a central bank would have to become more sensitive to familiar indicators than in the past, and would likely need to develop additional indicators to guide its interest-rate policy actions.

9. Summary and Conclusions

The models of the New Neoclassical Synthesis are complex, since they involve intertemporal optimization, rational expectations, monopolistic competition, costly price adjustment and dynamic price setting, and an important role for monetary policy. Our main purposes in the paper were three fold: to motivate the separate components of the new synthesis, to present a conceptual framework for thinking about NNS models, and to use that apparatus to develop recommendations for monetary policy.

Two fundamental insights are at the core of our framework. First, Keynesian and RBC mechanisms can be viewed as operating through somewhat different channels. Holding the average markup constant, NNS model mechanics resemble those of a pure, albeit noncompetitive, RBC model. On the other hand, the Keynesian influence of aggregate demand on employment and output works by shrinking or increasing the markup, which acts like a distorting tax on economic activity.

Second, dynamic costly price adjustment means that firms adjust price according to an expected distributed lead of the price level and real marginal cost, where the price level is an average of current prices and those set in the past. We showed that a forward-looking price-setting equation and a price-level expression form a price block that can be solved to express the inflation rate as a function of prices set in the past, current real marginal cost, and a distributed lead of expected real marginal cost. Since real marginal cost is the inverse of the markup, the evolution of inflation in the NNS model depends importantly on current and expected future markups.

The recommended neutral monetary policy in the new synthesis follows directly from the above insights and the idea that the markup ought to be held constant. Markup constancy is attractive because it delivers the same response of the real economy to various shocks as would arise if all prices were perfectly flexible. We showed that the steady-state markup should be minimized at a near-zero inflation rate, and argued that most of the benefits for monetary exchange would be realized at near-zero inflation as well. Thus, we found that near-zero inflation targeting was both desirable and feasible in the NNS model.

Even though the new synthesis inherits much of the spirit of the old, it differs sharply in terms of the role of monetary policy. Economists working within the synthesis of the 1960s were pessimistic about taming inflation, viewing inflation as having a momentum of its own and fluctuating with unmanageable shifts in the psychology of price setters. The new synthesis also views expectations as critical to the inflation process, but sees expectations as amenable to management by a monetary policy rule.

The new synthesis has much to say about the practical implementation of inflation targets. Since expectations of future markups play a key role in the inflation-generating process, successful inflation targeting requires a credible commitment to low inflation, so that expectations of markup constancy anchor the inflation-generating equation. In order to maintain markup constancy, monetary policy must accommodate movements in potential GDP brought about by RBC forces such as productivity, fiscal policy, or materials cost shocks. Accommodation must be two-dimensional. First, money growth must satisfy induced movements in money demand. Second, the monetary authority must move its nominal short-term interest-rate instrument to support real short-term interest-rate movements called for by underlying RBC forces. Ironically, in spite of the fact that Keynesian effects of monetary policy on real activity are powerful in NNS models, monetary policy is best when it eliminates Keynesian effects entirely.

Researchers have merely scratched the surface in thinking about NNS models: such models will surely be elaborated and improved in the future. Looking backward: NNS models should improve our understanding of macroeconomic outcomes during volatile inflationary periods, such as that extending from the mid-1960s through the early-1980s, when both large monetary policy shocks and large supply shocks were important. Moreover, the division of the effect of an increase in money growth between inflation and output in the NNS model depends sensitively on the extent to which the faster money growth is expected to persist. Thus, NNS models should help us understand the time-varying effect of money on prices and output that characterizes historical time series. Looking forward: as the United States and other countries around the world maintain low inflation, supply-side forces should loom as large as demand-side forces for the business cycle. We expect NNS models to become increasingly important in providing monetary policy advice in such an environment.

Appendix

Derivation of Neutral Monetary Policy

The equations of that implicitly define neutral monetary policy are the following. First, there is the dynamic price-setting equation,

$$\ln P_t^* = E_t \sum_{j=0}^{J-1} [\frac{\beta^j \omega_j}{\sum_{h=0}^{J-1} \beta^h \omega_h}][\log(P_{t+j}) + \log(\psi_{t+j}/\psi)]$$

with β being driven to one to get the invariance of the steady-state markup to inflation. Second, the companion equation for the price level is

$$\log P_t = \sum_{j=0}^{J-1} \omega_j \log P_{t-j}^*.$$

Third, we make use of the inverse relationship between the average markup and the level of real marginal cost, i.e.,

$$\log(\psi_t/\psi) = -\log(\mu_t/\mu)$$

where the values μ and ψ are constant steady-state values. We set the markup deviation, $\log(\mu_t/\mu)$, to zero at all dates according to our definition of neutral monetary policy.

To derive the restrictions on the path of the price level, it is convenient to use the operator methods, which earlier authors like Taylor [1980] and Shin [1996] have employed to study the positive implications of similar models. For this purpose, let B be the operator that shifts a variable backwards, $Bx_t = x_{t-1}$, and let F be the operator that shifts forward the dating of a variable but not its expectation, $FE_t x_{t+j} = E_t x_{t+j+1}$. Then, we can write the price-setting equation as

$$\log P_t^* = \theta_\beta(F)[E_t \log P_t - E_t \log(\mu_t/\mu)]$$

and we can write the price level as

$$\log P_t = \theta(B) \log(P_t^*).$$

In these expressions, the polynomials $\theta_\beta(z)$ and $\theta(z)$ are defined by the weights in the equations above, $\theta_\beta(z) = \sum_{j=0}^{J-1}[\frac{\beta^j\omega_j}{\sum_{h=0}^{J-1}\beta^h\omega_h}]z^j$ and $\theta(z) = \sum_{j=0}^{J-1}\omega_j z^j$. Accordingly, they have two important properties: (i) they are equivalent if $\beta = 1$; and (ii) in each case, the sum of coefficients is unity, i.e., $\theta_\beta(1) = 1$ and $\theta(1) = 1$.

Combining these equations and imposing the requirement that the markup is constant at all dates, we arrive at:

$$[1 - \theta_\beta(F)\theta(B)]\log(P_t^*) = 0$$

as the general specification that defines neutral monetary policy. In the text, we implicitly used this requirement earlier to demonstrate that the complete stabilization of the path of the price level at any level leads to a neutral monetary policy: since $\theta_\beta(1) = 1$ and $\theta(1) = 1$, it is satisfied for any level of $\log(P^*)$ that is constant through time.

To determine the more general implications of neutral monetary policy, we "factor" the polynomial $[1 - \theta_\beta(F)\theta(B)]$ as $H(F)S(B)$, with the roots of $S(B)$ being less than or equal to unity. If $\beta = 1$, then some general properties of this factorization are easy to establish since the polynomial $\Phi(z) = [1 - \theta_\beta(z^{-1})\theta(z)]$ is symmetric so that the roots of Φ occur in reciprocal pairs. This case is a convenient one for characterizing the analytical solution in low order systems. In such derivations, one assigns all of the roots with modulus less than unity to $S(B)$ and also a unit root. One also assigns all of the roots with modulus greater than unit to $H(F)$ and also a unit root. With β strictly less than one, there are J explosive roots (roots greater than unity) and J nonexplosive roots (modulus less than or equal to unity; one of these is exactly unity). The simulations of the Taylor model reported in the text are based on a value of β that is just less than one.

The general specification of neutral monetary policy can be written as:

$$S(B)\log(P_t^*) = 0$$

where $S(B) = \sum_{j=0}^{J-1} s_j B^j$ with $s_0 = 1$. That is, the monetary authority must produce a pattern of price adjustment at date t based on the previous pattern of price adjustments that are initial conditions to the problem. One general property is that $S(B)$ will always contain a unit root, so that we may write the implications of neutral monetary policy as

$$\pi_t^* = \sum_{j=1}^{J-2}\sigma_j\pi_{t-j}^*$$

where π_t^* is the growth rate $\log(P_t^*) - \log(P_{t-1}^*)$.[46] The σ coeffiecients in this expression are related to the s coefficients. For example, it $J = 2$ so that

$$s_0 \log(P_t^*) + s_1 \log(P_{t-1}^*) + s_2 \log(P_{t-2}^*) = 0$$

is the general specification of neutral monetary policy, then this implies that

$$s_0 \pi_t^* + (s_1 + s_0)\pi_{t-1}^* = 0$$

using the definition of π_t^* and the fact that $(s_0 + s_1 + s_2) = 0$.

Tthe implications of this rule for the general rate of inflation can be determined from $\pi_t = \log(P_t) - \log(P_{t-1}) = \theta(B)\pi_t^*$.

[46]The fact that there will generally be a unit root for any value of β there can be seen by inspecting the polynomial $[1 - \theta_\beta(z)\theta(z)]$ and using the fact that $\theta_\beta(1) = 1$ and $\theta(1) = 1$. Then, it is clear that $z = 1$ is a root since $[1 - \theta_\beta(1)\theta(1)] = 0$.

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