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December 1996

Research Department

Working Paper

96-15

Federal Reserve Bank of Dallas

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The views expressed here are not necessarily those of the Federal Reserve Bank of Dallas or the Federal Reserve System. Thanks to Jeremy Nalewick for research assistance and to Jeffrey Fuhrer for insightful comments on an earlier draft.

Abstract

I consider an economy in which a fraction of contracts is renegotiated each period. In the spirit of Fischer (1977) and in contrast to Taylor (1979, 1980), Calvo (1983), and Fuhrer and Moore (1992, 1995a,b), contracts specify a price *path* rather than a fixed price *level*. The aggregate price adjustment rule derived from these assumptions is an expectations-augmented Phillips curve with a built in "speed" or "Lipsey Loop" effect. The rule is consistent with the natural rate hypothesis and implies that disinflations are unambiguously contractionary. When supplemented with a specification of aggregate demand, the model can be used to find the money-supply path required to achieve a given desired path of the aggregate price level. Alternatively, the model can be used to find the aggregate-price-level path implied by a given monetary policy. Policy-induced recessions can be quite persistent even when contracts are renegotiated frequently. For realistic parameter values, the model generates a liquidity effect: disinflations are initially accompanied by a rising short-term interest rate and a declining money supply.

Introduction

Calvo (1983) presents an elegant reformulation of the Taylor (1979, 1980) model of overlapping contracts. Like Taylor, Calvo assumes that each firm's price is fixed over the life of its contract, and that the contract price is a function of the expected future aggregate price level and expected future excess demand. Realism is added by dropping the assumption that contracts are all of the same length, in favor of an exponential distribution of expiration dates. An attractive feature of the Calvo model is that by varying the mean rate at which contracts come up for renewal one can easily move from an economy in which the price level is almost completely rigid to an economy in which the price level is almost completely flexible.[1]

Although the assumptions that underlie it are plausible and its simplicity is appealing, Calvo's price adjustment model has two undesirable properties. First, the model implies that policy makers can keep output permanently above its market-clearing level--an implication inconsistent with the natural-rate hypothesis. Second, the model implies that even sudden, surprise disinflations can be achieved at zero cost in terms of foregone output. Indeed, disinflation may be accompanied by a boom (Phelps 1978, Ball 1991). To many, this implication seems unrealistic.

Recent attempts to develop a more satisfactory model of aggregate price adjustment have resolved one or the other--*but not both*--of the problems affecting the Calvo model. McCallum (1980, 1994) has championed a price adjustment rule that allows perfect flexibility of the inflation rate while prohibiting jumps in the price level.[2] The McCallum rule is consistent with the natural-rate hypothesis, but remains subject to the criticism that it allows immediate, zero-cost reductions in inflation. Fuhrer and Moore (1992, 1995a,b) develop a variant of the Calvo model in which the change in the

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[1] For interesting applications, see Yun (1994) and Kimball (1995). Woodford (1995, pp. 1281-4) discusses the advantages of this general approach. A more complicated alternative approach is to split the economy into flexible price and sticky price sectors, and then analyze how the economy's performance depends on the size of the sticky-price sector relative to the flexible-price sector (Ohanian, Stockman, and Kilian 1995).

[2] The rule was initially proposed by Grossman (1974). Also see Barro and Grossman (1976), Mussa (1981a,b) and--for a critique of Mussa's analysis--Rotemberg (1983).

new-contract price depends upon expected future aggregate price inflation. Disinflations are always costly in the Fuhrer-Moore model. More generally, the model does a good job of matching the short-run dynamics of real-world inflation and output. However, like the Calvo model, the Fuhrer-Moore model is inconsistent with the long-run neutrality of money. Moreover, the intuition underlying the Fuhrer-Moore model is fuzzy, at best.

In the model presented here, inflation is more flexible than in the Calvo and Fuhrer-Moore models, but not as flexible as in the McCallum model. Like Calvo and Fuhrer-Moore, I assume overlapping contracts, with an exponential distribution of contract lengths. However, much as in Fischer (1977), each contract specifies a *path* of prices rather than a fixed price level.[3] The result is an aggregate price adjustment equation that looks like an expectations-augmented Phillips curve with a built in "speed" or "Lipsey Loop" effect.[4] The long-run Phillips curve is vertical: monetary policy cannot keep output permanently above its market-clearing level. Moreover--because the expectations that are relevant to aggregate price adjustment respond sluggishly to new information--disinflations that are not fully anticipated are inevitably associated with recessions.

Two main criticisms have been directed at Fischer contracts.[5] The first criticism is that Fischer-style price-setting is seldom observed in practice, except in multi-year union labor contracts. However, it may be that many firms without formal Fischer-style contracts follow procedures that have much the same effect. For example, it is common for non-unionized firms to conduct pay surveys every few years, to gauge whether and to

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[3] Yun (1994) also looks at Fischer-style contracts. However, he assumes the contract renegotiations are distributed uniformly over a finite interval rather than exponentially. Yun focusses most of his attention on the Calvo model. The McCallum model is not included in his analysis.

[4] This effect is the tendency for inflation to be higher in periods during which output is growing rapidly relative to capacity than in periods during which output is growing slowly, taking inflation expectations and the *level* of output-market slack as given. The speed effect was noted by Phillips (1958) in his original analysis of the relationship between unemployment and the growth rate of wages. Lipsey (1960) proposed an explanation for the speed effect. However, Smyth (1979) casts doubt on Lipsey's story.

[5] See, for example, Woodford (1995).

what extent their wages are out of line with the wages offered by competitors. Between surveys, firms' wages are not typically constant. Insofar each firm's wage path depends primarily upon information available at the time of its most recent pay survey, the Fischer model may accurately describe aggregate wage dynamics. More generally, the frequency with which firms change their prices is likely to exceed the frequency with which firms reevaluate the competitiveness of those prices whenever the direct costs of price changes (so-called "menu costs") are small relative to the costs of renegotiating contracts or gathering information on market conditions.

The second main criticism of Fischer contracts is that they imply too brief an output response to monetary shocks. This criticism takes it for granted that firms whose price contracts are up for renegotiation will move directly to the expected market-clearing price path. There are good reasons to believe that firms will, instead, typically move to a price path that is *intermediate* between the expected market-clearing and expected average price paths. When Fischer's contracting model is generalized to allow for this possibility, the economy's adjustment to shocks can be considerably delayed.

The paper begins with a review of the Calvo, McCallum, and Fuhrer-Moore price-adjustment models. Next, I discuss the aggregate price dynamics of an economy in which contracts specify a price path rather than a fixed price level. Finally, I illustrate the response of this economy to disinflationary policy using a simple model of aggregate demand. Important quantitative and qualitative differences in the behavior of output, interest rates, and the demand for money are observed, depending upon the sensitivity of the contract price to output market disequilibrium and the elasticity of intertemporal substitution. Simulations show that monetary-policy-induced fluctuations in output can be quite persistent even when contracts are renegotiated frequently. For realistic parameter values, disinflations are initially accompanied by rising interest rates and a declining money supply.

Existing Price Adjustment Models

The Calvo Model. Suppose that there is a large number of otherwise identical firms whose output prices are fixed in overlapping contracts. Over any small interval, Δ, of time there is probability $\delta\Delta$ that a given contract will expire, where $\delta > 0$. The (log of the) new-contract price is a function of expected market conditions over the life of the contract. In particular, if v_t is the (log of the) price level fixed at time t by a firm that changes its price at time t, then

$$v_t = \delta \int_t^{\infty} E_t[p_s + \beta z_s]\, e^{-\delta(s-t)} ds \tag{1}$$

where

$$p_t = \delta \int_{-\infty}^{t} v_s\, e^{-\delta(t-s)} ds \tag{2}$$

is the aggregate price level at time t, $E_t(\cdot)$ is the mathematical expectation conditional on information available at time t, and $\beta > 0$ is a fixed parameter. The variable z_t is a measure of market disequilibrium--either the gap, $y_t - y^*_t$, between actual output and market-clearing output (Calvo 1983, McCallum 1980, 1994) or, alternatively, the gap, $p^*_t - p_t$, between an appropriately defined market-clearing price and the actual price (Grossman 1974, Barro and Grossman 1976, Mussa 1981a,b). The price gap formulation is more general, but also more ambiguous.[6] In any case, the intuition is that firms will

[6] Whether a particular price level is "market clearing" or not will depend upon expected future monetary policy and upon how "monetary policy" is defined. For example, the price level that is market clearing given the current level and expected future path of the money supply will not typically be the same as the price level that is market clearing given the current level and expected future path of nominal spending. If the latter definition of p^* is adopted, the price-gap and output-gap measures of

want to charge more than the aggregate price if the aggregate price leaves excess demand for output and to charge less than the aggregate price if the aggregate price results in excess supply.[7] When $\beta = 1$ and $z = p^* - p$, v equals the average (over the life of the contract) of the expected market-clearing price level.

Note that although the arrival of new information can cause v_t to jump at time t, the aggregate price level, p_t, is necessarily continuous.

Let π denote the aggregate inflation rate. Differentiation of equation 2 yields $\pi_t = \delta(v_t - p_t)$. But, from equation 1, $\dot{v}_t = \delta(v_t - p_t) - \delta\beta z_t$ at all times, t, when no new information is arriving. Combining these results,

$$\pi_t = \dot{v}_t + \delta\beta z_t, \tag{3}$$

and, hence,

$$\dot{\pi}_t = -\delta^2\beta z_t, \tag{4}$$

absent new information. Equation 3 says that current inflation depends not only upon current slack in the output market, but also the rate of change of a weighted average of expected future prices and expected future slack. Equation 4 says that anticipated declines in inflation are associated with excess demand for output (alternatively, with a price level that is below its market-clearing value). An immediate implication is that policymakers, by allowing inflation to rise or fall without limit, can keep the output

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disequilibrium are equivalent, for then, by construction, $p^* + y^* = p + y$. If, instead, p^* is defined as the market-clearing price level given current and expected future money supplies, then one will not have $y - y^* = p^* - p$ except if either the demand for money is completely interest inelastic or the representative household's elasticity of intertemporal substitution equals one. Details are given in an appendix.

[7] The determinants of the price sensitivity parameter, β, are discussed below.

market in permanent disequilibrium.

Unexpected changes in inflation need not imply any disturbance to output-market equilibrium at all. From equation 1, a downward revision in firms' expectations of future prices will cause an instantaneous fall in the new-contract price, v. This fall will occur even if expectations of future z's are unchanged. In particular, it will occur even if the output market is expected to remain in equilibrium. As noted above, $\pi_t = \delta(v - p)_t$-- hence an instantaneous fall in the new-contract price will cause an equally sudden disinflation. Finally, from equation 4, once inflation has dropped, maintaining the new inflation rate does not require that there be any output-market disequilibrium. However, maintaining the new inflation rate does require appropriate changes in monetary policy. If money demand is to equal money supply, the growth rate of the latter must fall, discontinuously, at the same time that inflation falls. Moreover, if the demand for money is interest sensitive, the *level* of the money supply will have to jump upward, discontinuously.

The McCallum Model. McCallum (1980) develops a discrete-time model in which firms match output to sales, set price one period in advance, and face costs that are quadratic in both the level and the change in the gap between actual and potential output. He derives a price-adjustment equation of the form

$$p_t - p_{t-1} = E_{t-1}(p_t^* - p_{t-1}^*) + \gamma(y_{t-1} - y_{t-1}^*), \tag{5}$$

where $\gamma > 0$. An alternative version of equation 5 replaces the output gap, $(y - y^*)_{t-1}$, with a price gap, $(p^* - p)_{t-1}$ (Grossman 1974, Barro & Grossman 1976, Mussa 1981a,b).

The continuous-time counterpart of equation 5 is

$$\pi_t = \pi_t^* + \gamma z_t \tag{6}$$

where z_t may represent either an output gap or a price gap and where π^*_t denotes the time derivative of the market-clearing price.[8] As in the Calvo model, the time path of the price level is continuous, but the inflation rate can jump.

Note that equation 6 is similar to equation 3 in form, with π^*_t taking the place of $\dot{v}_t$. The connection between the Calvo and McCallum models is especially close in the case where $\beta = 1$ and $z_t = p^*_t - p_t$, for then equation 1 says that

$$v_t = \delta \int_t^\infty E_t(p^*_s) \; e^{-\delta(s-t)} ds. \tag{7}$$

Thus, in Calvo's model, inflation moves one-for-one with the rate of change of a weighted average of expected *future* market-clearing prices. In McCallum's model, inflation moves one-for-one with the rate of change in the *current* market-clearing price.

Because of the responsiveness of inflation to current market conditions in the McCallum model, it is impossible for policy-makers to keep the output market in permanent disequilibrium. This result is easiest to see in case where output-market disequilibrium is written as a function of the price gap, for then equation 6 reduces to $\dot{z}_t = -\gamma z_t$, which has as its solution $z_t = z_0 e^{-\gamma t}$. Thus, any initial disequilibrium is eliminated at the constant rate γ.[9]

According to equation 6, once a McCallum economy is in market-clearing equilibrium, it will remain in equilibrium as long as π^* remains finite. Hence, disinflations will involve no output loss provided the market-clearing price level does not jump. Preventing a jump in the market-clearing price level may require that the money supply vary discontinuously, since the demand for real balances will--assuming an interest-elastic money demand--jump upward when a disinflationary policy is announced.

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[8] More generally, one might have $\pi_t = E_{t-\Delta}(\pi^*_t + \gamma z_t)$, where $\Delta \geq 0$.

[9] For discussion of the case in which disequilibrium is measured by the output gap, see McCallum (1995) and Koenig (1990b).

The Fuhrer-Moore Model. Fuhrer and Moore (1992) put forward a variant of the Calvo model that is quite successful at mimicking the autocorrelation pattern of real-world inflation. Equation 2 is retained, but equation 1 is replaced by[10]

$$\dot{v}_t = \delta \int_t^{\infty} E_t[\pi_s + \beta z_s]\, e^{-\delta(s-t)} ds. \tag{8}$$

Differentiating equation 8 with respect to time yields $\ddot{v}_t = \delta[\dot{v}_t - (\pi_t + \beta z_t)]$ at all times, t, when no new information is arriving. As before, equation 2 implies $\pi_t = \delta(v_t - p_t)$. Differentiate the latter expression and subtract it from the former to obtain

$$\dot{\pi}_t = \ddot{v}_t + \delta\beta z_t, \tag{9}$$

which is the counterpart of equation 3 in the Calvo model. It follows that[11]

$$\ddot{\pi}_t = -\delta^2\beta z_t. \tag{10}$$

Hence, $\dot{\pi}_t$ cannot jump except in response to new information. The inflation rate itself is continuous: any disinflation will necessarily be gradual.

Consider an economy making the transition to a new, lower inflation rate. In the

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[10] In a series of later papers, Fuhrer and Moore propose a slightly more complicated variant of the Calvo model (Fuhrer and Moore 1995a,b). In equation 8, $\dot{v}_t$ and π_t are replaced by $v_t - v^m_t$ and $p_t - p^m_t$, respectively, where v^m_t is a weighted average of past new-contract prices and p^m_t is a weighted average of past aggregate prices. The qualitative properties of the two Fuhrer-Moore models are quite similar.

[11] In Fuhrer and Moore's alternative variant of the Calvo model (see previous note), equation 10 is replaced by $\ddot{\pi}_t = -\delta\beta(\delta z_t + \dot{z}_t)$.

course of this transition, $\dot{\pi}_t$ must take on negative values, but cannot be bounded away from zero from above.[12] Hence, there must be intervals during the transition to lower inflation in which $\dot{\pi}_t$ is rising. From equation 10, it follows that during disinflations there must be intervals in which output falls short of potential.

As a specific example, suppose that policymakers want to gradually reduce inflation from $\pi_0 > 0$ to 0 according to $\pi_t = \pi_0 e^{-\lambda t}$, for some fixed $\lambda > 0$. Then $\ddot{\pi}_t = \lambda^2 \pi_0 e^{-\lambda t} > 0$, and equation 9 implies $z_t = -\lambda^2 \pi_0 e^{-\lambda t}/(\delta^2 \beta) < 0$. In words, the disinflation triggers a recession.[13]

While the Fuhrer-Moore model rules out costless disinflations, it clearly violates the natural rate hypothesis. In particular, a concave inflation path will keep output above its market-clearing level, even if the inflation deceleration is fully anticipated. Similarly, a convex inflation path will keep output below its market-clearing level. (See equation 10.) Perhaps a more serious problem with the model is that its price adjustment equation (eq. 8) has a weak underlying rationale.[14]

A Generalized Fischer Model of Price Adjustment

The Model. Fischer (1977) analyzes the effectiveness of monetary policy in a world of overlapping two-period labor contracts and rational expectations. Fischer's contracts--

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[12] That is, the least upper bound on $\dot{\pi}_t$ is greater than or equal to zero.

[13] What time path of the money supply is needed to implement this policy? For simplicity, suppose that the demand for money is interest inelastic--so that $y_t + p_t = m_t = y^*_t + p^*_t$--and that the market-clearing output level, y^*, is constant. Then one must have $m_t = y^* + p^*_t = y^* + p_t - z_t = y^* + p_t - \theta^2 \pi_0 e^{-\theta t}/(\delta^2 \beta)$, where $p_t = p_0 + \pi_0(1 - e^{-\theta t})/\theta$. Thus, the money supply must drop discontinuously at $t = 0$, when the disinflationary policy is first announced. The money supply then grows, at a decelerating pace, asymptotically approaching $y^* + \pi_0/\theta$.

[14] Fuhrer and Moore justify their pricing equation by asserting that workers are concerned about their relative--not their absolute--real wages.

unlike Taylor's--specify a wage *path* rather than a fixed wage *level*. Specifically, Fischer assumes that the contract wage equals the expected market-clearing wage in each period, where the expectation is conditional on information available at the time the contract was negotiated. Here, I introduce Fischer-style contracts into an economy in which the time until any given contract expires has an exponential distribution. Moreover, I relax the assumption that the contract price equals the expected market-clearing price. To facilitate comparison with other contracting models, I apply the generalized Fischer model to finished goods prices rather than to factor prices.

In an economy with Fischer-style price contracts, the analog to equations 1 and 2 is the single equation[15]

$$p_t = \delta \int_{-\infty}^{t} E_s[p_t + \beta z_t]\, e^{\delta(s-t)}\, ds, \tag{11}$$

where, as before, z_t is either the gap, $y_t - y^*_t$, between actual output and market-clearing output or the gap, $p^*_t - p_t$, between an appropriately defined market-clearing aggregate price level and the actual aggregate price level. Intuitively, firms will want to charge more than the aggregate price if the aggregate price leaves excess demand for output and to charge less than the aggregate price if the aggregate price results in excess supply. Accordingly, firms that were locked into contracts at time $s < t$ will charge $E_s[p_t + \beta z_t]$ at time t. The aggregate price is simply the average of the prices charged by firms with different contract dates. It is completely pre-determined: while p_t need not be continuous with respect to time, it cannot jump in response to new information.

When $z_t = p^*_t - p_t$ and $\beta = 1$ (as in Fischer's original specification), equation 11 says that the aggregate price level will be a weighted average of past expectations of the current market-clearing price level.

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[15] If new information is incorporated into contracts with a lag, then $E_{s-\Delta}[\bullet]$ replaces $E_s[\bullet]$ in the equations below.

Differentiating equation 11 with respect to time, one obtains

$$\pi_t = \pi_t^e + \delta\beta z_t + \beta\dot{z}_t^e, \tag{12}$$

where

$$\pi_t^e \equiv \delta \int_{-\infty}^{t} E_s[\pi_t]\, e^{\delta(s-t)} ds,$$

$$\dot{z}_t^e \equiv \delta \int_{-\infty}^{t} E_s[\dot{z}_t]\, e^{\delta(s-t)} ds.$$

Equation 12 is an expectations-augmented Phillips curve. It says that current inflation will be high relative to an average of lagged expectations of current inflation if either there is excess demand for output or people have been expecting rapid growth in current excess demand. The dependence of inflation on expectations of current growth in excess demand may explain the so-called "speed effect," first noted by Phillips (1958).

Equation 12 is similar to equation 3 in the Calvo model. In both models, inflation is an increasing function of excess demand in the output market. In the Calvo model, inflation is also increasing in the growth rate of a weighted average of *current* expectations of *future* prices and excess demands. Here, inflation is instead an increasing function of a weighted average of *lagged* expectations of *current* growth in the price level and excess demand.

If β equals 1 and z_t is interpreted as a price gap, equation 12 reduces to

$$\pi_t = \pi_t^{*e} + \delta\beta z_t, \tag{15}$$

which is closely analogous to the price adjustment equation favored by McCallum, equation 6. Here, however, inflation is increasing in a weighted average of past *expectations* of current growth in the market-clearing price. In the McCallum model, inflation is increasing in *actual* current growth in the market-clearing price.

In the absence of surprises, $\pi_t^e = \pi_t$ and $\dot{z}_t^e = \dot{z}_t$. Equation 12 reduces to $\dot{z}_t = -\delta z_t$, which has $z_t = z_0 e^{-\delta t}$ as its unique convergent solution. Thus, any initial disequilibrium is eliminated at the constant rate δ: in a world of Fischerian contracts, it is impossible for policymakers to keep the output market in permanent disequilibrium. This result suggests that Fischer contracts are robust to a wider range of monetary policies than are Calvo contracts.

Surprise reductions in inflation are inevitably costly in a Fischerian world. Consider an economy that has been--and is expected to remain--in market-clearing equilibrium. Suddenly, at t = 0, a disinflationary policy is announced.* From equations 13 and 14, neither π_0^e nor $\dot{z}_0^e$ can jump in response to the announcement. From equation 12, it then follows that any decline in π_0 due to the new policy must be accompanied by excess supply in the output market. Further details are presented below.

The Determinants of the Price-Sensitivity Parameter. In a model of monopolistically-competitive, utility-maximizing producer-consumers, Blanchard and Fischer (1989, pp. 376-80) derive a formula for agent i's optimal price, taking the prices charged by other agents as given. In particular, Blanchard and Fischer show that

$$\frac{P_i}{P} = \left(\frac{P^*}{P}\right)^{\frac{b}{1+\theta b}}$$

where P_i, P, and P* denote the price charged by agent i, the average price level, and the market-clearing price level, respectively; where $\theta > 1$ is the elasticity of substitution between products; and where $b \geq 0$ is the elasticity of the marginal disutility of work with respect to output. (As such, b captures both the rising marginal disutility of work and the decreasing marginal productivity of labor.) After taking logarithms, one has

$$p_i - p = \beta\,(p^* - p)$$

with $\beta = b/(1 + \theta b) \geq 0$. Consistent with the discussion accompanying equation (11), those agents who have the ability to adjust their prices in the current period do not typically move directly to the market-clearing price. Only a fraction of the price gap is closed. This fraction is larger the more difficult it is for agents to expand production (the larger is b) and the less competitive is the output market (the smaller is θ).[16]

One can obtain some sense of the likely magnitude of β from empirical estimates of the Phillips curve. When inflation is regressed on lagged values of itself and a measure of the gap between actual and potential GDP, the output gap is typically estimated to have a coefficient of about .18.[17,18] Equation 12 suggests that this gap coefficient should equal the product of β and the contract renegotiation rate, δ. Hence, if $\delta = .69$ (implying that 50% of firms reset their price paths in a year or less), then $\beta = .26$. If $\delta = 3$ (implying that 95% of firms reset their price paths in a year or less), then β

[16] That increased competition is associated with greater price *in*flexibility is emphasized by Nishimura (1992). It is competition between firms whose contracts are expiring and those whose contracts remain in force that prevents the former firms from charging a price that deviates very far from the average price.

[17] Hoeller and Poret (1991) obtain this estimate, which is bracketed by the .21 estimate of Hallman, Porter, and Small (1991) and the .16 estimate of Ebrill and Fries (1991).

[18] When the output gap is replaced with the Hallman-Porter-Small (1991) measure of the gap between the long-run equilibrium and current price levels, the coefficient of this price gap lies between .07 and .22. The high figure is due to Hallman, Porter, and Small. Hoeller and Poret (1991) obtain estimates of .07 and .12 depending on the method for estimating potential output (which is one of the ingredients needed for calculating p*). Similarly, Christiano (1989) reports price-gap coefficient estimates of .08 and .13, after annualization, while Ebrill and Fries (1991) report a price-gap coefficient of .14.

= .06. More generally, for any reasonable assumption about the frequency of contract renegotiation, it turns out that ß must be quite small to be consistent with the data. Turning this around, large values of ß imply highly unrealistic contract renegotiation frequencies. (For example, setting ß = 1 implies that only 16.5% of firms reevaluate their pricing each year.) Apparently, the typical firm prefers to stay fairly close to the prevailing average price level.

Solving the Model. It is possible to solve for the path of the output gap (or, more generally, the price gap) without specifying the demand side of the economy. As above, consider an economy that is in market-clearing equilibrium and that is expected to remain in market-clearing equilibrium indefinitely. Suddenly, at t = 0, a new monetary policy is announced. The change in policy will be treated as a complete surprise and completely credible: both before and after time zero, I will assume that there is no uncertainty about policy or the economy's response to policy. Two alternative solution strategies are available. One strategy is to assume that policymakers choose actions designed to achieve a desired path of the price level. The other strategy is to take the path of the *market-clearing* price, p*, as given. In either case, once the model is expanded to include a specification of aggregate demand, one can find the path of the money supply required by the new policy, along with the associated interest rate path.

Under the above assumptions, equation 12 becomes

$$\pi_t = \delta\beta z_t + \delta\int_{-\infty}^{0} \overline{\pi}_t \, e^{\delta(s-t)} ds + \delta\int_{0}^{t} (\pi_t + \beta\dot{z}_t) \, e^{\delta(s-t)} ds, \qquad (16)$$

for t ≥ 0. Here a bar over a variable denotes the value that people had expected prior to the announcement of the new policy. After evaluating the integrals, and rearranging terms, equation 16 reduces to

$$\beta(e^{\delta t} - 1)\dot{z}_t + \beta\delta e^{\delta t} z_t - (\pi_t - \overline{\pi}_t) = 0, \tag{17a}$$

or, since one can always write $z_t = p^*_t - p_t$ for a suitably defined p^*_t (c.f. note #6),

$$[1 + \beta(e^{\delta t} - 1)]\dot{z}_t + \beta\delta e^{\delta t} z_t - (\pi^*_t - \overline{\pi}_t) = 0. \tag{17b}$$

The solution to the first of these differential equations takes the form

$$z_t = (p_t - \overline{p}_t)/[\beta(e^{\delta t} - 1)], \tag{18a}$$

while the solution to the second equation is

$$z_t = (p^*_t - \overline{p}_t)/[1 + \beta(e^{\delta t} - 1)]. \tag{18b}$$

Perfect price flexibility is achieved in the limit as $\delta \to \infty$.

Equation 18a gives the path of the market-clearing price level implied by a given desired path of the actual price level. Equation 18b gives the path of the actual price level implied by a given path of the market-clearing price level. One can use these equations to illustrate the difference between price adjustment in an economy with Fischer contracts and price adjustment in economies with McCallum or Fuhrer-Moore contracts.

Consider, first, the difference between price adjustment under Fischer contracts and price adjustment under Fuhrer-Moore contracts. Suppose that the economy is initially in market-clearing equilibrium with a 5% annual inflation rate. Suddenly, policymakers decide they want to reduce inflation to zero. In the notation of equation

18a, $p_t - \overline{p}_t = 0$ for t < 0 and $p_t - \overline{p}_t = -.05t$ for t ≥ 0. With Fuhrer-Moore contracts an immediate move to zero inflation is out of the question: inflation is necessarily continuous (c.f. equation 10). With Fischer contracts, an immediate disinflation is perfectly feasible: the monetary authority need only engineer a suitably large, discontinuous fall in the market-clearing price level. Figure 1 displays two examples--one for the case in which 95% of contracts are renegotiated each year and one for the case in which 50% of contracts are renegotiated each year.[19] The bottom line is that inflation is less persistent under Fischer contracts than under Fuhrer-Moore contracts.

A similar exercise illustrates the difference between price adjustment under Fischer contracts and price adjustment under McCallum contracts. Again, suppose that the economy is initially in market-clearing equilibrium with constant, 5% inflation. Suddenly, the monetary authority lowers the market-clearing inflation rate to zero. (In eq. 18b, $p_t^* - \overline{p}_t = 0$ for t < 0 and $p_t^* - \overline{p}_t = -.05t$ for t ≥ 0.) With McCallum contracts, the actual inflation rate also falls immediately to zero. The economy remains in market-clearing equilibrium (c.f. equation 6). With Fischer contracts, equation 18b implies price and inflation paths like those displayed in Figure 2. The actual price level overshoots the market-clearing price level, so that the inflation rate falls only gradually, and eventually approaches zero from below. Clearly, inflation is more persistent, in response to unanticipated changes in policy, under Fischer contracts than under McCallum contracts.

Aggregate Demand in an Economy with Fischer Contracts

An aggregate demand specification is essential if one is to find the money supply and interest rate paths associated with a given price path. This section begins by laying out a simple, illustrative model of aggregate demand. It then derives the money supply and interest rate paths associated with the disinflations depicted in Figures 1 and 2.

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[19] In each case, the renegotiation frequency and price sensitivity parameters satisfy the equation $ß\delta = .18$.

Aggregate Demand. The model of aggregate demand used throughout this section consists of a money demand equation and an optimality condition for allocating consumption through time. Specifically, I assume that the consumption-velocity of money is increasing in the nominal interest rate:

$$c_t - (m_t - p_t) = \alpha R_t, \tag{19}$$

where c_t and m_t are the logarithms of real consumption and nominal money, respectively, R_t is the nominal interest rate, and $\alpha \geq 0$ is a fixed parameter. Consumption adjusts according to

$$\dot{c}_t = \sigma(r_t - \rho), \tag{20}$$

where r_t is the real interest rate and σ, $\rho \geq 0$ are fixed parameters. Equation 20 is simply the Euler equation for an infinitely-lived representative agent with rate of time preference ρ and elasticity of intertemporal substitution σ.[20]

Equations 19 and 20 will be assumed to hold at all times, t, when no new information is arriving, regardless of whether or not the output market clears. These equations can be used in conjunction with equation 18a or 18b to find the money-supply and interest-rate paths associated with a given monetary policy. Two examples follow. Throughout, I assume that z_t equals the gap, $c_t - c^*_t$, between the current and the market-clearing rates of consumption. Equivalently, $z_t = p^*_t - p_t$, where p^*_t is defined as the price level consistent with market clearing, given the current rate of nominal consumer

[20] For simplicity, I assume that the marginal utility of consumption is independent of real money balances. Estimation results presented in Koenig (1990a) suggest that a relaxation of this assumption may be worth exploring.

spending.[21] Moreover, I assume that the economy is initially operating at potential, with inflation constant at rate $\overline{\pi}$. At t = 0 a new monetary policy is announced and implemented. The announcement is completely credible. Finally, for simplicity I assume that potential consumption is constant through time.

Calibration. In the simulations presented below, equation 19 is used to find the time path of the money supply needed to achieve a given desired path for the price level or the level of nominal spending. It is the least important equation in the model in the sense that it is not invoked until *after* the time paths of consumption, prices, and interest rates have already been determined. Empirically, equation 19 fails to capture some of the short-run dynamics of the money-consumption-interest rate relationship, but does a fairly good job of explaining long-run co-movements in these variables. For the M1 monetary aggregate, Lucas (1988) reports interest semi-elasticities of 7 and 9 over 1958-85 and 1900-85 sample periods, respectively. I set α equal to 8.

Equation 20 is one of the more empirically troublesome relationships in modern dynamic macroeconomic theory, especially at short horizons. Estimates using aggregate quarterly data typically find that the elasticity of intertemporal substitution (σ) is quite low (about 0.1), and reject the model's overidentifying restrictions.[22] More encouraging results have recently been reported by analysts using panel data. Attanasio and Weber (1994) find that $\sigma \approx 0.55$, and fail to reject the overidentifying restrictions. Beaudry and Van Wincoop (1996) obtain estimates of σ that are close to 1. In view of these disparate results, I report simulation results for all three values of the elasticity of intertemporal

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[21] So $p^*_t \equiv (c_t + p_t) - c^*_t$. See note #6, above. An alternative definition of p^*_t--as the price level consistent with market clearing given the current and future levels of the money supply--is explored in the appendix.

[22] See Hall (1988). Cochrane (1989) argues that, nevertheless, the equation is a good approximation. Attempting to improve its aggregate performance, Campbell and Mankiw (1989) modify equation 20 to allow some fixed fraction of consumers to rigidly link their consumption to current income. Other researchers have suggested that the equation be modified to incorporate habit formation (Constantinides 1990).

substitution whenever the path of output is sensitive to σ. (Otherwise, I assume σ = 0.55.) I set the rate of time preference, ρ, equal to .025.

Policy Shock #1: A Sudden Disinflation. Suppose that the monetary authority wishes to engineer an immediate, surprise disinflation. Since $p^*_t - p_t = z_t = c_t - c^*_t$, equation 18a determines both the required path of the market-clearing price and the associated path of the output gap. With output determined, equation 20 determines the path of the real interest rate. Together, the real interest rate and inflation determine the nominal interest rate. Finally, equation 19 determines the money supply path needed to generate the desired price path. Specifically, one has $z_t = 0$, $r_t = \rho$, $R_t = \rho + \bar{\pi}$ and $m_t - p_t = c^* - \alpha(\rho + \bar{\pi})$ for $t < 0$, while

$$z_t = \frac{-\bar{\pi} t}{\beta(e^{\delta t} - 1)},$$

$$r_t = \rho + \dot{z}_t/\sigma = \rho + \frac{\bar{\pi}[1 + e^{\delta t}(\delta t - 1)]}{\sigma\beta(e^{\delta t} - 1)^2},$$

$$R_t = r_t + \pi_t = \rho + \frac{\bar{\pi}[1 + e^{\delta t}(\delta t - 1)]}{\sigma\beta(e^{\delta t} - 1)^2},$$

$$m_t - p_t = c_t - \alpha i_t = c^* - \alpha\rho - \frac{\bar{\pi}}{\beta(e^{\delta t} - 1)}[t + \frac{\alpha[1 + e^{\delta t}(\delta t - 1)]}{\sigma(e^{\delta t} - 1)}],$$

for $t \geq 0$. Using L'Hospital's rule, one can show that

$$z_0 = -\frac{\bar{\pi}}{\beta\delta},$$

$$R_0 = r_0 = \rho + \frac{\bar{\pi}}{2\sigma\beta},$$

$$m_0 - p_0 = c^* - \alpha\rho - \frac{\bar{\pi}}{\beta}\left(\frac{1}{\delta} + \frac{\alpha}{2\sigma}\right).$$

As previously noted, a sudden disinflation is accompanied by a recession. The recession will be milder (z_0 will be smaller in magnitude) the more sensitive is each firm's pricing to market disequilibrium (the larger is β). An increase in the mean frequency with which contracts come up for renegotiation (an increase in δ) is unambiguously stabilizing: it leads both to a milder recession and a speedier recovery. The elasticity of intertemporal substitution (σ), on the other hand, is completely irrelevant to the time path of output.

The patterns of interest rate and money supply movement that the model predicts will be associated with a disinflationary policy are in line with the conventional wisdom. Thus, the real interest rate rises when the new policy goes into effect, and the nominal yield curve becomes inverted. As long as $\sigma\beta < 1/2$--a condition that our calibration exercises suggest is very likely to be met in practice--the short-term nominal interest rate jumps upward and the money supply jumps downward. For given values of σ and β, the magnitude of the initial jump in short-term real and nominal interest rates is completely independent of the frequency of contract renegotiation.

Figure 3 illustrates the responses of consumption, the nominal interest rate, and the money supply to the immediate elimination of a 5% annual inflation.[23] In the simulations, the interest semi-elasticity of money demand (α) is fixed at 8.0, the elasticity of intertemporal substitution (σ) is fixed at .55, and the product of the contract renegotiation rate (δ) and the price sensitivity parameter (β) is fixed at .18. Two alternative values of the renegotiation rate are considered. The first, $\delta = 3.0$, implies

[23] The consumption and money supply panels plot log deviations from pre-shock values.

that 95% of contracts are renegotiated within one year. The second, δ = .69, implies that only 50% of contracts are renegotiated each year.

Consumption falls precipitously in response to the sudden disinflation, declining nearly 25% relative to its pre-shock level. The nominal interest rate rises from 7.5% to 20% (if δ = .69) or 78% (if δ = 3.0). The larger the upward jump in the nominal interest rate, the larger is the initial required cut in the money supply: with δ = .69, the money supply must fall to 28% of its pre-shock level, while with δ = 3.0, the money supply must fall to less than 0.3% of its pre-shock level. Obviously, although a cold-turkey disinflation of this magnitude is theoretically feasible in a world of Fischerian contracts, the implications of such a policy for the economy are extreme.[24]

Policy Shock #2: A Sudden Deceleration of Nominal Spending. Rather than engineer an immediate reduction in inflation, suppose that the monetary authority suddenly (and unexpectedly) reduces the growth rate of nominal spending. What are the consequences for an economy with Fischerian price adjustment? Given our assumptions that $p^*_t - p_t = z_t = c_t - c^*_t$ and that c^*_t is constant, a sudden reduction in the rate of nominal spending growth is equivalent to a sudden reduction in the growth rate of p^*_t--the experiment illustrated in Figure 2. In an economy with McCallum-style price adjustment, this policy would have no output effects. In an economy with Fischer-style adjustment, the output gap is given by equation 18b: it is the mirror image of the price gap in Figure 2. As in the analysis of Policy Shock #1, equation 20 determines the path of the real interest rate; the real interest rate and inflation determine the nominal interest rate; and, finally, equation 19 determines the money supply path needed to achieve the desired spending deceleration. For $t \geq 0$ one now has

[24] The initial interest-rate and money-supply jumps become somewhat more moderate at higher values of the elasticity of intertemporal substitution. With σ = 1, for example, the nominal interest rate jumps upward from 7.5% to 41.7% if β = .06 and to only 9.6% if β = .26. Similarly, the money supply must be cut to 4% of its pre-shock level if β = .06 and to 52% of its pre-shock level if β = .26.

$$z_t = \frac{-\bar{\pi} t}{1 + \beta(e^{\delta t} - 1)},$$

$$r_t = \rho + \dot{z}_t/\sigma = \rho - \frac{\bar{\pi}[1 + \beta(e^{\delta t} - 1) - \beta\delta t e^{\delta t}]}{\sigma[1 + \beta(e^{\delta t} - 1)]^2},$$

$$R_t = r_t + \pi_t = \rho + \dot{z}_t(\frac{1 - \sigma}{\sigma}) = \rho - \frac{(1 - \sigma)\bar{\pi}[1 + \beta(e^{\delta t} - 1) - \beta\delta t e^{\delta t}]}{\sigma[1 + \beta(e^{\delta t} - 1)]^2},$$

$$m_t - p_t = c^* - \alpha\rho - \frac{\bar{\pi}}{1 + \beta(e^{\delta t}-1)}[t + \frac{\alpha(1-\sigma)[1 + \beta(e^{\delta t}-1) - \beta\delta t e^{\delta t}]}{\sigma[1 + \beta(e^{\delta t}-1)]}]$$

The output, interest rate, and money supply implications of eliminating a 5% annual increase in nominal spending are depicted in Figure 4 for the same parameter combinations that were examined in Figure 3. The gradual initial declines in consumption shown in the top panel of Figure 4 contrast with the discontinuous declines observed in the top panel of Figure 3. The fall in consumption is both deeper and more sustained the less frequently are contracts renegotiated. When 95% of contracts are renegotiated within one year ($\delta = 3$), for example, consumption troughs 10 months after the new policy goes into effect, at which point consumption is 2.5% below potential. Recovery is not 90% complete until 17 months later. When only 50% of contracts are renegotiated within one year ($\delta = .69$), the economy doesn't hit bottom for 27 months, when consumption is fully 5.7% below potential. Recovery takes almost an additional 6 years. So, combined, recession and recovery take over 2 years when $\delta = 3$ and just over 8 years when $\delta = .69$.

Real and nominal interest rates initially fall in response to the sudden deceleration of spending. Thereafter, movements in interest rates either mimic ($\sigma < 1$) or mirror ($\sigma > 1$) those in the growth rate of real output. In the middle panel of Figure 4, with $\sigma = .55$, the nominal interest rate is actually predicted to become negative in the months immediately following implementation of the disinflationary policy. A negative nominal interest rate is a practical impossibility, of course. The implication is that an immediate, 5-percentage-point spending deceleration is not feasible except if the elasticity of intertemporal substitution is above .55.[25]

Money moves opposite to the nominal interest rate. In particular, the money supply must jump upward, discontinuously, at the time the new spending policy is announced. As illustrated in the bottom panel of Figure 4, this upward jump can be quite large, potentially creating a credibility problem for the monetary authority.

Fischer Contracts and the Taylor Rule

General Discussion. While Figures 3 and 4 are useful for illustrating important differences between Fischer contracts and other contracting models, the policies considered are extreme in their implications for output, interest rates, and the money supply. An interesting and realistic alternative policy assumption is that the monetary authority adjusts the short-term nominal interest rate in response to movements in inflation and the output gap, as suggested by Taylor (1985). Taylor argues that an interest-rate reaction function of the form

$$R_t = \bar{r} + \pi_t + \nu[(\pi_t - \hat{\pi}) + z_t],$$

--where $\bar{r}$ denotes the long-run equilibrium real interest rate, $\nu > 0$ is a fixed parameter, and $\hat{\pi}$ is the target long-run inflation rate--has desirable stabilization properties and fairly accurately describes actual Federal Reserve behavior. One can

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[25] The initial post-shock interest rate is $\rho - (\frac{1-\sigma}{\sigma})\bar{\pi}$. It follows that an instantaneous spending deceleration of size $\bar{\pi}$ will be feasible if and only if $\sigma \geq \frac{\bar{\pi}}{\rho + \bar{\pi}}$. Equivalently, the largest feasible instantaneous spending deceleration is $\frac{\rho\sigma}{1-\sigma}$.

enhance the descriptive realism of the Taylor rule by making allowance for the Federal Reserve's propensity to smooth short-term interest rates. As shown in Koenig (in preparation) a reaction function of the form

$$\dot{R}_t = \gamma\,[\bar{r} + \pi_t + \nu\,[(\pi_t - \hat{\pi}) + z_t] - R_t] \tag{21}$$

does well empirically. For the United States, estimates of equation 21 indicate that $\gamma \approx 2$ and $\nu \approx .75$.

Equations 18a, 20, and 21 can be combined to yield a system of two first-order differential equations in the output gap and the nominal interest rate:[26]

$$\dot{z}_t = \left(\frac{\sigma}{1 + \beta\sigma(e^{\delta t} - 1)}\right)[R_t - \rho - \bar{\pi} - \beta\delta e^{\delta t} z_t] \tag{22}$$

$$\dot{R}_t = \left(\frac{\gamma}{1 + \beta\sigma(e^{\delta t} - 1)}\right)[(1 + \nu)\bar{\pi} + [\nu\beta\sigma(e^{\delta t} - 1) - 1](R_t - \rho)$$

$$+ [(1 + \nu)\beta\delta e^{\delta t} + \nu + \nu\beta\sigma(e_{\delta t} - 1)]\,z_t]\,. \tag{23}$$

These equations can be solved numerically. Equation 19 then yields the time-path of money balances.

Policy Simulations. Figures 5, 6, and 7 illustrate how the economy responds to a sudden reduction in the monetary authority's long-run inflation target ($\hat{\pi}$), from 5% to 0% per year. The new policy is announced at t = 0, which is also when the simulations begin. As suggested by existing Phillips curve estimates, the product ($\beta\delta$) of the price-sensitivity

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[26] In deriving equations 22 and 23, I assume that the target long-run inflation rate is 0 and that potential output is constant. It follows that $\bar{r} = \rho$.

and renegotiation-frequency parameters is set equal to .18. The simulations in Figure 5 assume that 75% of contracts are renegotiated each year, while those in Figures 6 and 7 assume that 50% and 95% of contracts are renegotiated each year, respectively. The different panels within each figure illustrate the effect of the elasticity of intertemporal substitution, σ, on the behavior of the economy.

Qualitatively, the responses depicted in Figures 5A-C are roughly in line with policy practitioners' conventional wisdom. The monetary authority's new, tougher anti-inflation stance is initially marked by a cut in the money supply and--except for large values of the elasticity of intertemporal substitution--an increase in the short-term nominal interest rate. Thus, the "liquidity effect" is no puzzle in the context of this model. Even though three fourths of all contracts are renegotiated each year, inflation falls slowly: it takes over three years for inflation to drop below 1%. Moreover, the fight against inflation is costly: consumption initially falls by 1.1-to-3.6% relative to potential, and over four years are required for 90% of the consumption gap to be eliminated. Eventually the nominal interest rate approaches a new, lower steady-state level. The money supply must rise to accommodate the resultant increase in money demand.

One criticism of the Taylor rule is that it fails to provide a nominal anchor for the economy. In particular, there is no effort to offset past deviations from the long-run inflation target. This tendency to "let bygones be bygones" is evident in Figure 5D, which shows that the Taylor rule allows the price level to drift upward from its pre-shock level. A policy of immediate disinflation would allow no such drift, of course, and the nominal spending policy illustrated in Figures 2 and 4 allows only a temporary price deviation.

Figures 6A-D demonstrate that a reduction in the frequency of contract renegotiation (while holding $\beta\delta$ constant) has little effect on the qualitative pattern of the economy's response to a reduction in the long-run inflation target, but substantially deepens the recession that follows implementation of the new policy and substantially slows the economy's convergence to its new equilibrium. With only 50% of contracts renegotiated each year, it takes 6-to-8 years for inflation to fall below 1%, and over 7.5 years for 90% of the initial consumption gap to be eliminated.

Conversely, an increase in the frequency of contract renegotiation reduces the impact effect of disinflationary policy and speeds the economy's convergence. In Figure 7, where 95% of contracts are renegotiated within 1 year, it takes under 2 years for the annualized inflation rate to fall from 5% to 1%. Less than 2.5 years are required for 90% of the initial consumption gap to be eliminated.

Sacrifice Ratios

The sacrifice ratio gives the cumulative percentage reduction in output required to lower inflation by one percentage point. Table 1 presents sacrifice ratios for a sudden disinflation, a sudden deceleration in nominal spending, and a sudden cut in the Taylor inflation target.[27] Parameter values are the same as those used in the simulation exercises. (In particular, $\beta\delta$ = .18 throughout.) Note that for each policy, the sacrifice ratio varies inversely with the frequency of contract renegotiation (δ). Also, the sacrifice ratio is increasing in the elasticity of intertemporal substitution (σ) when the monetary authority follows the Taylor rule. Regardless of the values of δ and σ, the sacrifice ratios associated with a deceleration of nominal spending are lower than the ratios associated with an immediate disinflation. Except when both the renegotiation frequency and the elasticity of intertemporal substitution are high, the spending rule is, in turn, outperformed by the Taylor rule.

[27] In the tables, output losses are discounted at a 2.5 percent annual rate.

Table 1. Sacrifice Ratios for Various Disinflationary Policies

	Price Sensitivity/Renegotiation Frequency		
	ß = .06, δ = 3.00	ß = .13, δ = 1.39	ß = .26, δ = .69
Immediate Disinflation	3.24	6.61	12.84
Nominal Spending Deceleration	0.62	1.88	4.86
Taylor Rule: σ=.1	0.19	0.55	1.45
Taylor Rule: σ=.55	0.50	1.22	2.69
Taylor Rule: σ=1	0.64	1.45	3.00

Gordon (1985) reports that most real-world estimates of the sacrifice ratio lie between 3 and 10.[28] For a permanent, "cold turkey," 5-percentage-point reduction in nominal GNP growth (the experiment analyzed in row 2 of Table 1) he calculates a sacrifice ratio of 7.5. At first glance, most of the entries in Table 1 seem unrealistically low. Keep in mind, however, that we have excluded the most volatile components of output (business and residential investment, consumer durables) from our model. Given that output is twice as variable as nondurables and services consumption at business-cycle frequencies (Backus, Kehoe, and Kydland 1996), the entries in Table 1 ought to be doubled before they are compared with Gordon's figures. Moreover, we have abstracted from the credibility issue in our analysis.[29] All things considered, the Fischer contracting model is fairly successful at generating realistic sacrifice ratios provided that no more than three fourths of firms reevaluate their pricing each year ($\delta \leq 1.39$).

[28] Ball's estimated sacrifice ratios are much lower, ranging from 0.0 to 3.6 and averaging 1.4. See Ball (1994).

[29] If the new, disinflationary policy only gradually becomes credible, consumption would likely fall more slowly and fall farther than in the simulations presented here--increasing the sacrifice ratio and giving the consumption path more of an inverted "humped shape." In an economy with inventories, the decline in output would likely be even more gradual than the decline in consumption.

Concluding Remarks

Both for determining how price stickiness affects the economy's dynamic response to shocks and for assessing the empirical importance of price stickiness as a propagation mechanism for monetary policy, it is useful to have a price adjustment model that permits the degree of price flexibility to vary continuously over a range of values. Unfortunately, existing price-adjustment models with this feature are unsatisfactory along one or more dimensions. Thus, Calvo's version of the Taylor contracting model has the implication that disinflationary policies need not be associated with recessions and, indeed, may trigger booms. Moreover, in the Calvo model it is possible to find monetary policies that keep output permanently away from its market-clearing level. McCallum's price adjustment model eliminates the latter problem but retains the former. Fuhrer and Moore's model eliminates the former problem but retains the latter. Moreover, the Fuhrer-Moore model lacks a convincing rationale.

This paper has developed a generalized, continuous-time version of Fischer's model of overlapping contracts. The Fischer model is distinguished from those of Taylor, Calvo, and Fuhrer and Moore in that contracts specify a price path rather than a fixed price level. The intuition is that the costs of renegotiating contracts and gathering information on market conditions are likely to be large relative to the costs of changing prices *per se*. The Fischer contracting specification introduces sufficient additional price flexibility that there is no longer any monetary policy that will keep output permanently away from its market-clearing level. Nevertheless, prices are sufficiently rigid that any disinflation that is not fully anticipated and fully credible triggers a recession.

The generalized Fischer model is analytically tractable. It implies an expectations-augmented Phillips curve with a built in speed effect. When combined with a money demand schedule and a rule for allocating consumption through time, the model can be used to find the monetary policy needed to achieve a given price or spending path, and to find the price path implied by a given monetary policy. Analyses of three alternative disinflationary policies demonstrate the importance of having a framework in which price stickiness is not an "all or nothing" proposition. In these examples, the economy's response to a policy shock changes substantially--both quantitatively and qualitatively--depending upon the frequency with which contracts are renegotiated and the sensitivity of contract prices to output market disequilibrium. The examples also serve to illustrate that monetary-policy-induced fluctuations in output can be quite pronounced and quite persistent even when contracts are renegotiated frequently.

In future work, it would be desirable to seek more precise estimates of the parameters of the Fischer model. There is also certainly room for exploring the implications alternative aggregate demand specifications, stochastic shocks, and imperfect policy credibility. Preliminary results (not presented here) suggest that an aggregate demand specification that includes durable goods expenditures would be particularly worthwhile. Finally, the current analysis treats the mean rate at which contracts come up for renegotiation as a fixed parameter. This assumption may be reasonable during periods in which the inflation process is fairly stable, but seems certain to break down for sufficiently large policy shocks or sufficiently sustained changes in inflation uncertainty (Ireland 1996).

Appendix: The Relationship Between the Price-Gap and Output-Gap Models of Price Adjustment--An Example

Throughout the main body of this paper, it is assumed that firms adjust their prices in response to expected disequilibrium between actual and potential output. This is the output-gap model of price adjustment. As noted in the discussion of the Calvo model, a more general specification has firms adjust their prices in response to the expected gap between the market-clearing aggregate price level and the actual current aggregate price level. This "price-gap" specification is incomplete, however, without a definition of "the market-clearing price level." For example, the output-gap model is that special case of the price-gap model in which the market-clearing price, p^*_t, is defined as the price level that would prevail if output equaled potential output, given the current rate of nominal spending. This appendix briefly explores an alternative definition of p^*_t, as that price level consistent with market-clearing given the current level and future path of the money supply.[30]

If the current level and future path of the money supply are taken as given, it follows from equations (19) and (20) that

$$(c_t - c_t^*) + (p_t - p_t^*) = \alpha(i_t - i_t^*) \tag{A.1}$$

and

$$(\dot{c}_t - \dot{c}_t^*) = \sigma(r_t - r_t^*) \tag{A.2}$$

[30] Hallman, Porter, and Small (1991) take yet another approach. They define p* as the price level that would prevail, given the current money supply, if output equaled potential output and the nominal interest rate was at its long-run average level.

where c^*, r^*, and i^* denote the market-clearing levels of consumption, the real rate of interest, and the nominal rate of interest, respectively. But $i = r + \pi$, so equations A.1 and A.2 can be combined to yield

$$\alpha(\dot{c}_t - \dot{c}_t^*) - \sigma(c_t - c_t^*) = -\alpha\sigma(\pi_t - \pi_t^*) + \sigma(p_t - p_t^*) . \qquad \textbf{(A.3)}$$

When $\alpha = 0$, so that the demand for money is interest inelastic, fixing the current money supply is equivalent to fixing the current level of nominal spending. We know that the output-gap and price-gap models of price adjustment are equivalent in this case. Sure enough, with $\alpha = 0$ equation A.3 reduces to $(c_t - c_t^*) = -(p_t - p_t^*)$. If, however, $\alpha > 0$, the solution to equation A.3 is

$$x_t = \sigma[z_t + \frac{(1 - \sigma)}{\alpha}\int_t^{\infty} z_s\, e^{-(\sigma/\alpha)(s - t)} ds] , \qquad \textbf{(A.4)}$$

where $x \equiv c - c^*$ is the output gap and $z \equiv p^* - p$ is minus the price gap.[31] In general, the output gap depends on a weighted average of expected future price gaps as well as the current price gap. When the elasticity of intertemporal substitution is less than 1, high future prices have a depressing effect on current demand, just as does a high current price level. When the elasticity of intertemporal substitution is greater than 1, high future prices have a positive effect on current demand. When utility is logarithmic ($\sigma = 1$), we're back in the case where the output and price gaps are equal, apart from sign.

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[31] Alternatively, equation A.3 can be solved for the price gap as a function of current and expected future output gaps. One obtains

$$z_t = \frac{1}{\sigma}[x_t + \frac{(\sigma - 1)}{\alpha}\int_t^{\infty} x_s\, e^{-(s - t)/\alpha} ds] .$$

To understand what makes the case in which utility is logarithmic special, note that with $\sigma = 1$ equations 19 and 20 imply

$$n_t - m_t = \alpha(\dot{n}_t + \rho), \tag{A.5}$$

where n_t is the level of nominal spending at time t. The solution to equation A.5 is

$$n_t = \int_t^\infty (\rho + m_s/\alpha)\, e^{-(s-t)/\alpha} ds. \tag{A.6}$$

Thus, with $\sigma = 1$ the future path of the money supply completely determines the current rate of nominal spending. We know, however, that the output-gap and price-gap models of price adjustment are equivalent if the current rate of nominal spending is held fixed when defining the market-clearing price.

We can combine our aggregate demand relationship (equation A.4), with either of equations 18a and 18b to obtain a formula for the output gap as a function of the actual price level relative to the previously expected price level $(p_t - \bar{p}_t)$ or as a function of the market-clearing price level relative to the previously expected price level $(p_t^* - \bar{p}_t)$:

$$x_t = \frac{\sigma}{\beta}\left[\frac{p_t - \bar{p}_t}{e^{\delta t} - 1} + \frac{1-\sigma}{\alpha}\int_t^\infty \frac{p_s - \bar{p}_s}{e^{\delta s} - 1} e^{-(\sigma/\alpha)(s-t)} ds\right] \tag{A.7a}$$

$$x_t = \sigma\left[\frac{p_t^* - \bar{p}_t}{1 + \beta(e^{\delta t} - 1)} + \frac{1-\sigma}{\alpha}\int_t^\infty \frac{p_s^* - \bar{p}_s}{1 + \beta(e^{\delta s} - 1)} e^{-(\sigma/\alpha)(s-t)} ds\right]. \tag{A.7b}$$

These two equations can be used in conjunction with equations A.1 and A.2 to fully characterize the economy's response to policy shocks.

FIGURE 1. The Market-Clearing Price Needed to Achieve an Instant Disinflation

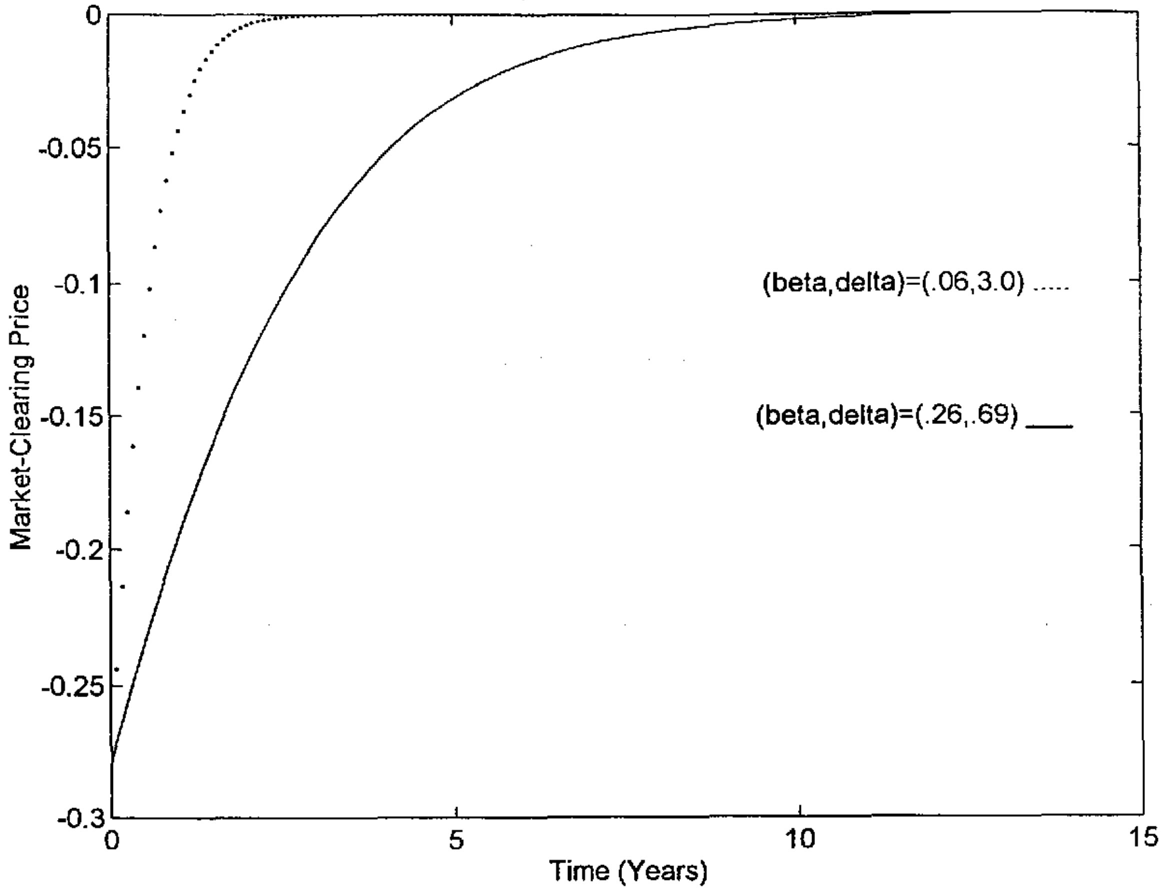


FIGURE 2. The Price Level & Inflation Rate Implied by a Constant Market-Clearing Price Level

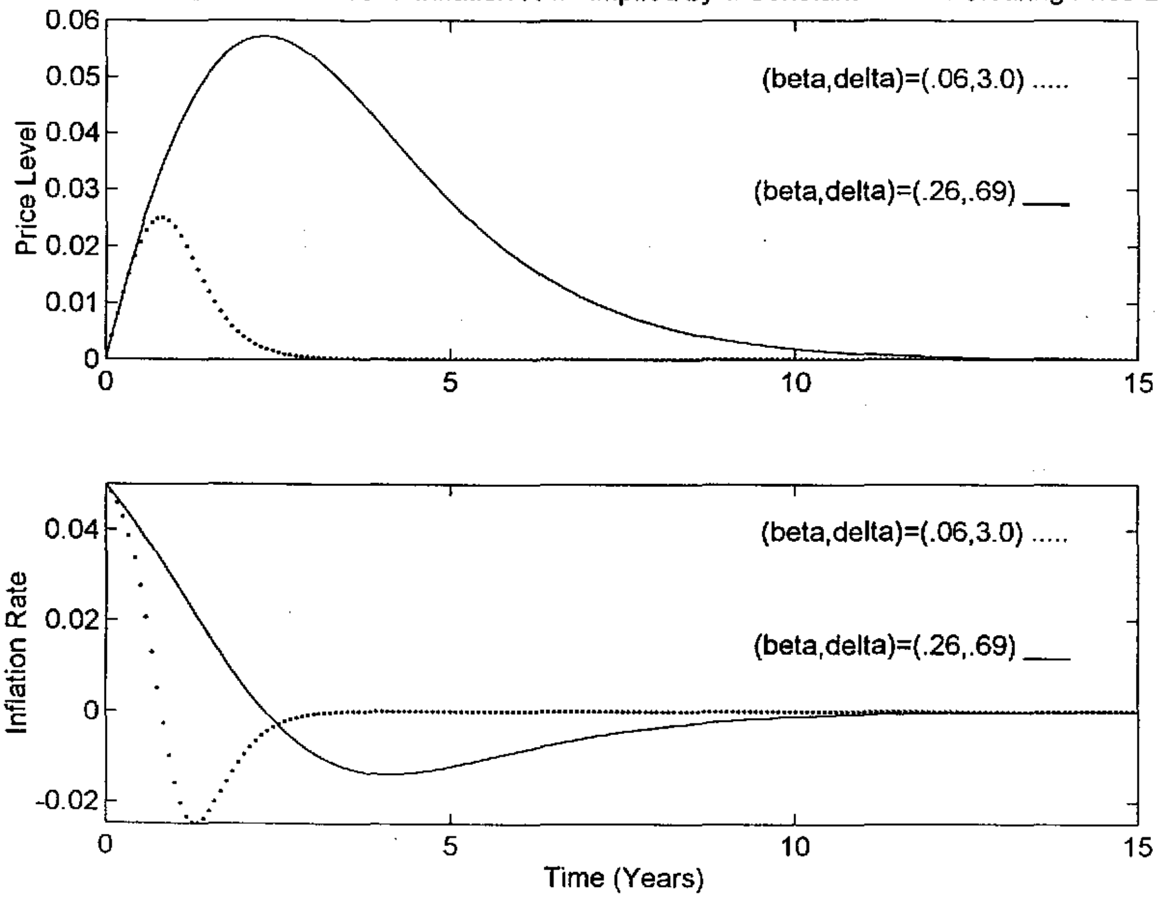


FIGURE 3. The Consequences of an Instantaneous Disinflation

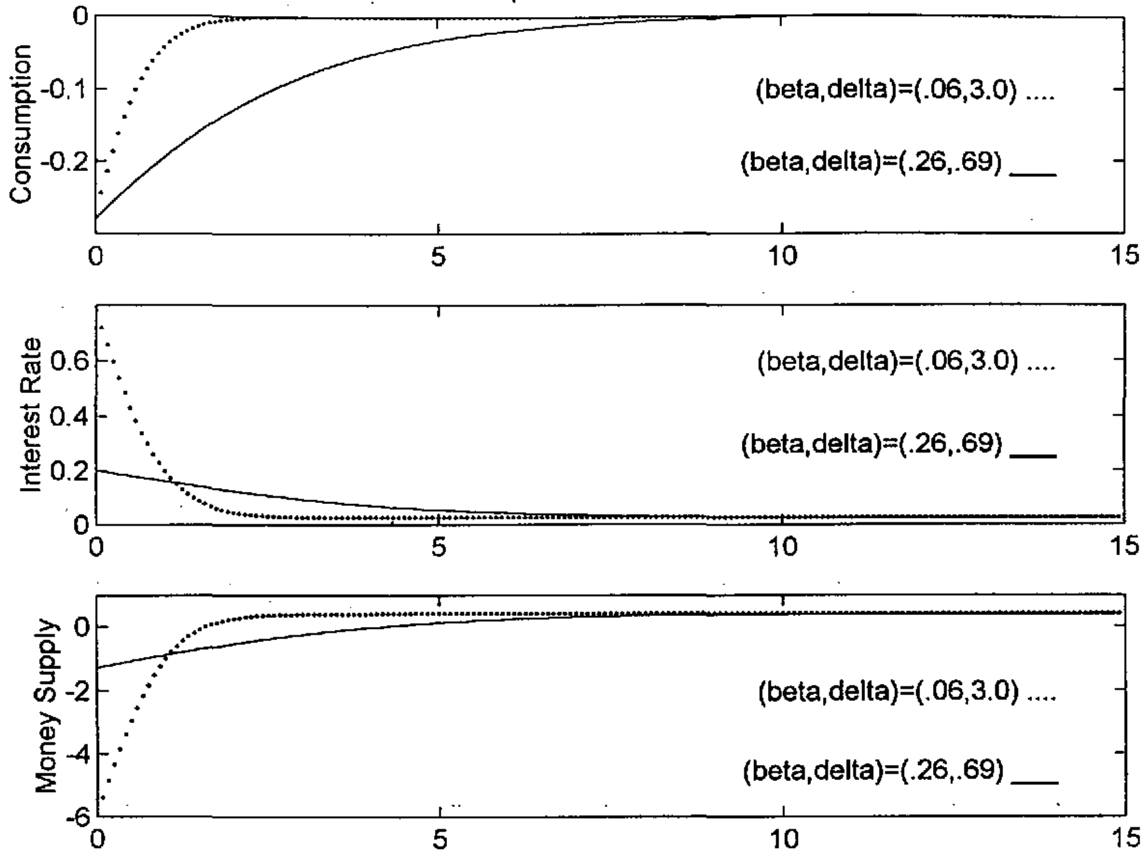


FIGURE 4. The Consequences of an Instantaneous Spending Deceleration

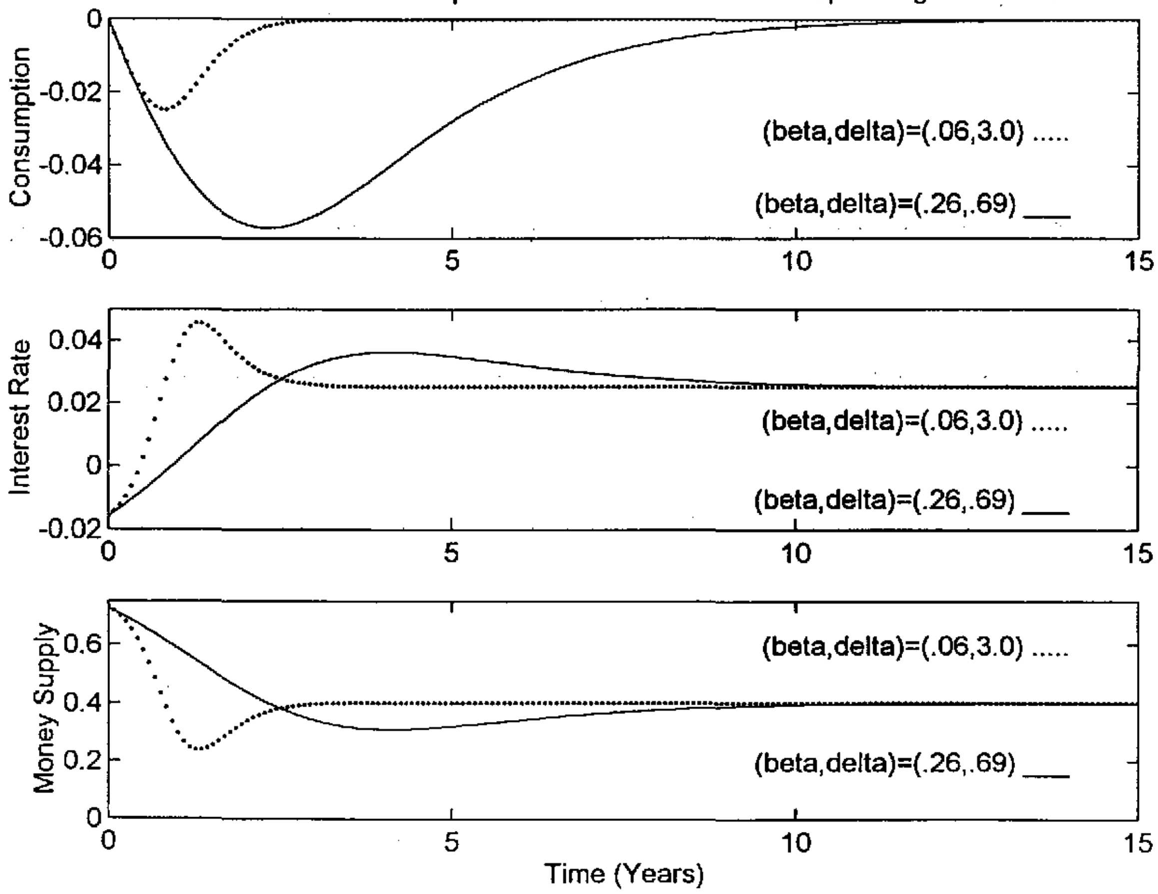


FIGURE 5A. Interest Rate & Inflation (beta = .13, delta = 1.39)

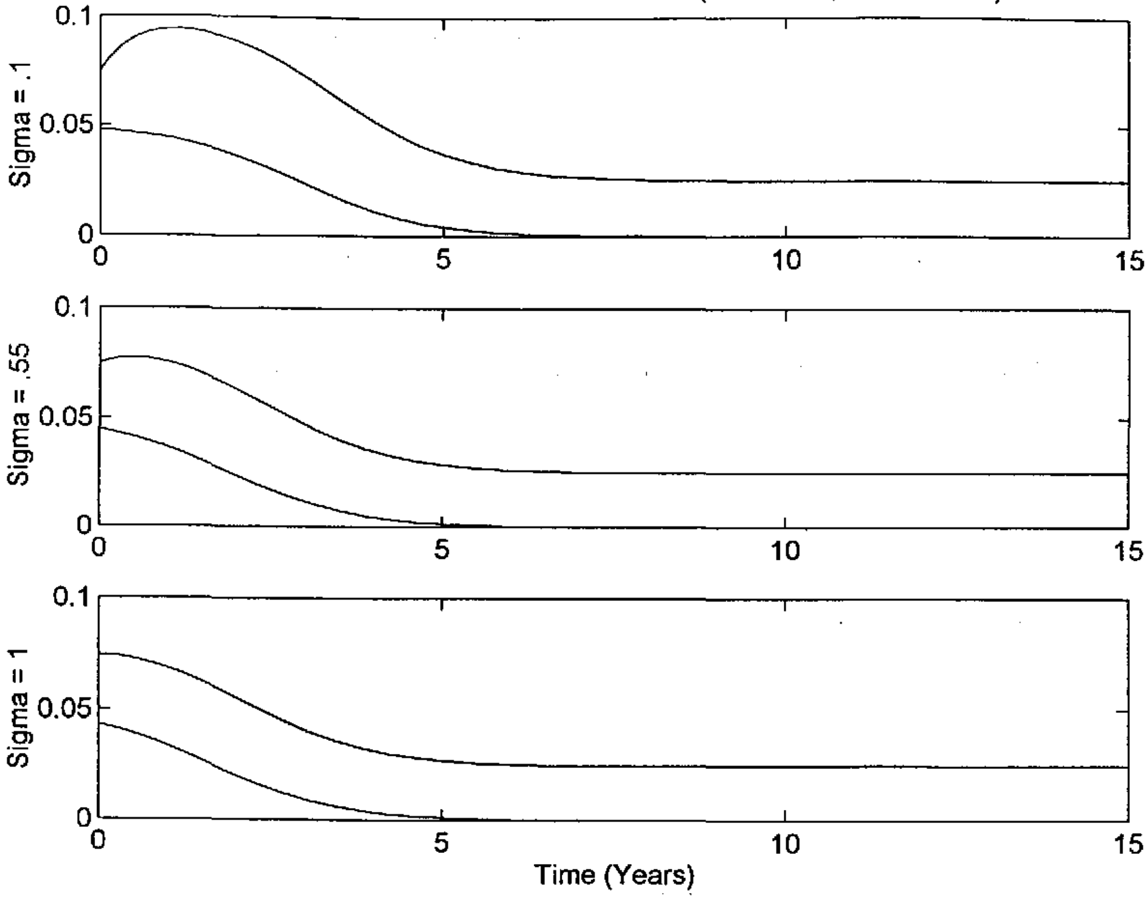


FIGURE 5B. Consumption (beta = .13, delta = 1.39)

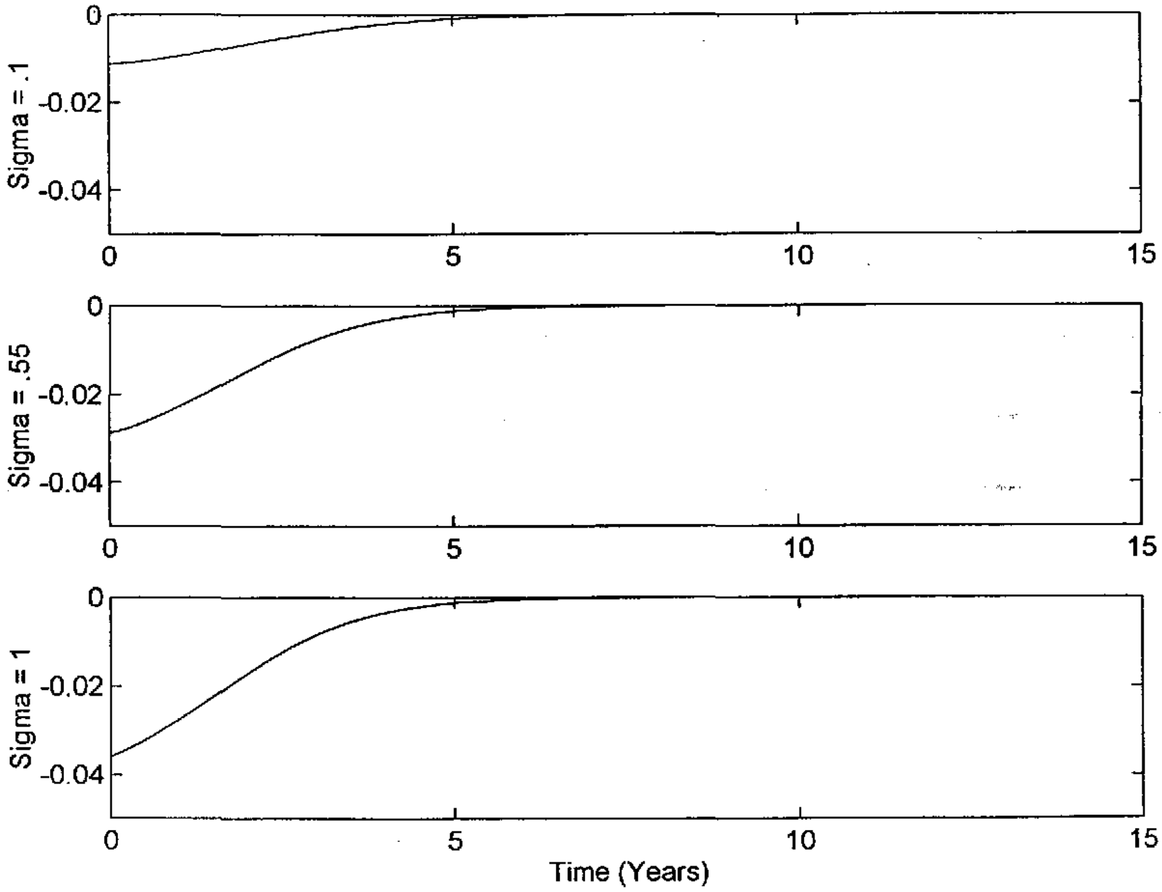


FIGURE 5C. Money Supply (beta = .13, delta = 1.39)

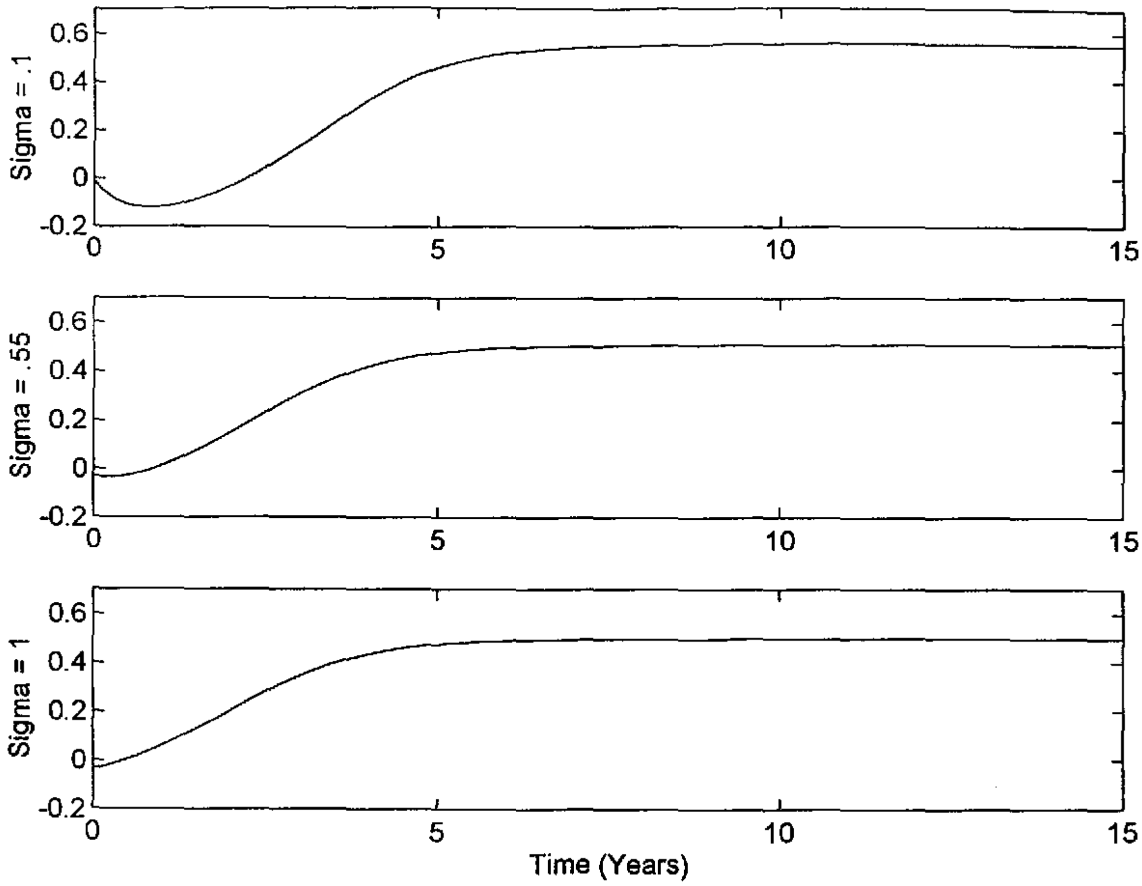


FIGURE 5D. Price Level (beta = .13, delta = 1.39)

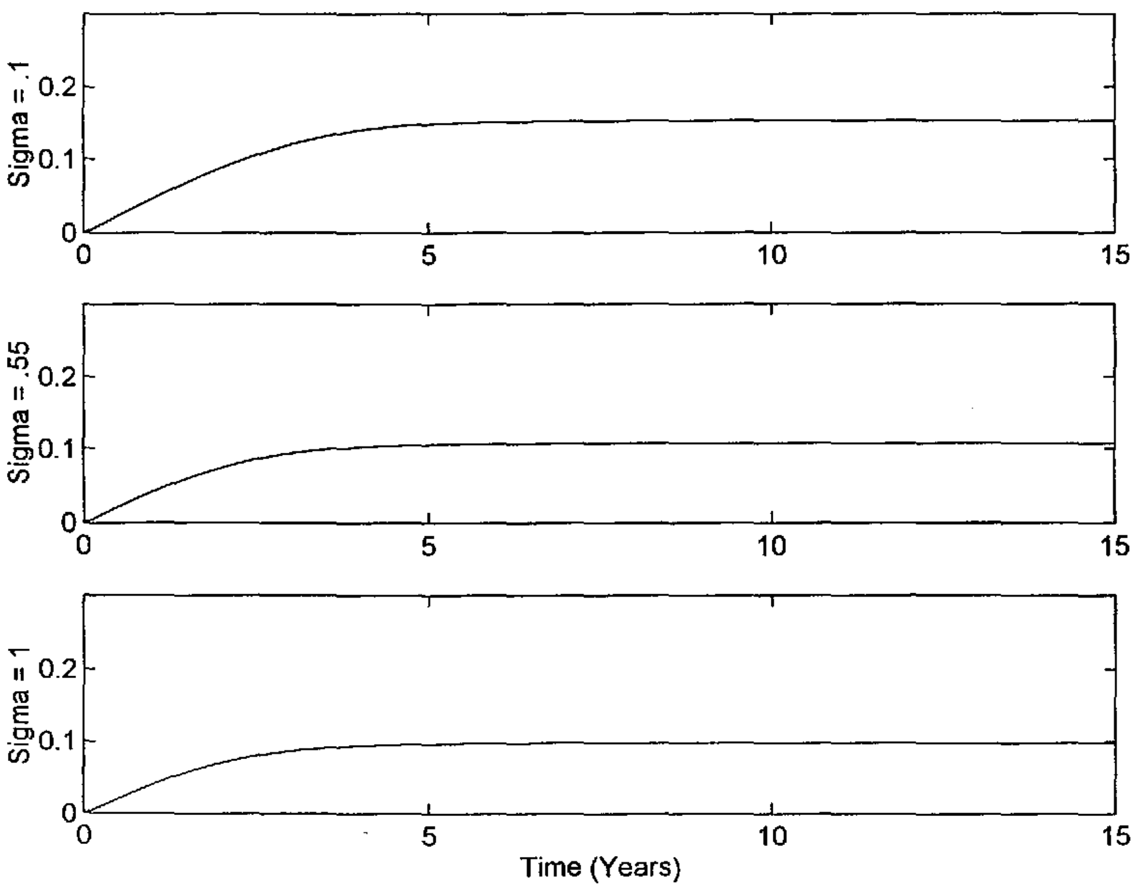


FIGURE 6A. Interest Rate & Inflation (beta = .26, delta = .69)

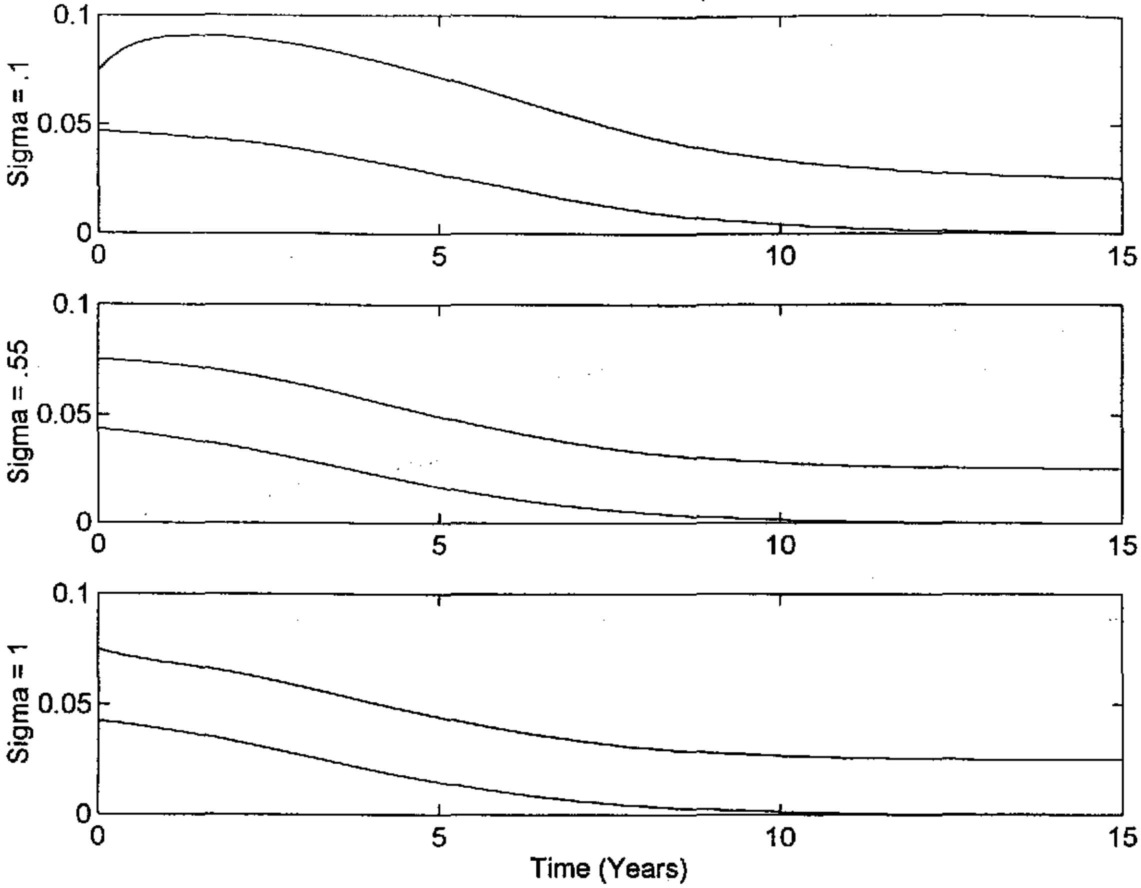


FIGURE 6B. Consumption (beta = .26, delta = .69)

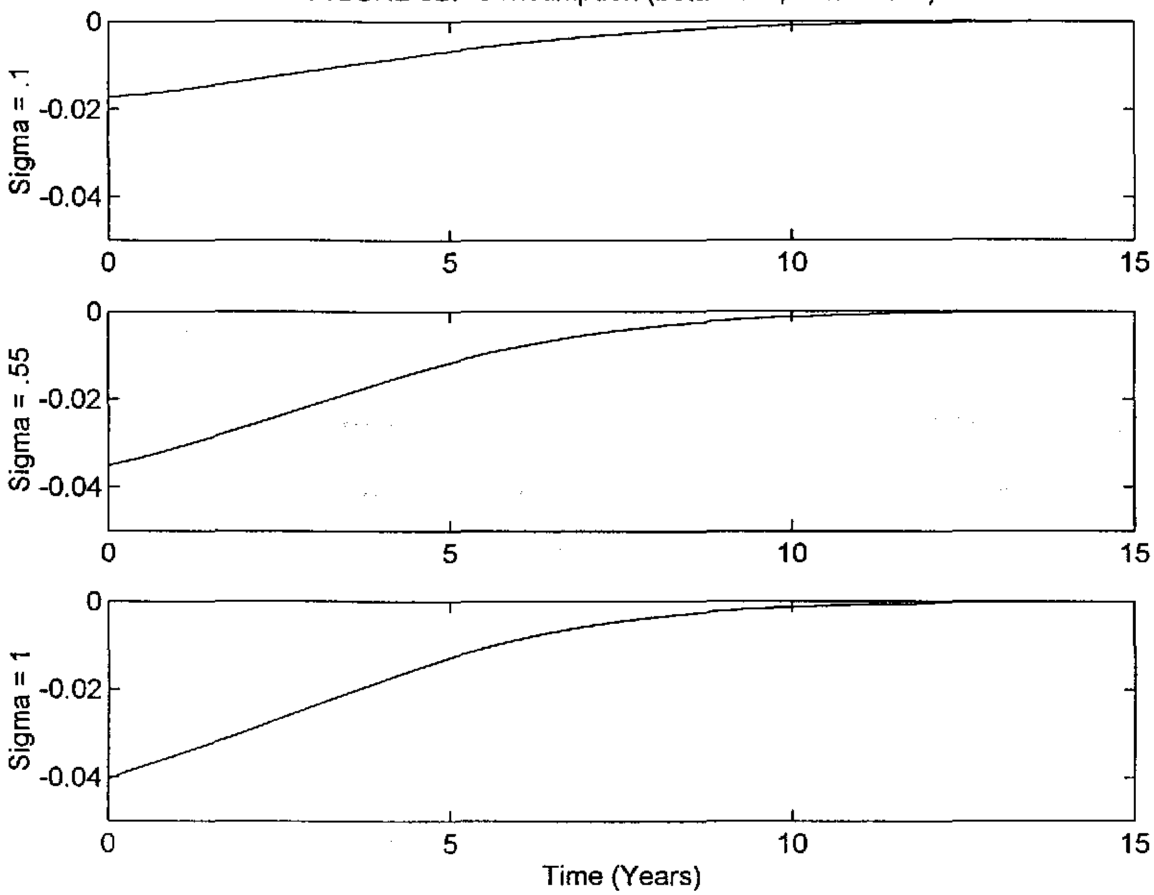


FIGURE 6C. Money Supply (beta = .26, delta = .69)

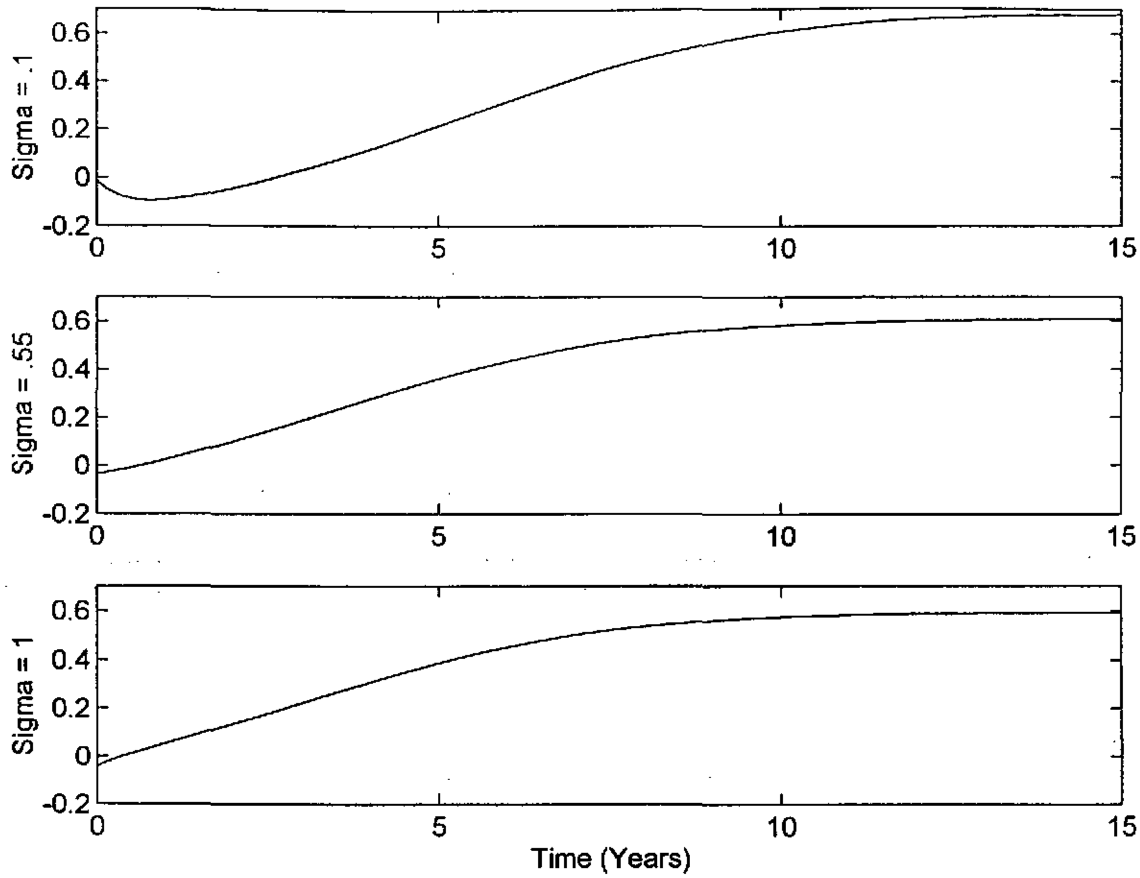


FIGURE 6D. Price Level (beta = .26, delta = .69)

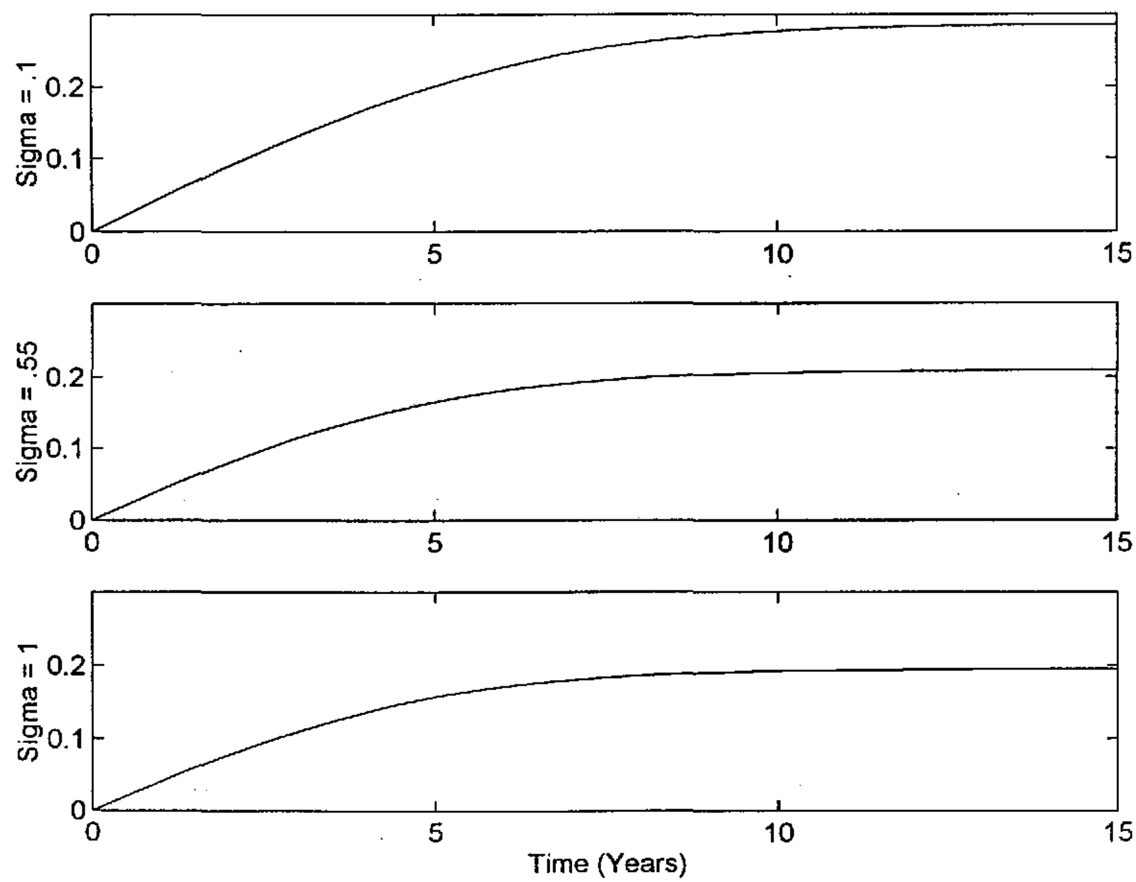


FIGURE 7A. Interest Rate & Inflation (beta = .06, delta = 3)

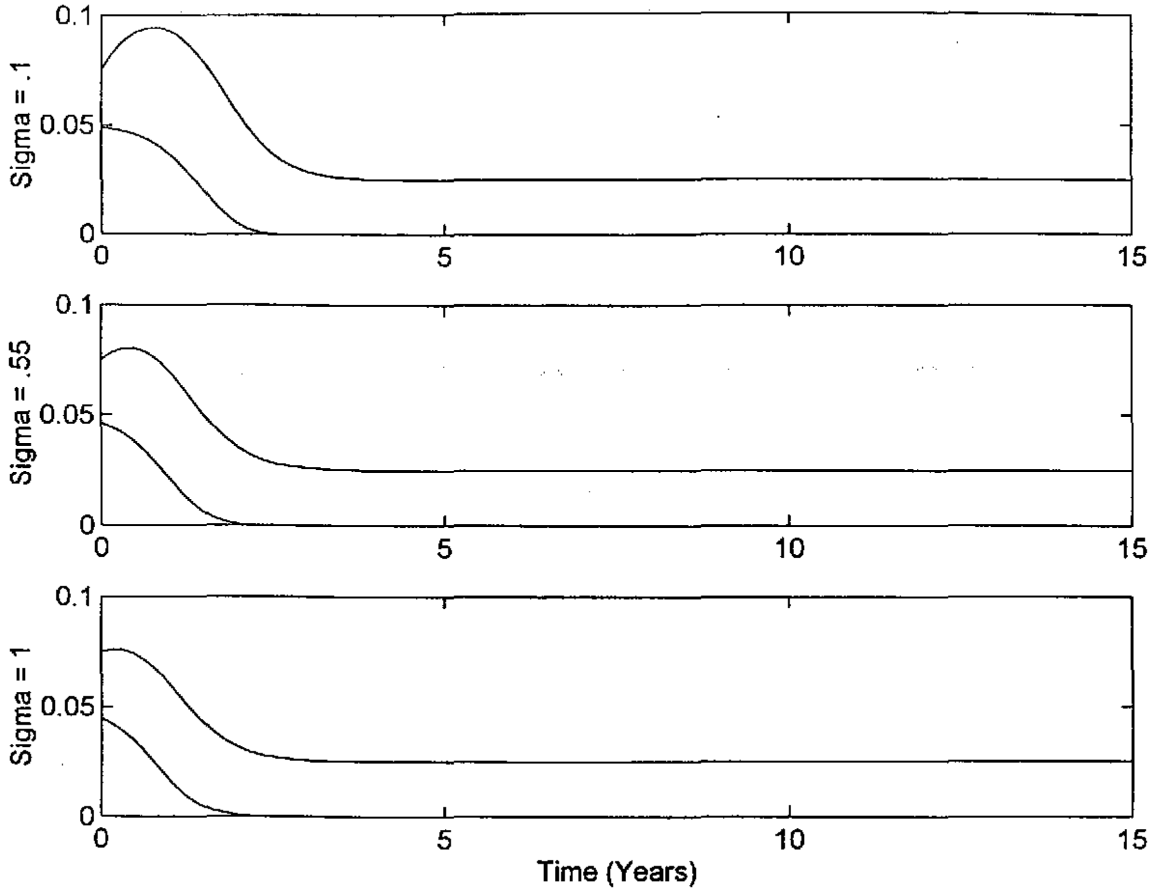


FIGURE 7B. Consumption (beta = .06, delta = 3)

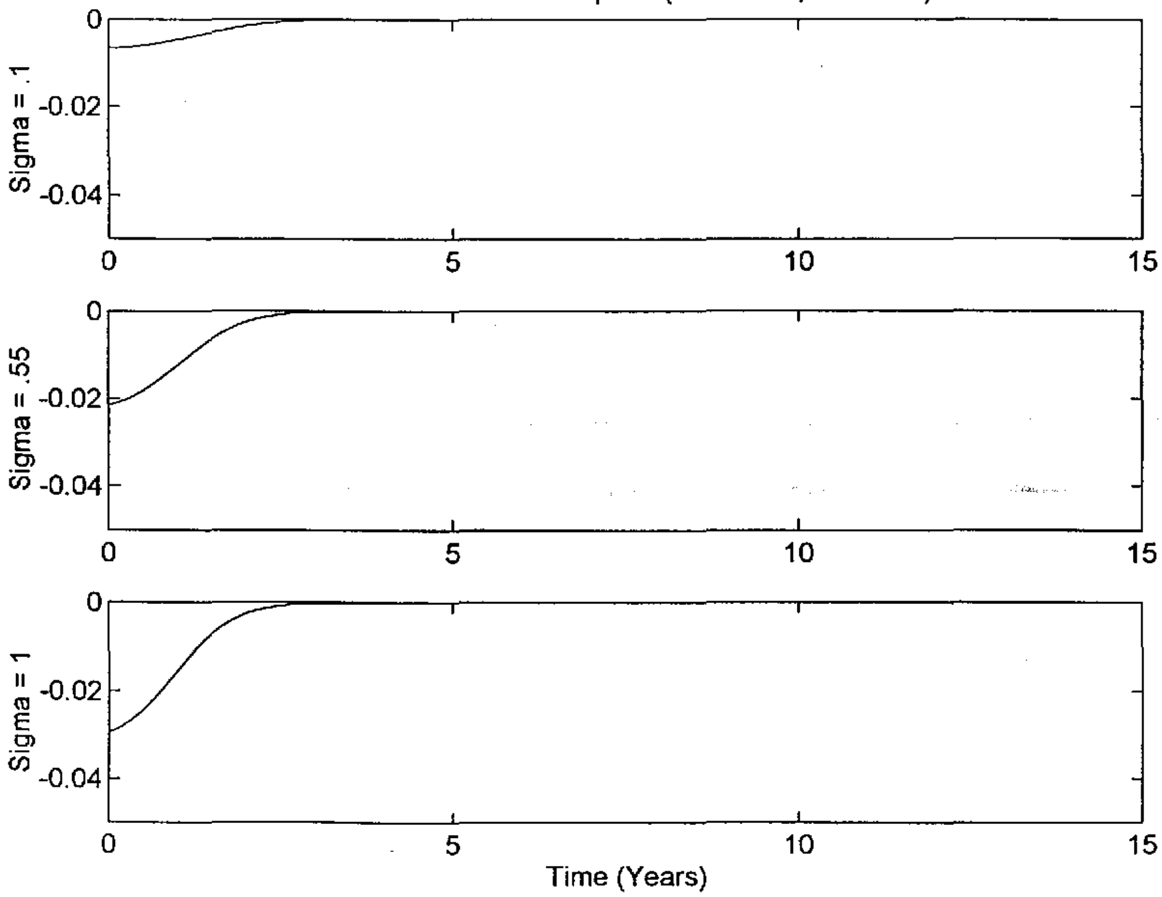


FIGURE 7C. Money Supply (beta = .06, delta = 3)

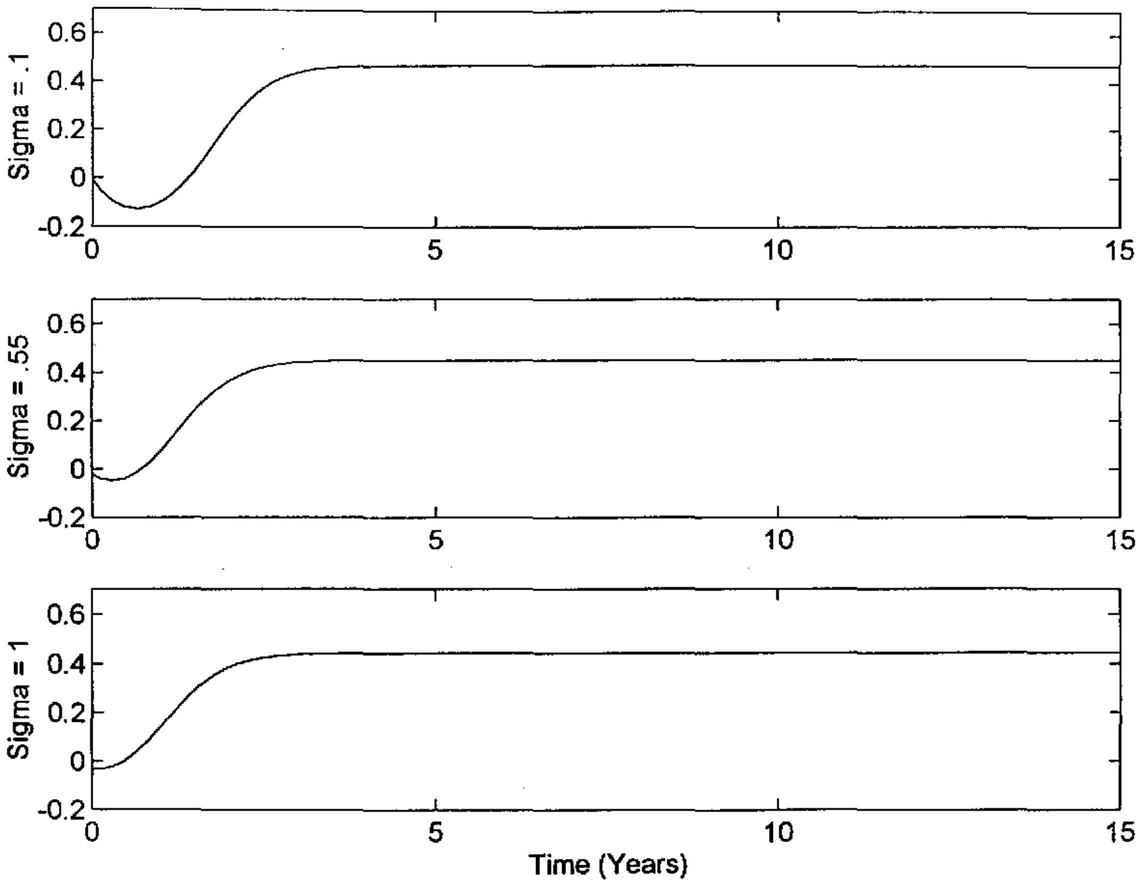
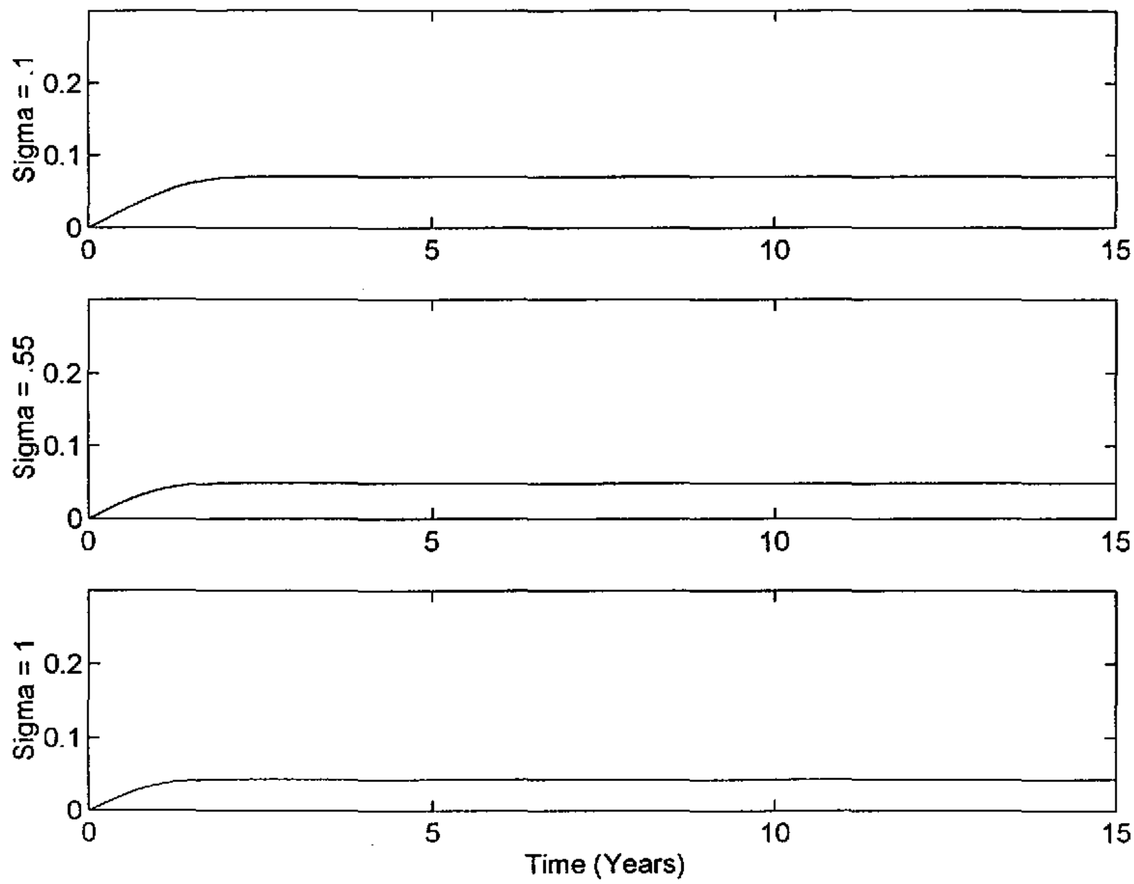


FIGURE 7D. Price Level (beta = .06, delta = 3)



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