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STICKY-PRICE MODELS OF THE BUSINESS CYCLE: SPECIFICATION AND STABILITY

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ABSTRACT

This paper focuses on the specification and stability of a dynamic, stochastic, general equilibrium model of the American business cycle with sticky prices. Maximum likelihood estimates reveal that the data prefer a version of the model in which adjustment costs apply to the price level but not to the inflation rate. Formal hypothesis test detect instability in the estimated parameters, particularly in estimates of the representative household's discount factor. Evidently, more detailed descriptions of the economy are needed to explain movements in interest rates before and after 1979.

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1. Introduction

Recent years have witnessed a heightened interest in the role played by nominal price rigidity in shaping key features of the American business cycle. A growing body of literature, surveyed by Nelson (1998*a*) and Taylor (1998), shows how sticky prices can be fruitfully incorporated into dynamic, stochastic, general equilibrium (DSGE) models of economic fluctuations.

These new sticky-price models of the business cycle, like the earlier models of Fischer (1977) and Taylor (1980), assume that private agents have rational expectations. These new models go beyond their predecessors, however, by providing more explicit accounts of how the optimizing behavior of households and firms helps determine the time paths of aggregate variables such as output and inflation. Thus, as emphasized by Ireland (1997) and Rotemberg and Woodford (1997), these new models respond to the Lucas (1976) critique by identifying parameters describing private agents' tastes and technologies—parameters that ought to remain invariant to changes in the monetary policy regime.

Recent work with sticky-price models of the business cycle is criticized, however, by Estrella and Fuhrer (1999), who call attention to the fact that little evidence has been brought to bear in assessing whether or not these new models actually live up to their promise of being truly structural. Thus, one purpose of this paper is to provide and examine such evidence. Accordingly, the paper develops and estimates a DSGE model with sticky prices. It then performs a series of formal econometric hypothesis tests to determine whether the model's estimated parameters have remained stable in the face of the changes in monetary policy that are widely believed to have occurred in the US over the past four decades and to pinpoint exactly where in the model the instability, if any, lies.

Recent work with sticky-price models of the business cycle is also criticized by Fuhrer and Moore (1995*a*) and Nelson (1998*b*), who suggest that a full explanation of the US time series data may require a model in which the inflation rate, as well as the price level, responds sluggishly to the shocks that hit the economy. Thus, a second purpose of this paper is to reconsider the price adjustment mechanism in a DSGE framework. Accordingly, the monetary business cycle model developed here generalizes those used previously by allowing for rigidity in both the price level and the inflation rate. The maximum likelihood procedure used to estimate the model lets the data decide which form of nominal rigidity is most important.

Thus, as its title suggests, this paper focuses on the specification and stability of a sticky-price model of the business cycle. Section 2, below, sets up the model. Section 3 describes the data, estimates, and tests. Section 4 concludes.

2. The Model

Here, the model developed in Ireland (1997) is extended in three ways. First, Ireland (1997) assumes that nominal goods prices move sluggishly because firms face a quadratic cost of price adjustment, as originally suggested by Rotemberg (1982). Here, a more general specification for the costs of price adjustment, proposed by Price (1992), Nelson (1998a), and Tinsley (1998), gives rise to sluggishness in the inflation rate as well as the price level. As noted above, this first extension allows the data to decide on the relative importance of sticky prices and sticky inflation in the US economy. Second, Ireland (1997) characterizes monetary policy as one that adjusts the growth rate of a broad monetary aggregate in response to the shocks that hit the economy. Here, policy is instead characterized as one that adjusts the short-term nominal interest rate in response to changes in output, inflation, and money growth. This second extension reflects growing recognition, following the influential work of Taylor (1993), that Federal Reserve policy is more accurately described by its effects on interest rates than by its effects on the monetary aggregates. Third, and finally, Kimball (1995), King and Watson (1996), and Kim (1999) find that adjustment costs for physical capital help monetary DSGE models explain the behavior of interest rates; these adjustment costs, absent in

Ireland (1997), are introduced here.

The economy consists of a representative household, a representative finished goods-producing firm, a continuum of intermediate goods-producing firms indexed by $i \in [0,1]$, and a monetary authority. During each period $t = 0, 1, 2, \ldots$, each intermediate goods-producing firm produces a distinct, perishable intermediate good. Hence, intermediate goods are also indexed by $i \in [0,1]$, where firm i produces good i.

The representative household carries M_{t-1} units of money, B_{t-1} bonds, and K_t units of capital into period t. At the beginning of the period, the household receives a lump-sum nominal transfer T_t from the monetary authority. Next, the household's bonds mature, providing B_{t-1} additional units of money. During period t, the household supplies labor and capital to each intermediate goods-producing firm. Thus, the household receives total nominal factor payments $W_tH_t + Q_tK_t$, where W_t denotes the nominal wage, H_t denotes total labor supply, and Q_t denotes the nominal rental rate for capital. The household also receives a nominal dividend payment from each intermediate goods-producing firm, for a total of D_t in dividends during period t.

The household uses these funds to purchase the finished good from the representative finished goods-producing firm at the nominal price P_t, dividing its purchase into amounts C_t and I_t to be consumed and invested. The household then carries M_t units of money, B_t bonds, and K_{t+1} units of capital into period $t+1$; these quantities must satisfy the budget constraint

$$\begin{aligned} & \frac{M_{t-1} + B_{t-1} + T_t + W_t H_t + Q_t K_t + D_t}{P_t} \\ \geq \; & C_t + I_t + \frac{\phi_K}{2}\left(\frac{K_{t+1}}{K_t} - 1\right)^2 K_t + \frac{B_t/R_t + M_t}{P_t} \end{aligned}$$

and the capital accumulation constraint

$$(1-\delta)K_t + I_t \geq K_{t+1},$$

where R_t denotes the gross nominal interest rate between t and $t+1$, $\phi_K > 0$ governs the magnitude of the capital adjustment cost, which is measured in terms of the finished good, and the depreciation rate satisfies $1 > \delta > 0$.[1]

The household seeks to maximize its expected utility, given by

$$E \sum_{t=0}^{\infty} \beta^t \{a_t[\gamma/(\gamma-1)] \ln[C_t^{(\gamma-1)/\gamma} + b_t^{1/\gamma}(M_t/P_t)^{(\gamma-1)/\gamma}] + \eta \ln(1-H_t)\},$$

[1] Of course, the household also faces a set of nonnegativity constraints. However, the functional forms introduced below to describe tastes and technologies guarantee that the household's choices of consumption, labor supply, and capital stocks will always be positive. A binding nonnegativity constraint for investment cannot be ruled out but is extremely unlikely under the parameter settings used below.

where the discount factor and the weight on leisure satisfy $1 > \beta > 0$ and $\eta > 0$. Ireland (1997) and Kim (1999) show that $\gamma > 0$ measures the absolute value of the interest elasticity of money demand while the preference shock b_t acts like a shock to money demand. McCallum and Nelson (1999) show that the preference shock a_t resembles a shock to the IS curve in more traditional Keynesian analyses. The two preference shocks follow autoregressive processes, with

$$\ln(a_t) = \rho_a \ln(a_{t-1}) + \varepsilon_{at}$$

and

$$\ln(b_t) = (1 - \rho_b) \ln(b) + \rho_b \ln(b_{t-1}) + \varepsilon_{bt},$$

where $1 > \rho_a > 0$, $1 > \rho_b > 0$, and $b > 0$. The zero-mean, serially uncorrelated innovations ε_{at} and ε_{bt} are normally distributed with standard deviations σ_a and σ_b.

The representative finished goods-producing firm uses $Y_t(i)$ units of each intermediate good i, purchased at the nominal price $P_t(i)$, to produce Y_t units of the finished good according to the technology described by

$$\left[\int_0^1 Y_t(i)^{(\theta-1)/\theta} di\right]^{\theta/(\theta-1)} \geq Y_t.$$

The finished goods-producing firm acts to maximize its profits; the first-order conditions for its problem imply that

$$Y_t(i) = [P_t(i)/P_t]^{-\theta} Y_t,$$

which reveals that $\theta > 1$ measures the absolute value of the price elasticity of demand for intermediate good i. Competition in the market for the finished good drives the representative firm's profits to zero; this zero-profit condition determines P_t as

$$P_t = \left[\int_0^1 P_t(i)^{1-\theta} di\right]^{1/(1-\theta)}.$$

Intermediate goods-producing firm i hires $H_t(i)$ units of labor and $K_t(i)$ units of capital from the representative household during period t to produce $Y_t(i)$ units of intermediate good i according to the technology described by

$$K_t(i)^{\alpha}[z_t H_t(i)]^{1-\alpha} \geq Y_t(i),$$

where capital's share in production satisfies $1 > \alpha > 0$. The aggregate technology shock z_t follows the autoregressive process

$$\ln(z_t) = (1 - \rho_z)\ln(z) + \rho_z \ln(z_{t-1}) + \varepsilon_{zt},$$

where $1 > \rho_z > 0$, $z > 0$, and the zero-mean, serially uncorrelated innovation ε_{zt} is normally distributed with standard deviation σ_z. Since the intermediate goods substitute imperfectly for one another in producing the finished good, each intermediate goods-producing firm sells its output in a monopolistically competitive market. Thus, firm i sets the price $P_t(i)$ for its output, subject to the requirement that it satisfy the representative finished goods-producing firm's demand, taking P_t and Y_t as given.

In addition, each intermediate goods-producing firm faces costs of adjusting its nominal price, measured in terms of the finished good and given by

$$\frac{\phi_{P1}}{2}\left[\frac{P_t(i)}{\pi P_{t-1}(i)} - 1\right]^2 Y_t + \frac{\phi_{P2}}{2}\left[\frac{P_t(i)/P_{t-1}(i)}{P_{t-1}(i)/P_{t-2}(i)} - 1\right]^2 Y_t,$$

where $\phi_{P1} > 0$ and $\phi_{P2} > 0$ govern the magnitudes of the costs and $\pi > 1$ denotes the gross steady-state rate of inflation. This specification generalizes Rotemberg's (1982) quadratic cost of price adjustment as suggested by Price (1992) and Tinsley

(1998), so that costs apply to changes in both the price level and the inflation rate. Nelson (1998*a*) shows that these generalized costs allow the model to reproduce the inflation dynamics implied by Fuhrer and Moore's (1995*a*) contracting model, while Brayton, Levin, Tryon, and Williams (1997) describe how these generalized costs are incorporated into the Federal Reserve's large-scale FRB/US econometric model. Similar specifications are used by Pesaran (1991) to model employment in the UK coal industry and by Kozicki and Tinsley (1999) to model the demand for producers' durable equipment in the US. The costs of price adjustment make each intermediate goods-producing firm's problem dynamic; rather than maximizing its profits period-by-period, each firm i acts to maximize its total market value, as described in Ireland (1997).

The monetary authority conducts monetary policy by adjusting the short-term nominal interest rate R_t in response to deviations of output Y_t, inflation $\pi_t = P_t/P_{t-1}$, and money growth $\mu_t = M_t/M_{t-1}$ from their steady-state values Y, π, and μ according to the rule

$$\ln(R_t/R) = \rho_y \ln(Y_t/Y) + \rho_\pi \ln(\pi_t/\pi) + \rho_\mu \ln(\mu_t/\mu) + \varepsilon_{Rt},$$

where R denotes the steady-state value of R_t and the zero-mean, serially uncorrelated innovation ε_{Rt} is normally distributed with standard deviation σ_R. This policy rule resembles the one originally used by Taylor (1993) to describe Federal Reserve behavior from 1987 through 1992, but generalizes Taylor's specification by allowing policy to respond to changes in money growth as well as output and inflation. Different monetary policy regimes correspond to different choices of the parameters π, ρ_Y, ρ_π, ρ_μ, and σ_R.

In a symmetric equilibrium, all intermediate goods-producing firms make identical decisions, so that $P_t(i) = P_t$, $Y_t(i) = Y_t$, $H_t(i) = H_t$, $K_t(i) = K_t$, and $D_t(i) = D_t$ for all $i \in [0, 1]$. In addition, the market-clearing conditions $M_t = M_{t-1} + T_t$ and $B_t = B_{t-1} = 0$ must hold. These conditions, together with the first-order conditions for each private agent's problem, the laws of motion for the aggregate shocks, and the monetary authority's policy rule, form a system of difference equations describing the model's symmetric equilibrium. This system implies that in the absence of shocks, the economy converges to a steady state. When the system is log-linearized around its steady state, the methods of Blanchard and Kahn (1980) can be applied to obtain a solution of the form

$$\mathbf{s}_t = \mathbf{\Pi}\mathbf{s}_{t-1} + \mathbf{\Omega}\boldsymbol{\varepsilon}_t$$

and

$$\mathbf{f}_t = \mathbf{U}\mathbf{s}_t.$$

In the solution, the vector $\mathbf{s}_t$ keeps track of the model's state variables, which include the lagged values of real balances $m_{t-1} = M_{t-1}/P_{t-1}$ (because prices are sticky) and inflation π_{t-1} (because inflation is sticky). The vector $\mathbf{f}_t$ keeps track of the model's flow variables, which include the interest rate R_t and output Y_t. The vector $\boldsymbol{\varepsilon}_t$ contains the four innovations ε_{at}, ε_{bt}, ε_{zt}, and ε_{Rt}. Finally, the matrices $\mathbf{\Pi}$, $\mathbf{\Omega}$, and $\mathbf{U}$ have elements that depend on the parameters describing private agents' tastes and technologies and the parameters of the monetary authority's policy rule. Since the model's solution takes the form of a state-space econometric model, driven by the four innovations in $\boldsymbol{\varepsilon}_t$, maximum likelihood estimates of the parameters embedded in $\mathbf{\Pi}$, $\mathbf{\Omega}$, and $\mathbf{U}$ can be obtained, as described by Hamilton (1994, Ch.13), using data on four variables: Y_t, m_t, π_t, and R_t.

3. Data, Estimates, and Tests

In the data, output is measured by real GDP, while real balances are measured by dividing the M2 money stock by the GDP implicit price deflator. Inflation is measured by changes in the GDP deflator, and the interest rate is measured by the rate on three-month Treasury bills. All series, except for the interest rate, are seasonally adjusted; the series for output and real balances are expressed in per-capita terms by dividing by the civilian, noninstitutional population, age 16 and over.

The data are quarterly and run from 1959:1 through 1998:4. Since one objective of this paper is to test for the stability of the model's estimated parameters, the data are divided into two subsamples, the first covering the period ending in 1979:2 and the second covering the period starting in 1979:3. The breakpoint corresponds to the beginning of Paul Volker's tenure as Chairman of the Federal Reserve System, when a fundamental change in US monetary policy is widely believed to have occurred.

Distinct upward trends appear in the series for output and real balances, reflecting the secular growth of the US economy. Ireland (1997) accounts for these trends in data through 1995 by including a deterministic term that captures the effects of labor-augmenting technological progress in the production function for each intermediate good. The model then implies that Y_t and m_t grow at the same rate g along a balanced growth path; g can be estimated together with the other parameters describing tastes and technologies. Two recent developments preclude the use of the same approach here. First, real M2 has grown at a much slower rate than output since 1990; Mehra (1997) shows that M2 demand equations like the one emerging here from the representative household's problem must be modified to correct for this shift. Second, the Federal Reserve redefined its monetary aggregates in 1996, removing overnight repurchase agreements and Eurodollar deposits from M2; Orphanides and Porter (1998) find that this change introduced differential trends into real M2 and output even in pre-1990 data. To accommodate these developments, output and real balances are expressed here as deviations from separate linear trends that are allowed to change across subsamples. Thus, the model is not required to explain the institutional changes, described more fully in Ireland (1994*a*, 1994*b*, 1995), that have generated long-run trends in the velocity of money, nor is the model required to account for the productivity slowdown that lowers the annualized trend rate of growth in real per-capita GDP from 1.9 percent in the pre-1979 data to 1.6 percent in the post-1979 data.

Here, as in Ireland (1997), the data do not contain enough information to estimate all of the model's parameters; some must be fixed prior to estimation. In particular, the parameters η, δ, α, and ϕ_K are difficult to estimate without data on employment and investment. Thus, the weight on leisure η is set equal to 1.5, implying that the representative household spends about one-third of its time working. The quarterly depreciation rate δ is set equal to 0.025, and capital's share α is set equal to 0.36, values commonly used in the literature. The capital adjustment cost parameter ϕ_K is set equal to 10; higher values for ϕ_K led to unreasonably large estimates of σ_z, the standard deviation of the innovation to the technology shock. Finally, the model's monopolistically competitive market structure works mainly to lower the equilibrium level of output; the effects of changes in θ, measuring the degree of market power possessed by each intermediate goods-producing firm, are difficult to distinguish from the effects of changes in z, the average value of the technology shock. Thus, θ is set equal to 6, implying a steady-state markup of price over marginal cost equal to Rotemberg and Woodford's (1992) benchmark of 20 percent.

Table 1 displays maximum likelihood estimates of the model's remaining 17 parameters along with their standard errors, computed by taking the square roots of the diagonal elements of the inverted matrix of second derivatives of the maximized log likelihood function. Before turning to the issues of model specification and parameter stability, it is useful to get a feel for the extent to which the estimated model succeeds in explaining the data. Following McCallum's (1999) suggestions, the model developed here is evaluated along two dimensions: its ability to match the volatilities of output, real balances, inflation, and interest rates in the data and its ability to match the vector autocorrelation function for the same four variables in the data.

Thus, table 2 reports the standard deviations of the logarithms of Y_t, m_t, π_t, and R_t in both the model and the data. The model overpredicts the volatility of output in the post-1979 period, underpredicts the volatility of inflation in both periods, and underpredicts the volatility of interest rates in the post-1979 period. Overall, however, the match between model and data is quite good. In the model as in the data, output is always less volatile than real balances; in the model as in the data, inflation is more volatile than interest rates before 1979 and less volatile than interest rate after 1979.

Figures 1 and 2 compare vector autocorrelation functions for the model and data in both sample periods. For the data, the vector autocorrelations are those implied by unconstrained, fourth-order vector autoregressions.[2] The panels along the diagonal of each figure reveal that the model underpredicts the degree of persistence in Y_t, m_t, and π_t before 1979 and overpredicts the degree of persistence in the same three variables after 1979. The model overpredicts the degree of persistence in R_t for both sample periods, even though the policy rule used here lacks the interest rate smoothing term that Clarida, Gali, and Gertler (1998)

[2]This procedure for computing vector autocorrelations in the data is suggested by Fuhrer and Moore (1995*a*, 1995*b*).

include in their specification. Once again, however, the match between model and data is surprisingly good, considering that the model has just 17 estimated parameters.[3] Overall, the model appears to fit the pre-1979 data somewhat better than the post-1979 data. But in both periods, for instance, the estimated model accounts for the stylized fact emphasized by King and Watson (1996): output is negatively correlated with lagged values of the interest rate.

Returning now to table 1, the estimates of π translate into annualized, steady-state inflation rates of 5.3 percent for the pre-1979 period and 3.5 percent for the post-1979 period. Related, the interest rate response to inflation, measured by ρ_π, is larger when estimated with post-1979 data. These findings suggest that Federal Reserve Chairmen Volker and Greenspan have been more aggressive than their predecessors in fighting inflation. Clarida, Gali, and Gertler (1998) reach a similar conclusion; indeed, their estimates suggest that by responding only weakly to inflation in the pre-1979 period, the Fed failed to guarantee the uniqueness of the economy's equilibrium. Unlike the interest rate rules considered by Clarida, Gali, and Gertler, however, those estimated here include money growth in the list of variables with which the Fed is concerned. Here, the combined response of the

[3] By contrast, a first-order vector autoregression that contains a constant term for each variable has 30 parameters, while the fourth-order VAR that is used in the figures to characterize the data has 78 parameters.

interest rate to both inflation and money growth makes the model's equilibrium unique, even under the pre-1979 estimates.

Turning next to the parameters describing the costs of price adjustment, the estimates of ϕ_{P1} are large, though imprecise, while the estimates of ϕ_{P2} are very small. In fact, the results obtained from estimating a constrained version of the model in which ϕ_{P2} is simply set equal to zero are indistinguishable from those shown for the original model in tables 1 and 2 and figures 1 and 2. Similarly, the value of the log likelihood function is unaffected by the imposition of the constraint $\phi_{P2} = 0$: a likelihood ratio test cannot reject the null hypothesis that $\phi_{P2} = 0$.

On the other hand, table 2 and figures 1 and 2 show that the model's implications do change somewhat when the model is reestimated with the alternative constraint $\phi_{P1} = 0$ imposed. In this case, the estimates of ϕ_{P2} rise markedly, to 14.66 for the pre-1979 period and 17.10 for the post-1979 period. Nevertheless, the original model with ϕ_{P1} large and ϕ_{P2} close to zero actually generates more persistence in inflation than the constrained model with ϕ_{P2} large and ϕ_{P1} equal to zero. Moveover, a likelihood ratio test rejects the null hypothesis that $\phi_{P1} = 0$ at the 1 percent level for both sample periods. Taken together, these results indicate that the data prefer a version of the model in which costs of adjustment apply to the price level but not to the inflation rate.

Why is rigidity in inflation found to be unimportant here, contradicting the earlier results of Fuhrer and Moore (1995a)? Rotemberg (1997) suggests that the special features of the Fuhrer-Moore model are unessential if serially correlated shocks to preferences and technologies are allowed for. In fact, the estimates of ρ_a, ρ_b, and ρ_z shown in table 1 imply that these shocks are extremely persistent. Here, therefore, the observed persistence in inflation is attributed to persistence in the exogenous shocks rather than to large costs of adjustment.

What can be said about the stability of the model's estimated parameters? Let the vectors $\mathbf{\Theta}_q^1$ and $\mathbf{\Theta}_q^2$ contain q parameters estimated with pre-1979 and post-1979 data; let $\mathbf{H}_q^1$ and $\mathbf{H}_q^2$ denote their covariance matrices. Andrews and Fair (1988) show that under the null hypothesis of parameter stability, $\mathbf{\Theta}_q^1 = \mathbf{\Theta}_q^2$, the Wald statistic

$$W = (\mathbf{\Theta}_q^1 - \mathbf{\Theta}_q^2)'(\mathbf{H}_q^1 + \mathbf{H}_q^2)^{-1}(\mathbf{\Theta}_q^1 - \mathbf{\Theta}_q^2)$$

is asymptotically distributed as a chi-square random variable with q degrees of freedom. When computed to test for the stability of the model's 17 estimated parameters, $W = 132.3078$; the 1 percent critical value for a chi-square random variable with 17 degrees of freedom is 33.4. Hence, the Wald test easily rejects the null hypothesis that the estimated parameters are stable.

In interpreting this test result, however, it is important to note that among the 17 estimated parameters are those describing Federal Reserve policy before and after 1979. Thus, the instability detected by the test may reflect instability in policy rather than instability in the parameters describing tastes and technologies. In order to determine whether or not the model successfully copes with the Lucas (1976) critique, additional tests must be used to pinpoint the exact source of the instability. Accordingly, the last column of table 1 reports Wald statistics for the stability of each of the model's parameters. The 10 percent, 5 percent, and 1 percent critical values for these statistics are 2.71, 3.84, and 6.63.

Surprisingly, perhaps, the tests fail to reject the null hypotheses that each of the five policy parameters, π, ρ_Y, ρ_π, ρ_μ, and σ_R, has remained stable; evidently, the differences in point estimates discussed above are not statistically significant.[4] The tests also fail to reject the null hypotheses that the price adjustment cost parameters ϕ_{P1} and ϕ_{P2} have remained stable, although this result may reflect the fact that the estimates of ϕ_{P1} are imprecise. The parameters ρ_a, σ_a, z, ρ_z,

[4] Fuhrer and Moore (1995*b*) and Estrella and Fuhrer (1999) also have difficulty finding statistically significant shifts in the Federal Reserve's interest rate rule.

and σ_z describing the behavior of the preference and technology shocks and the parameters γ, b, and ρ_b describing money demand appear stable as well. Instead, the null hypothesis of stability is rejected for σ_b, the standard deviation of the money demand shock, and for β, the representative household's discount factor.

That the money demand parameter σ_b exhibits instability comes as no surprise; Goldfeld and Sichel (1990), among others, describe the chronic instability that has plagued US money demand specifications for most of the past 25 years. Nor does instability in money demand necessarily present a problem for DSGE models of the business cycle; Rotemberg and Woodford (1997), for example, show how a sticky-price DSGE model can be constructed without any reference to the demand for, or supply of, money. The instability in β, however, is far more troubling, as this preference parameter is one that ought to be structural. In the model, β is most closely linked to the behavior of interest rates. In fact, the shifting estimates of β imply that the annualized steady-state real interest rate, measured by β^{-4}, rises from 1.05 percent in the pre-1979 period to 3.64 percent in the post-1979 period.

Thus, several explanations for the instability in β, all having to do with the behavior of interest rates before and after 1979, suggest themselves. First, it may be that the Federal Reserve allowed inflation to rise before 1979 by keeping interest rates too low, on average, and that conversely, the Federal Reserve has brought inflation down since 1979 by keeping interest rates high, on average. Related, increased uncertainty about the future course of monetary policy may have contributed to an increase in the risk premia built into short-term interest rates since 1979, a possibility discussed by Mascaro and Meltzer (1983). As the interest rate rule used here is not flexible enough to fully capture either of these effects, the introduction of a more general policy rule might serve to improve the model's performance. Second, it may be that US real interest rates have been influenced by changes in fiscal policy variables, including tax rates and budget deficits, that are not considered here. Indeed, Blanchard and Summers (1984) and Hendershott and Peek (1992) argue that a combination of changes in fiscal and monetary policies is needed to explain the behavior of interest rates during the 1970s and 1980s. Thus, adding an explicit role for fiscal policy might also improve the model's performance. Third, and most generally, the instability in β detected here might be related to rejections of the representative agent, consumption-based asset pricing model first documented by Mankiw (1981) and Hansen and Singleton (1983). It may be possible to find more stable preference specifications in the literature on asset prices and consumption that responds to those rejections.

4. Conclusion

As its title suggests, this paper focuses on the specification and stability of an estimated, sticky-price model of the American business cycle. Regarding specification, the results indicate that the data prefer a DSGE model in which adjustment costs apply to the price level but not to the inflation rate; here, persistent movements in inflation are attributed to persistence in exogenous shocks to preferences and technologies rather than to large costs of adjustment. Regarding stability, the results provide evidence that the DSGE model fails to deliver on its promise of being truly structural: instability is detected in estimates of the representative household's discount factor. In the model, this parameter is closely linked to the behavior of interest rates. Evidently, future work with sticky-price models of the business cycle must confront the fact that more detailed descriptions of the economy are needed to explain movements in interest rates before and after 1979.

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Table 1. Maximum Likelihood Estimates and Standard Errors

Parameter	Pre-1979 Estimate	Standard Error	Post-1979 Estimate	Standard Error	W
β	0.9974	0.0012	0.9911	0.0013	12.3482***
γ	0.1908	0.0401	0.1184	0.0315	2.0206
ρ_a	0.9399	0.0197	0.8920	0.0369	1.3118
σ_a	0.0306	0.0049	0.0351	0.0079	0.2427
b	1.4383	0.2420	1.9130	0.2415	1.9277
ρ_b	0.8919	0.0419	0.9680	0.0205	2.6558
σ_b	0.0174	0.0026	0.0109	0.0013	4.8662**
z	3999	210	4528	250	2.6285
ρ_z	0.9203	0.0439	0.9564	0.0302	0.4595
σ_z	0.0159	0.0046	0.0082	0.0020	2.3071
ϕ_{P1}	72.01	34.56	77.10	84.62	0.0031
ϕ_{P2}	0.00005	0.24698	0.000004	0.087183	0.0000
π	1.0129	0.0021	1.0087	0.0028	1.4424
ρ_Y	0.0499	0.0255	0.0823	0.0473	0.3641
ρ_π	0.8617	0.0984	0.9918	0.3650	0.1185
ρ_μ	0.7351	0.1928	0.5867	0.2697	0.2001
σ_R	0.0071	0.0015	0.0051	0.0013	0.9736

Notes: W denotes the Wald statistic for testing the null hypothesis of parameter stability. ** and *** denote significance at the 5 percent and 1 percent levels.

Table 2. Standard Deviations

Pre-1979 Estimates

Variable	Data	Estimated Model	Constrained Model with $\phi_{P1} = 0$
$\ln(Y_t)$	0.0389	0.0378	0.0393
$\ln(m_t)$	0.0497	0.0515	0.0547
$\ln(\pi_t)$	0.0069	0.0051	0.0057
$\ln(R_t)$	0.0045	0.0045	0.0045

Post-1979 Estimates

Variable	Data	Estimated Model	Constrained Model with $\phi_{P1} = 0$
$\ln(Y_t)$	0.0227	0.0318	0.0289
$\ln(m_t)$	0.0546	0.0547	0.0486
$\ln(\pi_t)$	0.0056	0.0049	0.0048
$\ln(R_t)$	0.0076	0.0062	0.0055

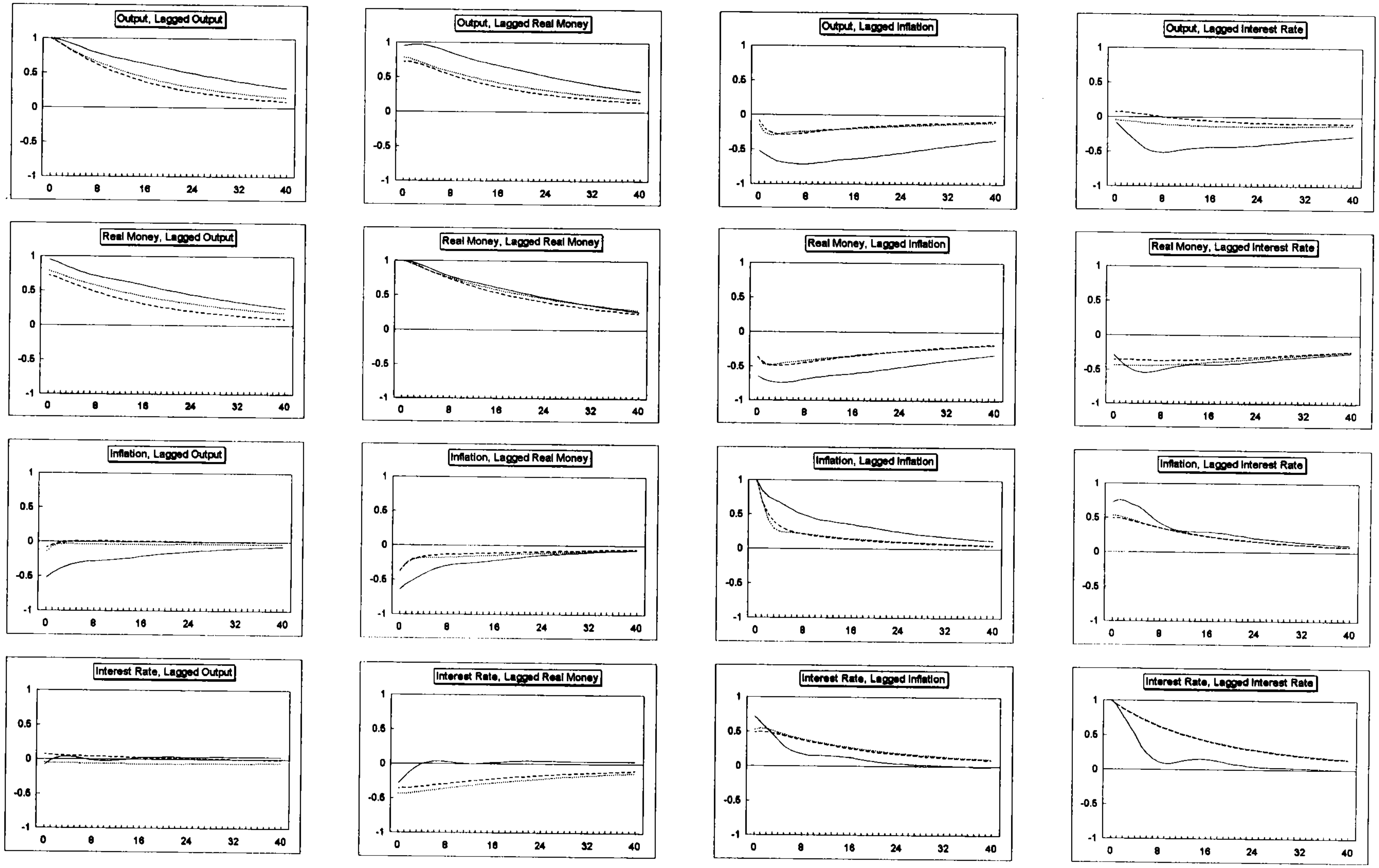

Figure 1. Vector Autocorrelation Functions, Pre-1979 Subsample

Solid line = data
Dashed line = estimated model
Dotted line = constrained model

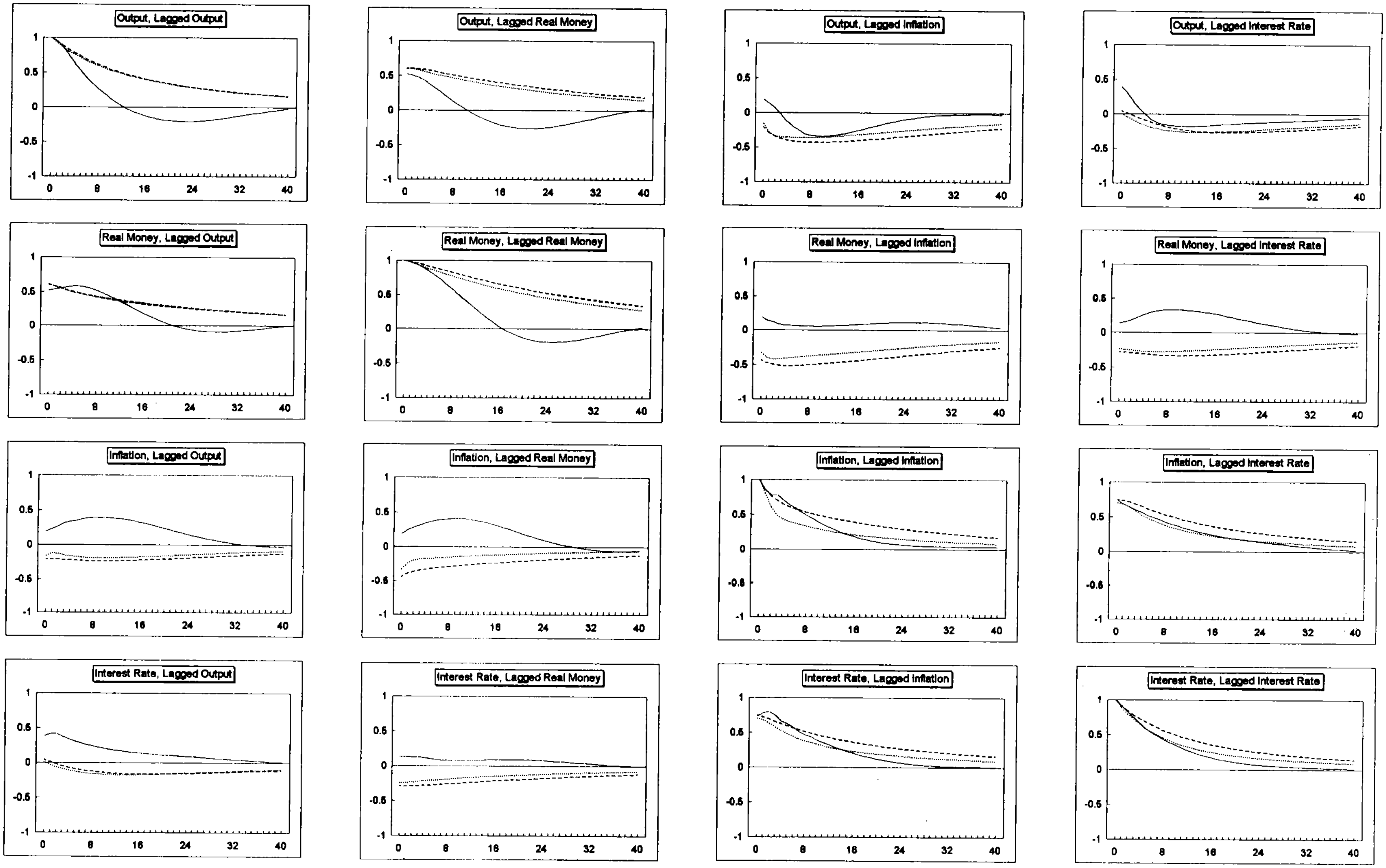

Figure 2. Vector Autocorrelation Functions, Post-1979 Subsample

Solid line = data
Dashed line = estimated model
Dotted line = constrained model