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Seasonal cycles, business cycles, and monetary policy☆

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Abstract

This paper presents a dynamic general equilibrium model that is consistent with both seasonal and business cycle facts in the U.S. economy. The model features consumption durability and a transaction technology, both crucial in accounting for seasonal patterns of nominal variables. A calibrated version of the model is used to quantitatively evaluate welfare consequences of three alternative monetary policy rules: (1) the Fed's historical policy that smooths nominal interest rates at the seasonal frequency, but not at the business cycle frequency; (2) a constant-money-growth rule; and (3) a constant-interest-rate rule. We find that the historical policy is associated with higher welfare than both alternatives.

JEL classification: E32; E41; E52

Keywords: Seasonality; Business cycles; Monetary policy; Consumption durability

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1. Introduction

The post-war U.S. economy has been characterized by both the traditional business cycle fluctuations and recurrent seasonal swings. Recent empirical work reveals that there is a seasonal cycle that bears many similarities to the business cycle in terms of co-movements and relative variabilities among aggregate variables (e.g., Barsky and Miron, 1989; Miron, 1996). Despite these empirical similarities, the Federal Reserve System (Fed) has followed different monetary policy rules in response to aggregate fluctuations across these two types of cycles. Since its inception in 1913, the Fed has tried to accommodate seasonal swings in money demand so that short-term nominal interest rates are smoothed. This is a well-documented aspect of the monetary policy practice in the United States (see Fig. 1). In contrast, the policy has been much less accommodative over the business cycle, resulting in strongly procyclical behaviors of nominal interest rates.[1] An important issue of concern is whether such asymmetric policy reactions over the two types of cycles are socially desirable.

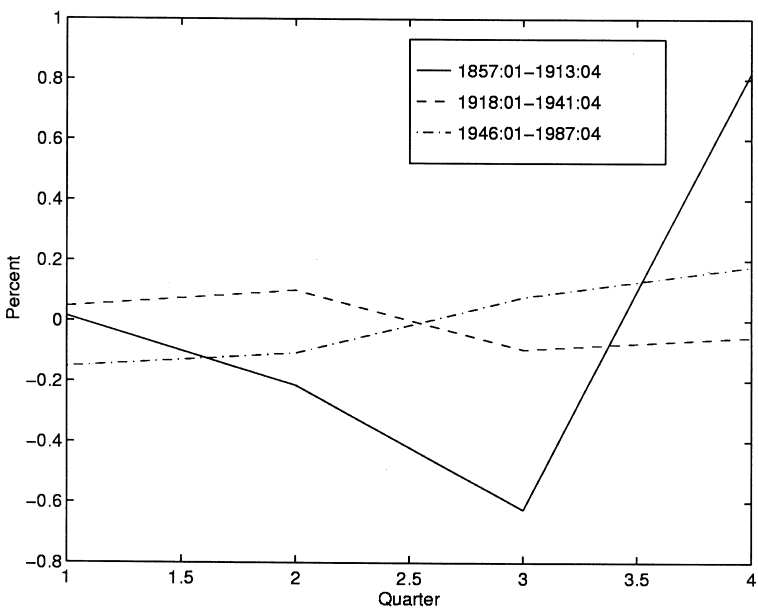

Fig. 1. Nominal interest rate seasonal patterns (four- to six-month commercial paper rates, taken from Barro (1989)).

[1] Cooley and Hansen (1995) find that the correlation coefficient between real GNP and one month T-bill rates is about 0.4. Cagan (1971) shows that short-term nominal interest rates have become more procyclical after the founding of the Fed.

There has been a prolonged debate in the literature about how the Fed should set monetary policy rules at the seasonal frequency and at the business cycle frequency. One popular view is the '*k*-percent' rule. Under this rule, the monetary authority should not actively accommodate fluctuations in the demand for money and credit. Instead, it should try to keep money growth rates constant over both types of cycles, and allow nominal interest rates to fluctuate (e.g., Friedman, 1959,1982). On the other hand, the classical real-bills doctrine prescribes that the central bank should fully accommodate fluctuations in money demand, and thereby effectively dampen nominal interest rate fluctuations. Sargent and Wallace (1982) provide a general equilibrium framework to study the implications of monetary policy prescriptions in the spirit of the real-bills doctrine and compare them with the quantity theory of money. More recently, Carlstrom and Fuerst (1995,1996) argue for keeping nominal interest rates constant at both the seasonal and cyclical frequencies, which is reminiscent of the real-bills doctrine. The current paper provides a resolution to the policy debates by examining the *quantitative* welfare implications of alternative policy rules. To accomplish this, I first develop a general equilibrium monetary business cycle model that is consistent with both seasonal and business cycle observations, and then use it to compare the welfare associated with three alternative policies: (1) the historical policy that smooths nominal interest rates across seasons but not over the business cycle; (2) a policy that keeps money growth rates constant while allowing nominal interest rates to fluctuate over both cycles; and (3) a policy that always keeps nominal interest rates constant.

The model developed in this paper is capable of explaining the seasonal patterns of both real and nominal variables. In the literature, some progress has been made in extending a standard real business cycle model to account for seasonal variations in real quantities (e.g., Braun and Evans, 1995; Chatterjee and Ravikumar, 1992). Yet, it remains a challenge to explain seasonal patterns of nominal variables such as nominal interest rate and inflation rate. A standard cash-in-advance model (CIA) along the line of Cooley and Hansen (1991) implies a one-for-one variation between the nominal interest rate and the velocity of money in the money demand equation, which is at odds with the fact that velocity is highly seasonal while nominal interest rates are not. To alleviate this tension, I introduce a transaction technology shock that captures residual seasonality in the money demand equation so that velocity can respond to seasonal shifts in preferences and technologies without large seasonal swings in nominal interest rates. On the other hand, to explain the lack of seasonality in the inflation rate, I assume that preferences of consumption exhibit local durability (e.g., Dunn and Singleton, 1986). That is, the representative household enjoys utility from consumption purchases made during both the current period and the previous period. Consumption durability enhances the consumer's ability of intertemporal substitution, and thus dampens seasonal variations in the real interest rate. Since both the real interest rate and the nominal interest rate are smoothed across seasons, so is the inflation rate as a consequence of Fisher's relation.

The model's parameters are calibrated based on post-war U.S. data that are not adjusted for seasonality. A quantitative welfare experiment is then conducted. The main finding is that the historical monetary policy attains higher social welfare than both the constant-money-growth rule and the constant-interest-rate rule, given that they all generate the same steady-state seigniorage revenue. When the economies under the three alternative policy rules are compared to the economy under Friedman's rule (the rule that calls for zero nominal interest rates), the historical policy incurs a welfare loss of about 0.85% of aggregate consumption, while the money growth rule and the interest rate rule result in a loss of 0.97% and 0.94% of consumption, respectively.

This paper adds to the study of economic fluctuations and monetary policy in two aspects. First, in a positive sense, it represents an attempt to study both seasonal variations and business cycle fluctuations in an integrated framework. The model featuring consumption durability and a transaction technology distinguishes from similar monetary models in its ability of explaining seasonal variations in nominal variables. Second, in a normative sense, the current paper adds to other recent work that focuses on welfare properties of alternative monetary policies. It provides a quantitative welfare evaluation of three important policy rules at both the seasonal frequency and the business cycle frequency. In the literature, Sargent and Wallace (1982) compare the real-bills doctrine to the quantity theory of money in a general equilibrium environment, focusing on the *qualitative* implications of the two alternative policies. More recent work by Carlstrom and Fuerst (1995) compares the welfare associated with the constant-money-growth rule and with the constant-interest-rate rule in an economy with cash-in-advance constraints and portfolio rigidity. They emphasize the welfare implications of these two policy rules at the business cycle frequency. In addition, Mankiw and Miron (1991) show that a seasonal interest-rate-smoothing policy results in lower welfare cost than other alternatives, and Chatterjee (1993) also finds that smoothing interest rates across seasons can be welfare improving. Other authors such as Miron (1986) and Canova (1991) have investigated the role of the seasonal interest-rate-smoothing policy in eliminating bank runs and financial panics at the time when the Fed was established. Yet, little has been done to quantify the welfare effects of alternative monetary policies based on a unified framework that incorporates both seasonal and business cycle fluctuations. The current paper represents such an attempt. It thus contributes to better understanding of the role of monetary policies over the two types of cycles.

The rest of the paper is organized as follows. Section 2 presents a two-sector monetary business cycle model with seasonal variations. Section 3 describes the calibration of parameters. Section 4 evaluates the model's empirical plausibility by comparing the first- and the second-moment properties of the equilibrium series generated from the model with those of the U.S. data. Section 5 outlines the policy experiments. Finally, Section 6 concludes the paper.

2. The model

This section presents a two-sector monetary business cycle model with seasonal variations. In the model economy, there is a large number of identical households and identical firms, all of whom are infinitely lived. The discussion is therefore restricted to a representative agent of each type. There is a government who conducts monetary policy. I first describe the optimizing behaviors of the representative firm and the household, taking government policy as given, and then characterize a competitive equilibrium.

There are two production sectors, both using capital and labor as inputs. The first sector produces 'regular' goods and the second sector produces credit services. There is a continuum of types of regular goods indexed in the interval [0,1] and a homogeneous type of credit services.[2]

Production technologies for the two sectors are given by

$$\int_0^1 X_{1t}(z)\,\mathrm{d}z = K_{1t}^{\alpha}(A_t N_{1t})^{1-\alpha}, \quad X_{2t} = K_{2t}^{\alpha}(A_t N_{2t})^{1-\alpha}, \tag{1}$$

where $X_{1t}(z)$ is the output of a type z regular goods, and X_{2t} is the output of credit services. The variables K_{jt} and N_{jt} denote the capital and labor employed in sector j, where $j = 1,2$. The labor-augmenting technology shock A_t follows a stochastic process given by $A_t = A_{t-1}\exp(\lambda_t)$, in which λ_t consists of a seasonal component and a stochastic residual component. Specifically, $\lambda_t = \sum_{s=1}^{4} \lambda_s D_{st} + \tilde{\lambda}_t$, where D_{st} is a seasonal dummy variable that equals one if period t corresponds to season s and zero otherwise, and $\tilde{\lambda}_t$ is the stochastic component of λ_t.

Firms are price takers. Given the constant returns to scale technologies in (1), the following two equations fully characterize firms' profit maximization behavior:

$$W_t = (1-\alpha) A_t K_{jt}^{\alpha}(A_t N_{jt})^{-\alpha}, \tag{2}$$

$$R_t^k = \alpha K_{jt}^{\alpha-1}(A_t N_{jt})^{1-\alpha}, \tag{3}$$

where $j \in \{1,2\}$, W_t is the real wage, and R_t^k is the real rental rate of capital.

[2] For a similar model without seasonality, see Aiyagari et al. (1998).

The representative household enjoys utility from consumption services and leisure time. The utility function is given by

$$\mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \{\ln(\hat{C}_t) + \theta_t \ln(T - N_t)\}, \quad 0 < \beta < 1, \tag{4}$$

where

$$\hat{C}_t = C_t + \gamma C_{t-1}. \tag{5}$$

In the above equations, E is an expectation operator, β a discount factor, T the total endowment of time, N_t the hours worked, and C_t the household's consumption purchases. If $\gamma \neq 0$, preferences of consumption are not time-separable, and the household derives utility from consumption purchases during both the current period and the previous period. Positive values of γ indicate local durability in consumption (e.g., Dunn and Singleton, 1986), and negative values of γ imply habit persistence (e.g., Constantinides, 1990). In what follows, I assume that $\gamma > 0$ so that there is local durability in consumption.[3] The term θ_t is a deterministic preference seasonal shifter given by $\theta_t = \sum_{s=1}^{4} \theta_s D_{st}$.

The household has access to a home production technology to produce an aggregate good using all types of regular goods as inputs. The home production function is given by

$$Y_t = \inf_z \{Y_t(z)\}, \tag{6}$$

where Y_t is an aggregate good and $Y_t(z)$ is a regular good of type z.[4] The aggregate good can be either consumed or invested, thus

$$Y_t = C_t + K_{t+1} - (1 - \delta)K_t, \tag{7}$$

where K_t is the period t stock of capital and $0 < \delta < 1$ is a depreciation rate.

The household purchases regular goods either with cash or with credit. If cash is paid up-front, the price of type z goods is given by $P_{1t}(z)$, and the goods are interpreted as 'cash goods'. If the purchase is made with credit, some credit services are required, and the goods are called 'credit goods'. The amount of credit services required for each unit of type z goods is $q_t \mathcal{S}(z)$, where q_t is a transaction technology shock which follows a stochastic process with a seasonal component: $\ln q_t = \sum_{s=1}^{4} q_s D_{st} + \ln \tilde{q}_t$, with $\ln \tilde{q}_t$ being a stochastic

[3] This assumption reflects the casual observation that when a period is as short as a quarter, some goods traditionally classified as nondurables have some durable properties.

[4] The author is grateful to an anonymous referee for suggesting this home production interpretation. The Leontiff-type of technology is assumed here to simplify analysis. It does not seem to be too restrictive because, when inflation arises, what matters to the agents is the option of paying with cash or with credit, not the identity of each good.

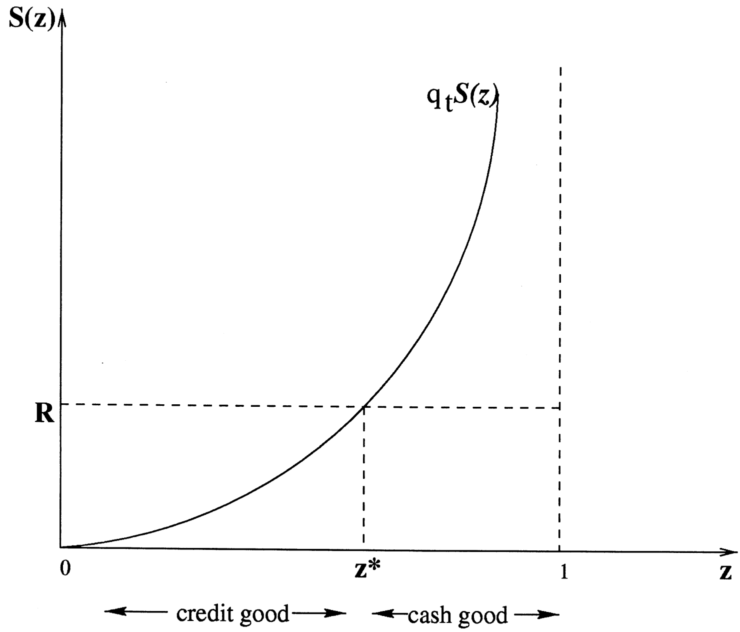

Fig. 2. Determination of cash goods versus credit goods.

residual. The implied price of type z credit goods is thus given by $P_{2t}(z) = P_{1t}(z)(1 + q_t\mathscr{S}(z))$.

To facilitate analysis, I assume that the $\mathscr{S}(z)$ schedule is increasing in $z \in [0,1]$ and $\mathscr{S}(0) = 0$ (see Fig. 2). Thus, goods with higher indices require more credit services. Since the opportunity cost of cash goods is the nominal interest rate which is independent of z, there exists a cut-off index $z_t^\star \in [0,1]$ such that goods indexed $z > z_t^\star$ are purchased with cash and the rest with credit. This is so because the cost of using credit services for those goods indexed higher than $z_t^\star$ exceeds the opportunity cost of holding cash. In light of the Leontiff form of the home production technology, all types of goods are purchased in equal amounts in equilibrium so that the total purchase of credit goods is $z_t^* Y_t$ and that of cash goods is $(1 - z_t^*)Y_t$. It also follows that $P_{1t}(z) = P_{1t}$ for all z.

The timing of transactions for the household is described below. At the beginning of period t, the household carries money balances M_{t-1} and nominal bond holdings B_t from the previous period. It receives a lump-sum nominal transfer of H_t from the government prior to the opening of a centralized securities market. In the securities market, the household rearranges its portfolio of money and bonds. Upon completion of these transactions, the securities market is closed and the goods market is open. The household's purchase of cash goods is subject to a cash-in-advance constraint

$$Y_t(1-z_t^\star) \le \left(M_{t-1} + H_t + B_t - \frac{B_{t+1}}{1+R_t}\right)\Big/ P_{1t}, \tag{8}$$

where R_t is a nominal interest rate.

At the end of period t, the household receives wage and rental payments from firms. This income, along with the money leftover after purchasing cash goods, is used to purchase credit goods and to accumulate money balances for the next period. Since credit goods are those indexed by $z \le z_t^\star$, the total expenditure on credit goods is $\int_0^{z_t^\star} Y_t P_{2t}(z)\,\mathrm{d}z$, and the budget constraint is given by

$$\left(\int_0^{z_t^\star} Y_t P_{2t}(z)\,\mathrm{d}z + M_t\right)\Big/ P_{1t} \le \left(M_{t-1} + H_t + B_t - \frac{B_{t+1}}{1+R_t}\right)\Big/ P_{1t} - Y_t(1-z_t^\star) + W_t N_t + R_t^k K_t. \tag{9}$$

Given prices and initial conditions K_0, C_{-1}, M_{-1}, and B_0, the household maximizes utility (4) subject to the constraints (5)–(9).

Finally, the model descriptions can be closed by specifying a monetary policy. The monetary authority prints money to finance the lump-sum transfers. Thus, $H_t = M_t^s - M_{t-1}^s$, where M_t^s is the money supply of period t and

$$M_t^s = g_t M_{t-1}^s. \tag{10}$$

The money growth rate g_t follows a stationary stochastic process given by $\ln g_t = \ln g_t^d + \ln \tilde{g}_t$, with $\ln g_t^d = \sum_{j=s}^4 g_s D_{st}$ and $\ln \tilde{g}_t$ being the stochastic component of $\ln g_t$.[5]

To summarize, there are six markets in the model economy: a regular goods market, a credit service market, a labor market, a capital market, a money market, and a bond market. The respective market-clearing conditions are

$$C_t + K_{t+1} - (1-\delta)K_t = K_{1t}^\alpha (A_t N_{1t})^{1-\alpha}, \tag{11}$$

$$\int_0^{z_t^\star} Y_t q_t \mathscr{S}(z)\,\mathrm{d}z = K_{2t}^\alpha (A_t N_{2t})^{1-\alpha}, \tag{12}$$

[5] In the policy experiments, I also consider an alternative policy regime in which the monetary authority chooses the nominal interest rate R_t as a policy instrument, and the money growth rate g_t is thus endogenously determined. In this case, there is a well-known problem of nominal price indeterminacy in the presence of uncertainty. To solve this problem, I assume that the government follows a 'no dice' policy in the sense that the period $t+1$ money growth rate only depends on the realization of events up to period t. For similar treatments, see Carlstrom and Fuerst (1995) and McCallum (1983,1986).

$$N_{1t} + N_{2t} = N_t, \tag{13}$$

$$K_{1t} + K_{2t} = K_t, \tag{14}$$

$$M_t = M_t^s, \tag{15}$$

$$B_t = B_t^s = 0. \tag{16}$$

Definition 1. A competitive equilibrium in this economy consists of a sequence of allocations $\{C_t, N_t, K_{t+1}, Y_t, N_{1t}, N_{2t}, K_{1t}, K_{2t}, M_t, B_{t+1}\}_{t=0}^{\infty}$ and prices $\{P_{1t}, P_{2t}(z), R_t, W_t, R_t^k\}_{t=0}^{\infty}$ that satisfy: (i) taking prices as given, the allocations solve the household's utility maximization problem; (ii) taking prices as given, the allocations solve the firm's profit maximization problem; (iii) markets for regular goods, credit services, labor, capital, money, and bond all clear; and (iv) monetary policy is as specified.

A stationary competitive equilibrium can be analogously defined, with the growth components in all equilibrium variables appropriately removed. To induce stationarity, I follow the procedure described in King et al. (1988) and make the following variable transformations:

$$C_t^\star = \frac{C_t}{A_t}, \quad K_t^\star = \frac{K_t}{A_{t-1}}, \quad Y_t^\star = \frac{Y_t}{A_t}, \quad K_{it}^\star = \frac{K_{it}}{A_{t-1}} \quad (i = 1,2),$$
$$W_t^\star = \frac{W_t}{A_t}, \quad P_{1t}^\star = \frac{A_t P_{1t}}{M_{t+1}^s}, \quad M_t^\star = \frac{M_t}{M_t^s}, \quad B_t^\star = \frac{B_t}{M_t^s}.$$

The model is solved using numerical methods similar to King et al. (1987), in which a stationary equilibrium involving small fluctuations around a steady state is approximated by solving a log-linearized version of equilibrium conditions with the transformed variables. The steady state in this economy is a perfect foresight stationary equilibrium path in which every variable X has the characteristic that $X_{j+4} = X_j$ for all $j \geq 1$. That is, all equilibrium variables repeat themselves every four periods. A non-linear solution method is used to solve for this seasonal steady-state equilibrium.[6]

3. Calibration of parameters

This section describes the calibration strategies in the model economy. The calibration is based on quarterly U.S. data that are not adjusted for seasonality. All series are taken from Barsky and Miron (1989) except for labor hours, which

[6] Details of the computation methods are available upon request.

are the efficiency units constructed by Hansen (1991) based on the current population survey, and are not seasonally adjusted. The sample period covers the first quarter of 1960 through the fourth-quarter of 1984.

I begin with specifying the $\mathscr{S}(z)$ schedule:

$$\mathscr{S}(z) = \begin{cases} \frac{\eta}{\psi}(1-(1-z)^{\psi}) & \text{if } \psi \neq 0, \\ -\eta \ln(1-z) & \text{if } \psi = 0, \end{cases} \tag{17}$$

where $\eta > 0$ is a constant. The money demand equation derived from the household's first order conditions is then given by

$$R_t = \begin{cases} \frac{\eta}{\psi} q_t(1-(M_t/(P_{1t}Y_t))^{\psi}) & \text{if } \psi \neq 0, \\ -\eta q_t \ln(M_t/(P_{1t}Y_t)) & \text{if } \psi = 0. \end{cases} \tag{18}$$

I next specify the stochastic process of the exogenous shocks. In particular, I assume that the vector process $\{\tilde{\lambda}_t, \ln(\tilde{q}_t), \ln(\tilde{g}_t)\}$ is stationary and ergodic and has the following autoregressive representation:

$$\begin{pmatrix} \tilde{\lambda}_t \\ \ln \tilde{q}_t \\ \ln \tilde{g}_t \end{pmatrix} = B_0 + B(L)\begin{pmatrix} \tilde{\lambda}_{t-1} \\ \ln \tilde{q}_{t-1} \\ \ln \tilde{g}_{t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{\lambda t} \\ \varepsilon_{qt} \\ \varepsilon_{gt} \end{pmatrix}, \tag{19}$$

where B_0 is a constant vector, $B(L)$ is a polynomial in the lag-operator L, and the ε's are white noise variables with zero means and constant variances.

The parameters to be calibrated include the subjective discount factor β, the capital share α, the depreciation rate δ, the parameters in the money demand equation η and ψ, the consumption durability parameter γ, and the total time endowment T, in addition to the seasonal parameters in preferences and technologies, including the seasonal shifters θ_t and the seasonal components of λ_t and of q_t. The rest of the parameters to be calibrated are those in the shock process (19), including B_0, $B(L)$, and the covariance matrix $\Sigma = \mathrm{var}(\varepsilon_t)$, where $\varepsilon_t \equiv [\varepsilon_{\lambda t}, \varepsilon_{qt}, \varepsilon_{gt}]'$.

Following the standard business cycle literature, β is set to 0.99 and T to 1369 (e.g., Christiano and Eichenbaum, 1992). I choose $\alpha = 0.41$ and $\delta = 0.025$ so that the model predicts an annualized capital-output ratio of 2.7 and an investment-output ratio of 0.3 in the non-seasonal steady state, in accordance with the data. The parameter η is a scale factor and is thus set to unity. The value of ψ governs the interest rate elasticity of money demand and is set to 0.2. The parameter γ determines the effective elasticity of intertemporal substitution in consumption. In the literature, a wide range of values of γ is obtained. For example, Dunn and Singleton's (1986) estimate of γ is between 0.27 and 0.58 based on seasonally adjusted data, while Braun and Evans (1998) suggest that γ is 0.44 if seasonally unadjusted data are used. Eichenbaum et al. (1988) find that the values of γ range from 0.40 to 0.73. I set $\gamma = 0.65$ in light of these studies.[7]

The seasonal components of q_t and of λ_t are obtained by regressing each series on four seasonal dummies, where the q_t series is constructed from the inverse money demand equation (18) and the λ_t series is obtained from the production functions. I choose the four preference seasonal shifters $[\theta_1,\theta_2,\theta_3,\theta_4]$ to match the four values of seasonal means of the log-growth rate of labor hours.[8]

In the shock process (19), B_0 is a zero vector since all the random variables have zero means. The parameters in $B(L)$ and in Σ are obtained by estimating a tri-variate VAR with one lag, using the conditional maximum likelihood method suggested by Hamilton (1994). If a parameter turns out to be statistically insignificant, it is set to zero.[9]

Tables 1 and 2 present the calibrated parameters. There are several notable features in the parameter values. First, there is a large magnitude of seasonal variations in the total factor productivity (the λ_t term). The productivity growth has a sharp drop of nearly 14% in the first quarter, recovers substantially in the second quarter, and then continues to grow at a moderate pace in the last two quarters. The first quarter downturn cannot be explained by weather effects alone in light of the study by Beaulieu and Miron (1992), who find that output falls in the first quarter in some countries in the southern hemisphere such as Argentina and Australia. It is more likely attributable to unobserved seasonal variations in labor efforts and capital utilization rates (e.g., Braun and Evans, 1998). Given that the objective of this paper is to evaluate the welfare properties of seasonal and cyclical monetary policies, I choose to approximate the technology seasonality based on Solow residuals to keep the model tractable. There are no obvious reasons to speculate the policy analysis to be significantly affected if the measurement issues are explicitly taken into account.

Unlike the technology seasonal shifters, the preference seasonal shifters have a first quarter trough and a third quarter peak. This peak represents a higher

[7] This value of γ is close to the higher end of previous estimates. Since the magnitude of seasonal variations in consumption directly depends on γ, this high value seems to be necessary in order to capture the residual seasonality in the consumption Euler equation where the real interest rate has little seasonality.

[8] This is implemented by repeatedly solving the model to minimize a quadratic loss function. Specifically, given an initial guess of the θ's, along with all other parameters calibrated above, I solve for the seasonal steady-state equilibrium and find the model's predictions about the seasonal patterns of labor hours. The distance between the model's prediction and the 'true' patterns from the data is measured by a quadratic loss function. The Matlab function *fmins* is called to minimize this loss function by choosing the θ's. The initial guess is obtained by regressing the implied θ_t series in the consumption-leisure decision equation on four seasonal dummies.

[9] To test the VAR(1) specification, I perform a likelihood ratio test as proposed by Sims(1980). The null hypothesis that the set of stochastic variables is generated from a Gaussian VAR with one lag against the alternative specification with two lags (or four lags) is accepted at a 5% critical level.

Table 1
Parameters of preferences and technologies

Preferences		
$U(\hat{C}_t, N_t) = \ln(\hat{C}_t) + \theta_t \ln(T - N_t)$	$\gamma = 0.65$	$T = 1369$
$\hat{C}_t = C_t + \gamma C_{t-1}$	$\theta_1 = 2.1739$	$\theta_2 = 2.2687$
	$\theta_3 = 2.3734$	$\theta_4 = 2.3143$
Production technologies		
$F(K_t, A_t N_t) = K_t^{\alpha}(A_t N_t)^{1-\alpha}$	$\alpha = 0.4124$	
$A_t = A_{t-1} \exp(\lambda_t)$	$\lambda_1 = -0.1361$	$\lambda_2 = 0.0932$
	$\lambda_3 = 0.0304$	$\lambda_4 = 0.0322$
Transaction technologies		
$q_t \mathcal{S}(z) = \frac{\eta}{\psi} q_t (1 - z^{\psi})$	$\eta = 1$	$\psi = 0.2$
	$q_1 = 0.0186$	$q_2 = 0.0184$
	$q_3 = 0.0183$	$q_4 = 0.0175$
Capital depreciation rate	$\delta = 0.025$	
Subjective discount factor	$\beta = 0.9926$	

Table 2
Parameters of the stochastic shock processes[a]

Autoregressive parameters			Covariance parameters		
$\tilde{\lambda}$	$\ln(\tilde{q})$	$\ln(\tilde{g})$	ε_λ	ε_q	ε_g
−0.2419	0	0	0.0226	0.1852	0.1364
0	0.7897	0	0.1852	0.0040	0.2669
0	0	0.6191	0.1364	0.2669	0.0050

[a] The zero elements in the first three columns correspond to the autoregressive parameters that are not statistically significant. The diagonal elements in the covariance matrix (the last three columns) are standard deviations of the innovation terms (i.e., the ε terms) in the shock process described in (19), and the off-diagonal elements are correlation coefficients.

marginal utility of leisure and can thus be interpreted as a 'vacation effect'. The transaction technology also displays significant seasonal variations. The level of q_t peaks in the first quarter, drops slightly in the second and the third quarter, and reaches its lowest level in the fourth quarter. When q_t is high, the required credit services for each unit of credit goods is high. Thus a higher q_t represents a 'negative shock' to the transaction technology.[10]

[10] Without data of the credit service output, it is difficult to interpret the seasonal components of q_t. Casual observations suggest that this seasonality may be attributable to seasonal changes in the composition of business activities and household activities. Business activities tend to require more credit transactions relative to the household sector, and, in general, the business sector is more efficient in using credit services due to economies of scale. During seasons when business activities are high, the required credit services for each unit of credit transactions tend to go down.

4. Model evaluation

This section compares the model's equilibrium predictions with the U.S. data that are not adjusted for seasonality. To obtain equilibrium predictions, the model is solved using standard numerical methods. Following Barsky and Miron (1989), I decompose each stationary time series into a deterministic seasonal component and a stochastic residual component. In the model, the log levels of variables including output, consumption, investment, capital stock, real money balances, and average labor productivity are all first-difference stationary. Thus these variables are logged and first differenced, both in the model and in the data. The seasonal components of each series are the regression coefficients of the log-differenced series on four seasonal dummy variables, and the stochastic components are the regression residuals.

4.1. Seasonal implications

Table 3 compares the seasonal patterns of the aggregate time series in the U.S. data with those from the model. The numbers reported are seasonal means of growth rates for each series. They are in terms of deviations from the (non-seasonal) average growth rates. All variables except for the capital rental rate (i.e., the real interest rate), nominal interest rate, and inflation rate are logged before taking the first difference. The first difference filter is applied to the levels of the real interest rate and of the nominal interest rate, while in the case for the inflation rate, the annualized level is reported. The standard errors are computed based on the Newey and West (1987) weighting matrix with 12 autocorrelation lags.

Before formally evaluating the model's ability in accounting for seasonal facts, it is necessary to identify the variables that provide independent information for the purpose of model evaluations. First, quantity variables including labor hours, capital stocks, and aggregate output do not provide such information for the following three reasons: (i) labor hours should be exactly matched by the choice of the preference seasonal shifter θ_t; (ii) capital stock is a stock variable, which should not display much seasonality either in the model or in the data; and (iii) the Solow residual λ_t is constructed to capture 'residuals' of output movements unaccounted for by the input variables in the production function, and thus it is not surprising to have output seasonals closely matched with the data. Second, given the match for the above three variables, average productivity and capital rental rate should not be used to evaluate the model's predictions because they are exact functions of the above variables. Third, both consumption and investment do not contain independent information because one implies the other given the resource constraint and the match for output. Finally, since the transaction technology seasonal shifter q_t is constructed to capture the residual movements between the velocity and the nominal interest

Table 3
Seasonal patterns[a]

Series	Data				Model forecast			
	Q_1	Q_2	Q_3	Q_4	Q_1	Q_2	Q_3	Q_4
Output	− 9.66	5.75	− 0.74	4.65	− 9.41	5.56	− 0.75	4.60
	(0.36)	(0.43)	(0.20)	(0.23)				
Consumption	− 7.50	2.90	− 0.06	4.66	− 2.25	1.94	− 1.90	2.21
	(0.37)	(0.32)	(0.18)	(0.25)				
Investment	− 14.75	12.35	− 2.23	4.62	− 24.22	13.37	1.60	9.24
	(0.47)	(0.79)	(0.36)	(0.40)				
Capital	− 0.26	0.08	0.02	0.16	− 0.38	− 0.00	0.05	0.34
	(0.02)	(0.02)	(0.01)	(0.02)				
Labor hours	− 2.18	0.91	− 3.82	5.08	− 2.18	0.91	− 3.82	5.08
	(0.16)	(0.26)	(0.31)	(0.26)				
Average	− 7.48	4.83	3.08	− 0.44	− 7.23	4.64	3.07	− 0.48
productivity	(0.42)	(0.40)	(0.28)	(0.39)				
Rental rate	− 0.83	0.49	− 0.07	0.40	− 0.37	0.22	− 0.03	0.18
	(0.04)	(0.04)	(0.02)	(0.02)				
Inflation rate	4.70	5.96	5.83	4.75	4.70	4.21	4.27	3.47
	(1.21)	(1.24)	(1.06)	(0.98)				
Nominal	− 0.01	0.06	− 0.02	− 0.03	0.04	0.05	− 0.02	− 0.06
interest rate	(0.04)	(0.09)	(0.05)	(0.09)				
Velocity	− 8.51	5.87	− 1.15	3.79	− 7.82	5.43	− 1.21	3.60
	(0.37)	(0.44)	(0.26)	(0.21)				

[a] All data series except for output, capital stock, and labor hours are taken from Barsky and Miron (1989). Output is constructed by adding up consumption and investment, and capital stock is computed from the investment flow and a quarterly depreciation rate of 0.025. The hours series is the efficiency units constructed by Hansen (1991). The sample period for all series runs from quarter one in 1960 to quarter four in 1984. The numbers in parantheses are standard errors. In the second row, the term Q_j denotes quarter $j \in \{1,2,3,4\}$.

rate in the money demand equation, only one of these two nominal variables needs to be examined. In summary, variables containing independent information for model evaluation purposes include investment (or consumption) on the real side, and inflation rate and nominal interest rate on the nominal side.

From Table 3, we see that the model successfully captures the seasonal patterns of investment, but the magnitude is larger than that in the data. This is so because, with perfect foresight at the seasonal frequency, the consumer can plan ahead to smooth consumption by drawing down or building up investment. Nonetheless, the magnitude of investment seasonals would have been more dramatic if the local durability of consumption were absent. With local durability, instead of smoothing consumption *purchases* across seasons, the consumer tries to smooth consumption *services* which depend on consumption purchases during both the current period and the previous period. The magnitude of investment seasonal variations is thus partially offset by the seasonal variations in consumption purchases.

The model is more successful in explaining seasonal patterns of nominal variables. Compared with a standard cash-in-advance (CIA) model, which can be nested from the baseline model by setting $q_t = \infty$ and $\gamma = 0$, the model here does a better job in matching the seasonality of the inflation rate and of the nominal interest rate (see Fig. 3).

Two features of the model are crucial in accounting for the seasonal observations: consumption durability and shocks to the transaction technology. The role of consumption durability can be best understood by examining the intertemporal Euler equation

$$\mathrm{E}_t\left\{\beta\frac{U_c(t)}{U_c(t+1)}\tilde{R}^k_{t+1} - 1\right\} = 0, \tag{20}$$

where $U_c(t)$ denotes the marginal utility of consumption at date t, and $\tilde{R}^k_{t+1}$ is the gross real interest rate adjusted for inflation tax. When $\gamma = 0$, Eq. (20) reduces to

$$\beta\frac{C_t}{C_{t+1}}\tilde{R}^k_{t+1} - 1 \equiv u_{t+1}, \tag{21}$$

where u_{t+1} is a white noise process with $\mathrm{E}_t\{u_{t+1}\} = 0$. In consequence, any deterministic seasonal components of the processes $\{C_t/C_{t+1}\}$ and $\{\tilde{R}^k_{t+1}\}$ must net out from the left-hand side of (21). However, this is not true given that the growth rate of consumption exhibits much stronger seasonality than the real interest rate in the U.S. data that are not adjusted for seasonality.[11] Thus, in general, γ should not be zero. In this sense, the durability property of consumption (i.e., $\gamma > 0$) performs a role of seasonal adjustment in (20) so that seasonal fluctuations in the real interest rate are effectively dampened.

The transaction technology shock q_t also plays an important role in explaining the seasonal facts, especially on the nominal side. In a standard CIA model without this feature, the velocity and the nominal interest rate vary in a one-for-one fashion in the money-demand equation. This is inconsistent, however, with the seasonally unadjusted data in which velocity is strongly seasonal but nominal interest rates are not. In light of the money-demand equation (18), the transaction technology shock q_t drives a 'wedge' between the velocity and the nominal interest rate, and thus effectively absorbs the residual seasonality. It

[11] For a similar line of arguments, see Singleton (1988).

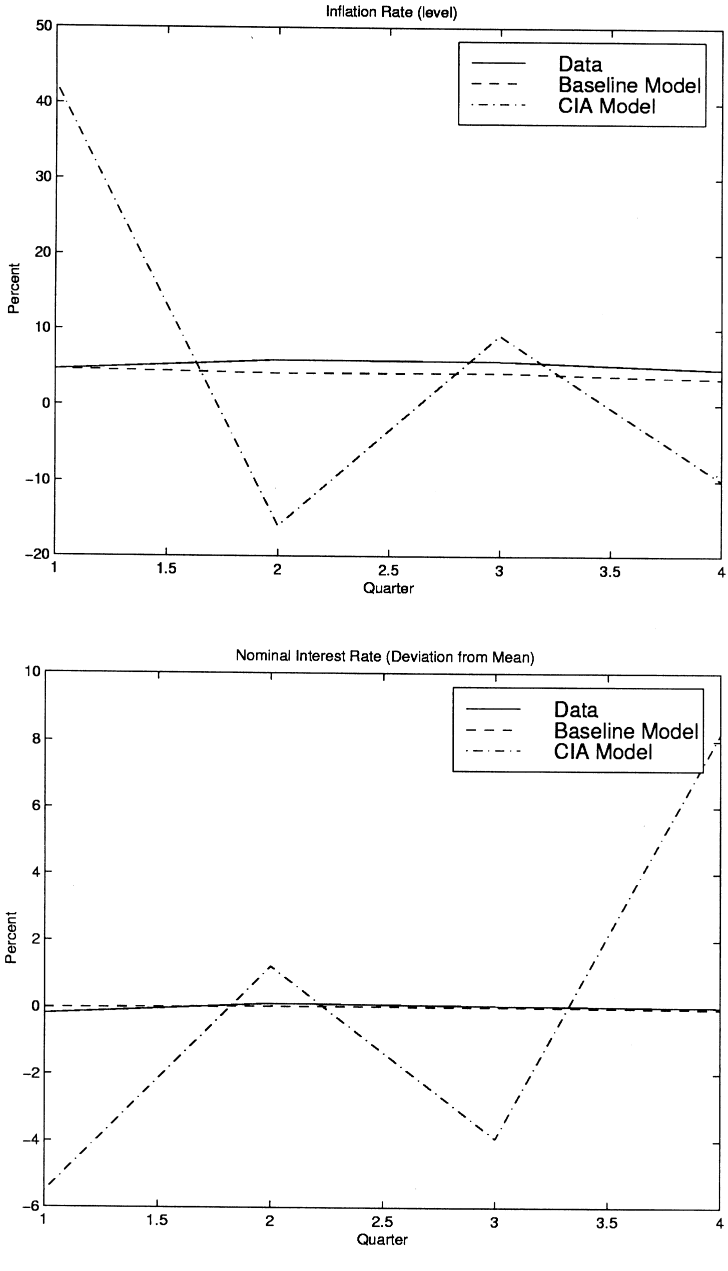

Fig. 3. Seasonal patterns of nominal variables: the baseline model versus a cash-in-advance (CIA) model.

Table 4
Business cycle statistics[a]

	Data		Model forecast	
Series (x)	σ_x/σ_y	corr(x, y)	σ_x/σ_y	corr(x, y)
Output	1.53	1.00	1.85	1.00
Consumption	0.76	0.85	0.84	0.87
Investment	2.04	0.89	1.85	0.84
Capital	0.18	0.14	0.12	0.29
Labor hours	0.89	0.27	0.47	0.98
Rental rate	0.09	0.95	0.04	0.98
Inflation rate	0.31	0.05	0.02	0.25
Price level	0.58	− 0.46	0.79	− 0.45
Nominal interest rate	0.29	0.35	0.58	0.71
Velocity	0.92	0.79	0.90	0.99

[a] The statistics are computed based on seasonally adjusted series. The seasonal adjustment is made by removing the seasonal dummies. In the second and the fourth columns, the first number is the standard deviation of output (σ_y), in percentage terms, and the remaining numbers are the standard deviations of series x relative to that of the output.

allows the velocity to fluctuate in response to seasonal shifts in preferences and technologies, while keeping the nominal interest rate relatively smoothed.

With both consumption durability that serves to dampen seasonal variations in the real interest rate and the transaction technology shock that effectively smooths fluctuations in the nominal interest rate, the inflation rate is also smoothed due to Fisher's parity. Thus, both consumption durability and seasonal variations in transaction technologies are important in accounting for the seasonal facts, especially for nominal variables.

4.2. Business cycle implications

I now examine the model's business cycle implications by looking at the second moment properties of the seasonally adjusted time series. The seasonal adjustment is implemented by removing seasonal dummies from the unadjusted series. Table 4 displays the relative volatility and cross-correlations with output for selected series in the U.S. data and from the model. All the reported statistics from the model are sample averages of 500 random draws with length 100, which corresponds to the sample length in the data.[12]

[12] The actual sample length of each random draw is 300. To avoid dependence of the results on initial conditions, I discard all but the last 100 observations in computing the business cycle statistics.

The cyclical properties of both the real and nominal variables in the model match the data reasonably well. The model predicts, in accordance with the data, that consumption is less volatile than output which is in turn less variable than investment. But it overstates fluctuations in output and understates the relative volatility of labor hours. The cross-correlation patterns in the model for all real variables except for capital stock and labor hours closely match the data. These are all common features of a standard real business cycle model. On the nominal side, the model correctly predicts that inflation rate, price level and nominal interest rate are less volatile than output, that output is positively correlated with inflation rate but negatively with price level, and that nominal interest rate and velocity are both procyclical.

To summarize, the model performs reasonably well in matching the seasonal and cyclical patterns of real variables in the data, and it does a better job than a standard CIA model on the nominal side. There are two key elements that contribute to the model's empirical success, namely the consumption durability and the transaction technology shock.

5. Policy experiments

This section evaluates the welfare implications associated with three alternative monetary policy rules: (1) the historical policy that smooths nominal interest rates across seasons but allows interest rates to be procyclical, (2) the constant-money-growth rule advocated by Friedman (1959, 1982), and (3) the constant-interest-rate rule proposed by Carlstrom and Fuerst (1995, 1996). I compute the welfare gains or losses incurred by switching from one policy rule to another, while keeping the (non-seasonal) steady-state seigniorage revenue constant.

The welfare loss under each policy is measured by the percentage increase in consumption that is necessary to make the representative household as well off as under Friedman's rule (the rule that calls for zero nominal interest rate). In particular, I solve for x in the following equation:

$$\sum_{t=0}^{\bar{T}-1} \beta^t [\ln((C_t^{\star} + \gamma C_{t-1}^{\star})(1+x)) + \theta_t \ln(T - N_t^{\star})] - \bar{U}_{\bar{T}} = 0, \tag{22}$$

where $\bar{T} = 100$ is the sample length and $\bar{U}_T$ is the welfare in the economy under Friedman's rule

$$\bar{U}_{\bar{T}} \equiv \sum_{t=0}^{\bar{T}-1} \beta^t [\ln(\bar{C}_t + \gamma \bar{C}_{t-1}) + \theta_t \ln(T - \bar{N}_t)]. \tag{23}$$

The star variables $C_t^\star$ and $N_t^\star$ denote equilibrium allocations in an economy under one of the three monetary policy rules, while the bar variables $\bar{C}_t$ and $\bar{N}_t$ are those under Friedman's rule.

Equilibrium allocations under the historical policy are obtained by solving the model based on the calibrated monetary policy process along with other calibrated parameters. The same procedure is followed to obtain equilibrium allocations under the constant-money-growth rule and under the constant-interest-rate rule, where I set the money growth rate and the nominal interest rate to a constant, respectively. When the monetary policy is conducted by choosing nominal interest rates, money supply becomes endogenous. The equilibrium allocations $\bar{C}_t$ and $\bar{N}_t$ under Friedman's rule are obtained as a special case of the constant-interest-rate rule, with nominal interest rate being zero. Upon obtaining $\bar{C}_t$ and $\bar{N}_t$, the lifetime discounted utility of the representative household under Friedman's rule can be computed using (23). The welfare associated with each of the three policy rules is computed analogously.

In the policy experiments, I keep the (non-seasonal) steady-state seigniorage revenue constant across the three alternative policies. To accomplish this, I first find the steady-state seigniorage level under the historical policy and then peg the seigniorage under each of the two alternative policies at this target level. For example, under the constant-money-growth rule, I can solve the model for any given money growth rate and obtain the corresponding steady-state seigniorage level. I choose the money growth rate that minimizes the distance between the model's predicted seigniorage and the target level by repeatedly solving the model. Similarly, under the constant-interest-rate rule, I can find the level of nominal interest rate that induces the targeted seigniorage revenue.[13]

Table 5 displays the results of the policy experiments. The upper panel shows the welfare losses associated with each policy, both in terms of percentage losses in consumption relative to the economy under Friedman's rule and in terms of billions of dollars. The welfare losses are computed based on 300 random draws with the exogenous shock processes appropriately specified. Each draw has a sample length of 300. To avoid dependence on initial conditions, I discard all but the last 100 observations in each draw. The lower panel of Table 5 displays the (non-seasonal) steady-state implications of each policy.

The table shows that, in the dynamic equilibrium, the historical policy attains higher welfare than both alternatives. Compared with an economy under Friedman's rule, it incurs a welfare loss of about 0.85% of aggregate consumption, whereas the welfare losses associated with the constant-money-growth rule and the constant-interest-rate rule are 0.97% and 0.94%, respectively. In terms of the U.S. real consumption in 1997 ($4913.5 billion), the welfare loss that might

[13] Since the model implies that seigniorage revenue contains a growth component, I divide the seigniorage level by the Solow residual (i.e., the A_t term in the production functions) to induce stationarity and thereby to obtain the steady-state level.

Table 5
Policy comparisons[a]

	Historical policy	Money growth rule	Interest rate rule
Welfare losses			
Consumption equivalence	0.8487	0.9679	0.9404
In billion dollars	41.70	47.56	46.21
Steady-state implications			
Seigniorage-output ratio	0.3443	0.3446	0.3435
Credit service share	0.7025	0.7843	0.5088
Effective inflation tax	1.2464	1.2933	1.1093

[a] The welfare loss of each policy rule is measured by the increase in consumption that is necessary to make the household as well off as under Friedman's rule. The steady-state numbers are those in the non-seasonal steady state. All numbers are in percentage terms except indicated otherwise.

be incurred by switching from the historical policy to the money growth rule is about 5.9 billion dollars, and to the interest rate rule, it is about 4.5 billion dollars. It is also worth noting that the interest rate rule is better than the money growth rule, and this welfare ordering is consistent with previous studies (e.g., Carlstrom and Fuerst, 1995).

The table also shows that, in the steady state, the interest rate rule is a more effective way of collecting seigniorage revenues than the money growth rule: given the target level of seigniorage revenue, the interest rate rule results in a smaller seigniorage-output ratio, and thus higher-steady-state output level, than the money growth rule. The interest rate rule also allocates more resources in the regular goods sector and creates less distortion via the inflation tax. Thus, in the absence of uncertainty, it is a better policy than the money growth rule.

To understand these findings, notice that a main implication of the model is that an inflationary monetary policy associated with higher nominal interest rates causes resources to shift from the regular goods production sector to the credit service production sector, and thereby creates inefficiency. The interest rate rule prevents such resource shifting from happening because it smooths the effective inflation tax rate. Under the money growth rule, however, nominal interest rates fluctuate so that the resource shifting effect is strong. Thus, the interest rate rule is welfare improving relative to the money growth rule because it reduces the inefficiency caused by the resource shifting effect. We also find that, in the dynamic equilibrium with both seasonal and cyclical fluctuations, the historical policy performs better than both alternatives. To understand this finding, it is sufficient to compare the historical policy rule with the interest rate rule, since the latter dominates the money growth rule at both the seasonal and cyclical frequencies. Among all the main factors that affect welfare in addition to the resource shifting effect, there is a ‘Fisherian effect’ which is explained below. In a standard real business cycle world, the real interest rate is strongly procyclical. In the monetary economy here, Fisher’s equation relates the real interest rate to the nominal interest rate and the inflation rate. Since the inflation rate is weakly procyclical, if the nominal interest rate is procyclical, it would allow the real interest rate to co-move with output according to Fisher’s equation. But if the nominal interest rate is pegged, the real interest rate will have to be counter-cyclical. Since the equilibrium allocation in a real business cycle economy is Pareto optimal, the policy with a procyclical nominal interest rate is ‘closer’ to efficiency than the alternative with constant interest rate, *ceteris paribus*. The ‘Fisherian effect’ applies to the seasonal cycle as well. Thus, there are two offsetting effects associated with the interest rate smoothing policy in terms of social welfare. On one hand, it increases welfare by preventing resources from shifting in and out of the credit service production sector. On the other hand, it causes distortions through the ‘Fisherian effect’ since the real interest rate cannot co-move with output under the interest rate rule. The overall welfare consequence depends on which effect is dominant. It turns out that the resource shifting effect dominates over the seasons while the ‘Fisherian effect’ dominates over the business cycles. This is mainly because seasonal variations are perfectly anticipated, while cyclical fluctuations are not. Over the seasonal cycle, if agents anticipate resource shifting across sectors, they will have to plan ahead of time to respond to such shifting, which creates a larger distortion than the welfare gain from the ‘Fisherian effect’. Thus, seasonal interest rate smoothing policy is a better policy than one allowing interest rates to be pro-seasonal. Over the business cycles, the reverse is true because the ‘Fisherian effect’ dominates. Therefore, the historical policy is a better policy than the interest rate rule.

6. Conclusions

I have developed a general equilibrium monetary model to explain the observed seasonal and cyclical patterns of aggregate fluctuations in the postwar U.S. economy. The model has three distinctive features. First, the model’s equilibrium paths display both seasonal variations and cyclical fluctuations, where seasonality is introduced through periodical seasonal shifts in preferences and technologies. Second, credit service production is explicitly modeled, and the distinctions between cash goods and credit goods are endogenous. Finally, and most importantly, there are two key elements in the model, namely consumption durability and a shock to transaction technologies, that contribute significantly to the model’s overall success in accounting for seasonal and business cycle facts. The model is used to answer two sets of questions. One is positive in nature and studies whether a standard real business cycle model can be extended to explain both the seasonal and cyclical behaviors of aggregate variables, including both real and nominal variables. The other is normative and evaluates the welfare costs of alternative monetary policy rules in response to aggregate fluctuations over the two types of cycles. In particular, the Fed's historical monetary policy that smooths nominal interest rates at the seasonal frequency but not at the business cycle frequency is compared with a constant-money-growth rule and with a constant-interest-rate rule.

The answer to the first set of questions suggests that a standard real business cycle model can be extended in a straightforward way to account for seasonal facts in the U.S. economy, and it does a reasonably good job in doing so. The model is successful in accounting for seasonal variations in *nominal* variables, including inflation rates and nominal interest rates. This success is mainly attributable to the assumptions of consumption durability and seasonal variations in transaction technologies. Additionally, consumption durability is crucial in explaining seasonal variations in aggregate variables such as consumption and investment. The answer to the second set of questions reveals that, although the seasonal cycle and the business cycle display similar characteristics of aggregate fluctuations, they do differ in key aspects that call for different monetary policy treatments. In particular, the anticipated versus unanticipated nature of the two types of cycles implies that the historical monetary policy that treats the two cycles differently is welfare improving relative to the constant-interest-rate rule and the constant-money-growth rule. We conclude that for the purpose of evaluating alternative monetary policy rules in response to aggregate fluctuations, seasonal variations are an important aspect of the economy that should be explicitly integrated into the model. We also learn that modeling consumption durability and an explicit transaction technology is important in accounting for the seasonal and business cycle facts.

Finally, a comparison between the general equilibrium welfare analysis in this paper and that of Poole's (1970) reveals some interesting points. Poole (1970) shows that if shocks to money demand dominate, smoothing nominal interest rates is a desirable policy; if the shocks mainly originate in the goods market, then interest rates should be allowed to move because the interest rate movements would partially offset output fluctuations. In the economy studied in this paper, the transaction technology shock acts like a money demand shock, and it is more important over the seasons. However, over the business cycles, the effects of the more-persistent technology shocks build up while the less-persistent transaction technology shocks average out. Thus, Poole's (1970) insights also suggest that the policy that calls for interest rate smoothing at the seasonal frequency but not at the business cycle frequency is desirable. This is perhaps surprising given the fact that the welfare criterion in this paper is the representative agent's lifetime discounted indirect utility, while in Poole's (1970) economy, it is the stability of output fluctuations.

A natural extension of this research is to investigate welfare consequences of alternative exchange-rate regimes in an open economy environment. As pointed out by Taylor (1993), Poole's (1970) insights suggest that if a country specific shock to money demand is dominant, then a fixed exchange-rate system works better because it offers the same advantage as smoothing nominal interest rates; if a country specific shock to the goods market is more important, then a flexible exchange-rate system works better. It would be interesting to find out whether this intuition holds in analyzing alternative exchange-rate regimes in a dynamic general equilibrium open economy model.

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