Seasonal monetary policy

Marcelo Veracierto

Introduction and summary

It is widely known that economic activity does not evolve smoothly over the course of a year, but that it varies systematically across the different seasons. This is not surprising: Weather is an important factor in many sectors of production. While agriculture is an obvious example, construction is another important activity affected by weather: No doubt, it is much harder to build a house in Chicago during the winter months than during the rest of the year. Institutional arrangements also lead to seasonal fluctuations in economic activity. For instance, a disproportionate fraction of American families take vacations during the summer months partly because they coincide with school recess. Another example is Christmas, which sharply increases retail activity during the last month of the year. While most modern discussion about monetary policy centers on what is the best policy to follow over booms and recessions, very little is said about what is the best policy to follow across different seasons. However, this has not always been the case. The evolution of U.S. monetary institutions and, in particular, the creation of the Federal Reserve System have been partly guided by this discussion.

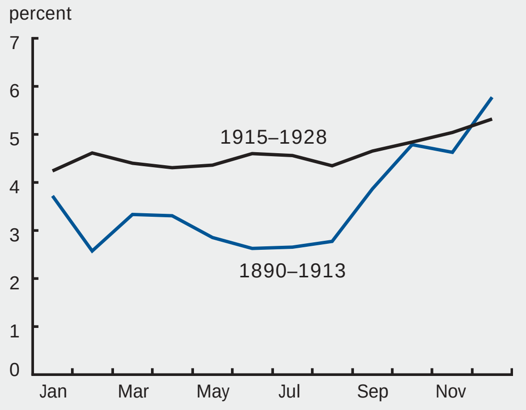
Before the creation of the Federal Reserve System in 1914, the U.S. monetary system was commonly criticized for its alleged “inelasticity” in responding to fluctuations in the demand for credit. While some of these fluctuations were associated with business cycles and bank panics, an important part of them were the result of regular seasonal fluctuations in economic activity. As a matter of fact, in those days it was common for the U.S. economy to go through recurrent periods of monetary tightness during the fall crop-moving and Christmas seasons (September through December). To illustrate this, it suffices to consider the seasonal pattern for short-term interest rates. The reason is that, to the extent that the end-of-year increase in the demand for credit was not matched by a comparable increase in money supply, the short-term interest rates would have to increase. A classic source for the seasonal behavior of interest rates is Kemmerer (1910), who reported the seasonal weekly pattern for average interest rates on call loans in the New York Stock Exchange between 1890 and 1908. Indeed, Kemmerer showed a strong seasonal pattern: He reported that the call rate decreased quite rapidly from 7.38 percent during the last week of the year to 2.50 percent during the last week of January. Moreover, after a long period of relative stability, the call rate increased from 3.04 percent during the first week of September to reach a peak of 7.38 percent during the last week of the year.

To use the words of Friedman and Schwartz (1963, p. 292): “That seasonal movement was very much in the minds of the founders of the (Federal Reserve) System and was an important source of their belief in the need for an ‘elastic’ currency.” In fact, the creation of the Federal Reserve System in 1914 changed the seasonal behavior of interest rates quite dramatically. Figure 1 shows the average call rate in New York City during the periods 1890–1913 (before the creation of the Fed) and 1915–28 (after the creation of the Fed, but before the Great Depression). For the period before the creation of the Fed, we see the same seasonal pattern that Kemmerer reported in weekly data: Interest rates rising steadily between September and December, and dropping sharply in January. During the period after the creation of the Fed, we see interest rates behaving much more smoothly. We still

Marcelo Veracierto is a senior economist in the Research Department at the Federal Reserve Bank of Chicago.
The author benefited from helpful discussions with Bruce Smith while they were colleagues at Cornell University. He also thanks David Kang and Tina Lam for research assistance.

FIGURE 1

Average nominal call rates in New York City



observe a noticeable increase at the end of the year, but it is small compared to the sharp increases that took place before the creation of the Fed. This type of evidence led Friedman and Schwartz (1963, p. 293) to claim that "the System was almost entirely successful in the stated objective of eliminating seasonal strain."

In order to attain such a smooth path for interest rates, the Federal Reserve had to meet the seasonal variations in demand with accommodating expansions and contractions in the supply of high-powered money. Indeed, after presenting supporting evidence, Friedman and Schwartz (1963, p. 294) stated that "the seasonal variation in currency outside the Treasury and Federal Reserve Banks and, we presume, in the total stock of money were decidedly wider in the 1920s than in the earlier periods." In recent times the Federal Reserve has continued to generate large seasonal variations in the quantity of money. Figure 2 reports the seasonally unadjusted monetary base growth rate between 1959:Q2 and 1988:Q2. We see that the monetary base follows a strong seasonal pattern: Its growth rate is relatively low in the first quarter of the year and increases monotonically throughout the rest of the year.

The purpose of this article is to evaluate the consequences of the Federal Reserve following this type of seasonal policy. While smoothing interest rates across seasons was one of the initial objectives of the Federal Reserve System, it is surprising how little work has been done to analyze the associated effects. Would allocations and welfare be significantly different if, instead of following an "elastic" monetary policy across seasons, the Fed would follow more of a "lean against the wind" stance? More precisely, what would be the consequences of following a constant growth rate of money instead of smoothing interest rates across seasons?

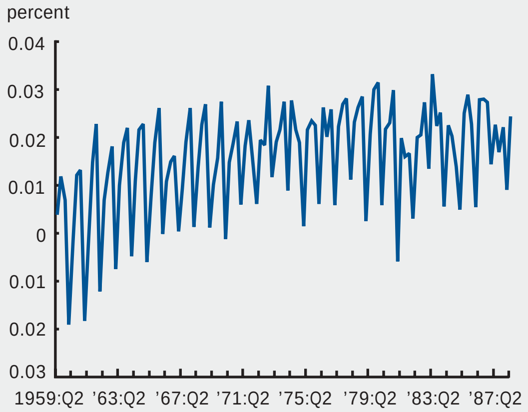
The main exercise in this article is to analyze what would the effects be of switching from the seasonal money growth rates that the Fed engineers to a constant growth rate of money. The results in terms of nominal interest rates are quite dramatic. Under a constant money growth rate, the nominal interest rate would be constant during the first three quarters, but would more than double during the last quarter of the year. That is, the pattern for nominal interest rates would resemble the one corresponding to the period before the creation of the Federal Reserve System. On the contrary, under current Federal Reserve policy, most of the seasonal variations in nominal interest rates are eliminated. Despite this, the seasonal monetary policy regime has no important consequences for real allocations: The seasonal patterns for consumption, output, hours worked, and real cash balances are basically the same if the Fed smooths interest rates or if it follows a constant rate of growth of money. As a consequence, the welfare effects of both types of policies are virtually the same.

Smoothing interest rates across the different seasons would have more significant effects if the nominal interest rate targeted were equal to zero at every quarter, that is, if the Federal Reserve followed the celebrated "Friedman rule." Output would increase by 1.1 percent in every season. However, the welfare benefits of switching to the zero interest rates would still be small: only 0.1 percent in terms of consumption.

The rest of the article is organized as follows. The related literature is discussed in the next section. I describe the environment in the third section. The benchmark economy is calibrated to U.S. data in the fourth section. I compare the effects of different

FIGURE 2

Monetary base quarterly growth rates, 1959:Q2 to 1988:Q2



seasonal monetary rules in the fifth section. In the sixth section, I investigate the main source of seasonal fluctuations in the U.S. economy. Three appendices provide all the technical details.

Related literature

This is not the first article to analyze the effects of seasonal monetary policy.[1] Miron (1986) analyzed the problem of a large number of identical banks that take the nominal interest rate as given and must decide how to allocate their deposits into reserves and loans. The banks face a cost function, which depends on their reserve–deposit ratios and on the stochastic realization of a variable called "withdrawals." The model is closed with an exogenous amount of deposits and a demand function for loans that depends negatively on the interest rate and an exogenous activity level. The price level and inflation rate are treated as exogenous. Analyzing this framework, Miron finds that if the Federal Reserve controls the demand for loans (through open market operations) in such a way that equilibrium rates are smoothed across different seasons, banks respond by reducing their seasonal changes in reserve–deposit ratios, which in turn lowers the average costs that the banks face (given the convexity of the cost function). This result is interpreted as a reduction in the likelihood of bank panics. While the paper illustrates that smoothing interest can decrease bank panics, it is hard to assess how plausible the model is, given its highly stylized nature and the lack of quantitative analysis.

Mankiw and Miron (1991) also provide an analysis of seasonal monetary policy, but using an IS–LM framework. After parameterizing the equations to U.S. observations, they use their model to evaluate the benefits of smoothing nominal interest rates across seasons, against the alternative of holding the stock of money constant across seasons. They find, both under "classical" and "Keynesian" assumptions, that holding the stock of money constant would lead to extremely seasonal interest rates: The seasonal amplitude would be about 500 basis points. They also find that, even under extreme Keynesian assumptions about the price level, moving to a constant stock of money regime would have small effects on the seasonal behavior of output.

This article is more closely related to Mankiw and Miron (1991) than to Miron (1986), since it is completely silent on "bank panics." However, a big methodological difference is that it follows a modern dynamic general equilibrium approach instead of an IS-LM analysis. An advantage of this approach is that it allows us to evaluate any welfare benefit of changes in monetary policy. Another advantage is the internal consistency between microeconomic decisions and macroeconomic outcomes. Despite these important differences, this article obtains results that are quite similar to Mankiw and Miron (1991): Switching to a smooth money rule would lead to extremely seasonal nominal interest rates but would have negligible effects on real variables.

The model economy

This article uses a prototype model that has been previously used to evaluate the effects of monetary policy over the business cycle. The model is the one studied by Cooley and Hansen (1995), which introduces a cash-in-advance constraint similar to Lucas and Stokey (1983) into the real business cycle model analyzed by Hansen (1985). An important difference with Cooley and Hansen (1995) is that, instead of having stochastic shocks, this article introduces systematic seasonal changes in preferences, technology, and monetary policy.

The model has a representative agent that likes consuming both a cash good and a credit good, but dislikes working. The household rents labor and capital to a representative firm, which uses them to produce the two consumption goods and investment. The household uses the wage and rental income that it receives from the firm, together with a lump-sum transfer of cash that the agent receives from the government, to purchase consumption goods, investment goods, cash, and bonds. Consumption of the cash good is subject to a cash-in-advance constraint. The cash transfers that the household receives from the government are completely financed by monetary injections.

In this economy the time discount rate, the weight of the cash good in the utility function, the disutility of work, total factor productivity, and the growth rate of money vary deterministically across seasons. Parameter values will be calibrated to reproduce the seasonal fluctuations in consumption, investment, hours worked, real cash balances, and money growth rate observed in U.S. data. Once the model is calibrated to the U.S. seasonal cycles, it will be used to assess the consequences of Federal Reserve monetary policy.

Hereon, a season will be identified with a quarter. For this reason, it will be important to keep track of the year and quarter of the different variables in the model economy. In what follows, $x_{t,s}$ will denote the value of variable x in year t and quarter s, for $s = 1, ..., 4$. To simplify notation, $x_{t,0}$ will be understood to be $x_{t-1,4}$. Similarly, $x_{t,5}$ will refer to $x_{t+1,1}$. A detailed description of the model economy now follows.

The economy is populated by a large number of identical agents. Each agent is endowed with one unit of time every period and has preferences described by the following utility function:

$$1)\quad \sum_{t=0}^{\infty}\beta^{t}\sum_{s=1}^{4}\phi_s\left[\alpha_s \ln c_{t,s}+\left(1-\alpha_s\right)\ln a_{t,s}-\gamma_s h_{t,s}\right],$$

where $0 < \beta < 1$ is the annual discount factor, $c_{t,s}$ is consumption of a cash good, $a_{t,s}$ is consumption of a credit good, and $h_{t,s}$ are hours worked. Note that the parameter ϕ_s introduces a seasonal pattern in quarterly discount factors. Similarly, α_s introduces seasonal variations in the desired mix between cash and credit goods, and γ_s introduces variations in the disutility of work effort (that is, on how much agents dislike working as opposed to enjoying leisure).[2]

Output is given by the following production function:

$$y_{t,s}=z_s k_{t,s}^{\theta}h_{t,s}^{1-\theta},$$

where $0 < \theta < 1$, $k_{t,s}$ is capital, and $h_{t,s}$ is labor. Note that total factor productivity z_s is assumed to vary across the different seasons.

There is a standard capital accumulation technology given by:

$$2)\quad k_{t,s+1} = (1-\delta)k_{t,s} + i_{t,s},$$

where $0 < \delta < 1$ is the depreciation rate of capital, and $i_{t,s}$ is investment.

Not only are the cash good, $c_{t,s}$, and the consumption credit good, $a_{t,s}$, perfect substitutes in production, but there also is a linear technology to transform consumption goods into investment, $i_{t,s}$. The feasibility condition for output is given by

$$c_{t,s} + a_{t,s} + i_{t,s} \leq y_{t,s}.$$

At the beginning of every period there is an asset trading session. Agents enter this session with $m_{t,s}$ units of cash brought from the previous period, principal plus interest payments $(1 + R_{t,s-1})b_{t,s}$ on nominal bonds purchased during the previous period, and current lump-sum cash transfers $T_{t,s}$ received from the government. Agents then acquire nominal bonds $b_{t,s+1}$ (which mature during the following period) and cash balances (which are required to purchase the cash good). Agents do not have access to any further cash balances to purchase the cash good once the asset trading session is over. Therefore, their cash-in-advance constraint is given by

$$3)\quad P_{t,s}c_{t,s} \leq m_{t,s} + (1 + R_{t,s-1})b_{t,s} + T_{t,s} - b_{t,s+1},$$

where $P_{t,s}$ is the price of the cash good in terms of money. This constraint will always hold with equality as long as the nominal interest rate is positive in every season.

Aside from this cash-in-advance constraint, households are subject to the following budget constraint:

$$4)\quad a_{t,s}+i_s+\frac{m_{t,s+1}}{P_{t,s}}\leq w_{t,s}h_{t,s}+r_{t,s}k_{t,s}+\left[\frac{m_{t,s}+\left(1+R_{t,s-1}\right)b_{t,s}+T_{t,s}-b_{t,s+1}}{P_{t,s}}-c_{t,s}\right],$$

where $w_{t,s}$ is the wage rate and $r_{t,s}$ is the rental rate of capital. This constraint states that any cash that was not used to purchase the consumption good or bonds, plus the total earnings from renting labor and capital to the firms, can be used to purchase credit consumption good, $a_{t,s}$, investment goods, i_s, and cash balances to carry into the following period, $m_{t,s+1}$.

The representative firm behaves competitively, taking the wage rate and rental rate of capital as given. The problem of the firm is to maximize profits, which are given by

$$5)\quad z_s k_{t,s}^{\theta}h_{t,s}^{1-\theta}-w_{t,s}h_{t,s}-r_{t,s}k_{t,s}.$$

For simplicity, I will assume that government expenditures are equal to zero and that the government doesn't issue bonds. The budget constraint of the government is then given by

$$6)\quad T_{t,s} = M_{t,s+1} - M_{t,s},$$

where $M_{t,s}$ is the aggregate stock of money in circulation. The monetary policy rule is assumed to be as follows:

$$7)\quad M_{t,s+1}=e^{\mu_s}M_{t,s}.$$

Observe that the government follows a constant annual growth rate of money rule, but allows the quarterly growth rate to vary in a systematic way across the different seasons.

In a competitive equilibrium: 1) households maximize their utility function (equation 1) subject to the cash-in-advance constraint, (equation 3), the budget constraint (equation 4) and the capital accumulation equation (equation 2); 2) firms maximize profits (equation 5); 3) the government budget constraint (equation 6) is satisfied; 4) the cash market clears

8) $m_{t,s} = M_{t,s}$;

and 5) the bonds market clears

9) $b_{t,s} = 0$.

The formal conditions characterizing a competitive equilibrium are described in appendix A.

Calibration

The rest of the article focuses on stationary competitive equilibria. That is, equilibria in which each real variable (including real cash balances) may take different values across the different seasons, but the seasonal values must be the same across the different years.[3] The purpose of this section is to select policy, preference, and technology parameter values such that the associated stationary competitive equilibria reproduce the seasonal fluctuations observed in the U.S. economy.

The first step in calibrating the model economy is to determine empirical counterparts for its variables. The empirical counterpart for total consumption, $c_{t,s} + a_{t,s}$, is chosen to be consumption of nondurable goods and services. At equilibrium, consumption of the cash good, $c_{t,s}$, is equal to real cash balances, $M_{t,s+1}/P_{t,s}$. Consequently, it is chosen to be the ratio of the monetary base to the Consumer Price Index. Investment, $i_{t,s}$, is in turn associated with fixed private investment plus consumption of durable goods (which entail purchases of capital goods by the households sector). Output, $y_{t,s}$, is then defined as the sum of these consumption and investment components. Finally, the empirical counterpart for hours worked, $h_{t,s}$, is given by the efficiency equivalent hours series constructed by Hansen (1993), which basically weighs the hours worked by individuals by their earnings.

Having determined the empirical counterparts for the different variables, statistical methods can be used to calculate the corresponding seasonal components. In particular, for each real variable, $x_{t,s}$, the following regression was estimated using non-seasonally adjusted time-series data:

10) $$\ln x_{t,s} = \psi_0(4 \times t + s) + \psi_1 d_1 + \psi_2 d_2 + \psi_3 d_3 + \psi_4 + \varepsilon_{t,s},$$

where ψ_0, ψ_1, ψ_2, ψ_3, and ψ_4 are coefficients, $\varepsilon_{t,s}$ is an i.i.d. (independently and identically distributed) normally distributed error with zero mean, and d_s is a dummy variable indicating the quarter (season) of $x_{t,s}$. Observe that the estimated coefficient $\hat{\psi}_0$ provides the quarterly growth rate of the variable. Since all real variables in the model economy are stationary in levels, the seasonal components x_s can then be defined as follows:

11) $$x_s = e^{\hat{\psi}_4 + \hat{\psi}_s}, \text{ for } s = 1, \ldots, 3, \text{ and}$$
$$x_4 = e^{\hat{\psi}_4},$$

where $\hat{\psi}_s$ is the estimated value of y_s, for $s = 1, \ldots, 4$.

Money, $M_{t,s}$, is the only non-stationary variable in the model. However, it is stationary in growth rates. For this reason, the following regression was estimated:

12) $$\frac{M_{t,s+1}}{M_{t,s}} = \psi_1 d_1 + \psi_2 d_2 + \psi_3 d_3 + \psi_4 + \varepsilon_{t,s},$$

where, again, ψ_1, ψ_2, ψ_3, and ψ_4 are coefficients, $\varepsilon_{t,s}$ is an i.i.d. normally distributed error with zero mean, and d_s is a dummy variable indicating the quarter (season) of $M_{t,s}$. The seasonal money growth rates μ_s are then obtained as follows:

13) $$\mu_s = \hat{\psi}_s + \hat{\psi}_4, \text{ for } s = 1, \ldots, 3, \text{ and}$$
$$\mu_4 = \hat{\psi}_4,$$

where $\hat{\psi}_s$ is the estimated value of ψ_s, for $s = 1, \ldots, 4$.

Table 1 reports the results of estimating equations (equations 10 and 12) using U.S. data. Figure 3 depicts the seasonal components obtained from equations 11 and 13 for the different variables, where the levels of all variables with meaningless units of measurement have been normalized to one during the fourth quarter (Q4). We see that the seasonal fluctuations are extremely large in U.S. data. For instance, the output level, y_s, drops to 0.926 during the first quarter (Q1), only to recover to 0.959 and 0.954 during the second (Q2) and third quarters (Q3), respectively. A similar pattern is followed by consumption, $c_s + a_s$, and investment, i_s. The seasonal pattern for hours, h_s, is also significant, but differs quite considerably from the previous variables: Its lowest level takes place during Q3, when it drops to 0.950. Real cash balances, on the other hand, have a weak seasonal pattern: In Q4, they are only 1 percent larger than during the rest of the year. However, (as was evident from figure 2) the growth rate of money, μ_s, has a strong seasonal pattern: The growth rate is basically zero during Q1, jumps to 1.7 percent during Q2, and rises slowly thereafter

TABLE 1

Regression coefficients

	ψ_0	ψ_1	ψ_2	ψ_3	ψ_4
Consumption	.0078222	–.0737527	–.0469182	–.0472672	.9310575
$c_s + a_s$	(71.78)	(–7.02)	(–4.47)	(–4.46)	(93.67)
Real cash balances	.0025632	–.011685	–.0105482	–.0094259	.353
c_s	(18.23)	(–0.86)	(–0.78)	(–0.69)	(27.53)
Investment	.0090536	–.0852452	–.0301924	–.0414874	.0175759
i_s	(31.55)	(–3.08)	(–1.09)	(–1.49)	(0.67)
Output	.0079711	–.0768262	–.0422016	–.0471908	1.297606
y_s	(53.00)	(–5.30)	(–2.91)	(–3.23)	(94.60)
Hours	.0044359	–.0196033	–.0113247	–.051248	.913498
h_s	(64.17)	(–2.94)	(–1.70)	(–7.63)	(144.89)
Money growth rate	N.A.	–.0212816	–.0059991	–.0026545	.022972
μ_s	N.A.	(–11.20)	(–3.18)	(–1.40)	(17.10)

Note: t-statistics are in parenthesis. N.A. indicates not applicable.

reaching 2.0 percent and 2.3 percent during Q3 and Q4, respectively.

Once the seasonal components of the different variables have been determined, parameter values can be selected so that the model economy mimics them quite closely. Appendix C describes this procedure in detail. All calibrated parameter values are depicted in figure 4.

Seasonal monetary policy

While Friedman and Schwartz (1963) acknowledged that “the [Federal Reserve] System was almost entirely successful in the stated objective of eliminating seasonal strain,” they had some doubts about the desirability of this type of policy. On page 295, they give the following qualified statement: “Within the year, there seems little harm and *perhaps* some merit in permitting the stock of money to decline during the summer months and rise in the fall and winter.” At the end of the same paragraph they state “This kind of ‘elasticity’ of the total money stock is *perhaps* desirable.” Friedman (1959, p. 92) takes a much stronger position: “My own tentative conclusion is that it would be preferable to dispense with seasonal adjustments and to adopt the rule that the actual stock of money should grow month by month at the predetermined rate.”

The following question thus arises: Which policy has more merit? Smoothing interest rates across seasons, Friedman’s proposal of following a constant growth rate of money, or some other alternative? The rest of this section explores the different possibilities.

Smooth nominal interest rates

The benchmark economy was calibrated under the actual money growth rates that the U.S. implements across seasons. Figure 4, panel D shows that this policy generates nominal interest rates that are relatively smooth but are not perfectly constant. The first policy question that concerns us is then: What would be the consequences of the Fed changing its actual policy to one of perfectly smoothing interest rates?

To answer this question, I perform the following experiment. I replace the benchmark quarterly money growth rates, μ_s^*, calibrated in the previous section with a seasonal pattern that generates a constant nominal interest rate. The constant interest rate is chosen so that the annual interest rate is the same as in the benchmark economy.[4] The effects of switching to this policy are shown in figure 5. To ease comparisons, benchmark values (corresponding to the economy calibrated in the previous section) are also reported.

Figure 5, panel D, shows the change in interest rates from the benchmark case to the constant interest rate. Observe that the change in interest rates is so small that an almost imperceptible change in monetary growth rates is required to generate it (see figure 5, panel A). With a higher interest rate in the first quarter and a lower interest rate in the third quarter (relative to the benchmark economy), the constant interest rate leads to real cash balances that are somewhat smaller in the first quarter and somewhat larger in the third quarter (figure 5, panel C). This in turn leads to a higher inflation rate in the first quarter and a lower inflation rate in the third quarter (figure 5, panel B). Aside from these changes, we see that the rest of the real variables remain mostly unaffected: The effects on hours, total consumption, investment, and output are negligible. The simulation results thus suggest that the Federal Reserve Bank policy has been quite effective in terms of smoothing interest rates across seasons: Allocations would be basically the same if it completely eliminated any seasonal variations in interest rates.

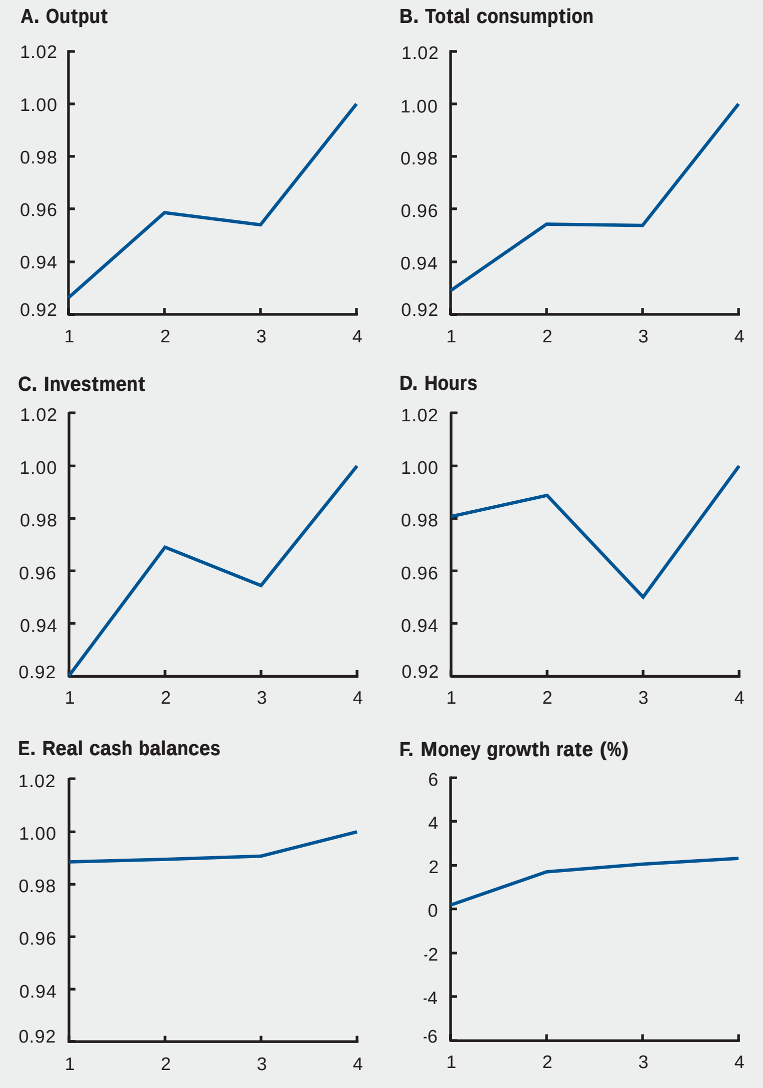
Constant money growth rate

This section evaluates Friedman's recommendation of switching to a constant growth rate of money. To do this, I replace the benchmark quarterly money growth rates calibrated earlier with a constant money growth rate that generates the same annual money growth rate.[5] Figure 6 shows the results.

Figure 6, panel A depicts the constant growth rate of money. We see that, relative to the benchmark case, the growth rate of money is now higher in the first quarter and lower in the third and fourth quarters. The more expansionary monetary policy in the first quarter puts upward pressure on the nominal interest rate during the fourth quarter of the year. Similarly, the more contractionary policy during the third and fourth quarters lower nominal interest rates in the second and third quarter.[6] As a result, the interest rate becomes sharply more seasonal than in the benchmark case. In particular, switching to a constant growth rate of money would make the nominal interest rate constant at about 1.54 percent during the first quarter of the year, but would more than double during the fourth quarter of the year, to 3.34 percent (see figure 6, panel D). Thus, a constant growth rate of money would lead to the same type of increase in fourth quarter nominal interest rates that were observed previous to the creation of the Federal Reserve.

FIGURE 3

U.S. seasonal patterns



Note that the lower nominal interest rates during the second and third quarters and the higher nominal interest rate during the fourth quarter make real cash balances increase during the second and third quarter and decrease during the fourth. The reason is that the nominal interest rate is the opportunity cost of holding money. The effects on the consumption of cash goods (that is, real cash balances) translate into qualitatively similar effects for total consumption. However, the effects are much smaller in magnitude. Figure 6, panel F and panel I, show that the effects on hours and output are also negligible.

Given the small effects on real allocations, the welfare gains of moving to a constant growth rate of money are equal to zero. We conclude that perfectly smoothing interest rates across seasons or following a constant growth rate of money is irrelevant from a welfare point of view: Real variables are hardly affected.

The Friedman rule

In the two previous subsections, I found that smoothing interest rates or the growth rate of money gives rise to similar outcomes, but this doesn't mean that money does not play a role in this economy. This section shows that allocations can be significantly affected by switching to a zero nominal interest rate across seasons (that is, by implementing the "Friedman rule"). Figure 7, panel A depicts the seasonal money growth rates that are needed to implement the zero nominal interest rule.[7] Since nominal interest rates are rather smooth in the benchmark economy, but at a relatively high level, it is not surprising that this path is basically a downward shift of the benchmark path.

With the zero interest rates, real cash balances increase during each season. The reason is that real cash balances have become uniformly cheaper. This, in turn, translates into an increase in total consumption in each quarter. To satisfy this uniform increase in consumption, hours worked, output, and investment must also increase in every season. The effects are substantial: Output increases by about 1.1 percent in every quarter.

Despite the significant effects on real allocations, the welfare consequences of switching to the Friedman rule are small.[8] Agents should be compensated by having their consumption levels increase by 0.1 percent at every date, to make them indifferent with living in a world where the Fed follows the Friedman rule. The intuition for why the Friedman rule increases welfare is quite straightforward. A positive nominal interest rate makes real cash balances

FIGURE 4

Calibrated values

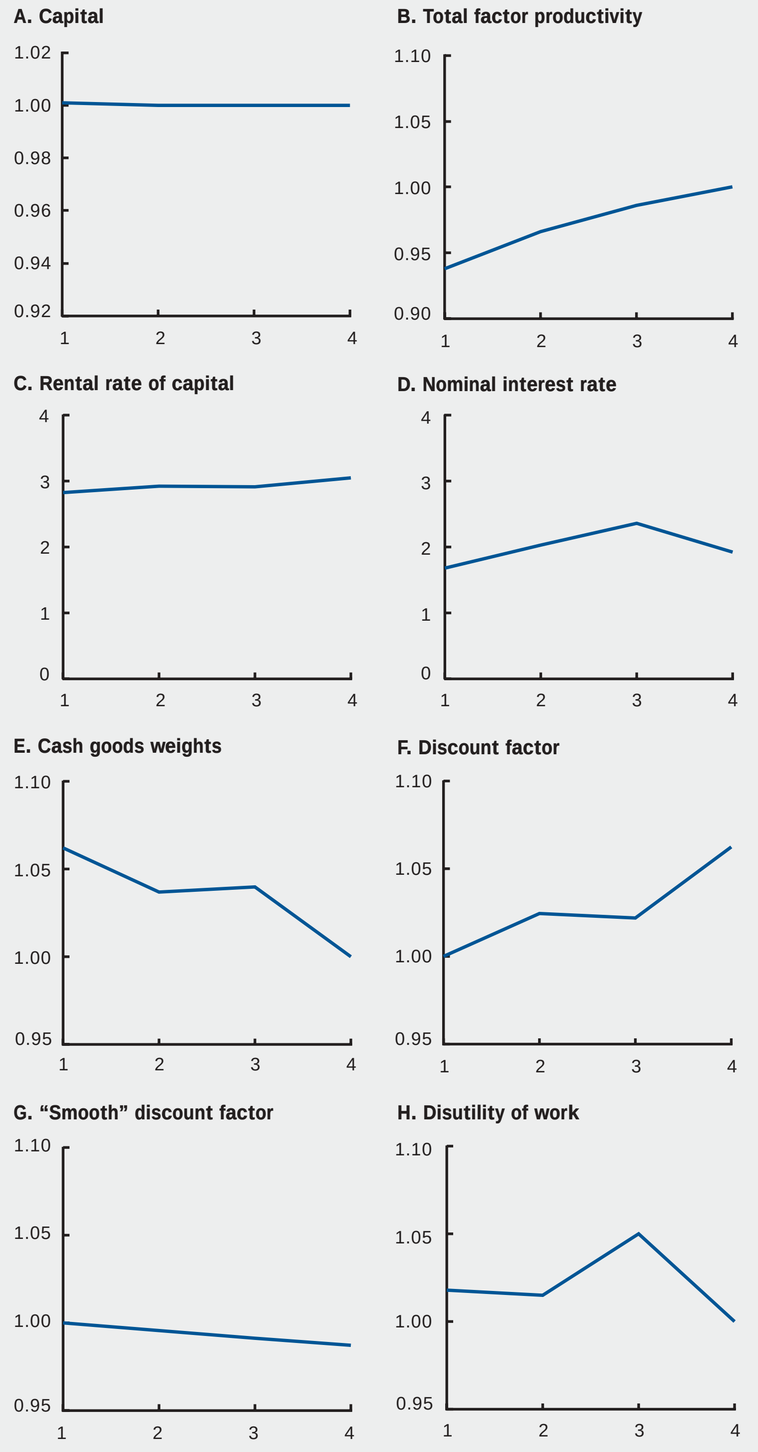
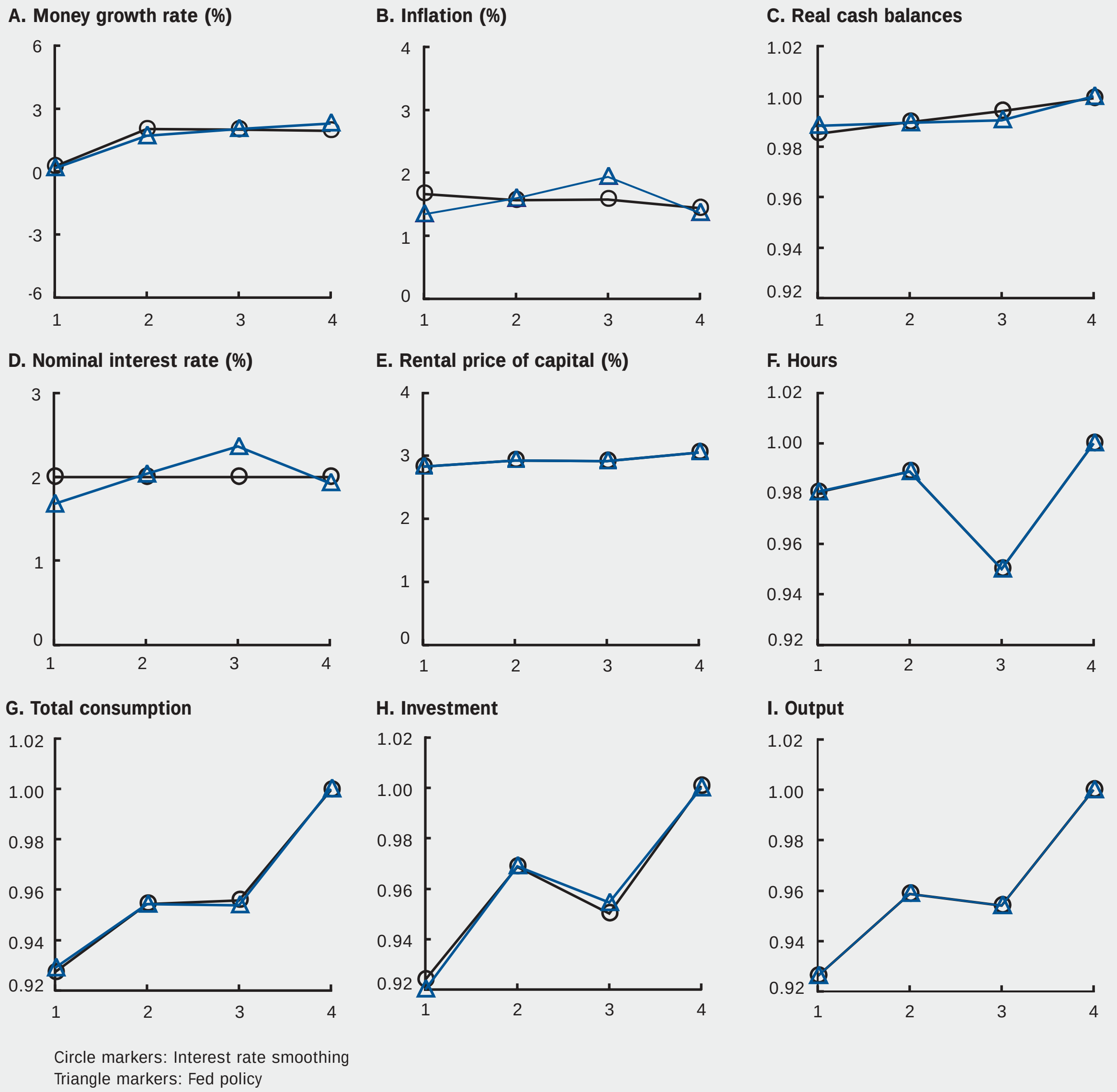


FIGURE 5

Interest rate smoothing



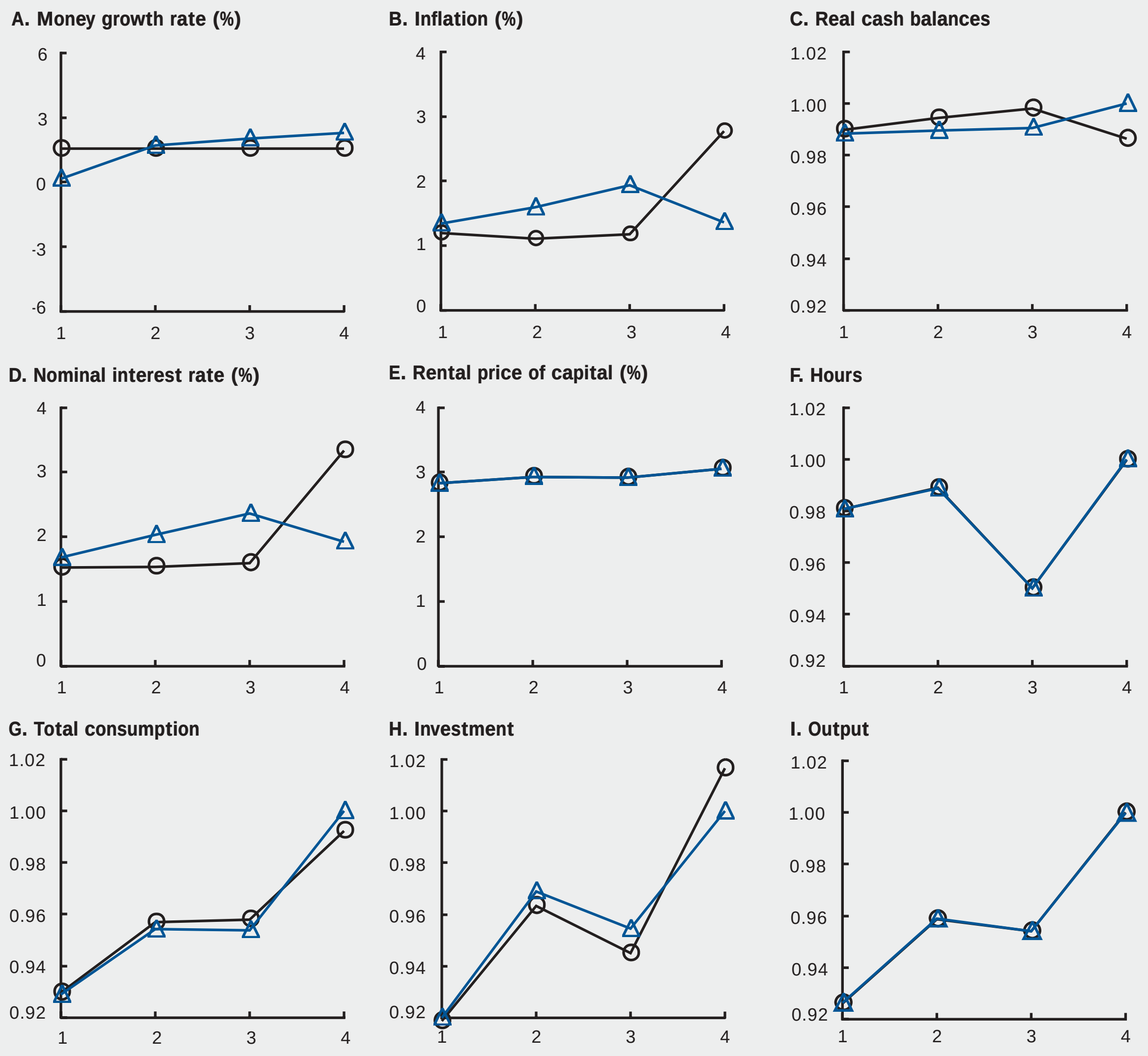
costly, so agents substitute credit goods for cash goods. However, the technological rate of transformation of cash goods to credit goods is equal to one. That is, there are no technological costs for transforming credit goods into cash goods. The only way to make agents internalize that this transformation is really costless is by driving the nominal interest rate to zero. With a zero nominal interest rate, agents are able to choose the optimal mix of credit goods and cash goods in the model economy.

The sources of seasonal fluctuations

The results so far indicate that monetary policy plays a negligible role in seasonal fluctuations. However, I have shown earlier that seasonal fluctuations in the U.S. are quite substantial. An important question that therefore remains is: What is the most important source for U.S. seasonal fluctuations? Since the model has used variations in different parameter values to generate these cycles, it can be used to explore which of these parameters play the most predominant role. This section pursues such analysis.

FIGURE 6

Constant growth rate of money



Circle markers: Constant growth rate of money
Triangle markers: Fed policy

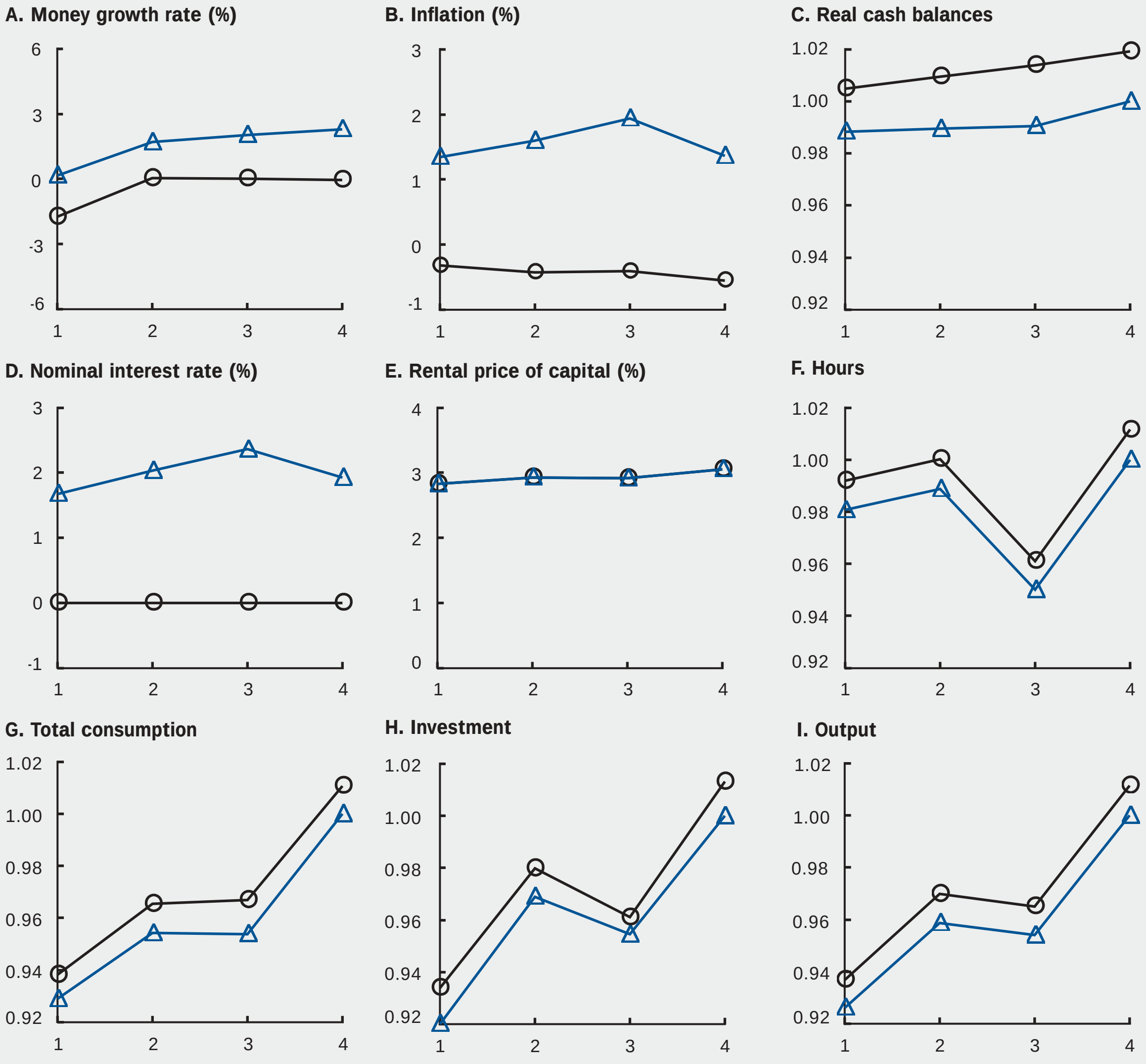
Preference weight on consumption of cash goods (α_s)

Figure 4, panel E shows that the benchmark economy embodies a strong seasonal pattern for the weight, α_s, of cash goods in the utility function. In particular, cash goods are much more valued in the first quarter of the year than in the last. To evaluate what role this plays in U.S. seasonal cycles, I perform the following experiment. I make these weights constant and equal to the cross-seasons average for the benchmark economy. Under the new constant weight, I reset the money growth rates, μ_s, so that the model generates the same seasonal pattern for nominal interest rates as in the U.S. economy. Thus, the Fed's monetary policy together with the rest of the parameter values are kept the same.

Figure 8 shows the results.[9] Removing the seasonal pattern for the α_s weights reduces real cash balances by 2.6 percent in the first quarter and increases them by 3.5 percent in the fourth quarter. But aside from that, the effects on the rest of the variables are negligible. Thus, variations in the velocity of circulation of money are found to play no important role in U.S. seasonal cycles.

FIGURE 7

The Friedman rule



Circle markers: Friedman rule
Triangle markers: Fed policy

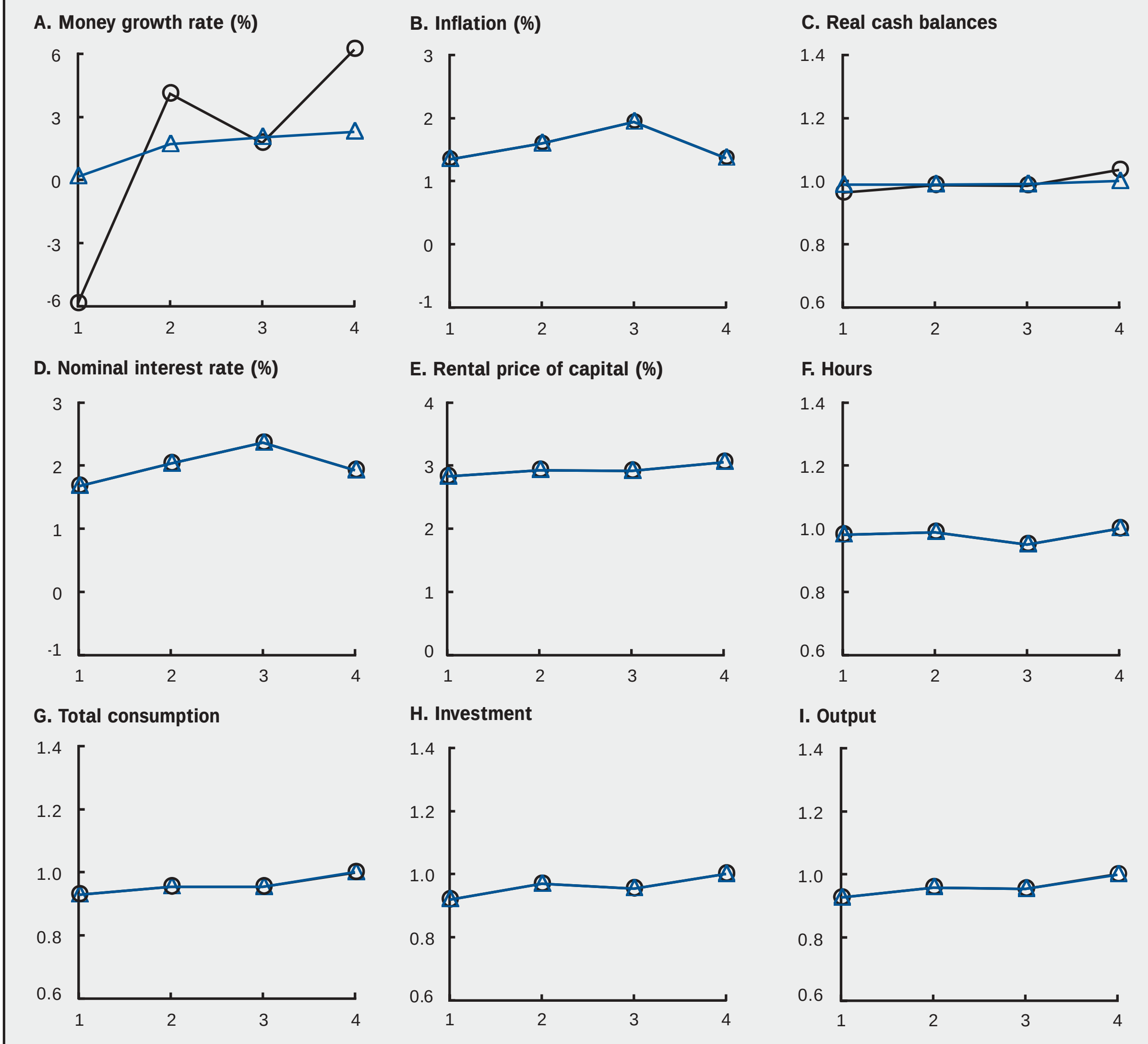
Disutility of work (γ_s)

Figure 4, panel H shows that in the benchmark economy there is a large spike in the disutility of work, γ_s, during the third quarter of the year. To evaluate what role this plays in U.S. seasonal cycles, I make the disutility of work constant and equal to the cross-seasons average for the benchmark economy. Similar to the previous subsection, I reset the money growth rates, μ_s, so that the model generates the same seasonal pattern for nominal interest rates as in the U.S economy.

Figure 9 shows the results. With a constant disutility of work, hours become 7.7 percent higher in the third quarter and 5.2 percent lower in the fourth quarter. The effects on hours worked are reflected on output, which becomes 4.8 percent higher in the third quarter and 3.3 percent lower in the fourth quarter. Given the strong preference for consumption smoothing, all the effects on output are translated into investment while consumption remains unaffected.

FIGURE 8

Smooth weights on consumption of cash goods



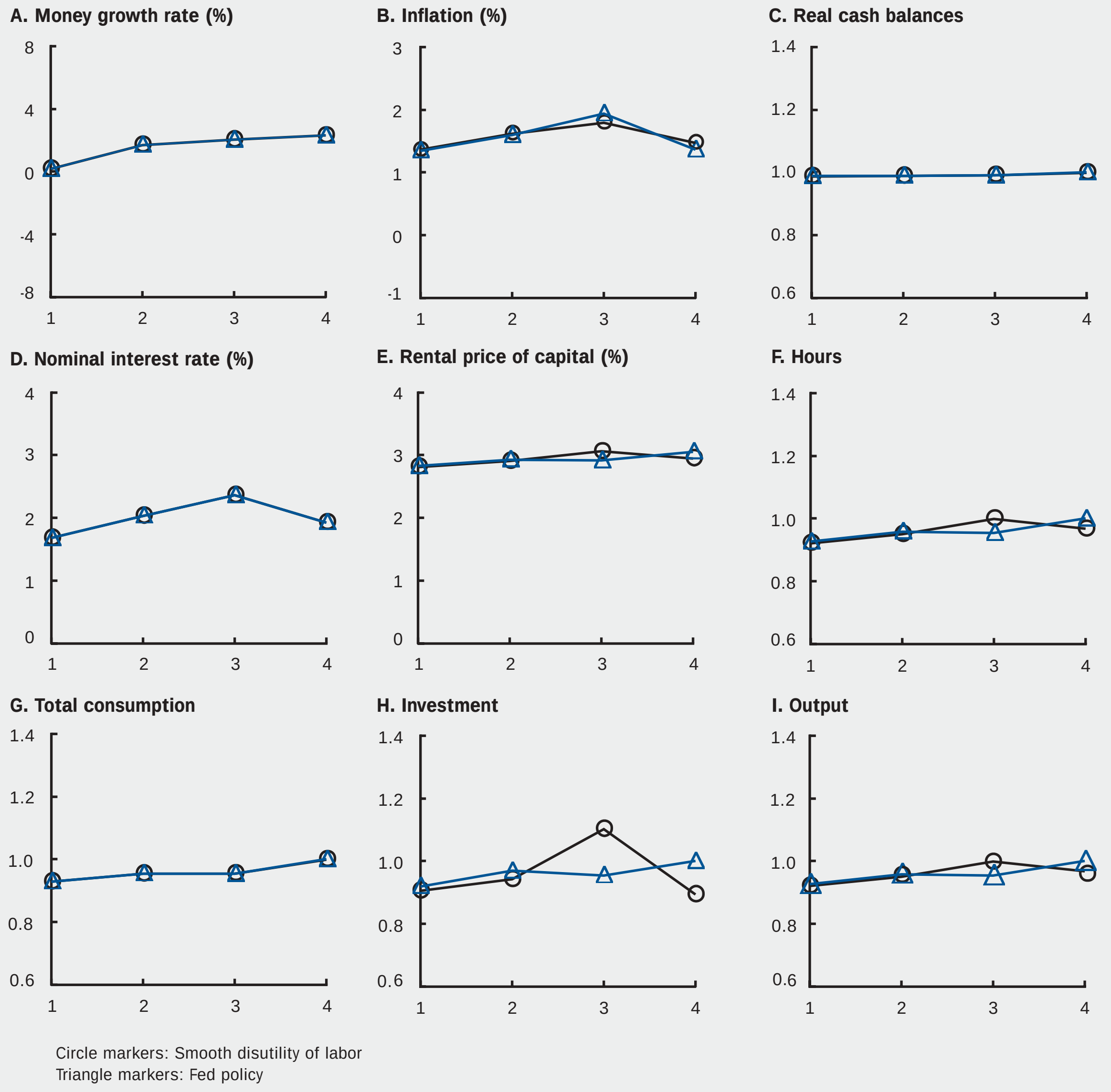
Discount factors (ϕ_s)

Figure 4, panel F shows that the discount factors increase sharply throughout the year. This section evaluates the effects of this exogenous increase by analyzing how the economy would behave if the agent discounted time equally across the seasons, that is, if the discount factors were given by those depicted in figure 4, panel G.[10]

The results are shows in figure 10. Absent the exogenous increase in discount factors throughout the year, consumption would be 3.5 percent higher in the first quarter and 3.7 percent lower in the fourth quarter. This is not surprising since with the increase in discount factors, consumption becomes more heavily weighted in the utility function toward the end of the year. Since nominal interest rates remain unchanged (by construction), the ratio of cash goods to total consumption remains the same as in the benchmark economy. As a consequence, the effects on real cash balances are a mirror of those on total consumption. Note that the smooth discount factors also make work more costly in the first quarter and less costly in the last quarter. As a consequence, hours decrease by 8.5 percent in the first quarter and increase by

FIGURE 9

Smooth disutility of labor



10.9 percent in the last quarter. The qualitative effects on output are the same as for hours, but they have a smaller magnitude. Investment has to decrease by 25.2 percent in the first quarter and increase by 30.4 percent in the fourth quarter to be consistent with the opposite effects on consumption and output.

Thus, exogenous changes in discount factors play a significant role in generating seasonal cycles in the U.S. economy.

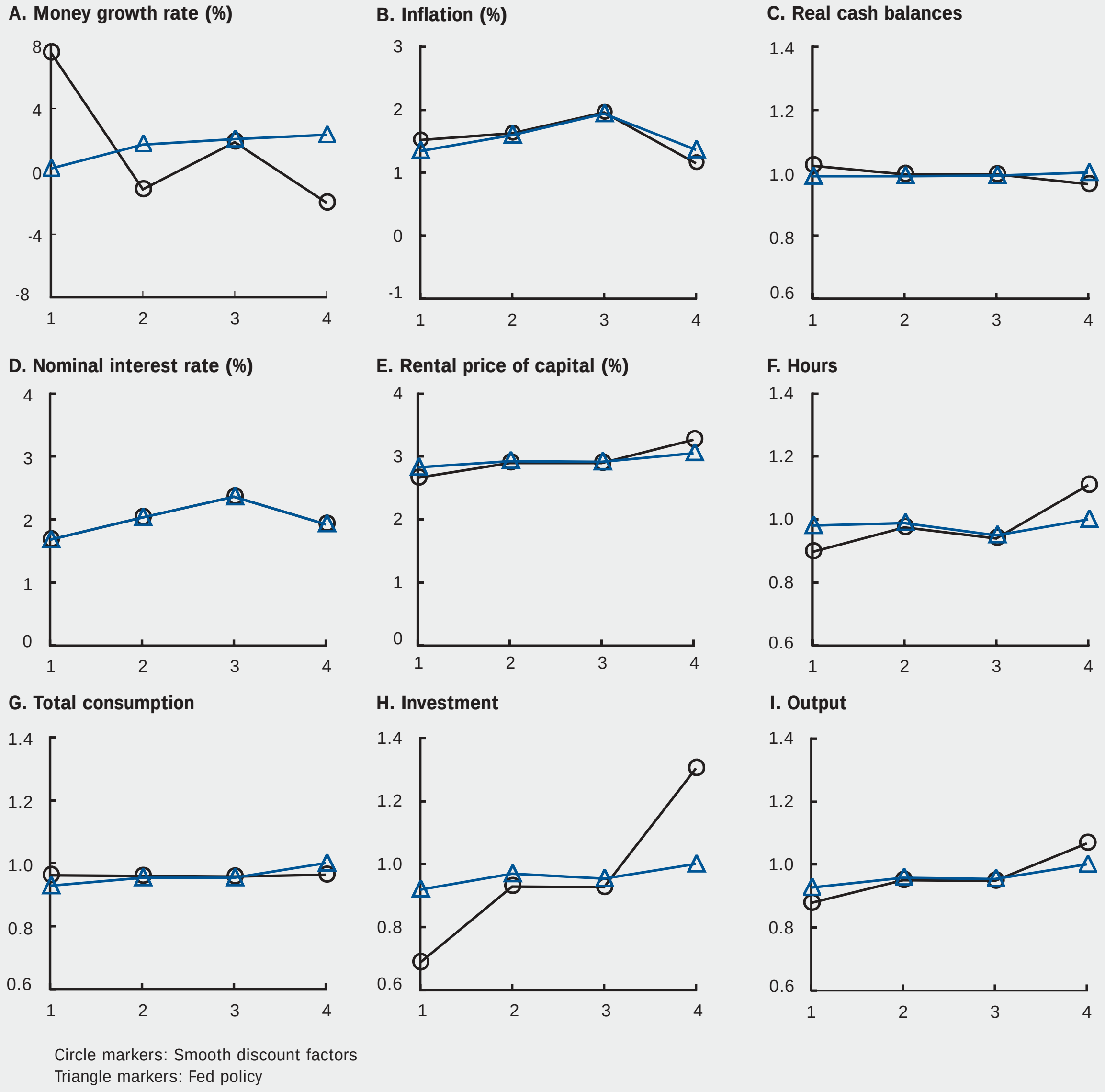
Total factor productivity (z_s)

Figure 4, panel B shows that in the benchmark economy, total factor productivity, z_s, is low in the first quarter and increases continuously throughout the year. This section analyzes the role that this plays in U.S. seasonal cycles by comparing the benchmark economy with one that has a constant total factor productivity.

The results are shown in figure 11. The strong preference for smoothing consumption over time implicit in the utility function (equation 1) means that

FIGURE 10

Smooth discount factors



the seasonal pattern for total consumption and consumption of cash goods remains unaffected by the switch to a constant total factor productivity. All the effects are felt in hours, investment, and output. This is not surprising: Since the productivity of capital is constant (instead of increasing), investment does not need to increase throughout the year. In fact, given the strong seasonal pattern in other parameters (in particular, in discount factors) investment would sharply decrease throughout the year. Since hours enter linearly in the utility function, there are no gains in smoothing them over time. As a result, the sharp decline in investment would be achieved by increasing hours by 9.6 percent during the first quarter and decreasing them by 7.1 percent during the fourth quarter, allowing consumption to remain unchanged.

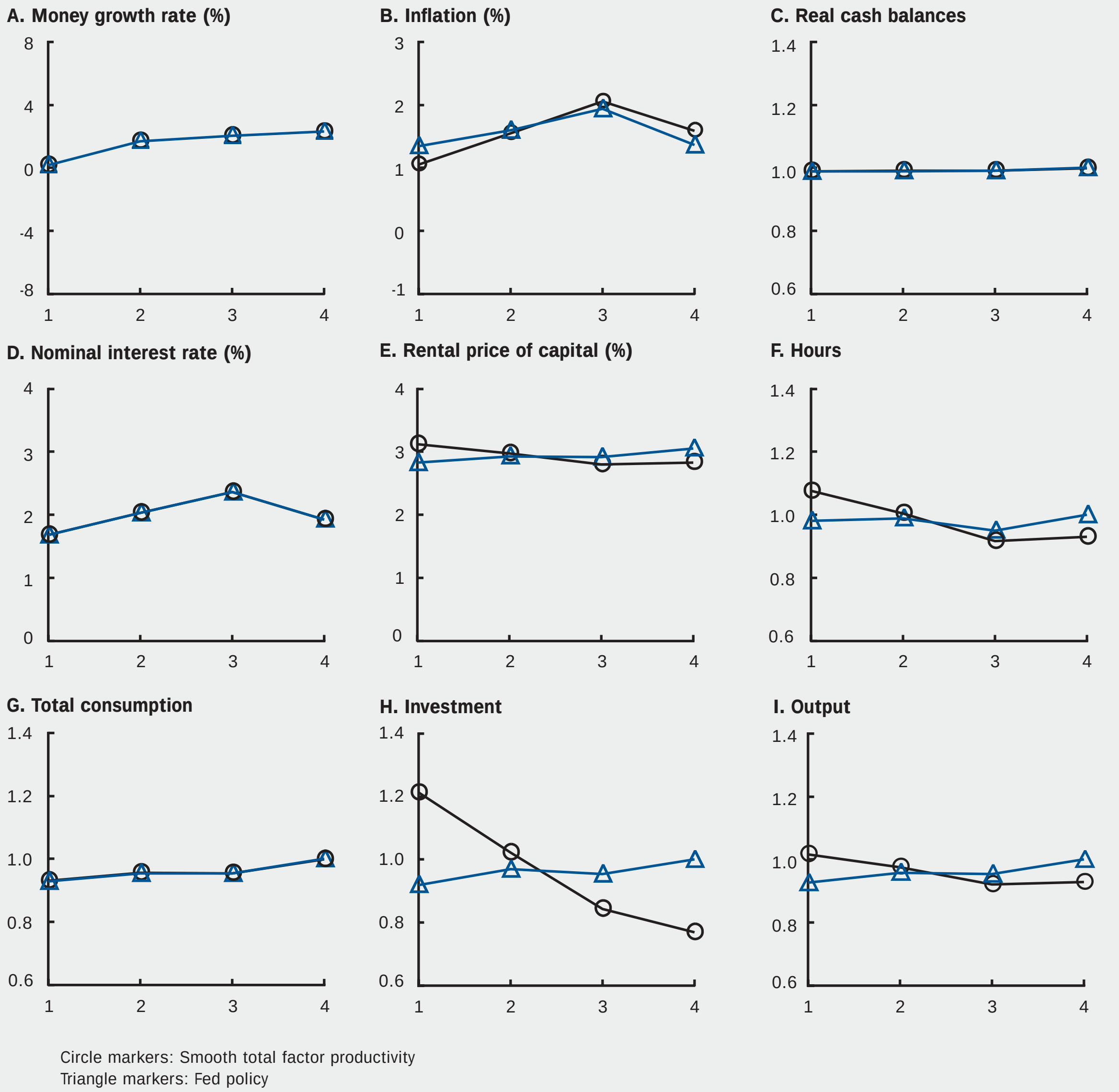
Thus, we see that seasonal variations in total factor productivity play a key role in offsetting the effects of seasonal variations in discount factors that were analyzed in the previous subsection.

Conclusion

In this article, I have used a dynamic general equilibrium cash-in-advance model to study the role

FIGURE 11

Smooth total factor productivity



of monetary policy in U.S. seasonal cycles. I have found that the seasonal monetary policy is largely irrelevant in the model economy: Smoothing interest rates across the seasons and following a constant growth rate of money lead to basically the same real allocations. Only nominal interest rates are significantly affected.

Smoothing interest rates can play a significant role if the level targeted is equal to zero. In particular, following the Friedman rule leads to considerable effects: Output increases by 1.1 percent in every quarter. However, the welfare effects are small: The consumption equivalent benefit of switching to the Friedman rule is only 0.1 percent. Not surprisingly these results are in line with Cooley and Hansen (1995), who evaluated the welfare costs of inflation abstracting from seasonal fluctuations.

I also find that the most important source of seasonal fluctuations in the U.S. economy is exogenous changes in demand, that is in how much agents value consumption over the different seasons. I find a large spike in demand during the last quarter of the year, suggesting that Christmas plays a key role, and a large drop during the first quarter, indicating that people tend to postpone consumption during cold weather. However, seasonal variations in total factor productivity play an important role in offsetting large parts of these effects. Cold weather directly affects activities like construction and agriculture, making total factor productivity hit its lowest values during the first quarter of the year. However, this does not impose much strain on the economy since demand is also the lowest during the first months of the year. After the first quarter, total factor productivity increases steadily to reach its peak during the last quarter of the year, just in time to meet the spike in aggregate demand. In turn, an increase in the value of leisure plays a significant role in flattening the path for hours, output, and investment during the third quarter of the year.

NOTES

[1]The list of papers analyzing seasonal fluctuations is more extensive than the one provided in this section, and includes Braun and Evans (1998) and Krane and Wascher (1999). However, the focus of these papers has been real activity and not monetary policy.

[2]The assumption of linear preferences with respect to labor can be justified on theoretical grounds as in Hansen (1985) and Rogerson (1988).

[3]Appendix B describes the formal conditions that a stationary competitive equilibrium must satisfy.

[4]In particular, let R_s^* be the nominal interest rates corresponding to the benchmark economy (depicted in figure 4, panel D). The constant interest rate, $\bar{R}$ chosen, satisfies the following condition:

$$\left(1+\bar{R}\right)^4 = \left(1+R_1^*\right)\left(1+R_2^*\right)\left(1+R_3^*\right)\left(1+R_4^*\right).$$

The money growth rates, μ_s, that generate this constant interest rate, $\bar{R}$, can be obtained from equations B.8 and B.9.

[5]In particular, let μ_s^* be the growth rates of money corresponding to the benchmark economy (depicted in figure 3, panel F). The constant money growth rate $\bar{\mu}$ satisfies the following condition:

$$4\bar{\mu} = \mu_1^* + \mu_2^* + \mu_3^* + \mu_4^*.$$

[6]Observe from equations B.8 and B.9 that the nominal interest rate R_s is directly related to the growth rate of money in the following quarter, μ_{s+1}.

[7]These growth rates are obtained from equations B.8 and B.9 once the R_s (for s = 1, ...,4) are set to zero. Note that, given the seasonal variations in ϕ_s and α_s, these money growth rates associated with the Friedman rule in general will not be constant.

[8]Despite this, the Friedman rule can be shown to be the optimal monetary policy in this environment (from a welfare standpoint).

[9]Observe that the scale for figures 8–11 is different than the scale for figures 5–7, since the effects are much larger in the former set of figures.

[10]Formally, the smooth discount factors, $\bar{\phi}_s$ are given as follows:

$$\begin{aligned}
\bar{\phi}_1 &= 1 \\
\bar{\phi}_2 &= \beta^{1/4} \\
\bar{\phi}_3 &= \bar{\phi}_2^2 \\
\bar{\phi}_4 &= \bar{\phi}_2^3,
\end{aligned}$$

where β is the annual discount factor in the benchmark economy.

APPENDIX A: FIRST ORDER CONDITIONS

At year t quarter s, the household must be indifferent to two alternatives: 1) using one less unit of the cash available for purchasing the cash good and sacrificing $1/P_{t,s}$ units of the cash good, which entails a loss in marginal utility equal to $\alpha_s\phi_s/c_{t,s}$ per unit, and 2) purchasing one more unit of the bond, obtaining $1 + R_{ts}$ units of cash the following period (as interest payment) that can be used to purchase $1/P_{t,s+1}$ units of the cash good, entailing a gain in marginal utility equal to $\alpha_{s+1}\phi_{s+1}/c_{t,s+1}$ per unit. Thus, the following conditions must hold:

A.1) $$\frac{1}{P_{t,s}}\frac{\alpha_s\phi_s}{c_{t,s}} = \frac{(1+R_{ts})}{P_{t,s+1}}\frac{\alpha_{s+1}\phi_{s+1}}{c_{t,s+1}}, \text{ for } s = 1, \ldots, 3$$
$$\frac{1}{P_{t,4}}\frac{\alpha_4\phi_4}{c_{t,4}} = \frac{(1+R_{t4})}{P_{t+1,4}}\frac{\alpha_1\beta\phi_1}{c_{t+1,1}}.$$

The household must also be indifferent to: 1) purchasing one less unit of the credit good ($a_{t,s}$), which entails a loss in marginal utility equal to $\phi_s(1 - \alpha_s)/a_{t,s}$, and 2) purchasing $1/P_{t,s}$ additional units of end-of-period cash balances that next period can be used to purchase $1/P_{t,s+1}$ units of the cash good, which entails a gain in marginal utility equal to $\phi_{s+1}\alpha_{s+1}/c_{t,s+1}$ per unit. Thus the following conditions must hold:

A.2) $$\frac{1}{P_{t,s}}\frac{\phi_s(1-\alpha_s)}{a_{t,s}} = \frac{1}{P_{t,s+1}}\frac{\phi_{s+1}\alpha_{s+1}}{c_{t,s+1}}, \text{ for } s = 1, \ldots, 3$$
$$\frac{1}{P_{t,4}}\frac{\phi_4(1-\alpha_4)}{\alpha_{t,4}} = \frac{1}{P_{t+1,1}}\frac{\beta\phi_1\alpha_1}{c_{t+1,1}}.$$

The household must also be indifferent to: 1) purchasing one less unit of the credit good ($a_{t,s}$), which entails a loss in marginal utility equal to $\phi_s(1 - \alpha_s)/a_{t,s}$, and 2) purchasing one unit of capital ($k_{t,s+1}$), and renting it to the firm and selling-off the undepreciated portion, obtaining $r_{t,s+1} + 1 - \delta$ units of the credit good the following period, which entails a gain in marginal utility equal to $\phi_{s+1}(1 - \alpha_{s+1})/a_{t,s+1}$ per unit. Thus, the following conditions must hold:

A.3) $$\frac{\phi_s(1-\alpha_s)}{a_{t,s}} = (r_{t,s+1}+1-\delta)\frac{\phi_{s+1}(1-\alpha_{s+1})}{a_{t,s+1}}, \text{ for } s = 1, \ldots, 3$$
$$\frac{\phi_4(1-\alpha_4)}{a_{t,4}} = (r_{t+1,1}+1-\delta)\frac{\beta\phi_1(1-\alpha_1)}{a_{t+1,1}}.$$

Finally, the household must be indifferent to: 1) working one less unit of time, losing $w_{t,s}$ units of the credit good that the wage rate could buy, which entail a loss in marginal utility equal to $\phi_s(1 - \alpha_s)/a_s$ per unit, and 2) obtaining one more unit of leisure, which entails gain in marginal utility equal to $\phi_s\gamma_s$. Thus, the following conditions must hold:

A.4) $$\frac{(1-\alpha_s)}{a_s} = \gamma_s, \text{ for } s = 1, \ldots, 4.$$

The conditions characterizing the optimal behavior of the representative firm are much easier to describe. The firm hires labor up to the point where the marginal productivity of labor equals the wage rate

A.5) $$w_{t,s} = z_s k_{t,s}^{\theta}(1-\theta)h_{t,s}^{-\theta}, \text{ for } s = 1, \ldots, 4,$$

and hires capital up to the point where the marginal productivity of capital equals its rental rate

A.6) $$r_{t,s} = z_s\theta k_{t,s}^{\theta-1}h_{t,s}^{1-\theta}, \text{ for } s = 1, \ldots, 4.$$

A competitive equilibrium is then a sequence $\{c_{t,s}, a_{t,s}, h_{t,s}, k_{t,s}, m_{t,s}, b_{t,s}, w_{t,s}, r_{t,s}, P_{t,s}, R_{t,s}, T_{t,s}, M_{t,s}\}$ for t = 0, ..., ∞, and s = 1, ..., 4, such that equations 2, 3, 4, 6, 7, 8, 9, A.1, A.2, A.3, A.4, A.5, and A.6 hold.

APPENDIX B: STATIONARY EQUILIBRIA

A stationary equilibrium is a vector (c_s, a_s, i_s, y_s, k_s, h_s, r_s, w_s, R_s), for s = 1, ..., 4, such that the following equations are satisfied:

B.1) $$c_s + a_s + i_s = y_s,$$

B.2) $$k_{s+1} = (1-\delta)k_s + i_s,$$

B.3) $$y_s = z_s k_s^{\theta} h_s^{1-\theta},$$

B.4) $$r_s = \theta \frac{y_s}{k_s},$$

B.5) $$w_s = (1-\theta)\frac{y_s}{h_s},$$

B.6) $$(1+R_s)\frac{c_s}{c_{s-1}}\frac{1}{e^{\mu_s}} = r_s + 1 - \delta,$$

B.7) $$\frac{c_s + a_s}{c_s} = \frac{1}{\alpha_s} + \frac{(1-\alpha_s)}{\alpha_s}R_s,$$

B.8) $$1 = \frac{\phi_{s+1}}{\phi_s}\frac{\alpha_{s+1}}{\alpha_s}\frac{1}{e^{\mu_{s+1}}}(1+R_s), \text{(except for } s=4\text{)},$$

B.9) $$1 = \beta\frac{\phi_1}{\phi_4}\frac{\alpha_1}{\alpha_4}\frac{1}{e^{\mu_1}}(1+R_4), \text{ and}$$

B.10) $$a_s = \left(\frac{1-\alpha_s}{\gamma_s}\right)(1-\theta)\frac{y_s}{h_s},$$

for s = 1, ..., 4.

APPENDIX C: PARAMETERIZATION

This appendix describes the procedure used to calibrate parameter values.

The depreciation rate of capital, δ, is chosen to be 0.025, which is a standard value in the real business cycle literature. The seasonal pattern for the stock of capital, k_s, is then chosen to reproduce the seasonal pattern for investment, i_s, when $\delta = 0.025$. The result is depicted in figure 4, panel A, which shows no significant seasonal variations for the stock of capital, k_s. This result is obtained, despite the strong seasonal pattern in investment, because investment is small relative to the size of capital.

The share of capital in national income is given, at equilibrium, by the curvature parameter θ in the production function. For this reason, θ is chosen to be 0.36, which is the share of capital implicit in the *National Income and Product Accounts*. Given θ, and the seasonal components for capital, k_s, hours, h_s, and output, y_s, the seasonal pattern for total factor productivity, z_s, can be obtained as a residual from the production function. The result is depicted in figure 4, panel B, which shows a strong seasonal pattern: Total factor productivity drops to 0.938 during Q1 and slowly recovers thereafter, reaching 0.966 and 0.986 during Q2 and Q3, respectively.

Given the capital share, θ, the capital–output ratios, k_s/y_s, have direct implications for the rental rate of capital, r_s, in the model economy. Figure 4, panel C shows that this rental rate has a significant seasonal pattern, taking the lowest value during Q1.

The rental rate of capital and the depreciation rate determine the seasonal pattern for the real interest rate in the economy. Considering the seasonal inflation rate pattern implied by real cash balances, c_s, and the money growth rate, μ_s, the nominal interest rates, R_s, can be obtained from a version of the Fisher equation. Figure 4, panel D, shows that the nominal interest rate goes through significant seasonal variations: It ranges from 1.67 percent during Q1 to 2.36 percent during Q3.

The weight of cash goods in the utility function, α_s, is a key determinant of the relation between the nominal interest rate, R_s, and the velocity of circulation of money, $c_s/(c_s + a_s)$, that is, of the demand for money. As a consequence, it was chosen to be consistent with the values for the nominal interest rate, R_s, real cash balances, c_s, and total consumption, $c_s + a_s$, obtained above. The weights, α_s, thus obtained are reported in figure 4, panel E. We see that they have a strong seasonal pattern, the desirability of cash goods being the highest during Q1 and decreasing smoothly throughout the rest of the year.

Given these weights α_s, the discount factors β, ϕ_1, ϕ_2, ϕ_3, and ϕ_4 were selected to be consistent with the nominal interest rates, R_s, and money growth rates, μ_s, reported above. Figure 4, panel F reports that these discount factors have a strong seasonal pattern. To make this clear, figure 4, panel G reports the discount factors that the representative agent should have if it discounted time equally across the seasons. We see that both paths differ quite substantially. In particular, the seasonal pattern for the calibrated values of ϕ_1, ϕ_2, ϕ_3, and ϕ_4 indicate a monotone increase in demand throughout the year, which becomes particularly sharp during Q4.

Finally, the disutility of work parameters, γ_s, are selected to reproduce the seasonal pattern for total hours worked, h_s. The resulting values of γ_s in figure 4, panel H indicate a large increase in the disutility of work during Q3 and a sharp reversal during Q4.

The rest of the appendix describes in detail which equations were used in each stage of the calibration procedure.

The following variables are directly obtained from the data (as described in the model economy section): i_s, c_s, a_s, h_s, and μ_s. Given these variables, model parameters are selected as follows.

1) Set $\delta = 0.025$.
2) Given i_s (for s = 1, ..., 4), choose seasonal pattern for k_s, that is consistent with equation B.2.
3) Set $\theta = 0.36$.
4) Given c_s, a_s, and i_s, obtain y_s from equation B.1.
5) Given y_s, k_s, h_s and θ, obtain z_s from equation B.3.
6) Given y_s, k_s and θ, obtain r_s from equation B.4.
7) Given c_s, μ_s, r_s, and δ, obtain R_s from equation B.6.
8) Given R_s, c_s, and a_s, obtain α_s from equation B.7.
9) Given α_s, μ_s, and R_s, set ϕ_1 (this is just a normalization) and obtain ϕ_s, for $s = 2, ..., 4$ and β from equations B.8 and B.9.
10) Given α_s, θ, a_s, y_s, and h_s, get γ_s from B.10.

Braun, R. A. and C. L. Evans, 1998, "Seasonal Solow residuals and Christmas: A case for labor hoarding and increasing returns," *Journal of Money, Credit, and Banking*, Vol. 30, No. 3, pp. 306–330.

Cooley T. F., and G. D. Hansen, 1995, "Money and the business cycle," in *Frontiers of Business Cycle Research*, T. F. Cooley (ed.), Princeton, NJ: Princeton University Press.

Friedman, M., 1959, *A Program for Monetary Stability*, New York City: Fordham University Press.

Friedman, M., and A. J. Schwartz, 1963, *A Monetary History of the United States, 1867–1960*, Princeton, NJ: Princeton University Press.

Hansen, G., 1993, "The cyclical and secular behavior of the labor input: Comparing efficiency units and hours worked," *Journal of Applied Econometrics*, Vol. 8, No. 1, pp. 71–80.

__________, 1985, "Indivisible labor and the business cycle," *Journal of Monetary Economics*, Vol. 16, No. 3, pp. 309–327.

Kemmerer, E. W., 1910, "Seasonal variations in the relative demand for money and capital in the United States," National Monetary Commission, report.

Krane, S., and W. Wascher, 1999, "The cyclical sensitivity of seasonality in U.S. employment," *Journal of Monetary Economics*, Vol. 44, No. 3, pp. 523–553.

Lucas, R. E., and N. L. Stokey, 1983, "Optimal fiscal and monetary policy in an economy without capital," *Journal of Monetary Economics*, Vol. 12, pp. 55–93.

Mankiw, N. G., and J. A. Miron, 1991, "Should the Fed smooth interest rates? The case of seasonal monetary policy," *Carnegie-Rochester Conference Series on Public Policy*, Vol. 34, pp. 41–69

Miron, J. A., 1986, "Financial panics, the seasonality of the nominal interest rate, and the founding of the Fed," *American Economic Review*, Vol. 76, No 1, pp. 125–140.

Rogerson, R., 1988, "Indivisible labor, lotteries, and equilibrium," *Journal of Monetary Economics,* Vol. 21, No. 1, pp. 3–16.