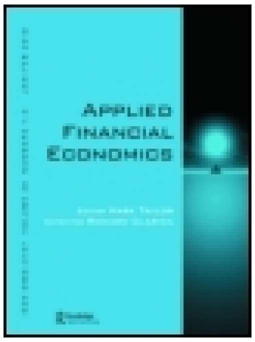

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A numerical analysis of the monetary aspects of the Japanese economy: the cash-in-advance approach

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This paper analyses the monetary aspects of the Japanese economy based on the cash-in-advance (CIA) model. The Svensson (1985) model and the Lucas and Stokey (1987) model are examined by calibration. The Euler equations obtained from the representative agent's optimization behaviour stand for a non-linear relationship including some random variables. We approximate a generating process of exogenous variables using the quadrature-based method developed by Tauchen and Hussey (1991) and apply the numerical method proposed in Hodrick *et al.* (1991) to the results. Several moments of monetary variables are calculated to satisfy the theoretical consistency of the CIA model. Comparing the theoretical values with actual sample statistics, we examine the validity of the CIA model in Japan. The numerical results show that theoretical moments generated by the Lucas and Stokey model are consistent with sample moments in the 1980s.

I. INTRODUCTION

Recently, some dynamic monetary models have been developed in macroeconomics to analyse the monetary aspects of an economy, and empirical research has been performed based on these models. This paper analyses numerically the moments of some monetary variables in the Japanese economy based on the cash-in-advance (CIA) model.

The CIA model was originally developed by Clower (1967). The CIA constraint is based on the idea that one requires money for the purchase of goods. Lucas (1982) formulated this idea in a dynamic general equilibrium framework, and this was extended by Svensson (1985) and Lucas and Stokey (1987). Since the quantity of expenditure is assumed to be known at the beginning of the period in the Lucas model, a household which faces a positive interest rate possesses an amount of money equal to that used for consumption. The CIA restriction therefore implies that the classical quantity theory of money holds true in this setting. As a result, the velocity of money is equal to one in this case.

Svensson (1985) amended the informational structure of the household, and assumed that the household needed to decide its demand for money before making consumption decisions. The household therefore has the possibility of holding excess money which may not be used in consumption. For this reason, the velocity of money may not be one. Moreover, Lucas and Stokey (1987) constructed a two-good model which consists of a cash good and a credit good. The fluctuation in the velocity of money increases in this model because the CIA constraint does not become effective for the credit good.

Some research empirically examines the validity of the CIA model using statistical estimation and tests. For example, Finn *et al.* (1990) examine some dynamic capital asset pricing models including the Svensson model by the generalized method of moments (GMM) proposed by Hansen (1982).

However, this paper employs a simulation approach to analyse the validity of the model. We approximate a generating process of exogenous variables using the quadrature-based method developed by Tauchen and Hussey (1991) and apply the numerical method proposed by Hodrick *et al.* (1991) to the results. Some moments with regard to the velocity of money, the inflation rate, and the interest rate are calculated to satisfy the theoretical consistency of the CIA model. Comparing theoretical moments with actual sample moments, we examine the validity of the CIA model in Japan.

There are several advantages to this approach. First of all, it is difficult to estimate and test the model if it involves an inequality restriction. Although Finn *et al.* (1990) estimate some Euler equations, they do not take into consideration the inequality constraint of the CIA model. A numerical method can reflect the whole structure of the model including the inequality constraint.

Secondly, there is a problem with using fixed parameters when analysing the validity of a theoretical model. If the model is not supported by statistical tests, there are two cases to be considered. One possibility is that the model is rejected because the economic model itself is inappropriate. The other is that the model is not accepted because the assumption of fixed parameters is inappropriate. Allowing for the possibility of a wide range in the value of structural parameters used in the numerical computation, we can incorporate the possibility of structural change and examine the validity of the theoretical model.

Thirdly, there is a problem concerning the data itself. In recent dynamic macro models, GMM is used to estimate and test the models. Although GMM has desirable properties in large samples, as Hansen (1982) showed, only a small number of time series data sets are available, and they may include measurement error in many cases (see Prescott, 1986). The simulation approach can reduce the degree of this problem.[1]

Finally, the more robust justifications for calibration include understanding the quantitative sensitivities of the model over a range of parameter values, and avoiding the computational cost of estimation in complex models.

Summarizing the results, we find that the Svensson model cannot reproduce the actual sample moments. However, the Lucas and Stokey model is able to generate realistic predictions about the sample moments of key endogenous variables in the 1980s.

This paper is organized as follows. In the next section, the CIA model is presented. In Section III, the VARs regarding the exogenous variables are estimated and their discrete approximation is compared with the estimated processes. In Section IV, the simulation algorithm is explained. In Section V, simulation results are reported. Some concluding remarks are made in the final section.

II. THE CIA MODEL

The problem of the representative consumer in the Lucas–Stokey model can be summarized as follows

$$\max \quad E_0\left[\sum_{t=0}^{\infty} \beta^t U(C_{1t}, C_{2t})\right] \tag{1}$$

$$\text{subject to} \quad P_t C_{1t} \leq M_t \tag{2}$$

$$M_{t+1} + Q_t Z_{t+1} = Z_t P_t Y_t + Q_t Z_t + (\omega_t - 1)X_t + M_t - P_t(C_{1t} + C_{2t}) \tag{3}$$

where $E_t[\bullet]$ is the conditional expectations operator based on the information available at time t; β is the subjective discount rate; $U(\bullet)$ is the utility function; C_{1t} is the quantity of the cash good at time t; C_{2t} is the quantity of the credit good at time t; P_t is the price level (the nominal price of two goods is assumed to be the same); M_t is the quantity of money demand at time t; Q_t is the nominal stock price at time t; Z_t is the share of stock at time t; Y_t is the quantity of endowments at time t; ω_t is the growth rate of the money supply; X_t is the quantity of money supply in the form of transfers at time t.

Equation 1 is the representative consumer's objective function. He or she tries to maximize the present value of expected utility obtained from consumption over a lifetime. The utility function depends on the quantity consumed of two types of goods. One is the cash good and the other is the credit good. A cash good is one that people need cash in order to buy and sell. A credit good can be bought and sold without money. There is no credit good in the Svensson model. Equation 2 shows the cash-in-advance constraint. The left-hand side and the right-hand side of Equation 3 respectively show the expenditure and revenue of the household. The left-hand side consists of the demand for money and stocks. The right-hand side comprises the dividend income, resale value of stocks, lump-sum money transfers and the unspent amount of money. Each period is divided into two subperiods. In the first subperiod, agents consume in the markets for cash and credit goods. The cash good can be purchased only with cash, while the credit good is bought on credit. In the second subperiod, agents trade financial assets and settle credit accounts in the securities market from the sale of either good. It is assumed that the goods market opens before the asset market in this paper. In Lucas and Stokey's model, the timing of these markets is the reverse. This was done to make the model nest the Svensson model.

The representative consumer chooses C_{1t}, C_{2t}, M_{t+1} and Z_{t+1} in order to maximize Equation 1 subject to Equation 2 and Equation 3. Let us parameterize the preference of the representative consumer as follows

$$U(C_{1t}, C_{2t}) = \frac{(C_{1t}^{\mu} C_{2t}^{1-\mu})^{1-\alpha} - 1}{1-\alpha} \tag{4}$$

Assuming that the growth rate of money ($\omega_t = X_t/X_{t-1}$) and the growth rate of endowments ($\gamma_t = Y_t/Y_{t-1}$) are exogenously given, we focus on the analysis of the stationary equilibrium in which endogenous variables depend on the current state in a time-invariant fashion.

[1] For the small sample properties of GMM, see Tauchen (1986), Kocherlakota (1990b), Hamori and Kitasaka (1992) and Hamori *et al.* (1996).

The first-order condition of this problem can be summarized as follows

$$C_1(s_t) \leqslant m(s_t) \tag{5}$$

$$\eta(s_t) \geqslant 0, \quad \text{and} \quad \eta(s_t)[m(s_t) - C_1(s_t)] = 0 \tag{6}$$

$$U_1(s_t) = \lambda(s_t) + \eta(s_t) \tag{7}$$

$$U_2(s_t) = \lambda(s_t) \tag{8}$$

$$\eta(s_t) = U_1(s_t) - \{\beta E[U_1(s_{t+1})m(s_{t+1})|s_t]\gamma_t^{1-\alpha}\} \times \{\omega_t m(s_t)\}^{-1} \tag{9}$$

$$\lambda(s_t)q(s_t) = \beta E\{\lambda(s_{t+1})[q(s_{t+1}) + \gamma_{t+1}]|s_t\}\gamma_t^{1-\alpha} \tag{10}$$

where

$s_t = \{\gamma_t, \omega_t\}$

η_t is the Lagrangian multiplier corresponding to the CIA constraint

λ_t is the Lagrangian multiplier corresponding to the budget constraint

$\eta(s_t) = \eta_t / Y_{t-1}^{-\alpha}$

$\lambda(s_t) = \lambda_t / Y_{t-1}^{-\alpha}$

$m(s_t) = X_t / P_t Y_{t-1}$

$q(s_t) = Q_t / P_t Y_{t-1}$

$C_1(s_t) = C_{1\,t} / Y_{t-1}$

$U_1(\bullet) = \mu\{\gamma_t - C_1(s_t)\}^{(1-\mu)(1-\alpha)} C_1(s_t)^{\mu(1-\alpha)-1}$

$U_2(\bullet) = (1-\mu)\{\gamma_t - C_1(s_t)\}^{(1-\mu)(1-\alpha)-1} C_1(s_t)^{\mu(1-\alpha)}$

Equation 5 shows the CIA constraint. The Kuhn–Tucker multiplier condition is given in Equation 6. Equations 7 and 8 are the first-order conditions associated with the cash good and the credit good. Equations 9 and 10 show the first-order conditions associated with holding money and stocks respectively. In equilibrium, all markets should clear

$$C_{1\,t} + C_{2\,t} = Y_t \quad \text{(goods markets)} \tag{11}$$

$$Z_{t+1} = 1 \quad \text{(stock market)} \tag{12}$$

$$M_{t+1} = X_{t+1} \quad \text{(money market)} \tag{13}$$

Endowments can be thought of as pay-offs on assets owned by the agent, and the aggregate stock of these assets is normalized to one.

The Svensson model is the special case of this model. Only the cash good yields positive utility ($\mu = 1$, $C_{2\,t} = 0$) and Equation 8 is dropped from the system. Equilibrium requires that $C_{1\,t} = Y_t$. Let us call the Svensson model the cash model and the Lucas–Stokey model the cash–credit model hereafter. Both the cash model and the cash–credit model consist of non-linear stochastic equations and thus we need to depend on numerical analysis to see the properties of the model.

III. SIMULATION ALGORITHM

VAR process and its discrete approximation

In order to simulate the results of the model, we have to follow two steps. The first is the estimation of the VARs of the exogenous variables, and the discrete approximation of the process. The second is the calibration of endogenous variables based on the Euler equations described above.

This section explains the approximation procedure of the two Markov processes obtained from VARs. A report is made of the results of discrete approximation based on the quadrature method developed by Tauchen and Hussey (1991). The target variables are the growth rate of per capita real consumption and the growth rate of per capita real money balances. Tauchen (1986) describes the quadrature procedure that constructs approximation Markov chains for VARs. This procedure chooses grid points and transition probabilities so as to match the conditional moments of the estimated VARs. The application of this method to the quarterly data VARs using 16 states provides a good approximation. We check this by estimating the VARs using data generated from the Markov chains.

This paper uses quarterly data starting with the fourth quarter of 1955 and ending with the first quarter of 1992. Per capita real consumption and per capita real money balances are used to estimate the VARs. The sources of the data are given in the Appendix. This paper uses the following three sets of sample periods:

[A] the fourth quarter of 1955–the first quarter of 1992;
[B] the fourth quarter of 1955–the first quarter of 1970;
[C] the second quarter of 1980–the first quarter of 1992.

Sample [A] is the total time period. Sample [B] consists of the sample of the period of high economic growth in Japan. Sample [C] comprises the 1980s, which corresponds to the period of financial liberalization. We exclude the 1970s to eliminate the influence of two oil crises, which is not explicitly taken into consideration in this model. The estimation results for the VARs are shown in Table 1. The induced VAR parameters based on the discrete approximation are reported in Table 2. The two VARs correspond very closely, which shows that the approximation is precise. Judging from the CIA model, M1 is appropriate as the definition of money. However, to take into consideration financial innovation, this paper also reports the results based on M2 in the case of [A]. Since there is no particular difference between the results of M1 and M2, we estimate the VARs based on M1 only for [B] and [C].

Table 1. *Estimated VAR parameters*

[A] Sample period: 1955:4–1992:1

Dependent variables	Coefficients			Covariance matrix	
	Constant	GRC(− 1)	GM1/2(− 1)	σ	ρ
GRC	0.9886 (12.030)	− 0.1718 (− 2.189)	0.1928 (4.687)	0.00016	0.000064
GM1	0.7369 (4.291)	0.1661 (1.012)	0.1185 (1.378)	0.00071	
GRC	0.8093 (8.750)	− 0.2474 (− 3.125)	0.4398 (5.665)	0.00015	0.000017
GM2	0.2566 (4.291)	0.0781 (1.199)	0.6743 (10.550)	0.00010	

[B] Sample period: 1955:4–1970:1

Dependent variables	Coefficients			Covariance matrix	
	Constant	GRC(− 1)	GM1(− 1)	σ	ρ
GRC	1.4032 (10.220)	− 0.4329 (− 3.617)	0.0555 (0.862)	0.00015	0.000005
GM1	1.1815 (4.122)	− 0.1073 (− 0.429)	− 0.0336 (− 0.250)	0.00066	

[C] Sample period: 1980:2–1992:1

Dependent variables	Coefficients			Covariance matrix	
	Constant	GRC(− 1)	GM1(− 1)	σ	ρ
GRC	1.0958 (7.816)	− 0.2015 (− 1.459)	0.1129 (2.503)	0.00004	0.000050
GM1	1.7053 (3.979)	− 0.2297 (− 0.544)	− 0.4582 (− 3.324)	0.00045	

Note: GRC is the per capita real consumption growth rate; GM1 (GM2) is the per capita money (M1 or M2) growth rate; σ is the estimated standard deviation of each residual; ρ is the contemporaneous covariance of the residuals; t-statistics are in parentheses.

The Hodrick, Kocherlakota and Lucas algorithm

This section summarizes the simulation algorithm employed in this paper. The first-order conditions of the cash–credit model can be written as follows:

$$C_1(s_i) \leqslant m(s_i), \gamma_i \leqslant m(s_i) \quad \text{and}$$

$$\eta(s_i) \geqslant 0, \eta(s_i)[\gamma_i - m(s_i)] = 0 \tag{14}$$

$$U_1(s_i) = U_2(s_i) + \eta(s_i) \tag{15}$$

$$\eta(s_i) = \gamma_i^{-\alpha} - \{\beta E[\gamma_j^{-\alpha} m_j(s_j)|s_i]\gamma_i^{1-\alpha}\}\{\omega_i m(s_i)\}^{-1} \tag{16}$$

where $s_i = \{\gamma_i, \omega_i\}$ and i indicates the state $i = 1, 2, \dots, n$.

Given the processes of $\{\gamma(s_i), \omega(s_i)\}$, the algorithm used to search for the equilibrium consists of the following four steps:

Step 1

Set $m_0(s_i) = C_{10}(s_i) = \gamma_i$ for all i. This implies that $\eta(s_i) = 0$.

Step 2

Use Equation 16 to solve for $\eta_0(s_i)$ for each state i. If $\eta_0(s_i) = 0$ for all i, then this is an equilibrium. Otherwise, go to Step 3.

Step 3

If $\eta_0(s_i) < 0$ for all i, then stop because there is no equilibrium. For any state s_i in which $\eta_0(s_j) \leqslant 0$, use Equation 15 to define $C_{11}(s_j)$ such that $\eta(s_j) = 0$, and solve for $m_1(s_j)$ in Equation 16 with $\eta(s_j) = 0$. If $C_{11}(s_j)$ is larger than $m_1(s_j)$, reduce $C_{11}(s_j)$ to $m_1(s_j)$. For all future iterations, this procedure will determine C_1 and m in this state. For any state s_i in which $\eta_0(s_i) > 0$, substitute Equation 15 for η in Equation 16, and solve Equation 16 for $m_1(s_i) = C_{11}(s_i)$ using the vector $m_0(s_i)$ and $C_{10}(s_i)$ from the previous iteration in the expectation on the right-hand side of Equation 16.

Table 2. *Induced VAR parameters by discrete approximations*

[A] Sample period: 1955:4–1992:1

Dependent variables	Coefficients			Covariance matrix	
	Constant	GRC(− 1)	GM1/2(− 1)	σ	ρ
GRC	0.9886	− 0.1715	0.1925	0.00016	0.000062
GM1	0.7369	0.1662	0.1184	0.00070	
GRC	0.8095	− 0.2468	0.4391	0.00015	0.000016
GM2	0.2796	0.0726	0.6574	0.00009	

[B] Sample period: 1955:4–1970:1

Dependent variables	Coefficients			Covariance matrix	
	Constant	GRC(− 1)	GM1(− 1)	σ	ρ
GRC	1.4020	− 0.4318	0.0554	0.00015	0.000004
GM1	1.1810	− 0.1073	− 0.0337	0.00066	

[C] Sample period: 1980:2–1992:1

Dependent variables	Coefficients			Covariance Matrix	
	Constant	GRC(− 1)	GM1(− 1)	σ	ρ
GRC	1.0950	− 0.2008	0.1119	0.00004	0.000046
GM1	1.6960	− 0.2261	− 0.4515	0.00042	

Note: GRC is the per capita real consumption growth rate; GM1 (GM2) is the per capita money (M1 or M2) growth rate; σ is the estimated standard deviation of each residual; ρ is the contemporaneous covariance of the residuals.

Step 4

Use Equation 16 to solve for $\eta_1(s_i)$ using $m_1(s_i)$ and $C_{11}(s_i)$ on the right-hand side. If $\eta_1(s_i) \geqslant 0$ in all states and $m_1(s_i) = m_0(s_i)$ and $C_{11}(s_i) = C_{10}(s_i)$, this is an equilibrium. If not, set $C_{10}(s_i) = C_{11}(s_i)$ and $m_0(s_i) = m_1(s_i)$ and repeat Step 3.

From the above algorithm, the following equilibrium values of endogenous variables are obtained:

$$\text{velocity of money: } \mathrm{vel}(s_i) = \frac{\gamma_i}{m(s_i)}$$

$$\text{inflation rate: } \inf(s_i|s_j) = \frac{m(s_i)\omega_i}{m(s_i)\gamma_i} - 1$$

$$\text{nominal interest rate: } n.r(s_i) = \frac{E[\eta(s_i)\inf(s_i|s_j)^{-1}|s_i]}{E[\lambda(s_i)\inf(s_i|s_j)^{-1}|s_i]}$$

$$\text{real interest rate: } r.r(s_i|s_j) = \frac{1 + n.r(s_i)}{\inf(s_i|s_j)} - 1$$

We can calculate some moments of the stationary distribution of the endogenous variables based on these values corresponding to each state and their probabilities.

IV. SIMULATION RESULTS

Using the algorithm described in Section III, we can investigate by simulation the predictions of the models for the joint distribution of the endogenous variables. In this section the simulation results are reported. The main question we address is whether the models can generate statistics consistent with sample moments computed from Japanese time-series data. In order to simulate the results of the model, it is necessary to specify the values of the parameters in the utility function. We choose the range for each parameter as follows:

$$\beta \in \{0.975, 0.980, 0.985, 0.990, 0.995, 1.000, 1.005, 1.010, 1.015, 1.025, 1.030, 1.035, 1.040, 1.045, 1.050\}$$

$$\alpha \in \{0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5\}$$

$$\mu \in \{0.2, 0.4, 0.6, 0.8\}$$

Since we have weak prior beliefs about the preference parameters, we calculate several first and second unconditional moments for some variables of interest over a large parameter range. The parameter range of the subjective discount rate is chosen as being within the range of 0.975 to 1.005.

Table 3. *Simulation results of the cash model (M1; 1955:4–1992:1)*

	Simulations		
	Min (β, α)	Max (β, α)	Data
inf	0.0140 (0.985, 0.0)	0.0142 (1.050, 9.5)	0.0118
n.r	0.0260 (1.000, 1.0)	0.1614 (0.975, 9.5)	0.0178
r.r	0.0123 (1.000, 1.0)	0.1459 (0.975, 9.5)	0.0059
mon-inf	0.2437 (1.050, 5.5)	0.8493 (0.975, 3.5)	0.1448
n.r-inf	0.3027 (1.050, 9.5)	0.8278 (0.975, 0.0)	0.4018
r.r-inf	− 0.9946 (0.975, 0.0)	− 0.9247 (0.980, 9.5)	− 0.8728
vel	0.0016 (0.975, 6.0)	0.0200 (1.050, 5.5)	0.1404

Note: inf is the mean of the inflation rate; n.r is the mean of the nominal interest rate; r.r is the mean of the real interest rate; mon-inf is the correlation of the money and the inflation rate; n.r-inf is the correlation of the nominal interest rate and the inflation rate; r.r-inf is the correlation of the real interest rate and the inflation rate; vel is the coefficient of variation of the velocity of money.

Table 4. *Simulation results of the cash model (M2; 1955:4–1992:1)*

	Simulations		
	Min (β, α)	Max (β, α)	Data
inf	0.0183 (1.005, 9.0)	0.0185 (1.050, 5.5)	0.0118
n.r	0.0312 (1.035, 4.0)	0.1653 (0.975, 9.5)	0.0178
r.r	0.0129 (1.035, 4.0)	0.1443 (0.975, 9.5)	0.0059
mon-inf	0.1223 (1.050, 5.5)	0.5542 (1.005, 9.0)	0.1198
n.r-inf	0.2329 (1.050, 5.5)	0.5912 (0.975, 9.0)	0.4018
r.r-inf	− 0.9147 (0.980, 0.0)	0.1916 (0.975, 9.5)	− 0.8728
vel	0.0000 (1.005, 9.0)	0.0206 (1.050, 5.5)	0.2587

Note: inf is the mean of the inflation rate; n.r is the mean of the nominal interest rate; r.r is the mean of the real interest rate; mon-inf is the correlation of the money and the inflation rate; n.r-inf is the correlation of the nominal interest rate and the inflation rate; r.r-inf is the correlation of the real interest rate and the inflation rate; vel is the coefficient of variation of the velocity of money.

Some earlier studies such as Finn *et al.* (1990), Hansen and Singleton (1982) and Hamori (1992a) report that the subjective discount rate is estimated as being near to but smaller than 1.0. However, Kocherlakota (1990a) finds that the subjective discount rate can exceed one in a growing economy. Kocherlakota (1990b) also assumes the subjective discount rate to be 1.139 in order to reproduce the Treasury bill rate in US annual data. The parameter range for relative risk aversion runs from 0.0 to 9.5. Although Finn *et al.* (1990), Hansen and Singleton (1982), and Hamori (1992a) report that the relative risk aversion parameter is estimated between 0.0 and 1.0 in many cases, Rietz (1988), Kocherlakota (1990b), and Kandel and Stambaugh (1990) assume larger values for the study of risk premiums. The parameter space for the weight between the cash good and credit good is chosen as the range from 0.2 to 0.8 for the cash–credit model. Needless to say, when this weight is equal to one, the model becomes the cash good model.

Based on the specification described above, we calculate the stationary distribution of the endogenous variables for the cash model (320 cases) and the cash–credit model (1280 cases). We compare the simulated moments and the actual sample moments to evaluate the validity of the model. The targets are the following unconditional moments: the means of the inflation rate (inf), the nominal interest rate (n.r) and the real interest rate (r.r); the coefficient of variation of velocity (vel); the correlations of inflation with money growth (mon-inf), the nominal interest rate (n.r-inf), and the real interest rate (r.r.-inf). It is known that the velocity of money is non-stationary. It, therefore, does not make sense to match the theoretical mean and variance of velocity with its sample counterpart. Thus, this paper calibrates the

Table 5. *Simulation results of the cash–credit model (M1; 1955:4–1992:1)*

	Simulations		Data
	Min (β, α, μ)	Max (β, α, μ)	
inf	0.0139 (0.975, 0.0, 0.4)	0.0181 (0.975, 9.5, 0.2)	0.0118
n.r	0.0260 (1.000, 1.0, 0.6)	0.1617 (0.975, 9.5, 0.8)	0.0178
r.r	0.0123 (1.000, 1.0, 0.6)	0.1505 (0.975, 9.5, 0.2)	0.0059
mon-inf	− 0.4703 (0.975, 9.5, 0.2)	0.8010 (0.975, 0.0, 0.8)	0.1448
n.r-inf	0.0435 (1.040, 4.5, 0.2)	0.7882 (0.975, 0.0, 0.8)	0.4018
r.r-inf	− 0.9934 (1.040, 4.5, 0.2)	− 0.9158 (0.975, 9.5, 0.8)	− 0.8728
vel	0.0058 (0.975, 0.0, 0.8)	0.0734 (0.975, 9.5, 0.2)	0.1404

Note: inf is the mean of the inflation rate; n.r is the mean of the nominal interest rate; r.r is the mean of the real interest rate; mon-inf is the correlation of the money and the inflation rate; n.r-inf is the correlation of the nominal interest rate and the inflation rate; r.r-inf is the correlation of the real interest rate and the inflation rate; vel is the coefficient of variation of the velocity of money.

Table 6. *Simulation results of the cash–credit model (M2; 1955:4–1992:1)*

	Simulations		Data
	Min (β, α, μ)	Max (β, α, μ)	
inf	0.0182 (0.975, 0.0, 0.2)	0.0209 (0.975, 9.5, 0.2)	0.0118
n.r	0.0312 (1.035, 4.0, 0.2)	0.1661 (0.975, 9.5, 0.8)	0.0178
r.r	0.0129 (1.035, 4.0, 0.8)	0.1480 (0.975, 9.5, 0.2)	0.0059
mon-inf	− 0.1814 (1.050, 9.5, 0.2)	0.5615 (0.985, 0.0, 0.6)	0.1198
n.r-inf	− 0.0024 (1.050, 5.5, 0.2)	0.5552 (0.985, 0.0, 0.6)	0.4018
r.r-inf	− 0.9018 (0.975, 0.0, 0.8)	− 0.3754 (1.000, 7.5, 0.8)	− 0.8728
vel	0.0018 (0.985, 0.0, 0.8)	0.0587 (1.050, 9.5, 0.2)	0.2587

Note: inf is the mean of the inflation rate; n.r is the mean of the nominal interest rate; r.r is the mean of the real interest rate; mon-inf is the correlation of the money and the inflation rate; n.r-inf is the correlation of the nominal interest rate and the inflation rate; r.r-inf is the correlation of the real interest rate and the inflation rate; vel is the coefficient of variation of the velocity of money.

coefficient of variation for the velocity. Tables 3–8 summarize the results of this analysis. For each individual statistic, tables show the maximum and minimum attainable predictions over the entire estimate values. The parameters generating the maximum and minimum predictions are in parentheses next to the estimated values. The last column lists the corresponding sample statistics from the quarterly data.

Tables 3 and 4 report the results of the cash model for the entire sample period (sample [A]). The difference between both tables is the definition of money used in the research. Table 3 reports results based on M1, whereas Table 4 reports results based on M2. These tables show the overall poor performance of the cash model. The sample value falls outside the range attainable from the cash model for six out of seven statistics in Table 3 and for five out of seven statistics in Table 4.

Tables 5 and 6 report similar results for the cash–credit model for the entire sample period (sample [A]). M1 is used in Table 5, whereas M2 is used in Table 6. The model fails to reproduce five out of seven statistics in Table 5 and four out of seven statistics in Table 6. The results obtained from Tables 3–6 show that the definition of money used in the research does not have a particularly important effect on the results. Thus, we use M1 as the definition of money hereafter.

Table 7 shows the results for the cash–credit model for the sample period of the fourth quarter of 1955 through the first quarter of 1970 (sample [B]). The explanatory power of the cash model is not high for sample [B]. Thus, we show the results only for the cash–credit model. Table 7 shows that the correlations of inflation with money growth, consumption growth, and the nominal interest rate fall inside the range attainable from the model. However, the coefficient of the variation of the velocity of money and the means of the real and nominal interest rates fall outside the range attainable from the model. In particular, the means of the actual

Table 7. *Simulation results of the cash–credit model (M1; 1955:4–1970:1)*

	Simulations		Data
	Min (β, α, μ)	Max (β, α, μ)	
inf	0.0171 (0.975, 0.0, 0.4)	0.0269 (0.975, 9.5, 0.2)	0.0109
n.r	0.0365 (1.000, 1.0, 0.6)	0.2512 (0.975, 9.5, 0.8)	0.0200
r.r	0.0194 (1.000, 1.0, 0.6)	0.2376 (0.975, 9.5, 0.2)	0.0090
mon-inf	− 0.2016 (0.975, 9.5, 0.2)	0.7993 (0.975, 0.5, 0.8)	0.2104
n.r-inf	0.8030 (0.985, 1.5, 0.8)	0.7566 (0.975, 9.5, 0.2)	− 0.0072
r.r-inf	− 0.9990 (1.005, 1.5, 0.8)	− 0.7304 (1.010, 9.0, 0.8)	− 0.8672
vel	0.0052 (0.975, 1.0, 0.8)	0.0854 (0.975, 9.5, 0.2)	0.1239

Note: inf is the mean of the inflation rate; n.r is the mean of the nominal interest rate; r.r is the mean of the real interest rate; mon-inf is the correlation of the money and the inflation rate; n.r-inf is the correlation of the nominal interest rate and the inflation rate; r.r-inf is the correlation of the real interest rate and the inflation rate; vel is the coefficient of variation of the velocity of money.

Table 8. *Simulation results of the cash–credit model (M2; 1980:2–1992:1)*

	Simulations		Data
	Min (β, α, μ)	Max (β, α, μ)	
inf	0.0051 (0.975, 0.0, 0.4)	0.0068 (0.975, 9.5, 0.2)	0.0051
n.r	0.0106 (1.045, 8.5, 0.6)	0.0891 (0.975, 9.5, 0.2)	0.0152
r.r	0.0058 (1.045, 8.5, 0.8)	0.0841 (0.975, 9.5, 0.2)	0.0101
mon-inf	− 0.7601 (0.975, 9.5, 0.2)	0.8769 (0.975, 0.0, 0.8)	− 0.3613
n.r-inf	− 0.8686 (0.975, 0.0, 0.8)	0.7534 (0.975, 9.5, 0.2)	0.6753
r.r-inf	− 0.9830 (0.975, 0.0, 0.8)	− 0.4447 (0.975, 9.5, 0.8)	− 0.4890
vel	0.0056 (0.975, 0.0, 0.8)	0.0432 (0.975, 9.5, 0.2)	0.0290

Note: inf is the mean of the inflation rate; n.r is the mean of the nominal interest rate; r.r is the mean of the real interest rate; mon-inf is the correlation of the money and the inflation rate; n.r-inf is the correlation of the nominal interest rate and the inflation rate; r.r-inf is the correlation of the real interest rate and the inflation rate; vel is the coefficient of variation of the velocity of money.

interest rates are lower than the means of the simulated sample based on the model. Note that the interest rates tend to be lower than the values expected from the model. This may reflect the policy management in Japan before the 1970s.

Table 8 shows the results of the cash–credit model for the sample period between the second quarter of 1980 and the first quarter of the 1992 (sample [C]). The explanatory power of the cash model is not high in this case either. Thus, we show the results only for the cash–credit model. This table shows the strong predictive power of the cash–credit model in the 1980s. The sample value falls inside the range attainable from the cash–credit model for all statistics. In the 1980s, Japanese asset markets were liberalized not only domestically but also internationally. The policy regime shifted from a control-oriented system to a market-oriented system. The policy shift resulted in flexible movements in asset prices in the 1980s. Given this situation, it is meaningful to find that the model can generate statistics consistent with sample moments computed from Japanese time-series data for the 1980s.

V. SOME CONCLUDING REMARKS

In this paper, we analysed the monetary aspects of the Japanese economy based on the cash-in-advance models developed by Svensson (1985) and Lucas and Stokey (1987). We found that the cash–credit model can generate statistics consistent with sample moments computed from Japanese time-series data in the 1980s. It is interesting to see that the Japanese economy in the 1980s can be explained by a dynamic macroeconomic model, which is consistent with Hamori's findings (see Hamori, 1992a, 1992b). The results for the period before the 1970s show that theoretical moments underestimate the mean values of interest rates, which is consistent with the policy management at that time. Research, taking account of more moments to predict the model, is to be completed in the near future.

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REFERENCES

Clower, R. W. (1967) A reconsideration of the microfoundation of monetary theory, *Western Economic Journal*, **6**, 1–9.

Finn, M. G., Hoffman, D. L. and Schlagenhauf, D. E. (1990) Intertemporal asset-pricing relationships in barter and monetary economies: an empirical analysis, *Journal of Monetary Economics*, **25**, 431–51.

Hamori, S. (1992a) Test of C-CAPM for Japan: 1980–1988, *Economics Letters*, **38**, 67–72.

Hamori, S. (1992b) On the structural stability of preference parameters obtained from Japanese financial market data, *Economics Letters*, **40**, 459–64.

Hamori, S. and Kitasaka, S. (1992) Small sample properties of generalized method of moments estimators with MA(1) error, *Journal of the Japan Statistical Society*, **22**, 161–72.

Hamori, S., Kitasaka, S. and Tanizaki, H. (1996) On a test for structural stability of Euler conditions parameters estimated via the generalized method of moments estimators: small sample properties, *Econometric Reviews*, **15**, 97–114.

Hansen, L. P. (1982) Large sample properties of generalized method of moments estimators, *Econometrica*, **50**, 1029–54.

Hansen, L. P. and Singleton, K. J. (1984) Errata, *Econometrica*, **52**, 267–68.

Hodrick, R. J., Kocherlakota, N. and Lucas, D. (1991) The variability of velocity in cash-in-advance models, *Journal of Political Economy*, **99**, 358–84.

Kandel, R. J. and Stambaugh, R. F. (1990) Expectations and the volatility of consumption and asset returns, *Review of Financial Studies*, **3**, 39–72.

Kocherlakota, N. R. (1990a) On the 'discount' factor in growing economies, *Journal of Monetary Economics*, **25**, 43–48.

Kocherlakota, N. R. (1990b) On tests of representative consumer asset pricing models, *Journal of Monetary Economics*, **26**, 285–304.

Lucas, E. R. Jr. (1982) Interest rates and currency prices in a two-country world, *Journal of Monetary Economics*, **10**, 335–59.

Lucas, E. R. Jr. and Stokey, N. L. (1987) Money and interest in a cash-in-advance economy, *Econometrica*, **55**, 491–513.

Prescott, E. C. (1986) Theory ahead of business cycle measurement, *Federal Reserve Bank of Minneapolis Quarterly Review*, **10**, 9–22.

Rietz, T. A. (1988) The equity premium: a resolution, *Journal of Monetary Economics*, **22**, 117–33.

Svensson, L. E. O. (1985) Money and asset prices in a cash-in-advance economy, *Journal of Political Economy*, **93**, 919–44.

Tauchen, G. (1986) Statistical properties of generalized method-of-moments estimators of structural parameters obtained from financial market data, *Journal of Business and Economics*, **4**, 397–416.

Tauchen, G. and Hussey, R. (1991) Quadrature-based methods for obtaining approximate solutions to nonlinear asset pricing models, *Econometrica*, **59**, 371–96.

APPENDIX

Consumption

Consumption is based on the seasonally adjusted purchase of final consumption goods. The data are obtained from the *Annual Report of National Account* (Economic Planning Agency).

Money supply

Money supply is the seasonally adjusted M1 and M2 and is obtained from the *Economic Statistics Annual* (Bank of Japan).

Population

The population figure is the number of people over 15 years old and is obtained from *Vital Statistics* (the Statistics and Information Department, Minister's Secretariat, Ministry of Health and Welfare).

Velocity of money

The velocity of money is measured as the ratio of nominal consumption divided by money supply.

Price

The price level is defined as the implicit deflator of the consumption series. These series are calculated from the real and the corresponding nominal consumption measure.

Nominal interest rate

The nominal interest rate is based on the call rate and is taken from the *Economic Statistics Annual* (Bank of Japan).