

UNCOVERING THE GOODHART'S LAW: THEORY AND EVIDENCE

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ABSTRACT. This paper addresses the Goodhart's Law in a cash-in-advance economy with monetary policy regime switching. Using the Japanese data of the money velocity, we found that although our cash-credit model fails to generate a downward trend in the actual velocity, the model succeeds in terms of velocity's variation and correlations with money growth rates or nominal interest rates, with procyclicality of velocity unpredictable.

KEYWORDS. Goodhart's Law, velocity of money, Taylor rule, Markov regime switching, cash-credit model.

JEL CLASSIFICATION CODES. E41, E52.

1. INTRODUCTION

The Goodhart's Law says that “ any observed statistical regularity will tend to collapse once pressure is placed upon it for control purposes ”(p.116, Goodhart, 1975). Following the recent papers exploring potential roles of monetary aggregates (Estrella and Mishkin, 1997; Nelson, 2002; Leeper and Roush, 2003; Miyao, 2005), this paper addresses the Goodhart's Law in a monetary model where money stock plays an explicit role in monetary policy rule.¹ The purpose of the

Date: December 14, 2005.

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¹The EconLit says as of October 22, 2005, that the last paper including *the Goodhart's Law* in a title is Evans(1985). The issue is also put aside in the US standard macroeconomics textbooks, with an exception of DeLong(2002) mentioning as follows:

”Political monetarism” crashed and burned in the early 1980s. It became clear that stable control of the money stock was not easy to obtain. It became clear that stable control of the money stock did not solve the problems of stabilization policy because the velocity of money was unstable. Indeed, *Goodhart's law* maintained that the better your control over any particular measure of the money stock, the more unstable its velocity would be (Goodhart, 1970). And the velocity of money turned extraordinarily unstable after 1980.

In honor of Charles Goodhart, Chrystal and Mizen(2003) also deal with the Law in details.

paper is to generate numerical predictions for the Japanese data of money velocity in a cash-in-advance economy with a Markov regime switching monetary policy rule including money growth rates.

The model of the paper closely draws on Hodrick, Kocherlakota and Lucas(1991), which develops a cash-credit model constructed for numerical study on variability in the US money velocity. We modify the model, incorporating instead of an exogenously given money growth rates a generalized Taylor-type rule with money growth another explanatory variable. Furthermore, the generalized monetary policy rule is assumed to be state-dependent, following a Markov transition process. An advantage of our model over Hodrick, Kocherlakota and Lucas(1991) lies in handling an instrument rule of nominal interest rate, not money growth. Considering the period of the US FRB Chairman Paul Volker, the state-dependence of monetary policy also expresses *occasional focus* on money growth in practice.

The paper is organized as follows. Section 2 accounts for stochastic properties of data on the velocity of money in Japan, suggesting that unpredictable variations in money velocity is probably due to changes in monetary policy. Section 3 introduces a cash-credit model of Lucas and Stokey(1987), incorporating a state-dependent monetary policy rule. In Section 4, we present a computational method of solving the cash-credit model, estimating Markov regime switching equations of the Japanese monetary policy. The computation results in a numerical comparison between the model's predictions and the actual velocity of money. Section 5 concludes the paper.

2. STOCHASTIC PROPERTIES OF MONEY VELOCITY IN JAPAN

We account for stochastic structures of the money velocity in Japan, which in terms of low variability of average money growth, Friedman(1983) evaluated more highly than US.² Figure 1 shows the Japanese quarterly data from 1967:1 to 2004:3. Our measure of velocity is defined as a ratio of (seasonally adjusted) nominal GDP divided by M2+CDs(average amounts outstanding). It is apparent that, in spite of the Friedman's praises, the Japanese velocity data has a consistently downward trend for the sample period. Though the data appears to be more stable relative to the call rates or the money growth rates, we can make sure of some observations in which the money velocity fluctuated to a considerable extent. The clearest is a rapid fall in 1971 and in reverse a sharp increase in 1973. Each coincides with the US abandonment of the gold standard, and either the start of the floating

²There are numerous empirical studies on the recent US velocity or money demand: for example, Mehra(1993), Thornton(1995), Miyao(1996a), McGrattan(1998), Carlson, Hoffman, Keen and Rasche(2000), and Ball(2001). As a whole, the literature suggests unstable demand for money in the 1980s and the restoration of the stability since the 1990s.

exchange rates or the first oil crisis that arose from the OPEC's oil embargo, the effects of which we will address below.

2.1. Descriptive statistics. We list some descriptive statistics on velocity of money in Japan: the mean, standard deviation, coefficient of variation, and correlations with output growth rates, money growth rates, or nominal interest rates. The results are in Table 1. The calculations are for the full sample period 1968:1 to 2004:3 and the limited sample ending at 1995:2. A choice of the latter sample is motivated by less variability of money growth rates after 1995 than before, as apparent in Figure 1. It is evident that the mean value of velocity is lower and the variations are higher for the full sample than for the limited one excluding the observations of low monetary volatility. According to the Friedman's hypothesis of money supply volatility (Friedman, 1983; Hall and Noble, 1987; Mehra, 1989), a decline in velocity and an increase in its volatility could be caused by an increase in volatility of money growth. Table 1 suggests evidence against the hypothesis. We also observe a procyclicality of money velocity in the Japanese data.

2.2. Stationarity. The detrended data of velocity may probably be of high serial correlation. We test stationarity of the Japanese data on money velocity using five unit root tests: the augmented Dickey-Fuller test (Dickey and Fuller, 1979; ADF); the modified Dickey-Fuller test based on GLS detrended series (Elliot, Rothenberg and Stock, 1996; DF-GLS); the Elliot-Rothenberg-Stock point optimal test (Elliot, Rothenberg and Stock, 1996; ERS); the Phillips-Perron test (Phillips and Perron, 1988; PP); the Kwiatkowski-Phillips-Schmidt-Shin test (Kwiatkowski, Phillips, Schmidt and Shin, 1992; KPSS). Note that a null hypothesis of all the tests except for the KPSS is a unit root.

The estimation period is limited up to 1995:2, taking into account any structural break in money demand detected by Nakashima and Saito (2004). The data is natural-log transformed. All the tests include a constant and a linear time trend. Lag lengths for correcting serial correlation in the ADF and DF-GLS, lag lengths for AR spectral regression in the ERS, and bandwidth in a Bartlett kernel for KPSS and PP are chosen based on Schwartz criterion. Table 2 supports stationarity of the level data as well as the first difference series, or the velocity being integrated of order one $I(0)$. Any tests else than the Phillips-Perron type can reject the null hypothesis of a unit root, and the KPSS test cannot reject the null hypothesis of stationarity.

2.3. GMM estimates. We estimate a velocity function in which the logged money velocity depends on the call rates besides a constant. Instead of cointegration tests which literature on money demand (Miyao, 1996b; Nakashima and Saito, 2004) pursued, we choose a GMM estimator, based on the unit root tests supporting stationarity of money

velocity. Bandwidth in a Bartlett kernel is fixed at 4 and the instrumental variables include three lags of the dependent and independent variables as well as a constant. Following Miyao(1996b), we split the full sample period of 1968:1 to 1995:2 into three types of subsample: 1968:1 to 1985:4, 1968:1 to 1989:4, and 1986:1 to 1995:2. The end and the beginning dates in the first and the third subsamples correspond to when a series of financial deregulations on interest rates started, while the second subsample is motivated by a fact that the asset bubbles in Japan had burst in 1989.

Table 3 shows the GMM estimates. The interest-rate semi-elasticity of money demand is estimated as equal to 0.04 for the full sample period. It is also evident that the parameter of the semi-elasticity exhibits instability, crucially depending on the sample periods. The recent subsample starting from 1986:1 particularly presents a significant positive relationship between money demand and nominal interest rates.

Figure 2 compares the actual values of money velocity to the predictions using the GMM estimates for the full sample period. Apparently, though the residuals display a high serial correlation, the predictions coincide with the timing of peaks and bottoms in the actual values up to the middle of the 70s. However, we cannot trace the downward trend in money velocity.

2.4. Changes in monetary policy. The residuals in Figure 2 indicate the observations of money velocity that deviate from the GMM predictions. We find three consecutive periods when the deviations range over a ± 1 standard error band: the early 70s, during the second half of 70s, and around 1990. Following the chronological studies of the Japanese monetary policy(Ito, 1993; Okina, 1993; Cargill, Hutchison and Ito, 1997), we can plausibly provide characterizations associated with these periods as when the Japanese monetary policy considerably changed.³

In 1971, Japan was faced with the US suspension of the dollar's convertibility into gold, so that it abandoned the fixed exchange rate system at 360 yen per dollar. After the Smithsonian Agreement set the exchange rate at 308 yen per dollar afterward, the exchange rates led to floating in 1973. During these few years, the Japanese government made efforts to keep the yen from overvaluing relative to 360 or 308 yen per dollar. " The Bank of Japan maintained high monetary growth in 1972-73 in order to keep the yen from appreciating further from the Smithsonian rate. This attempt to keep the yen undervalued created substantial inflationary pressure "(p.127, Ito, 1993). The first oil crisis beginning in 1973 further accelerated inflation. The Bank of Japan in

³Throughout the 1960s, the primary instrument of monetary policy by the Bank of Japan was the window guidance, which quantitatively limited commercial bank lendings. The window guidance policy officially continued till 1991.

reverse withdrew the excess liquidity in order to check those inflationary trend, resulting in a sharp increase in the velocity.

After the wild inflation in 1973-74, the Bank of Japan announced a new monetary policy procedure in 1975. Then the Bank of Japan came to emphasize money supply as an intermediate target, publishing a monetary forecast of annual changes in M2+CDs(Chapter 3, Cargill, Hutchison and Ito, 1997). Since the announcements of the monetary forecast, variability in monetary growth had been stabilized, as observed in Figure 1.

Consequently, the cause of the variations in velocity for those periods in the 70s may lie in such changes in monetary controls by the Bank of Japan.

Concerning the unpredictable velocity around 1990, however, there are disparate empirical evidences(Okina, 1993). On one hand, as is evident from the GMM estimates in Table 3, there were likely to be structural changes in money velocity in the second half of the 1980s. The parameters instability is probably due to the financial deregulations since 1985 or/and to the asset price bubble that had burst in 1989. On the other hand, Cargill, Hutchison and Ito(1997) show out-of-sample forecasts of their estimated money demand functions, indicating“ that a shift in the stance of monetary policy, and not financial deregulation, was primarily responsible for rapid monetary growth during 1987-89 ” (p.59, Cargill, Hutchison and Ito, 1997).

3. A CASH-IN-ADVANCE ECONOMY WITH MONETARY REGIME SWITCHING

In order to account for the stochastic structures of velocity shown in Section 2, we construct a cash-in-advance economy.

3.1. A cash-credit model. We follow the cash-in-advance model proposed by Hodrick, Kocherlakota and Lucas(1991). Consider a representative agent's problem that maximizes

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c_{1t}, c_{2t})$$

with an instantaneous utility function

$$U(c_{1t}, c_{2t}) = \frac{(c_{1t}^{\psi} c_{2t}^{1-\psi})^{1-\alpha} - 1}{1-\alpha}$$

where c_{1t} denotes cash goods that must be purchased with cash held in the first subperiod, and c_{2t} denotes credit goods that can be paid in the second subperiod later. The goods are purchased in the first subperiod, and money and stocks are traded in the second subperiod in the market. Thus, credit goods are purchased in the first subperiod, and credit accounts are cleared in the second subperiod. Note that agents face no uncertainty between the first and second subperiods.

Now the cash-in-advance constraint is given by

$$P_t c_{1t} \leq M_t$$

where P_t denotes the price of two types of goods, and M_t denotes the cash held in the first subperiod. The budget constraint is given by

$$M_{t+1} + Q_t z_{t+1} = z_t P_t y_t + Q_t z_t + (\omega_t - 1) X_t + M_t - P_t (c_{1t} + c_{2t})$$

where z_t denotes shares of stock, Q_t denotes stock price, X_t denotes monetary supply, and $\omega_t = X_{t+1}/X_t$ implies that $(\omega_t - 1)X_t$ indicates a lump-sum money transfer. With the market clearing condition, $X_t = M_t$, $z_t = 1$, and $c_{1t} + c_{2t} = y_t$ where y_t denotes the total output of cash goods and credit goods, and the growth of output $g_t = y_t/y_{t-1}$. Following Svensson(1985) and Lucas and Stokey(1987), we assume that prices and cash-goods consumption are expressed as

$$\begin{aligned} P_t &= p(f_t) X_t / y_{t-1} \\ Q_t &= q(f_t) P_t y_{t-1} \\ c_{1t} &= c(f_t) y_{t-1} \end{aligned}$$

where f_t implies state variables described later. The credit-goods consumption can be expressed as $c_{2t} = (g_t - c(f_t))y_{t-1}$, and the marginal utilities are expressed as

$$\begin{aligned} \frac{\partial U(c_{1t}, c_{2t})}{\partial c_{1t}} &= u_1(f_t) y_{t-1}^{-\alpha} \\ \frac{\partial U(c_{1t}, c_{2t})}{\partial c_{2t}} &= u_2(f_t) y_{t-1}^{-\alpha} \end{aligned}$$

where

$$(1) \quad u_1(f_t) = \psi(g_t - c(f_t))^{(1-\psi)(1-\alpha)} c(f_t)^{\psi(1-\alpha)-1},$$

and

$$(2) \quad u_2(f_t) = (1 - \psi)(g_t - c(f_t))^{(1-\psi)(1-\alpha)-1} c(f_t)^{\psi(1-\alpha)}.$$

Defining $m(f_t) = 1/p(f_t)$, the cash-in-advance constraint can be rewritten as

$$(3) \quad c(f_t) \leq m(f_t).$$

Introducing the multipliers $\mu(f_t)$ for the cash-in-advance constraint, the first-order conditions are reduced to the following two equations

$$(4) \quad u_1(f_t) = u_2(f_t) + \mu(f_t)$$

$$(5) \quad \mu(f_t) = u_1(f_t) - \frac{\beta E_t[u_1(f_{t+1})m(f_{t+1})]g_t^{1-\alpha}}{\omega(f_t)m(f_t)}$$

with the Kuhn-Tucker condition

$$(6) \quad \mu(f_t) \geq 0 \text{ and } \mu(f_t)(m(f_t) - c(f_t)) = 0.$$

Nominal interest rate is defined from nominal present value of a nominal bond held at the end of period t that pays one unit of money at the end of period $t + 1$, as follows.

$$(7) \quad i_t = \frac{E_t\left[\frac{\mu_{t+1}}{(1+\pi_{t+1})}\right]}{E_t\left[\frac{u_2(f_{t+1})}{(1+\pi_{t+1})}\right]}$$

where the inflation rate plus one is expressed as

$$(8) \quad 1 + \pi_{t+1} = \frac{m(f_t)\omega(f_t)}{m(f_{t+1})g_t}$$

from the formula of goods price $P_t = p(f_t)X_t/y_{t-1}$. Finally, velocity v is defined as

$$(9) \quad v_t = \frac{P_t y_t}{X_t} = \frac{g_t}{m(f_t)}$$

also using the formula of goods price.

While Hodrick, Kocherlakota and Lucas(1991) assume an exogenous state $f_t = \{g_t, \omega_t\}$ that follows a Markov process, we consider the money growth ω_t as an explanatory variable in a policy rule that depends on a policy state s_t . For simplicity, we assume such an information structure that the policy state s_t is observable for both private agents and central bank. Thus, in this paper, state $f_t = \{g_t, s_t\}$.

In the model, a stationary equilibrium is a set of functions $\{c(f_t), m(f_t), \mu(f_t), \omega(f_t)\}$ satisfying Equation (1), (2), (3), (4), (5) and (6). Nominal interest rates, inflation rates and velocity are determined vis-a-vis a stationary equilibrium.

3.2. Monetary policy rule. We incorporate into the cash-in-advance economy a monetary policy rule, in which monetary policy regimes can switch according to a Markov process. We identify each monetary policy regime, depending on how *systematic* central bank's monetary targeting is in controlling nominal interest rates. Thus, we ignore roles of an unsystematic part consisting of random shocks to monetary policy rule, as analyzed in the VAR literature on monetary policy.

Following Ireland(2001, 2003, 2004) and Leeper and Roush(2003), we assume a generalized Taylor-type rule as follows:

$$(10) \quad i_t = \theta_0(s_t) + \theta_1(s_t)E_t[\pi_{t+1}] + \theta_2(s_t)\omega_t$$

where the second term relates to the Taylor principle. Such a generalized policy rule deserves comparisons with the standard Taylor-type rule(Taylor, 1993).

First, as an explanatory variable in the forward-looking Taylor-type rule(Woodford, 2003), are not actual rates of inflation but the expected rates used for simplicity in solving the model.

Second, money growth rates are an explanatory variable added to the standard Taylor-type rule. Literature suggests two interpretations on roles of money growth in the nominal interest rate rule. One is

as information variable(Ireland, 2001, 2003, 2004; Leeper and Roush, 2003), which is on the basis of the conventional paper of Poole(1970). It suggests that it is desirable for central banks to control nominal interest rates so as to endogenously accommodate shocks to money demand, predicting any changes in financial environments. The informational role of money growth requires a positive coefficient θ_2 on money growth rates in the generalized Taylor-type rule.

The other interpretation of money growth is as intermediate target(Christiano and Rostagno, 2001), what is our standpoint in considering possibilities of the Goodhart’s Law in an application of the generalized Taylor-type rule. Exogenous concern of central bank over money growth could be perceived in the generalized rule with negative coefficient θ_2 . According to the Goodhart’s Law, such concern “ for control purposes ”would perilously causes variations in velocity of money.

4. COMPUTATION OF THE MODEL

4.1. Markov regime switching of monetary policy. Following Ireland(2001, 2003, 2004) and Leeper and Roush(2003), we estimate the following equation of monetary policy rule

$$(11) \quad i_t = \theta_0(s_t) + \theta_1(s_t)E_t[\pi_{t+1}] + \theta_2(s_t)\omega_t + \varepsilon_t(s_t).$$

All the coefficients on the independent variables including constant and error terms depend on the monetary policy regime s_t each period. Following Hamilton(1989), we estimate a Markov switching model of monetary policy regimes.

Prior to a Markov regime switching model, for a comparison, we use GMM estimator to estimate a generalized Taylor-type rule where there are assumed to be no regime switchings in monetary policy. We choose observations ending at 1995:2, since the zero bound of nominal interest rates seems to have been effective for the Bank of Japan, as obvious in Figure 1. The zero bound is another consideration for the Bank of Japan else than what this paper focuses on. The estimates for sample period 1968:1-1995:2 are as follows(standard errors in brackets):

$$i_t = \begin{array}{cccc} 2.28 & +1.09\pi_{t+1} & +0.47\omega_t & +\varepsilon_t \\ [0.70] & [0.21] & [0.23] & [2.42] \end{array}$$

The positive coefficient on money growth rates indicates the endogenous money supply by central bank. The endogenous money supply aims at accommodating shocks to money demand, resulting in interest rate smoothing.⁴ Note that in the estimated policy rule, the money growth plays a role of information variable, which the Goodhart’s Law does not presume.

⁴The term *endogenous money supply* may be misleading, since there is another class of endogenous money supply with the instrument monetary aggregates rather than nominal interest rates(Gavin and Kydland, 1999).

In a Markov regime switching model, we only allow for two states ($s_t = 1, 2$) identified depending on a parameter $\theta_2(s_t)$ in monetary policy rule. Table 4 shows the maximum likelihood estimates of an unrestricted model, as well as two models with equality restrictions on either coefficients or standard errors in the regressions. Either the Schwartz criterion, Akaike information criterion or log likelihood test favors the unrestricted model. Moreover, as a result of the Wald coefficient tests in the restricted model, we can identify $s_t = 1$ not only as a state where less active responses to inflation rates are exhibited, but also where monetary growth rates are more focused on as a policy target by the Bank of Japan. In the other state 2, since the coefficient $\theta_2(s_t = 2)$ is insignificant, the standard Taylor-type rule meeting the Taylor principle is introduced. The estimated stationary transition probabilities p_{ij} from state i to state j are

$$\begin{pmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{pmatrix} = \begin{pmatrix} 0.89 & 0.11 \\ 0.03 & 0.97 \end{pmatrix}.$$

In particular, it is evident that the active Taylor-type rule is quite persistently followed in state 2.

4.2. Parameters. Based on the Japanese GDP growth data from 1968:1 and 1995:2, we discretize the quarterly output growth of the full range of $[-0.3\%, 1.5\%]$ into 18 ranks by 0.1%, and pick up the middle point $\{-0.25\%, -0.15\%, -0.05\%, 0.05\%, \dots, 1.35\%, 1.45\%\}$. The state of policy rule is assumed to be two states $\{1, 2\}$. These two states are assumed to be independent, and thus, the total number of states becomes 36.

Monetary policy equation is from unrestricted ML estimates of the Markov regime switching model in Table 4:

$$i_t = 0.012064 + 0.990979E_t[\pi_{t+1}] - 0.329413\omega_t$$

for $s_t = 1$, and

$$i_t = 0.010130 + 1.811579E_t[\pi_{t+1}] + 0.003648\omega_t$$

for $s_t = 2$, transforming annual percentage data to quarterly process expressed as ratio in the model. Markov transition probability matrix of the policy state s_t is also from the same estimation result.

Markov transition probability matrix of the output growth g_t is constructed with the standard deviation 0.1582% of differences between g_t and g_{t+1} . Assuming the normal distribution, the probability from $g_t = g_i$ to $g_{t+1} = \{g_{i-5}, g_{i-4}, g_{i-3}, g_{i-2}, g_{i-1}, g_i, g_{i+1}, g_{i+2}, g_{i+3}, g_{i+4}, g_{i+5}\}$ becomes $\{0.00223, 0.01125, 0.04357, 0.11451, 0.20444, 0.24800, 0.20444, 0.11451, 0.04357, 0.01125, 0.00223\}$. When the matrix is truncated, the probability is re-calculated without truncated states; for example, a transition probability from $g_t = g_1$ to $g_{t+1} = \{g_1, g_2, g_3, g_4, g_5\}$ becomes $\{0.24800, 0.20444, 0.11451, 0.04357, 0.01125, 0.00223\}$ divided by the total of 0.62400.

Discount factor β is assumed to be 0.98, and ψ and α in the instantaneous utility function is assumed to be 0.5 and 3.0, respectively.

4.3. Solution algorithm. When the cash-in-advance constraint is not binding at the state $f_t = f_i$, the multiplier μ_t must be zero. From Equation (4), $u_1(f_t = f_i) = u_2(f_t = f_i)$, and from Equation (1), (2) and (3), this leads to $c(f_t = f_i) = \psi g_t$ that must be strictly smaller than $m(f_t = f_i)$. Using the result, we have only to solve for $m(f_t = f_i)$ Equation (5)

$$(12) \quad u_1(f_t)\omega(f_t)m(f_t) - \beta E_t[u_1(f_{t+1})m(f_{t+1})]g_t^{1-\alpha} = 0.$$

where $\omega(f_t)$ is reduced from the monetary policy equations.

On the other hand, when the cash-in-advance constraint is binding at the state $f_t = f_i$, it implies that $\psi g_t > c(f_t = f_i) = m(f_t = f_i)$ and the multiplier μ_t must be nonnegative. Thus, for $m(f_t = f_i)$ we solve Equation (5)

$$(13) \quad u_2(f_t)\omega(f_t)m(f_t) - \beta E_t[u_1(f_{t+1})m(f_{t+1})]g_t^{1-\alpha} = 0.$$

Note that the difference between Equation (12) and Equation (13) lies in whether the marginal utility at period t is of either cash-goods or credit goods.

Hodrick, Kocherlakota and Lucas(1991) proposes an algorithm to obtain $m(f_t)$ using discretized $\{g_t, \omega_t\}$ with 16 states. Although the proposed algorithm using simple iterations in Appendix B in Hodrick, Kocherlakota and Lucas(1991) show good performance with exogenous money growth process, it fails to obtain our solution with the endogenous money growth. Therefore, we solve a set of 36 nonlinear equations of either of the above first-order condition at each discretized states f_i , using a pre-supplied numerical library IMSL of FORTRAN. An initial guess is set as $m(f_i) = \psi g_i$.

4.4. Results. We compare the predictions of our cash-credit model including either the regime switching rule or the estimated state-independent rule. Note that the former model supposes the money supply's role as intermediate target, while the latter does the informational role. Figure 5 indicates the money velocity predicted by either of the model. It is apparent that neither prediction of the model can totally follow the actual velocity data. In case of the GMM estimates, the predicted velocity appears nearly fixed around 2.1. On the other hand, although the Markov regime switching rule cannot bring into existence the downward trend in the velocity, it barely generates the fluctuations in the middle of the 1970s. Table 5 presents another evidence of the advantage of the regime-dependent rule over the independent one. We find better statistics in the model's predictions relative to the GMM estimates, especially in terms of both the coefficient of variation and the standard deviation. These evidences weakly suggest that the Goodhart's Law is obtained in Japan.

However, there remain some stochastic properties of the Japanese data to be accounted for: for example, the downward trend and procyclicality of velocity, and the large variations in money growth rates. Further analyses will be needed.

5. CONCLUSION

This paper addresses the Goodhart's Law in a cash-credit model with a generalized Taylor-type rule depending on policy regimes. Using the Japanese data of the money velocity, we found that although our cash-credit model fails to generate a downward trend in the actual velocity, the model succeeds in terms of velocity's variation and correlations with money growth rates or nominal interest rates, with procyclicality of velocity unpredictable.

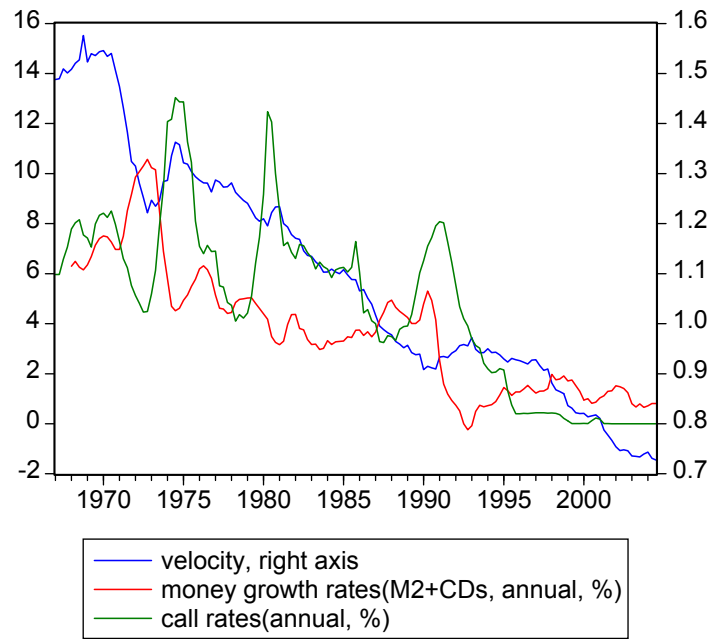
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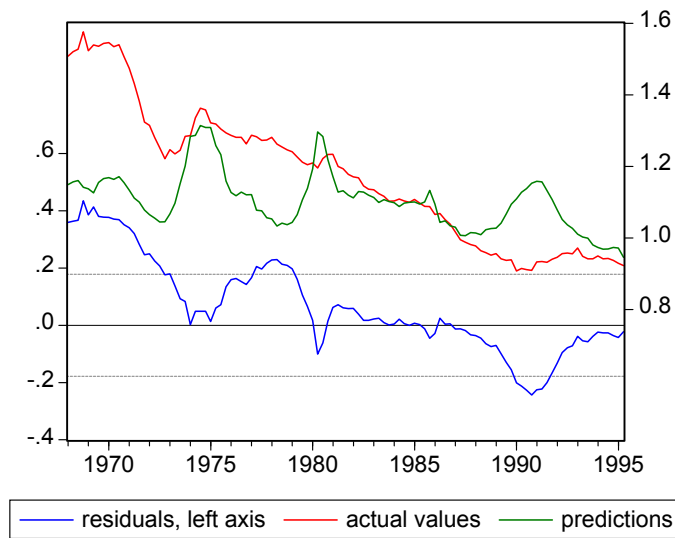
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FIGURE 1. Velocity of money and monetary policy



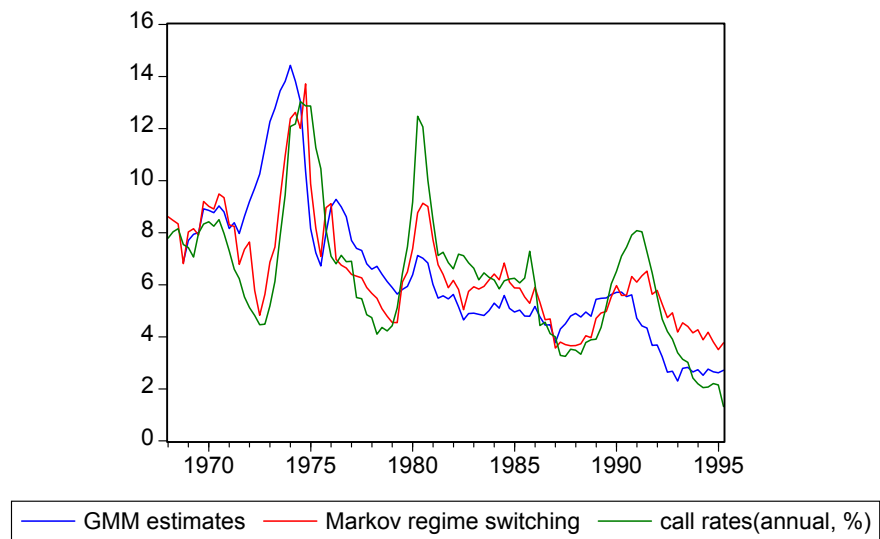
Note: Japan, quarterly, 1967:1-2004:3. Velocity of money is measured as a ratio of (seasonally adjusted) nominal GDP divided by M2+CDs(average amounts outstanding).

FIGURE 2. GMM estimates of money velocity



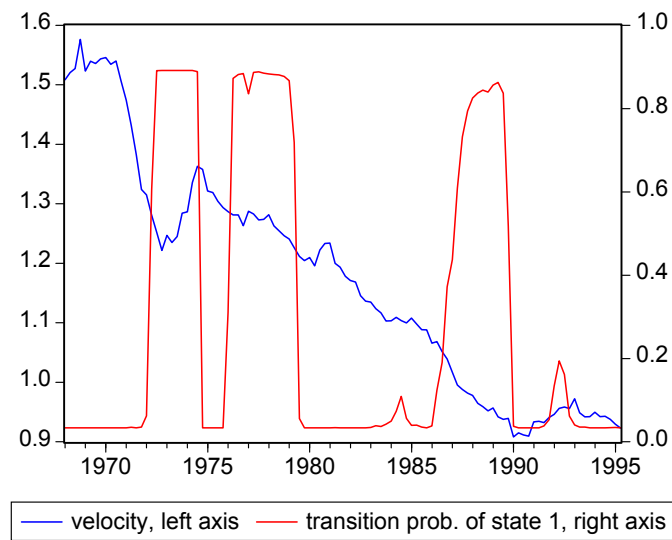
Note: Japan, quarterly, 1968:1-1995:2. Fitted values are calculated from GMM estimates. Thinner dotted lines indicate ± 1 standard errors of the residuals.

FIGURE 3. Predictions of call rates with Markov regime switching and GMM estimates



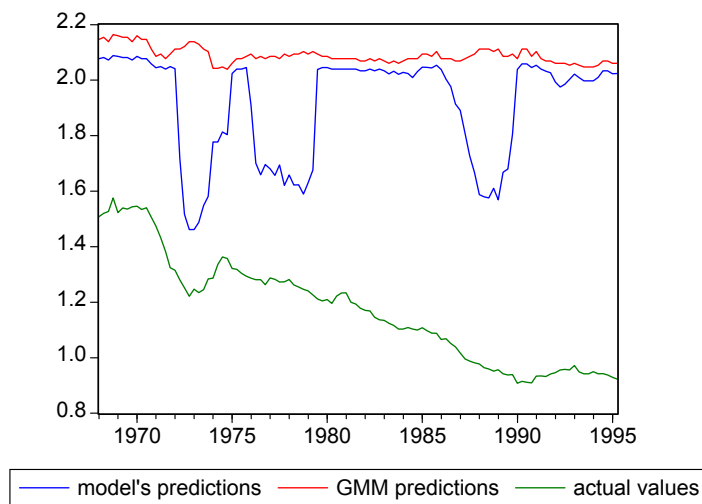
Note: Japan, quarterly, 1968:1-1995:2. Markov regime switching case is predicted using the transition probabilities.

FIGURE 4. State transition probability



Note: Japan, quarterly, 1968:1-1995:2.

FIGURE 5. Model's predictions of money velocity



Note: Japan, quarterly, 1968:1-1995:2. Markov regime switching case is predicted using the transition probabilities.

TABLE 1. Sample statistics of money velocity

sample periods (quarters)	statistics					
	$mean(v)$	$std(v)$	$cv(v)$	$corr(v, g)$	$corr(v, \omega)$	$corr(v, i)$
68:1-2004:3	1.08	0.23	0.21	0.61	0.79	0.77
68:1-95:2	1.17	0.19	0.16	0.55	0.68	0.63

Note: Japan. Statistics on velocity(v) are the mean $mean(v)$, standard deviation $std(v)$, coefficient of variation $cv(v)$ and correlations of velocity $corr(v, \cdot)$. g , ω and i denote output growth rates, money growth rates and nominal interest rates.

TABLE 2. Unit root tests on money velocity

tests	test statistics	
	level	first difference
ADF	-3.76(3)**	-5.07(1)*
DF-GLS	-3.61(3)*	-4.96(1)*
ERS	1.88(3)*	3.04(1)*
PP	-2.67(7)	-9.30(6)*
KPSS	0.064(8)	0.048(6)

Note: Japan, quarterly, 1968:1-1995:2. The data is natural-log transformed. All the tests include a constant and a linear time trend. Lag lengths or bandwidths are in each parenthesis. Lag lengths for correcting serial correlation in the ADF(Dickey and Fuller, 1979) and DF-GLS(Elliot, Rothenberg and Stock, 1996), lag lengths for AR spectral regression in the ERS(Elliot, Rothenberg and Stock, 1996), and bandwidth in a Bartlett kernel for PP(Phillips and Perron, 1988) and KPSS(Kwiatkowski, Phillips, Schmidt and Shin, 1992) are chosen based on Schwartz criterion. Test critical values are as follows: -4.04, -3.45, -3.15(t-statistics in ADF and PP); -3.57, -3.02, -2.73(t-statistics in DF-GLS); 4.23, 5.64, 6.80(p-statistics in ERS); 0.216, 0.146, 0.119(LM statistics in KPSS) for 1%, 5% and 10% significance levels, respectively. Each *, ** or *** remarks a rejection of each null hypothesis in 1%, 5% or 10% significance level. A null hypothesis of all the tests except for the KPSS is a unit root.

TABLE 3. GMM estimates of money velocity function

sample periods (quarters)	coefficients	
	constant	call rates
68:1-95:2	-0.09(0.05) ^{***}	0.04(0.008) [*]
68:1-85:4	0.14(0.05) [*]	0.007(0.006)
68:1-89:4	0.06(0.06)	0.02(0.006) ^{**}
86:1-95:2	-0.04(0.01) [*]	-0.004(0.002) ^{***}

Note: Japan. In each parenthesis, standard errors of the coefficient are reported. The data of money velocity is natural-log transformed. Bandwidth in a Bartlett kernel is fixed at 4 and the instrumental variables include three lags of the dependent and independent variables as well as a constant. Each *, ** or *** remarks 1%, 5% or 10% levels of significance.

TABLE 4. ML estimates of unrestricted and restricted models

parameters	unrestricted model	restricted models	
		equal coefficients	equal variances
θ_0	4.83(0.32)	4.68(0.31)	4.99(1.07)
	4.05(0.35)		3.85(0.29)
θ_1	0.99(0.04)	1.05(0.14)	1.03(0.14)
	1.81(0.17) [*]		2.25(0.16) [*]
θ_2	-0.33(0.05)	-0.04(0.07)	-0.35(0.14)
	0.004(0.08) [*]		-0.11(0.07)
σ	0.61(0.08)	1.19(0.1616)	1.21(0.09)
	1.42(0.13) [*]	2.59(0.53) [*]	
log LH	-184.35	-215.85	-190.00
SC	3.78	4.22	3.84
AIC	3.53	4.05	3.62
LR	-	6.58e-14	0.0004

Note: Japan, quarterly, 1968:1-1995:2. Estimates in the upper and lower row correspond to ones in state 1 or state 2, respectively. In each parenthesis, standard errors of the coefficient are reported. 1% significance of coefficient or variance inequality between two states is indicated by * as shown by Wald coefficient tests. SC, AIC and LR mean Schwartz criterion, Akaike information criterion and p-value from $\chi^2(k)$ for log likelihood ratio test where k is the number of restrictions, respectively.

TABLE 5. Statistics of actual and predicted money velocity

statistics	sample	predictions	
		model	GMM
$mean(v)$	1.17	1.91	2.09
$std(v)$	0.19	0.19	0.03
$cv(v)$	0.16	0.10	0.01
$corr(v, g)$	0.55	-0.12	1.00
$corr(v, \omega)$	0.68	0.95	1.00
$corr(v, i)$	0.63	0.70	1.00
$cv(\omega)$	0.53	0.04	0.02
$cv(i)$	0.40	0.67	0.31

Note: Japan, quarterly, 1968:1-1995:2. Statistics on velocity(v) are mean $mean(v)$, standard deviation $std(v)$, coefficient of variation $cv(v)$ and correlations of velocity $corr(v, \cdot)$. g , ω and i denote output growth rates, money growth rates and nominal interest rates.