Cointegrating Analysis of Monetary Transmission Mechanism*

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Abstract

In this paper, the mechanism is investigated by which monetary policy is transmitted to the real economy in Japan. The stationarity of variables is checked by unit root test and the cointegration property among nonstationary variables is tested by Johansen's method. The system is constructed in a form of VECM (Vector Error Correction Model) and finally impulse responses of real GDP are calculated under several situations where the shock of call rate influences to real GDP with two channels of money and credit.

1 Introduction

There exist two competing views of the transmission mechanism of monetary policy. The first view is a traditional textbook description in which changes in money supply affect the economy through changes in interest rates. The other view stresses the importance of the bank lending to affect the economy. The former is called the money view while the latter is called the credit view or the bank lending view.

Bernanke[1] showed, in his pioneering work, that shocks in the bank loans have strong effects on aggregate demand by using a method of the structural VAR model. Bernanke and Blinder[2] indicated that the structural model is very vulnerable to the identifying assumption. They found that a positive shock to the funds rate was followed by a decline in bank deposits and securities by calculating the impulse response function to a shock of the monetary policy. They concluded that bank loans are an important component of the monetary transmission mechanism from the fact that unemployment and bank loans move together after changes in the federal funds rate. They used innovations to the funds rate as a measure of changes in policy.

Gertler and Gilchrist[4] got the result to support the credit view. They disaggregated bank loans and

compared the behavior of small and large firms. They showed that large firms issued commercial paper during the time of tight monetary policy, while small firms and consumers which had no access to the CD market, reduced the bank loans.

Romer and Romer[5] argued that many empirical works investigating the money and lending view of the transmission mechanism have estimated a simple correlation of growth rates of money and output and of lending and output and avoided the issue of endogeneity. They concluded that the traditional money view is much more important than the credit view.

Ramey[6] tested the transmission mechanism of monetary policy by using a cointegration analysis in order to develop the Romer and Romer's approach. She estimated impulse responses of industrial production to the policy shock and found that shutting down the bank loans channel has no noticeable impact on the response of industrial production to policy innovation, while shutting down the money channel essentially eliminates the impact of policy on industrial production. Thus, her conclusion was that the money channel is much more important than the credit channel in the direct transmission of policy shocks.

Hosono[7] applied Ramey's approach to the Japanese data. He showed that the triplet (real GDP, real money, long-term interest rate) has a cointegration in the interval (1965,1992). Unfortunately, since (real GDP, real money, real bank loan) does not have a cointegration in that period, he could only suggest the importance of bank loans. However, a longer interval (...,1995) exhibits a cointegration property of (real GDP, real money, real bank loan) and a non-cointegration property of (real GDP, real money, long-term interest rate) which is shown in this paper. Since, in Ramey and hence Hosono's cointegration analysis, Johansen's multi-variable method was combined with Engle-Granger's two variable method and since these two methods are not necessarily consistent with each other, their resultant VECMs seem somewhat ambiguous. Furthermore, they introduced Dynamical Least Square Estimate (regression of the present state of a variable by both the past and future values of other

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variables), which makes the meaning of their prediction equations and impulse responses unclear.

In this paper, by investigating a cointegration property of (real GDP, real money, real bank loan) in Johansen's test and impulse responses of these variables to a shock of call rate, we shall show effects of monetary policy to real output through two channels of money and credit.

2 The Empirical Analysis

[Data Description] The data employed here is Japanese data, quarterly observed from 1967:1 through 1995:1 and original (i.e., seasonally unadjusted). They are obtained from Nikkei Needs Database. Variables used here are listed as: real GDP ($y(t)$), real money ($rm(t)$) which is $M_2 + CD$ deflated by GDP deflator, real bank loan ($rloan(t)$) which is bank loans deflated by GDP deflator and call rate ($r(t)$). All variables except for call rate are in logarithms.

[Unit Root Test] Dicky-Fuller test is applied for check of stationarity. This test requires to calculate t-ratio of the parameter λ_0 in the following equation:

$$x(t) - x(t-1) = a + bt + \lambda_0 x(t-1) + \sum_{i=1}^{k_0} \lambda_i \Delta x(t-i) + \Psi D(t), \quad (1)$$

where $x(t)$ is a scalar variable to be tested, the delay parameter k_0 is decided by AIC criterion and where $D(t)$ is a seasonal dummy variable with elements $W_2(t)$, $W_3(t)$ and $W_4(t)$.

If the null hypothesis $\lambda_0 = 0$ is rejected, then the $x(t)$ process does not have a unit root and becomes stationary. Table 1 shows results of the test *with trend* ($b \neq 0$) and *without trend* ($b = 0$). From estimated results, it is concluded that only call rate is stationary and the other three variables are difference-stationary.

Table 1 Unit Root Tests

variables	lags	with trend	lags	without trend
y	4	-3.1537*	4	-2.078
rm	6	-2.4185	6	-2.0619
rloan	6	-2.1807	5	-1.50
r	3	-3.99**	3	-3.1545**

where **(*) denotes rejection of the hypothesis at 5 percent (10 percent) significance level respectively. Critical values tabulated by Fuller (1976) are -3.45 (-3.15) for 5 percent (10 percent) in *with trend*, while the values are -2.89 (-2.58) for 5 percent (10 percent) significance levels respectively in *without trend*.

[Cointegration Property (Johansen Test [8])] If a non-stationary process is differenced to be stationary, then it may happen to lose low-frequency information of the process. In order to see this problem, let $x(t)$ be

a p -dimensional vector and assume that each element of $x(t)$ is $I(1)$, that is, difference-stationary. Consider the model:

$$x(t) = \Pi_1 x(t-1) + \cdots + \Pi_k x(t-k) + \mu + \Phi D(t) + \varepsilon(t). \quad (2)$$

Using $\Delta = 1 - L$ with the lag operator L , Eq.(2) can be rewritten as

$$\Delta x(t) = \Gamma_1 \Delta x(t-1) + \cdots + \Gamma_{k-1} \Delta x(t-k+1) + \Pi x(t-k) + \mu + \Phi D(t) + \varepsilon(t), \quad (3)$$

where

$$\Gamma_i = -(I - \Pi_1 - \cdots - \Pi_i), \quad (i = 1, \dots, k-1), \quad (4)$$

and where

$$\Pi = -(I - \Pi_1 - \cdots - \Pi_k). \quad (5)$$

Three cases can be considered: (case1) $\text{rank} \Pi = p$, i.e., the process $x(t)$ is stationary. (case2) $\text{rank} \Pi = 0$, i.e., Π is the null matrix. (case3) $\text{rank} \Pi = r < p$ implying that there are $p \times r$ matrices α and β such that $\Pi = \alpha \beta'$ and that $\beta' x(t)$ is stationary even though $x(t)$ itself is non-stationary. β is called the cointegration vectors. Our interest is concerned with (case3) and Eq.(3) in this case is called VECM (vector error correction model). Johansen gives us the method of rank estimation along with hypothesis test. Table 2 gives results of Johansen test.

Table 2 Cointegration Tests on 3 Variables (Johansen)

Eigenvalues	L.Ratio	Hypothesized No. of CE
0.2117	45.9861	none**
0.1622	20.5298	at most 1*
0.0147	1.5879	at most 2

where **(*) denotes rejection of hypothesis at 1 percent (5 percent) significance level and where 5 lagged differences were included in the VECM.

From Johansen test, $x(t) = (y(t), rm(t), rloan(t))$ has cointegrating vectors with $r = 2$. Thus, we have two sets of stationary processes each of which is a linear combination of non-stationary processes. Choosing two set of variables as $(y(t), rm(t))$ and $(y(t), rloan(t))$ and using OLS (Ordinary Least Square) method, cointegrating vectors can be estimated through relations:

$$y(t) = c_1 + c_2 rm(t), \quad (6)$$

$$y(t) = c_3 + c_4 rloan(t). \quad (7)$$

Stationary processes $z_{11}(t)$ and $z_{12}(t)$ can be defined as residuals of above relations and described by

$$z_{11}(t) = y(t) - c_1 - c_2 rm(t), \quad (8)$$

$$z_{12}(t) = y(t) - c_3 - c_4 rloan(t). \quad (9)$$

where Eqs.(6) to (9) contain seasonal dummy variables on the RHS of their equations.

The cointegrating term $\beta'x(t-k)$ in Eq.(3) has two elements $z_{11}(t-k)$ and $z_{12}(t-k)$ which are called "long equilibrium relations", while Eq.(3) itself exhibits short term relations among variables. Noting that $x(t-k) = x(t-k+1) - \Delta x(t-k+1)$ and inserting this relation into the RHS of Eq.(3), $x(t-k)$ can be replaced by $x(t-k+1)$ with different system parameters:

$$\begin{aligned} \Delta x(t) &= \Gamma_1 \Delta x(t-1) + \dots + (\Gamma_{k-1} - \Pi) \Delta x(t-k+1) \\ &\quad + \Pi x(t-k+1) + \mu + \Phi D(t) + \varepsilon(t). \end{aligned} \quad (10)$$

In fact, by iterating this procedure, the representation of cointegrating term is admitted by $x(t-1)$ through $x(t-k)$.

As stated in Introduction, a long-term interest rate has a cointegration property associated with (real GDP, real money) in the interval (... , 1992) and non-cointegration property in the interval (... , 1995), while real bank loan has non-cointegration property in (... , 1992) and cointegration in (... , 1995). We exclude a long-term interest rate in our model.

[Modelling of the System] Our aim is to research how monetary policy(call rate $r(t)$) transmits to output $\Delta y(t)$ through channels of $\Delta rm(t)$, $\Delta rloan(t)$, $z_{11}(t)$ and $z_{12}(t)$. Since cointegration in Johansen test assumes a set of variables with $I(1)$ and call rate is, on the contrary, stationary in its level(i.e., $I(0)$), we propose that the system model is given in Eq.(3) with additive terms $r(t-i)$ on the RHS and furthermore the dynamics of $r(t)$ itself is, at the same time, taken into consideration:

$$\begin{aligned} \Delta y(t) &= \sum_{i=1}^k a_{1i} \Delta y(t-i) + \sum_{i=1}^k a_{2i} \Delta rm(t-i) \\ &\quad + \sum_{i=1}^k a_{3i} \Delta rloan(t-i) + a_4 z_{11}(t-1) + a_5 z_{12}(t-1) \\ &\quad + \mu_y + \sum_{j=2}^4 s_{yj} W_j(t) + \sigma_y \varepsilon_y(t) \end{aligned} \quad (11)$$

$$\begin{aligned} \Delta rm(t) &= \sum_{i=1}^k b_{1i} \Delta y(t-i) + \sum_{i=1}^k b_{2i} \Delta rm(t-i) \\ &\quad + \sum_{i=1}^k b_{3i} \Delta rloan(t-i) + b_4 z_{11}(t-1) + b_5 z_{12}(t-1) \\ &\quad + \sum_{i=1}^q b_{ri} r(t-i) + \mu_m + \sum_{j=2}^4 s_{mj} W_j(t) + \sigma_m \varepsilon_m(t) \end{aligned} \quad (12)$$

$$\begin{aligned} \Delta rloan(t) &= \sum_{i=1}^k c_{1i} \Delta y(t-i) + \sum_{i=1}^k c_{2i} \Delta rm(t-i) \\ &\quad + \sum_{i=1}^k c_{3i} \Delta rloan(t-i) + c_4 z_{11}(t-1) + c_5 z_{12}(t-1) \\ &\quad + \sum_{i=1}^q c_{ri} r(t-i) + \mu_l + \sum_{j=2}^4 s_{lj} W_j(t) + \sigma_l \varepsilon_l(t) \end{aligned} \quad (13)$$

$$\begin{aligned} r(t) &= \sum_{i=1}^k d_{1i} \Delta y(t-i) + \sum_{i=1}^k d_{2i} \Delta rm(t-i) \\ &\quad + \sum_{i=1}^k d_{3i} \Delta rloan(t-i) + d_4 z_{11}(t-1) + d_5 z_{12}(t-1) \\ &\quad + \sum_{i=1}^q d_{ri} r(t-i) + \mu_r + \sum_{j=2}^4 s_{rj} W_j(t) + \sigma_r \varepsilon_r(t) \end{aligned} \quad (14)$$

where $\varepsilon_y(t)$, $\dots$, $\varepsilon_r(t)$ are sequences of i.i.d. random variables with standard deviations σ_y , $\dots$, σ_r respectively and where, from economical point of view such that call rate should indirectly affect the output $\Delta y(t)$ through the other variables, call rate is omitted on the RHS of Eq.(11).

The delay order k was decided by AIC to be $k = 4$. However, estimated parameters in Eqs.(11), (12) and (13) exhibit strongly periodic properties with periodicity 4 which should be removed by introducing seasonal dummy variables $W_j(t)$, $j = 2, 3$ and 4. Since AIC can not avoid the trap of seasonal variation, k was decided *a priori* to be $k = 2$. The delay order q of call rate was to be $q = 4$ from the practical reason such that $q \geq 4$. Figure 1 shows seasonal variation of $y = \ln(\text{real GDP})$. For estimated parameters in Eqs.(11) to (14), see Appendix.

Fig.1 Seasonal variation of $y = \ln(\text{real GDP})$

[Impulse Responses] Impulse responses of $\Delta y(t)$, $\Delta rm(t)$, $\Delta rloan(t)$, $z_{11}(t)$ and $z_{12}(t)$ are shown when $\varepsilon_r(t)$ changes impulsively with magnitude 1 and when the other $\varepsilon(t)$ hold to be zero. Calculation of impulse responses can be carried out by simulating Eqs.(11) to (14) with constant terms and seasonal dummy variables replaced by zero respectively. The procedure of this simulation is shown by:

procedure(1): Given initial conditions ($\Delta y(t-i)$, $\Delta rm(t-i)$, $\Delta rloan(t-i)$, $r(t-i)$, $z_{11}(t-1)$, $z_{12}(t-1)$) with zero values for $t = 1$ to $t_0 - 1$.

procedure(2): At $t = t_0$, set $\varepsilon_r(t)$ to be 1. Calculate ($\Delta y(t)$, $\Delta rm(t)$, $\Delta rloan(t)$, $r(t)$) in Eqs.(11) to (14).

procedure(3): At $t = t_0$, calculate $z_{11}(t)$ and $z_{12}(t)$ by using Eqs.(8) and (9) in differenced forms:

$$\begin{aligned} z_{11}(t_0) &= z_{11}(t_0 - 1) + \Delta z_{11}(t_0) \\ &= z_{11}(t_0 - 1) + \Delta y(t_0) - c_2 \Delta rm(t_0), \end{aligned} \quad (15)$$

$$\begin{aligned} z_{12}(t_0) &= z_{12}(t_0 - 1) + \Delta z_{12}(t_0) \\ &= z_{12}(t_0 - 1) + \Delta y(t_0) - c_4 \Delta rloan(t_0). \end{aligned} \quad (16)$$

procedure(4): At $t = t_0 + 1$, calculate Eqs.(11) to (14) with $z_{11}(t_0)$ and $z_{12}(t_0)$ given in the above procedure.

procedure(5): Go back to the procedure (3) and iterate these procedures.

It can be seen how the monetary policy $r(t)$ transmits to other variables (Fig.2).

There are mainly two channels from $r(t)$ to $\Delta y(t)$: one is the channel of money supply $\Delta rm(t)$ and the other is that of credit $\Delta rloan(t)$. In order to see their influences to $\Delta y(t)$ comparatively, impulse responses of $\Delta y(t)$ are calculated in two cases. In case 1, the loop from $r(t)$ to $\Delta rm(t)$ is closed by deleting terms $r(t-i)$ on the RHS of Eq.(12). In case 2, the loop from $r(t)$ to $\Delta rloan(t)$ is closed by deleting $r(t-i)$ on the RHS of Eq.(13). Three cases of impulse responses of $\Delta y(t)$ (including the basic one in Fig.2) are depicted in Fig.3.

The importance of the traditional money channel must be emphasized when we compare the two cases once we shut down the bank loan channel and the money channel. Impulse response of real output did not show any noticeable difference even though we closed the credit channel. On the contrary, the impact of policy on real output was dramatically reduced when we closed the money channel. However, we can not ignore the credit channel because its impact on real output is certainly much weaker but keeps longer than impact of money.

Fig.2 Impulse responses dy, drl, drloan, r, z11 and z12
subjected to the call rate shock

Fig.3 Impulse responses of dy to the call rate shock
(1)base (2)the path r-->drl is shut down (3)the path r-->drloan is shut down

3 Conclusion

We can conclude that the traditional money channel is important, while the credit channel enhances the effect of monetary policy. This conclusion is consistent with the view of the proponents of the credit view who stress the credit market imperfections may play an important role in the transmission of money policy. They do not think of the credit channel as a distinct, free-standing alternative to the traditional monetary transmission mechanism, but rather as a set of factors that modify and propagate conventional interest rate effects(see Bernanke and Gertler[3]).

Appendix

The estimation results of VECM in Eqs.(11) to (14) are described in Table 3.

Table 3 Estimation of VECM

<i>RHS of VECM</i>	Δy_t <i>coeff.</i>	Δrm_t <i>coeff.</i>	$\Delta rloan_t$ <i>coeff.</i>	r_t <i>coeff.</i>
Δy_{t-1}	-0.3425 (-3.5140)	0.0905 (1.2915)	0.1114 (1.2134)	7.7387 (2.0645)
Δy_{t-2}	0.02355 (0.2550)	0.1857 (2.7703)	0.1917 (2.1820)	2.1371 (0.5959)
Δrm_{t-1}	-0.0854 (-0.4395)	-0.6173 (4.2131)	0.1500 (0.7812)	-1.8004 (-0.2297)
Δrm_{t-2}	0.4446 (2.1925)	0.0483 (0.3209)	0.1040 (0.5263)	2.7900 (0.3461)
$\Delta rloan_{t-1}$	0.0905 (0.5589)	-0.1241 (-1.0760)	0.3420 (2.2616)	-4.0063 (-0.6490)
$\Delta rloan_{t-2}$	-0.0032 (-0.0195)	0.0134 (0.1139)	-0.0955 (-0.6177)	0.1197 (0.0190)
r_{t-1}	-	-0.0063 (-3.1264)	-0.0058 (-2.2175)	1.4248 (13.2767)
r_{t-2}	-	0.0087 (2.4396)	0.0085 (1.8038)	-0.4471 (-2.3323)
r_{t-3}	-	-0.0037 (-1.0357)	-0.0045 (-0.9640)	-0.0386 (-0.2029)
r_{t-4}	-	0.0011 (0.5592)	0.0014 (0.5078)	-0.0557 (-0.5109)
$z11_{t-1}$	-0.0299 (-0.2632)	0.1648 (1.9899)	0.0434 (0.3996)	-6.6134 (-1.4927)
$z12_{t-1}$	-0.0719 (-1.4660)	-0.0770 (-1.3926)	0.0359 (0.4952)	5.2902 (-1.4927)
const.	-0.1203 (-7.6509)	0.0331 (2.7413)	0.0416 (2.6271)	-0.5040 (-0.7802)
W_2	0.0819 (3.0203)	-0.0701 (-3.5022)	-0.0864 (-3.2958)	2.3132 (2.1608)
W_3	0.1691 (6.3537)	0.0331 (1.6994)	0.0390 (1.5269)	1.5918 (1.5277)
W_4	0.2623 (16.4808)	-0.0796 (-6.7035)	-0.0873 (-5.6111)	0.7777 (1.2244)

where the parenthesis denotes t-statistics.

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