Discussion Papers In Economics And Business

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Cycle Model of the Japanese Economy

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Is There a Direct Effect of Money?: Money's Role in an Estimated Monetary Business Cycle Model of the Japanese Economy

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Abstract

In this paper, I estimate the monetary business cycle model of the Japanese economy by the method advocated by Ireland (2002a), the maximum likelihood estimation of the dynamic stochastic general equilibrium model in a state-space representation.

The model estimated here includes the direct role of money on output and inflation so that we could study the alternative transmission mechanism of monetary policy to traditional interest rate channel, which may even work under the zero nominal interest rate as in Japan now.

However, estimation results report that the direct effect of money is extremely small even if there could be. This finding is consistent with the ones obtained for US data in Ireland (2002a) and Euro area in Andres, Lopez-Salido and Valles (2001).

JEL Classification: C31; E32; E52.
Key words: Direct Role of Money; Cross-Restriction;
Maximum Likelihood Estimation;
Dynamic Stochastic General Equilibrium Model

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1 Introduction

Japanese economy has been stagnant since the burst of the bubble economy around 1990. To respond to those economic downturns, the Bank of Japan gradually lowered the overnight call rate until it hit a record low in 1996, 0.25% per annum. However, because the negative shocks were more severe than had been expected initially; magnified by the balance sheet problem due to the collapse of stockes and land prices, the Bank of Japan and the Japanese government just by intensifying public investments were not able to settle the economy on the steady growth path. Then, in 1997, the bankruptcy of the fourth largest securities company in Japan "Yamaichi Shoken" ignited financial crises and hit the Japanese economy. Moreover, deflationary pressure become manifest, a pressure brought on mainly by cheaper imported goods from China. As a result of the financial crises and the deflationary pressure, the GDP annual growth rate dropped to 0.7% and the deflation rate per annum measured by the GDP deflator to 1.6% for the average of last five years. Such numbers were not really seen by the industrially advanced countries since the Great Depression.

Although there were almost no room left for stimulating the economy by way of traditional interest rate channel literally after the introduction of "zero nominal interest rate policy" in February 1999, the Bank of Japan resumed new monetary policy scheme called "quantitative easing" as an alternative device of monetary policy to the traditional short-term interest rate control in March 2001. With "quantitative easing" scheme, the Bank of Japan started to target not the overnight call rate but the outstanding balance of the current accounts at the Bank.[1]

It has been only two years since the introduction of the "quantitative easing" monetary policy. Therefore, it may not be appropriate to judge the effect of the "quantitative easing" monetary as the policy may effect with long lags. However, recent researches with VAR (Vector AutoRegression) models state that the effect of monetary expansion without traditional interest rate channel is limited. Kimura, Kobayashi, Muranaga and Ugai (2002) claim that according to the Bayesian VAR with time varying parameters, although there can be found some positive effect on output and inflation from quantitative easing, it is minuscule. Fujiwara (2003a) concludes with Markov switching VAR that since the traditional interest rate channel becomes almost incompetent in the middle of 1990s, the effects of monetary policy either through lowering nominal interest rate or monetary expansion become significantly weaker. Furthermore, the Bank of Japan's *Outlook and Risk Assessment of the Economy and Prices* released in April 2003 assesses the "quantitative easing" policy as effective but not satisfactory such that "As seen so far, the Bank's "quantitative easing"

[1] In *Q&A: New Procedures for Money Market Operations*, the Bank of Japan declares "The Bank has conducted market operations based on the guidelines set by the Monetary Policy Meeting of the Policy Board in terms of the uncollateralized overnight call rate. In the new procedures, the Monetary Policy Meeting will decide the guidelines in terms of the "outstanding balance" of the current accounts at the BOJ and operations will be conducted to meet the target balance."

policy and ample liquidity provision have contributed to (1) dispelling liquidity concerns, (2) reducing interest rates including those of longer-term maturities, and (3) shrinking credit spreads. Judging from such developments, the Bank's monetary easing seems to have effectively shielded channels through which various shocks lead to liquidity concerns, thereby securing financial market stability, and have contributed to preventing the economy from stumbling into a deflationary spiral. On the other hand, the growth rate of commercial lending has been negative and bank's financial intermediary function is still weak. Real economic activity has yet to be stimulated." Thus, the "quantitating easing" policy seems to work as a bulwark against further deterioration, but it can be concluded that its direct effect on output and inflation has been very limited so far.

Can we expect any direct effects from it in the near future? Several answers have been reported to this question. Such researches as Orphanides and Wieland (2000), and Coenen and Wieland (2002) conclude that there should be changes in the risk premium caused by "quantitative easing" policy as a result of the changes in the composition of financial assets owned by the country as a whole and this may bring the depreciation of the yen. These researches insist that this is an important channel of monetary transmission especially when the zero nominal interest rate bound is binding. This is called the "portfolio rebalance effect" of "quantitative easing" policy. However, the portfolio rebalance effect will not be considered in this paper as it has already been neatly tested by above two papers and its effect should be minuscule as the actual data has been telling us so far.[2]

Instead, I will examine whether we can find any evidence for the direct effect of money on real economic activities as no major effect cannot be expected without this channel. If the Bank's expansion of base money results in the growing money supply, which has not materialised, the "quantitative easing" policy should have some positive influence on the real economy without the traditional interest channel under the situation where money has some direct effect on output and inflation. In other words, if we cannot find any evidence of the direct effect even from money supply, there should almost be no effect from the current "quantitative easing" monetary policy for the present nor in the future.

Concerning this direct effect of money, Nelson (2002) shows that if the utility is non-separable in consumption and real money holdings such that

$$\log\left(\frac{\partial u_t}{\partial c_t}\right) \approx a_1 c_t + a_2 \log\left(\frac{M_t}{P_t}\right),$$

then the optimised IS curve as follows is obtained after log linearisation of the first order condition.

[2]Indeed, Coenen and Wieland (2002) comment that the effect through this portfolio rebalance effect is "small enough not to be noticeable in times of non-zero interest rates."

$$y_t = b_1 r_t + \frac{a_2}{a_1}\left[\log\left(\frac{M_t}{P_t}\right) - \mathrm{E}_t \log\left(\frac{M_{t+1}}{P_{t+1}}\right)\right] + \mathrm{E}_t y_{t+1}$$

u: utility from consumption and real money holdings, c: consumption, $\frac{M}{P}$: real money balances, y: output, r: real interest rate, a, b: parameters

The aim of this paper is to examine whether the utility function which the representative Japanese consumer owns is well represented by the utility form with non-separability between consumption and real money holdings as above and therefore the direct effect of money can be found in the macroeconomic dynamics of the Japanese economy.

This paper consists as follows: In the next section, the direct effect of money is tested by the estimation on a reduced form single equation such that the output is estimated by lagged real interest rate and real money balances. However even if the existence of the direct money channel is established in a single estimation framework, it is inappropriate to conclude this is the direct channel on output and inflation since it may just cover the effect through the traditional LM curve relationship not fully captured by real interest rate. If this is just covering the effect through the traditional channel additionally, it can be concluded that the monetary expansion has only limited impact on the macroeconomy when the nominal interest rate is constrained at zero as is happening in Japan. Under this circumstance, we naturally cannot expect any effect from the current "quantitative easing" monetary policy. Therefore, we need a method to identify the direct effect of money and to estimate it. The seminal research examined in Ireland (2002a) proposes a method to identify the money's effect on dynamic macroeconomy. It constructs an optimised general equilibrium model based on non-separable utility in consumption and real money holdings for the direct effect of money to be derived from microfoundations, then shows that "real money balances enter into a correctly-specified, forward-looking IS curve if and only if they enter into a correctly-specified, forward-looking Phillips curve," and evaluate the direct effect of money balances on output and inflation by maximum likelihood estimation on the dynamic stochastic general equilibrium (DSGE) model in state space form.[3] In section three and four, the model and its estimation procedure of Ireland (2002a) are summarised. In section five, I first show that the direct effect of money has not been found in Japanese data. Further, it is shown that the impulse responses of this estimated DSGE model has reasonable simulated properties and then simulated autocorrelations, variance decompositions obtained from an estimated DSGE model of Japanese economy are similar to those of identified VAR which mimics the actual data tendencies. Finally, section six concludes with comments on the possible future extension.

[3]Recently, constructing the more data-oriented dynamic stochastic general equilbrium model has become popular. These are well-summarised in Ruge-Murcia (2002).

2 Simple Estimates of Real Balance Effect

Nelson (2002) estimates several forms of reduced form IS curve following Koenig (1990) and Rudebusch and Svensson (2000). Here I estimate three equations of reduced form the IS curve. In the first estimated equation, output gap is estimated by its own lags and lagged real interest rate. Then, lagged real money balances and real exchange rate are added in the second and third estimated equation. Number of lags are always set to three.

These three estimated reduced form IS equations take forms as follows, where $\widetilde{y}$ denotes the output gap measured in Hirose and Kamada (2002), rr real interest rate measured by LIBOR three month rate[4] minus CPI inflation rate,[5] rmb real money gap[6] expressed as its log deviation from its HP filtered value, q real exchange rate[7] and a, b, and c are parameters.

IS equation (1)

$$\widetilde{y}_t = \text{cons}\tan\text{t} + \sum_{i=1}^{3} a_i \widetilde{y}_{t-i} + \sum_{i=1}^{3} b_i rr_{t-i}$$

IS equation (2)

$$\widetilde{y}_t = \text{cons}\tan\text{t} + \sum_{i=1}^{3} a_i \widetilde{y}_{t-i} + \sum_{i=1}^{3} b_i rr_{t-i} + \sum_{i=1}^{3} c_i rmb_{t-i}$$

IS equation (3)

$$\widetilde{y}_t = \text{cons}\tan\text{t} + \sum_{i=1}^{3} a_i \widetilde{y}_{t-i} + \sum_{i=1}^{3} b_i rr_{t-i} + \sum_{i=1}^{3} c_i rmb_{t-i} + \sum_{i=1}^{3} d_i q_{t-i}$$

The estimated period is set from 1983/Q2 to 1995/Q1. The starting date is fixed due to the availability of output gap series defined in Hirose and Kamada (2002).[8] Estimation is ended at 1995/Q1 as the estimation of DSGE model in section five.[9] The estimated results from these three IS equations are as follows.

[4] This series is downloaded from IFS, International Financial Statistics published by IMF.

[5] Perishables and utility prices are excluded.

[6] M2+CD is deflated by CPI excluding perishables and utility prices.

[7] Dollar/Yen exchange rate is deflated by Japanese CPI and US CPI.

[8] Results do not change significantly if the output gap estimated by other methods is employed.

[9] As the DSGE estimated includes monetary policy rule which determines the nominal interest rate, it is not appropriate to include the periods where Japanese economy is constrained by zero bound and short-term nominal interest rate is not following the specified policy rule which should be valid for the whole sample.

Table 1: Estimated results of IS equation (1)

	Estimate	Standard Error
constant	0.003	0.004
$\widetilde{y}_{t-1}$	0.947	0.162
$\widetilde{y}_{t-2}$	0.265	0.204
$\widetilde{y}_{t-3}$	-0.267	0.167
rr_{t-1}	-0.548	0.353
rr_{t-2}	1.012	0.565
rr_{t-3}	-0.559	0.357

Adjusted R^2: 0.87, S.E: 0.01

Table 2: Estimated results of IS equation (2)

	Estimate	Standard Error
constant	0.003	0.001
$\widetilde{y}_{t-1}$	0.415	0.173
$\widetilde{y}_{t-2}$	0.426	0.166
$\widetilde{y}_{t-3}$	0.279	0.179
rr_{t-1}	-0.736	0.308
rr_{t-2}	0.685	0.533
rr_{t-3}	-0.261	0.331
rmb_{t-1}	0.502	0.193
rmb_{t-2}	0.086	0.266
rmb_{t-3}	0.012	0.172

Adjusted R^2: 0.92, S.E: 0.01

Table 3: Estimated results of IS equation (3)

	Estimate	Standard Error
constant	-0.012	0.022
$\widetilde{y}_{t-1}$	0.383	0.176
$\widetilde{y}_{t-2}$	0.427	0.168
$\widetilde{y}_{t-3}$	0.293	0.184
rr_{t-1}	-0.761	0.346
rr_{t-2}	0.671	0.537
rr_{t-3}	-0.261	0.333
rmb_{t-1}	0.448	0.200
rmb_{t-2}	0.092	0.268
rmb_{t-3}	0.051	0.176
q_{t-1}	0.010	0.017
q_{t-2}	0.010	0.026
q_{t-3}	-0.016	0.019

Adjusted R^2: 0.92, S.E: 0.01

Above results demonstrate that the coefficients on lagged real money balances are always positive and the first lag of them enters the equation significantly. From these reduced form IS equation, real money balances seem to have some additional direct effect on output to the traditional interest rate channel, which effects should be captured by real nominal interest rate terms. However even if the existence of the direct money channel is established in a single estimation on reduced form equation to avoid simultaneity bias, it cannot be an evidence for the existence of direct effect of money in actual economy due to endogeneity bias etc. Kato (2002) shows the defect of single estimation with simple but explicit example. It first constructs DSGE model based on Kiyotaki and Moore (1998), where the debt outstanding of the firm affects the investment decision and therefore aggregate demand, and then collects artificial data series from stochastic simulation. Simple single estimation of debt outstanding on investment leads to insignificant coefficient although it should be strongly significant as the model is set to have a direct effect of debt on investment. This simple example tells us that a system estimation of the DSGE model where direct effect of money is explicitly derived from rigid micro-foundations is indispensable for testing the direct effect of money.[10] This will be examined in the following sections.

3 Dynamic Stochastic General Equilibrium Model with the Direct Effect of Money

I estimate the DSGE model examined in Ireland (2002a) for Japanese data in order to test if the direct effect of money really exists. In this section, this model is briefly summarised to understand the money's role in the estimated monetary business cycle model of the Japanese economy.[11]

In Ireland (2002a), the economy consists of a representative household, a representative finished goods-producing firm, a continuum of intermediate goods-producing firms indexed by $i \in [0, 1]$, and a monetary authority. A distinct, perishable intermediate good also indexed by $i \in [0, 1]$ are produced by each intermediate goods-producing firm at $t = 0, 1, 2, ...$

3.1 Households

The representative household maximises the following expected stream of utility:

$$\mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t a_t \{u[c_t, (M_t/P_t)/e_t] - \eta h_t\} \tag{1}$$

subject to the budget constraint as below.

[10]Of course, there is risk of mis-specification. However, the DSGE model here estimated is fairlly small and has very standard form.

[11]For the detailed derivation of the model and estimation procedure, see Ireland (2002b).

$$\frac{M_{t-1}+T_t+B_{t-1}+W_t h_t+D_t}{P_t}=c_t+\frac{B_t/r_t+M_t}{P_t}. \tag{2}$$

β: subjective discount rate, $u[\cdot]$: instantaneous utility function, M_t: money, P_t: price level, T_t: lump-sum nominal transfer from monetary authority, B_t: bonds, W_t: nominal wage, c_t: finished goods consumption purchased at P_t, r_t: nominal interest rate, and

a and e are preference shocks which are assumed to follow the stationary AR processes.

$$\ln(a_t)=\rho_a\ln(a_{t-1})+\varepsilon_{at} \tag{3}$$

$$\ln(e_t)=(1-\rho_e)\ln(e)+\rho_e\ln(e_{t-1})+\varepsilon_{et}, \tag{4}$$

$$1>\rho_a>-1,\ 1>\rho_e>-1,\ \varepsilon_{at}\tilde{\ }\mathrm{NID}(0,\sigma_a)\text{ and }\varepsilon_{et}\tilde{\ }\mathrm{NID}(0,\sigma_e)$$

h denotes units of labor supplied to each intermediate goods-producing firm for a total of $h_t=\int_0^1 h_t(i)di$ during period t, and D is the nominal profits received by representative household from each intermediate goods-producing firm for a total of $D_t=\int_0^1 D_t(i)di$.

As a result of household's choosing c_t, h_t, B_t, and M_t to maximise the utility in (1) subject to the budget constraint in (2), the first order conditions as follows are obtained.

$$a_t\frac{\partial u}{\partial c_t}=\lambda_t, \tag{5}$$

$$\eta a_t=\lambda_t w_t, \tag{6}$$

$$\lambda_t=\beta r_t E_t\left(\frac{\lambda_{t+1}}{\pi_{t+1}}\right), \tag{7}$$

$$\frac{a_t}{e_t}\frac{\partial u_t}{\partial m_t}=\lambda_t-\beta E_t\left(\frac{\lambda_{t+1}}{\pi_{t+1}}\right), \tag{8}$$

λ: Lagrange multiplier on budget constraint, $\pi_{t+1}=\frac{P_{t+1}}{P_t}$ and $m_t=\frac{M_t}{P_t}$

3.2 Firms

3.2.1 Finished Goods

The finished goods-producing firm maximises its profits, given by

$$P_t\left[\int_0^1 y_t(i)^{(\theta-1)/\theta}di\right]^{\theta/(\theta-1)}-\int_0^1 P_t(i)y_t(i)di, \tag{9}$$

subject to the constant-returns-to-scale technology described by

$$y_t = \left[\int_0^1 y_t(i)^{(\theta-1)/\theta} di \right]^{\theta/(\theta-1)}. \tag{10}$$

y_t: finished goods, $y_t\left(\cdot\right)$: intermediate goods, and
θ: constant elasticity of demand for each intermediate goods

Finished goods-producing firm's choice of $y_t\left(\cdot\right)$ to maximise (9) subject to the constraint (10) leads to the first order condition as follows.

$$y_t(i) = \left[\frac{P_t(i)}{P_t} \right]^{-\theta} y_t, \tag{11}$$

3.2.2 Intermediate Goods

The representative intermediate goods-producing firm competing in monopolistically competitive market maximises its total market value expressed as

$$E \sum_{t=0}^{\infty} \beta^t \lambda_t \left\{ \left[\frac{P_t\left(i\right)}{P_t} \right]^{1-\theta} y_t - \left[\frac{P_t(i)}{P_t} \right]^{-\theta} \left(\frac{w_t y_t}{z_t} \right) - \frac{\phi}{2} \left[\frac{P_t(i)}{\pi P_{t-1}(i)} - 1 \right]^2 y_t \right\}, \tag{12}$$

subject to the constant-returns-to-scale technology described by

$$y_t(i) = z_t h_t(i). \tag{13}$$

$w_t = \frac{W_t}{P_t}$, π: steady state inflation rate

The aggregate technology shock z denotes the aggregate technology shock following the stationary autoregressive process.

$$\ln(z_t) = (1 - \rho_z)\ln(z) + \rho_z \ln(z_{t-1}) + \varepsilon_{zt} \tag{14}$$

$$1 > \rho_z > -1,\ \varepsilon_{zt}\tilde{}\,\text{NID}(0, \sigma_z)$$

$\beta^t \lambda_t$ in the components of total market value of intermediate goods-producing firms in (12) measures the marginal utility value to the representative household of an additional dollar in profits received during period t. As the optimisation problem by finished goods-producing firm is expressed as in equation (10), terms within the parenthesis in (12) demonstrate profit defined as revenue minus costs when the intermediate goods-producing firm must satisfy the representative finished goods-producing firm's demand. In addition to the wage cost, the intermediate goods-producing firm faces a quadratic cost of adjusting its nominal price given by $\frac{\phi}{2}\left[\frac{P_t(i)}{\pi P_{t-1}(i)} - 1\right]^2 y_t$, where $\phi > 0$.

The intermediate goods-producing firms' optimal choice of $P_t(i)$ is obtained by maximising (12) subject to (13). The first order condition to this problem is expressed as

$$\begin{aligned} 0 \quad = \quad & (1-\theta)\lambda_t \left[\frac{P_t(i)}{P_t}\right]^{-\theta} \left(\frac{y_t}{P_t}\right) + \theta\lambda_t \left[\frac{P_t(i)}{P_t}\right]^{-\theta-1} \left(\frac{y_t w_t}{z_t P_t}\right) \\ & -\phi\lambda_t \left[\frac{P_t(i)}{\pi P_{t-1}(i)} - 1\right] \left[\frac{y_t}{\pi P_{t-1}(i)}\right] \\ & +\beta\phi E_t \left\{\lambda_{t+1} \left[\frac{P_{t+1}(i)}{\pi P_t(i)} - 1\right] \left[\frac{y_{t+1} P_{t+1}(i)}{\pi P_t(i)^2}\right]\right\} \end{aligned} \tag{15}$$

3.3 Central Bank

The monetary authority conducts monetary policy according to an augmented history dependent Taylor-type monetary policy rule, where lagged value of percentage deviation of nominal interest rate from its steady state is included. Therefore, the nominal interest rate is adjusted gradually in response to deviations of output and inflation from their steady state values.

$$\ln\left(\frac{r_t}{r}\right) = \rho_r \ln\left(\frac{r_{t-1}}{r}\right) + \rho_y \ln\left(\frac{y_t}{y}\right) + \rho_\pi \ln\left(\frac{\pi_t}{\pi}\right) + \varepsilon_{rt}, \tag{16}$$

r: steady state gross nominal interest rate, y: steady state output, ε_{rt} ˜NID$(0, \sigma_r)$, ρ_r, ρ_y, ρ_π: parameters

3.4 Equilibrium

In a symmetric equilibrium, all intermediate goods-producing firms make identical decisions, so that $y_t(i) = y_t$, $h_t(i) = h_t$, $P_t(i) = P_t$, and $d_t(i) = \frac{D_t(i)}{P_t} = \frac{D_t}{P_t} = d_t$. In addition, the market-clearing conditions $M_t = M_{t-1} + T_t$ and $B_t = B_{t-1} = 0$ must hold for each period. After imposing these conditions, strait-forward manipulation and log-linear approximation around steady state, equations (2), (3), (4), (5), (6), (7), (8), (11), (13), (14), (15) and (16) are written in a compact linear system of equations consisted of eight equations where variables with hat denote the log difference from steady state, namely, $\hat{y}_t = \ln\left(\frac{y_t}{y}\right)$, $\hat{\pi}_t = \ln\left(\frac{\pi_t}{\pi}\right)$, $\hat{m}_t = \ln\left(\frac{m_t}{m}\right)$, $\hat{r}_t = \ln\left(\frac{r_t}{r}\right)$, $\hat{a}_t = \ln\left(\frac{a_t}{a}\right)$, $\hat{e}_t = \ln\left(\frac{e_t}{e}\right)$, and $\hat{z}_t = \ln\left(\frac{z_t}{z}\right)$.[12]

$$\hat{a}_t = \rho_a \hat{a}_{t-1} + \varepsilon_{at} \tag{17}$$

[12]It is worth noting that equation (22) shows that money gap should be negatively correlated to inflation gap in this DSGE model with microfoundations, contrary to the behavioural equation based on non-microfounded P* model estimated by Gerlach and Svensson (2001) which find that real money stock terms enter very significantly as an explanatory variable in aggregate supply equation.

$$\hat{e}_t = \rho_e \hat{e}_{t-1} + \varepsilon_{et} \tag{18}$$

$$\begin{aligned} \hat{y}_t \quad = \quad & E_t\hat{y}_{t+1} - \omega_1\left(\hat{r}_t - E_t\hat{\pi}_{t+1}\right) + \omega_2(\hat{m}_t - E_t\hat{m}_{t+1}) \\ & -\omega_2(1-\rho_e)\hat{e}_t + \omega_1(1-\rho_a)\hat{a}_t \end{aligned} \tag{19}$$

$$\hat{m}_t = \gamma_1\hat{y}_t - \gamma_2\hat{r}_t + \gamma_3\hat{e}_t \tag{20}$$

$$\hat{z}_t = \rho_z \hat{z}_{t-1} + \varepsilon_{zt} \tag{21}$$

$$\hat{\pi}_t = \left(\frac{\pi}{r}\right) E_t\hat{\pi}_{t+1} + \psi\left[\left(\frac{1}{\omega_1}\right)\hat{y}_t - \left(\frac{\omega_2}{\omega_1}\right)\hat{m}_t + \left(\frac{\omega_2}{\omega_1}\right)\hat{e}_t - \hat{z}_t\right], \tag{22}$$

$$\hat{r}_t = \rho_r\widehat{r}_{t-1} + \rho_y\hat{y}_t + \rho_\pi\hat{\pi}_t + \varepsilon_{rt} \tag{23}$$

Steady state values and parameters in equations (17) to (23) are also defined as $r = \pi/\beta$, $c = y$, $r\frac{\partial u}{\partial m} = (r-1)e\frac{\partial u}{\partial y}$[13], $\frac{\partial u}{\partial y} = \left(\frac{\theta}{\theta-1}\right)\left(\frac{\eta}{z}\right)$, $\omega_1 = -\frac{\frac{\partial u}{\partial y}}{y\frac{\partial^2 u}{\partial y^2}}$, $\omega_2 = -\frac{\frac{m}{e}\frac{\partial^2 u}{\partial y \partial m}}{y\frac{\partial^2 u}{\partial y^2}}$, $\gamma_1 = \left(\frac{yr\omega_2}{m\omega_1} + \frac{r-1}{\omega_1}\right)\gamma_2$, $\gamma_2 = \frac{r}{(r-1)\frac{m}{e}}\left[\frac{\frac{\partial^2 u}{\partial m^2}}{(r-1)e\frac{\partial^2 u}{\partial y\partial m} - ru\frac{\partial^2 u}{\partial m^2}}\right]$, $\gamma_3 = 1-(r-1)\gamma_2$ and $\psi = \frac{\theta-1}{\phi}$.

In correctly specified model from agent's optimisation behaviour as above, real money holdings must have the direct effect on output and inflation as in equations (19) and (22) only when ω_2 is positive, namely utility is non-separable between consumption and real balances. Therefore, the proper evaluation of real balance effect on economic activities which is not captured fully in short-term nominal interest rate can only be possible with estimation under this cross-restriction.

4 Estimation Procedure

In this section, the estimation procedure, namely how to conduct maximum likelihood estimation on the DSGE model in state space form derived above, is introduced.[14]

Three optimality conditions: (19), (20) and (22), one decision rule: (23) and three distribution process for shocks: (17), (18), and (21) are represented as a linear system of equations:

$$Af_t^0 = Bs_t^0 + Cv_t, \tag{24}$$

[13]This is due to the fact that in steady state $c = y$.

[14]Again, this part is just a brief summary of Ireland (2002b).

$$DE_t s_{t+1}^0 + FE_t f_{t+1}^0 = Gs_t^0 + Hf_t^0 + Jv_t, \tag{25}$$

$$v_t = Pv_{t-1} + \varepsilon_t, \tag{26}$$

where $f_t^0 = \begin{bmatrix} \hat{m}_t & \hat{r}_t \end{bmatrix}'$, $s_t^0 = \begin{bmatrix} \hat{y}_{t-1} & \hat{m}_{t-1} & \hat{\pi}_{t-1} & \hat{r}_{t-1} & \hat{y}_t & \hat{\pi}_t \end{bmatrix}'$, $v_t = \begin{bmatrix} \hat{a}_t & \hat{e}_t & \hat{z}_t & \varepsilon_{rt} \end{bmatrix}'$ and $\varepsilon_t = \begin{bmatrix} \varepsilon_{at} & \varepsilon_{et} & \varepsilon_{zt} & \varepsilon_{rt} \end{bmatrix}'$.

Ireland (2002b) demonstrates that following Blanchard and Kahn (1980), systems of equations (24) to (26) are transformed into state space form as follows:

$$s_{t+1} = \Pi s_t + W\varepsilon_{t+1} \tag{27}$$

$$f_t = Us_t, \tag{28}$$

where $s_t = \begin{bmatrix} \hat{y}_{t-1} & \hat{m}_{t-1} & \hat{\pi}_{t-1} & \hat{r}_{t-1} & \hat{a}_t & \hat{e}_t & \hat{z}_t & \varepsilon_{rt} \end{bmatrix}'$, $f_t = \begin{bmatrix} \hat{m}_t & \hat{r}_t & \hat{y}_t & \hat{\pi}_t \end{bmatrix}'$ and $\varepsilon_t = \begin{bmatrix} \varepsilon_{at} & \varepsilon_{et} & \varepsilon_{zt} & \varepsilon_{rt} \end{bmatrix}'$.

Linear equation system (27) is so-called the state equation while (28) is the observation equation and therefore vector s_t is the state vector. As shown in Hamilton (1994) and Hansen and Sargent (2000), since the system is now represented in state space form and data in vector f_t are available, the coefficients can be obtained by maximum likelihood estimation.

First, conditional expectations, linear projections here and MSE matrix of state vector are defined as follows.

$$\hat{s}_{t|t-j} = E(s_t | f_{t-j}, f_{t-j-1}, ..., f_1) \tag{29}$$

$$\widehat{f}_{t|t-j} = E(f_t | f_{t-j}, f_{t-j-1}, ..., f_1) \tag{30}$$

$$\Sigma_{t|t-j} = E(s_t - \hat{s}_{t|t-j})(s_t - \hat{s}_{t|t-j})' \tag{31}$$

From (27), (29) and (31), the initial vector and MSE matrix with which recursion starts can be expressed as follows:

$$\hat{s}_{1|0} = Es_1 = 0 \tag{32}$$

$$vec(\Sigma_{1|0}) = vec(Es_1 s_1') = [I - \Pi \otimes \Pi]^{-1} vec(WVW'). \tag{33}$$

V is the variance-covariance matrix of vector ε_{t+1}.

Further from (28) and (30) linear projection of vector f_t becomes

$$\widehat{f}_{t|t-1} = U\hat{s}_{t|t-1}. \tag{34}$$

If we define the forecast error as u_t, then from (34)

$$u_t = f_t - \widehat{f}_{t|t-1} = U(s_t - \hat{s}_{t|t-1}), \tag{35}$$

with MSE

$$Eu_tu_t' = U\Sigma_{t|t-1}U'. \tag{36}$$

Combining the formula for updating a linear projection with (27), (35) and (36) leads to

$$s_{t+1} - \hat{s}_{t+1|t} = \Pi(s_t - \hat{s}_{t|t-1}) + W\varepsilon_{t+1} - \Pi\Sigma_{t|t-1}U'(U\Sigma_{t|t-1}U')^{-1}u_t,$$

and therefore

$$\Sigma_{t+1|t} = WVW' + \Pi\Sigma_{t|t-1}\Pi' - \Pi\Sigma_{t|t-1}U'(U\Sigma_{t|t-1}U')^{-1}U\Sigma_{t|t-1}\Pi'.$$

If we denote $\hat{s}_t = \hat{s}_{t|t-1} = E(s_t|f_{t-1}, f_{t-2}, ..., f_1)$ and $\Sigma_t = \Sigma_{t|t-1} = E(s_t - \hat{s}_{t|t-1})(s_t - \hat{s}_{t|t-1})'$, then the system can be summarised as follows.

$$\hat{s}_{t+1} = \Pi\hat{s}_t + K_tu_t, \tag{37}$$

$$f_t = U\hat{s}_t + u_t, \tag{38}$$

where

$$u_t = f_t - E(f_t|f_{t-1}, f_{t-2}, ..., f_1), \tag{39}$$

$$Eu_tu_t' = U\Sigma_tU' = \Omega_t, \tag{40}$$

$$K_t = \Pi\Sigma_tU'(U\Sigma_tU')^{-1}, \tag{41}$$

$$\Sigma_{t+1} = WVW' + \Pi\Sigma_t\Pi' - \Pi\Sigma_tU'(U\Sigma_tU')^{-1}U\Sigma_t\Pi'. \tag{42}$$

This system consists of equations (37) to (42) are updated recursively with the initial condition of $\hat{s}_1$ and Σ_1 provided by (32) and (33).

The innovations $\{u_t\}_{t=1}^T$ updated as above can then be used to form the log likelihood function as

$$\ln L = -2T\ln(2\pi) - \frac{1}{2}\sum_{t=1}^{T}\ln|\Omega_t| - \frac{1}{2}\sum_{t=1}^{T}u_t'\Omega_t^{-1}u_t. \tag{43}$$

Parameters are estimated as the values which minimise the log likelihood function (43).

5 Results

In this section, I first estimate the DSGE model which consists of equations (17) and (23) by minimising equation (43). Then, the impulse responses are shown, and the variance decomposition and simulated autocorrelation obtained from the DSGE model are compared to those from identified vector autoregression (VAR) model.

5.1 Parameter Estimates

Estimation is conducted using four variables contained in vector f_t, namely, real money balances (m_t), interest rate (r_t), output (y_t) and inflation rate (π_t). Real money balances are measured by dividing seasonally adjusted M2+CD by seasonally adjusted CPI excluding perishables and population of age 16 and over, interest rate is LIBOR three month rate, output is seasonally adjusted real GDP divided by population of age 16 and over, and inflation rate is measured by changes in seasonally adjusted CPI excluding perishables. All data are on quarterly bases.

As a distinct upward trend is found in real money balances and output measured as above, two measures are taken in this paper in order to transfrom the data series stationary.[15] First, the HP filter advocated by Hodrick and Prescott (1997) is employed. The estimated series are the ones from which the HP filtered trend is eliminated. In the second approach, linear the time trend is excluded so that these series become stationary. The ground for this removal of upward trend is that the shocks considered in this DSGE model do not affect deterministic trend which should obey TFP and Labour supply growth rate. There are no conclusive way to eliminate deterministic trend, and therefore two simple but quite different methods are employed. If results from both measures produce similar results, the conclusion can be considered to be very persuasive.

Estimation period is set from 1982/Q1 to 1995/Q1. The starting date is chosen so as to avoid some distortional effects from the second oil shock. As for the ending date, it is set at around the Bank of Japan resumed the de-facto zero nominal interest rate policy. Of course it would be possible to set the ending date as recent as possible, but this causes some problems: 1) The Bank of Japan should have changed the implicit monetary policy rule because there is no more room left to further lower the interest rate since around 1995.[16] Therefore, it would be very difficult to have a valid single decision rule for the estimation period here examined.[17] 2) Concerning this point, recent researches on the stability of monetary transmission mechanism in Japan, such as Miyao

[15]Hamilton (1994) recommends staionarity in data when estimating a state space model.

[16]It is true that zero nominal interest rate policy has started literally in Februally 1999 and official annoucement of the change in monetary policy regime by the Bank of Japan is made in March 2001 when the Bank has changed the monetary policy to target not the overnight call rate but base money henceforth, but the room for further easing has almost disappeared in 1995.

[17]Examining the "quantitative easing" policy rule should be intriguing. However, the time series data is not long enough to conduct maximum likelihood estimation.

(2000) and Fujiwara (2003a) suggest that there is a structural break around 1995 and since then the effect of monetary policy has become weaker than before. 3) Woodford (2002) discusses that even if the utility function is non-separable in consumption and real balances, there is no direct effect of real balances on output and inflation when the steady state interest rate is zero. It is true that almost zero nominal interest rate as in Japan now does not have to imply that the steady state interest rate is zero. However, in the process of maximum likelihood estimation, it is quite possible to obtain the result which tells that the steady state interest rate is almost zero. For these reasons, I have chosen the estimation period from 1982/Q1 to 1995/Q1. Unless any support for the existence of non-separability of utility from the estimation result from 1982/Q1 to 1995/Q1 could be obtained, we can conclude that there is almost no direct effect of real balances in Japanese macroeconomic dynamics.

When conducting estimation, some parameters are pre-fixed. As claimed in Ireland (2001), preliminary attempts to estimate all the parameters in equations (17) and (23) are not successful. This leads to implausibly low ω_1 and ψ. Since the aim of this paper is to examine the existence of the direct effect of money on real economic activities, I estimate the parameters with constrained maximum likelihood estimates with ω_1 and ψ pre-fixed as exactly examined in Ireland (2002a). ω_1 can be considered as the parameter for intertemporal elasticity of substitution. Fujiwara (2003b) estimates this parameter with GMM and obtained the value of 0.66. As for ψ, this can be considered as the parameter on the output gap in New Keynesian Philiips curve and implicitly contains the information on how frequently firms can change the price. As for Japanese data, Kimura and Kurozumi (2002) estimate New Keynesian Phillips curve[18] for annual inflation rate and obtains the value of 0.2 for this parameter. Further, several researches on Phillips curve conducted by the Bank of Japan, such as *Price Developments in Japan–A Review Focusing on the 1990s* released in October 2000 which report that this value for annual inflation is around 0.2. Transforming this into quarterly inflation rate bases with considering that the intertemporal elasticity of substitution is now 0.66, leads to that ψ should be set at 0.075.

Tables 4 and 5 show the estimation results when the HP filtered and the time trends are eliminated respectively, where standard errors are computed from inverse of Hessian matrix.

[18]Although it estimates the hybrid New Keynesian Phillips curve as appeared in Fuhrer and Moore (1995).

Table 4: Parameter Estimates when the HP trends are eliminated

Parameter	Estimate	Standard Error
β	0.9915	0.0010
ω_1	0.6600	-
ω_2	0.0112	0.0602
γ_1	0.0000	0.0010
γ_2	0.0000	0.0486
γ_3	0.9999	0.0006
ψ	0.0750	-
ρ_r	0.8168	0.0574
ρ_y	0.0142	0.0197
ρ_π	0.3362	0.0311
$\log(y)$	8.1503	0.0025
$\log(m)$	10.3018	0.0121
$\log(\pi)$	0.0041	0.0007
$\log(r)$	0.0126	0.0013
ρ_a	0.8172	0.0482
ρ_e	0.9439	0.0356
ρ_z	0.1978	0.1454
σ_a	0.0170	0,0029
σ_e	0.0063	0.0006
σ_z	0.0277	0.0045
σ_r	0.0014	0.0001

Table 5: Parameter Estimates when the time trends are eliminated

Parameter	Estimate	Standard Error
β	0.9917	0.0059
ω_1	0.6600	-
ω_2	0.0017	0.0097
γ_1	0.0000	0.0022
γ_2	0.0000	0.1159
γ_3	0.9999	0.0014
ψ	0.0750	-
ρ_r	0.7869	0.0337
ρ_y	0.0003	0.0142
ρ_π	0.3266	0.0473
$\log(y)$	8.1656	0.0262
$\log(m)$	10.3246	0.0962
$\log(\pi)$	0.0039	0.0092
$\log(r)$	0.0122	0.0151
ρ_a	0.9544	0.0398
ρ_e	0.9874	0.0132
ρ_z	0.9689	0.0747
σ_a	0.0230	0,0101
σ_e	0.0102	0.0010
σ_z	0.0139	0.0028
σ_r	0.0014	0.0001

Estimation results show that reasonable values are obtained for all the parameters[19] and almost the same results are obtained in both cases. A minor difference can be found in the persistence of technology shock represented as ρ_z. As the time span when the variables are away from their steady state value are naturally quite different whether the HP or the time trend is considered to be steady state pass, the parameter which decides this time span, namely the persistence of shocks are different in the two cases. Technology shock is very persistent in the time trend case. Other than this minor difference, the size of the parameters and their significance are almost the same.

The parameter which is of most interest most naturally ω_2 which decides the non-separability in consumption and real balances in utility function and therefore defines the magnitude of direct effect of money holdings on output and inflation. In both cases, this parameter is very small and insignificant. To ensure this finding further, I examined likelihood ratio test for the null hypothesis H_0: ω_2=0. Under this null hypothesis, likelihood ratio for the HP trend case is 1.3962e-008 and 7.0825e-009 for the time trend case. As the 95% significant level for the cumulated Chi-square distribution when the degree of freedom is

[19]Impulse responses obtained from estimated dynamic stochastic general equilibrium model here show reasonable properties as understood by standard macroeconomic theory and empirical intuition.

set to the number of restrictions, namely one in this case, is 3.75, this null hypothesis is not rejected at all in both cases. This finding suggests that there is no direct role of real money balances in Japan, which is consistent with the ones obtained for US data in Ireland (2002a) and Euro area in Andres, Lopez-Salido and Valles (2001). Hence, it is reasonable to assume separable utility function as examined in the analysis using a DSGE model with money in utility such as Fukunaga (2002) and Fujiwara (2003b) on the Japanese macroeconomic dynamics.

Another intriguing finding is that real money balances are following almost independent dynamics from other macroeconomic variables. Parameters γ_1, γ_2 and γ_3 which defines the dynamics in the money demand function, or LM curve in other words, indicate that dynamics in real money balances are solely defined by independently distributed shocks. This is consistent with the finding in Miyao (1996), which finds no robust co-integration relationship in money demand function when M2+CD is included,[20] and the current informal argument that money's relationship with macroeconomic variables such as inflation and output has become less significant.

5.2 Impulse Responses

In this and following subsections, we check whether the estimated DSGE model has reasonable simulation properties to determine the estimated model is appropriate tool for the analysis on Japan and therefore ensure the above results for non-existence of direct effect of money.

First, we evaluate the impulse responses of the estimated DSGE model so that we could judge that the models constructed above are considered to be a good approximation of macroeconomic dynamics of Japanese economy. Figure 1 shows the impulse responses of output, real balances, inflation rate and nominal interest rate to each shock assigned in the model.

5.2.1 Impulse responses to a preference shock, a_t

As seen in equations (1) and (19), this preference shock can be considered as a demand shock. Figure 1-a shows the impulse responses to this demand shock. A demand shock naturally increases the output level and from the Phillips curve relationship, this results in higher inflation. Against these backgrounds, monetary authority raises nominal interest rate. Although money demand function is included in this system of equations, the effect from expanding demand and higher interest rate on real balances is extremely limited.

5.2.2 Impulse responses to a preference shock, e_t

This preference shock determines the weight of preferences between consumption and real balances as in equation (1) and therefore can be called the money

[20]Sekine (1998) finds the cointegration relationship in money demand function with M2+CD by including wealth as a scale variable.

demand shock. The larger this preference shock becomes, the more the representative consumer increases the real balances compared to consumption. As shown in figure 1-b, after this shock, real balances increase. However, although the direction of the responses of other endogenous variables are consistent with theory such that increase in real money balances will raise the nominal interest rate and therefore these altogether lead to lower inflation and output, the magnitude of the responses of these three variables are minuscule.

5.2.3 Impulse responses to a technology shock, z_t

Figure 1-c demonstrates the impulse responses to a positive technology shock. A positive technology shock increases the output. However, as the demand does not catch up to the supply side immediately, output gap widens and this leads to lower inflation. In response to lower inflation, monetary authority lowers the nominal interest rate. Again, the response of real balances is extremely small, which implies how independent the movements of real balances in Japanese macroeconomy is.

The difference in the persistence of technology shock represented as ρ_z results in more graudal adjustment towards steady state in the time trend case compared to the HP filtered case. This is due to the the fact that the difference in the time span when the variables are away from their steady state value are naturally quite different depending on whether the HP or the time trend is considered to be steady state pass.

5.2.4 Impulse responses to a monetary policy shock, ε_{rt}

A shock term included in equation (23) can be considered as a monetary policy shock as it deviates the nominal interest rate from the level suggested by the monetary policy rule. A positive shock on nominal interest rate lowers the output and therefore inflation. Again, the effect on real balances is extremely small.

Thus far, we have learned that the impulse responses of these two estimated DSGE model have reasonable properties and the real balances' dynamics are almost independently determined from other macroeconomic variables in Japan before 1995.

5.3 Variance Decomposition

In this subsection, I evaluate the model property from a different perspective, the variance decomposition. The variance decomposition separates the variation in an endogenous variable into the component shocks and therefore, provides information about the relative importance of each random innovation in affecting the variables employed in the system.

Tables 6 and 7 illustrate the forecast error variance decompositions for output, real balances, inflation rate and nominal interest rate.

Table 6: Variance Decomposition on DSGE: the HP filtered case

	Output (y)				Real Balances (m)			
	ε_a	ε_e	ε_z	ε_r	ε_a	ε_e	ε_z	ε_r
1y	76.5	0.0	8.0	15.5	0.0	100.0	0.0	0.0
2y	76.4	0.0	8.2	15.4	0.0	100.0	0.0	0.0
	Inflation (π)				Interest Rate (r)			
	ε_a	ε_e	ε_z	ε_r	ε_a	ε_e	ε_z	ε_r
1y	51.9	0.0	37.7	10.5	41.9	0.0	11.2	46.9
2y	52.0	0.0	37.5	10.5	59.9	0.0	8.1	32.0

Table 7 Variance Decomposition on DSGE: the time trend case

	Output (y)				Real Balances (m)			
	ε_a	ε_e	ε_z	ε_r	ε_a	ε_e	ε_z	ε_r
1y	13.8	0.0	59.7	11.4	0.0	100.0	0.0	0.0
2y	8.0	0.0	89.2	2.8	0.0	100.0	0.0	0.0
	Inflation (π)				Interest Rate (r)			
	ε_a	ε_e	ε_z	ε_r	ε_a	ε_e	ε_z	ε_r
1y	74.2	0.0	18.6	7.2	48.3	0.0	11.8	39.9
2y	74.7	0.0	19.6	5.7	66.1	0.0	17.0	17.0

Both the HP filtered and the time trend cases show very similar results. Money demand shock only help to forecast real balances but they have almost no predictive power on other endogenous variables. As far as output and inflation are concerned, the demand and technology shocks are the most important sources of fluctuations. Therefore, these two shocks are also important driver of fluctuations in interest rate, but monetary policy shock itself has significant effects on interest rate formation.

Are those results from the forecast error variance decomposition consistent with the ones derived from more objective method, such as VAR? To examine this, I here estimate four variable VAR. The structural VAR estimated here is very standard as in Christiano, Eichenbaum and Evans (1999) and Teruyama (2001), which consists of a constant and four variables, output, price level, nominal interest rate and money supply.[21] Estimated period is set at 1982/Q1 to 1995/Q1 as the DSGE model estimated above and lag length is set at four. Impulse responses are derived by assuming recursive structure on contemporaneous relationship between variables where the order of Choleski decomposition is output, price level, nominal interest rate and money supply. The forecast error variance decomposition from this structural VAR is shown in table 8.

[21] Output: real GDP, price level: CPI excluding perishables and utility prices, Nominal interest rate: Libor three month rate, Money supply; M2+CD.

Table 8: Variance Decomposition on structural VAR

	Output				Money Supply			
	$\varepsilon_{\overline{y}}$	$\varepsilon_{\overline{p}}$	$\varepsilon_{\overline{r}}$	$\varepsilon_{\overline{m}}$	$\varepsilon_{\overline{y}}$	$\varepsilon_{\overline{p}}$	$\varepsilon_{\overline{r}}$	$\varepsilon_{\overline{m}}$
1y	58.2	4.0	1.5	36.2	1.9	12.3	1.4	84.3
2y	22.2	7.1	13.8	56.8	8.0	23.5	9.3	58.9
	Price Level				Interest Rate			
	$\varepsilon_{\overline{y}}$	$\varepsilon_{\overline{p}}$	$\varepsilon_{\overline{r}}$	$\varepsilon_{\overline{m}}$	$\varepsilon_{\overline{y}}$	$\varepsilon_{\overline{p}}$	$\varepsilon_{\overline{r}}$	$\varepsilon_{\overline{m}}$
1y	2.6	84.2	10.3	2.9	1.4	25.2	72.4	1.0
2y	4.4	70.0	12.2	13.4	5.3	35.1	43.3	16.3

Although the detailed definitions of shocks in this case are quite different from the estimated DSGE models, these shocks can be defined as follows: $\varepsilon_{\overline{y}}$: a demand shock, $\varepsilon_{\overline{p}}$: a supply shock or a technology shock, $\varepsilon_{\overline{r}}$: a monetary policy shock, $\varepsilon_{\overline{m}}$: a money demand shock.[22]

As in the case of estimated DSGE models, money demand shock is the most important source of money supply's fluctuations. Although money demand shock has some predictive power on output, demand and supply shocks are important sources of fluctuations on output and price level respectively, and further, a monetary policy shock is important in explaining the dynamics of nominal interest rate in Japan.

Although a consistent comparison is impossible as the variables employed are different from those of estimated DSGE models, we can conclude that the forecast error variance decompositions resembles the one obtained from a structural VAR.

5.4 Simulated Autocorrelations

Simulated autocorrelations contain another information concerning the model's plausibility. Figure 2 shows the simulated autocorrelation of four endogenous variables in the estimated DSGE models and the ones obtained from VAR estimation. The estimated VAR here is again forth order and the variables employed is the same as used for the DSGE estimation in the time trend case.

The results show that simulated autocorrelations obtained from VAR lie mostly between those from the HP filtered and the time trend case of the estimated DSGE models. As already mentioned, difference in the persistence of the technology shock results in the less persistent autocorrelations in the HP filtered case. From the evaluation with these simulated autocorrelations, it can be concluded that the estimated DSGE models mimic the VAR's simulated properties well.

[22] Miyao (2000) and Miyao (2002) consider this shock as a money demand shock rather than a liquidity shock.

6 Conclusion

In chapter two, I have estimated IS curves in reduced form and the finding is that real balances enter the equation significantly. However, using single estimation for the evaluation of such a vague effect as the direct effect of money tends to be problematic since the endogeneity of variables is not properly accounted for. Therefore, in chapters three and onwards, the DSGE model with a direct effect of money is constructed based on rigid microfoundations, and maximum likelihood estimates of the direct effects of money support no evidence on the direct effect of money due to the non-separability of utility in consumption and real balances. This finding is supported by two cases; the variables are detrended by the HP filter and by the time trend.

As for the simulated properties to evaluate the plausibility of these models, impulse responses obtained from these two estimated DSGE models have reasonable properties, which are consistent with our intuition on Japanese macroeconomics and macroeconomic theory. In addition, we have learned that the dynamics of real balances are almost independent from those of other variables. Furthermore, the forecast error variance decomposition and simulated autocorrelation from these two models resemble those from VARs.

Taking these findings into account, we can conclude that the direct effect of money is extremely small. Therefore, the effect of the "quantitative easing" monetary policy, which is currently employed by the Bank of Japan, on the real economic activities should be extremely limited, and this finding is consistent with the ones in Kimura, Kobayashi, Ugai and Muranaga (2002) and Fujiwara (2003a).

Future research replacing the policy rule as in (23) to the BOJ's current monetary policy rule, which targets not the nomianl interest rate but the base money, with more recent observations included in the estimation period would make this conclusion more persuasive.

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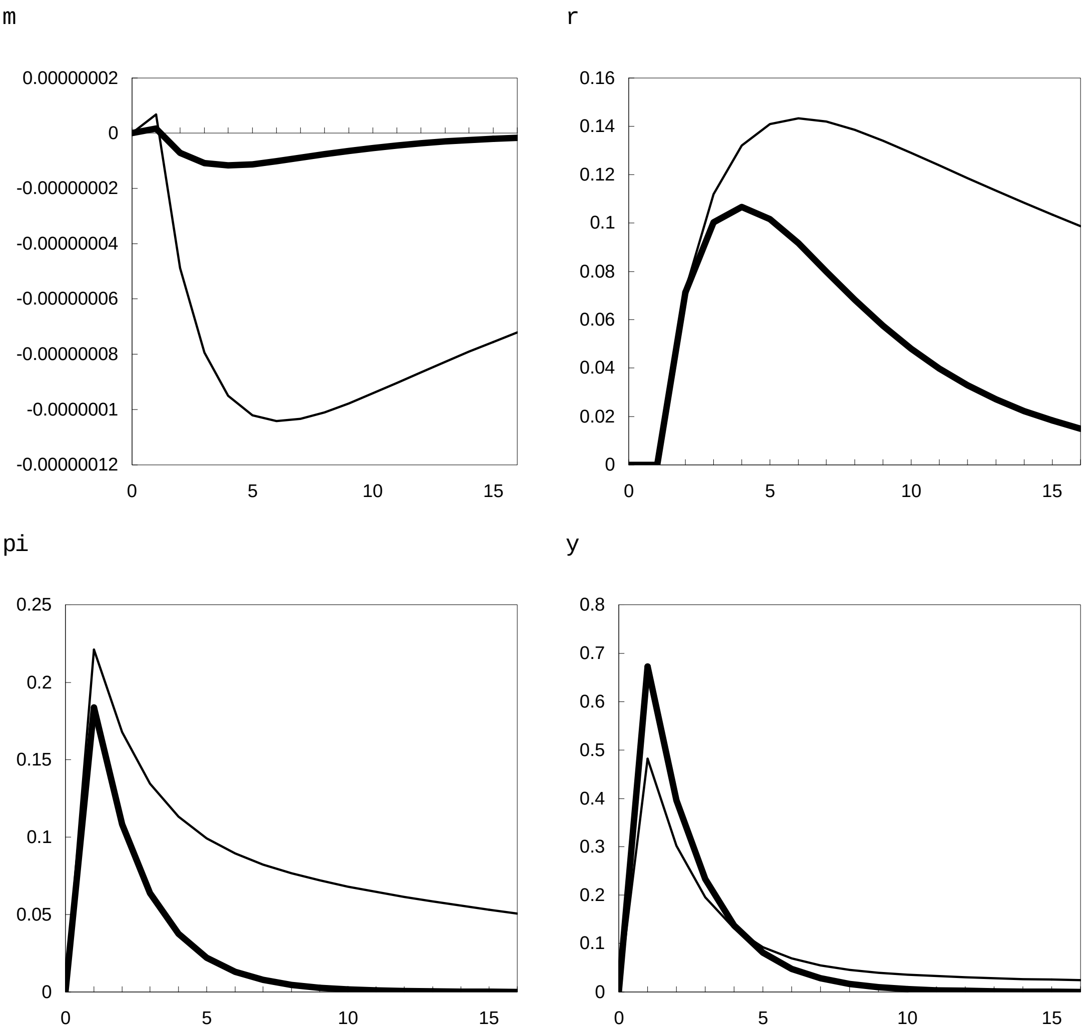
Figure 1-a: Impulse responses to a preference shock, a(t)



bold line: HP filter base
solid line: time trend base

Figure 1-b: Impulse responses to a preference shock, e(t)

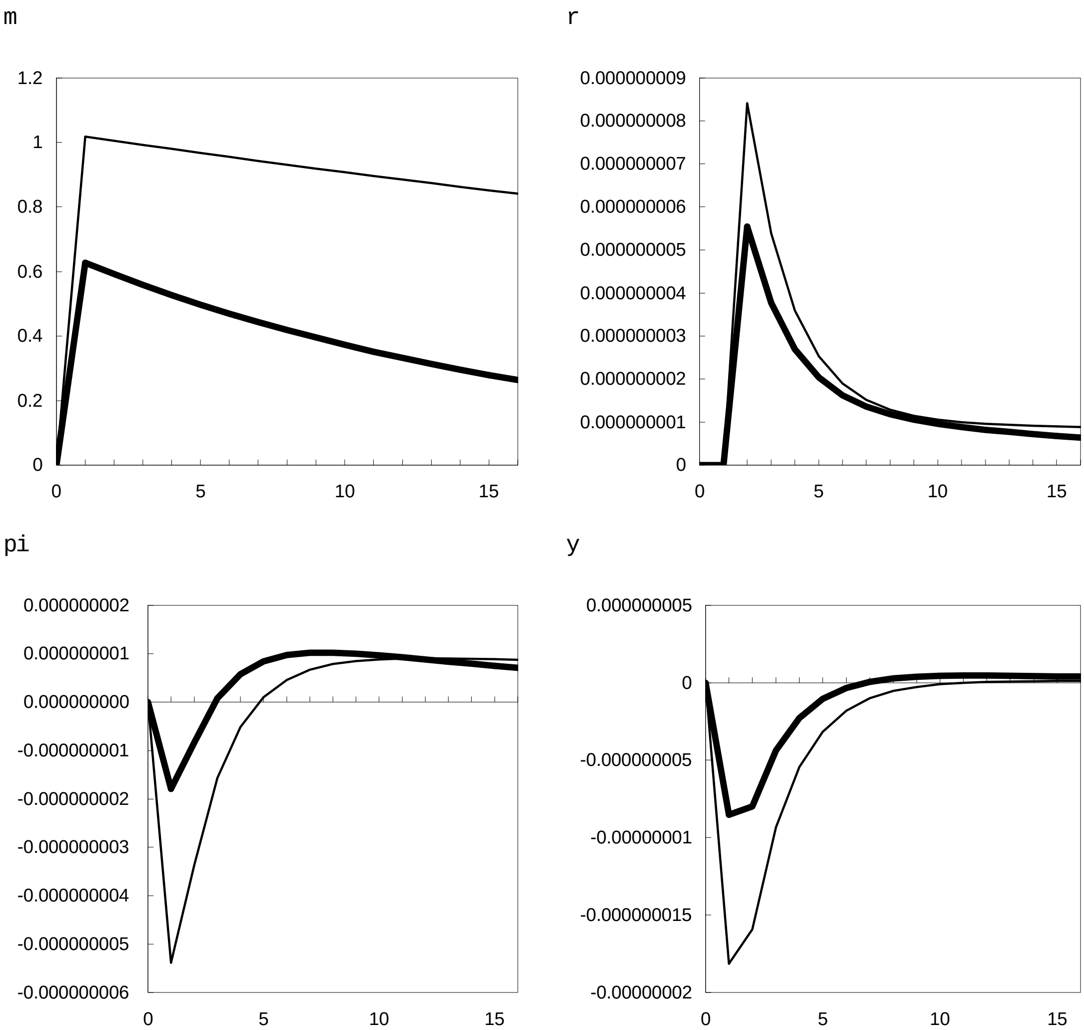


Figure 1-c: Impulse responses to a technology shock, z(t)

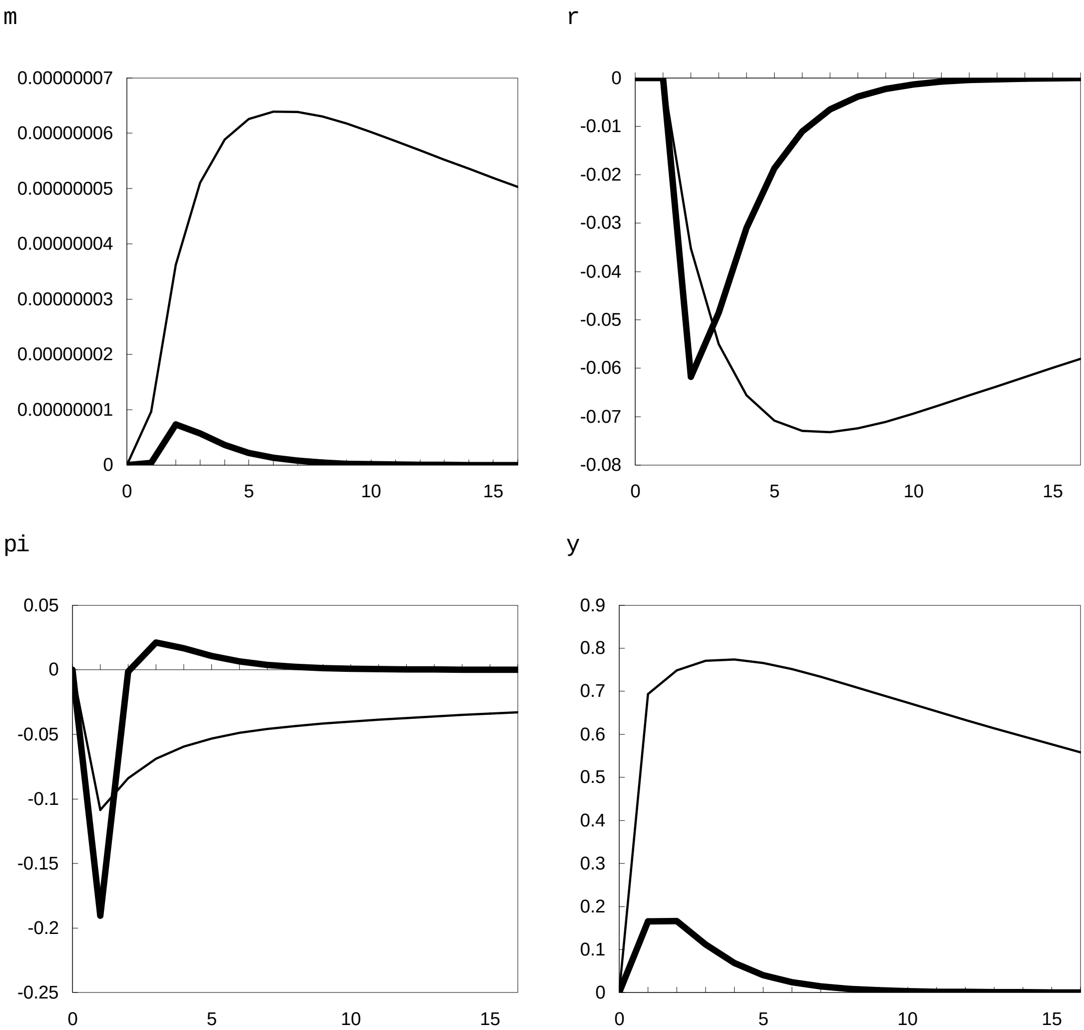


Figure 1-d: Impulse responses to a monetary policy shock, a(t)

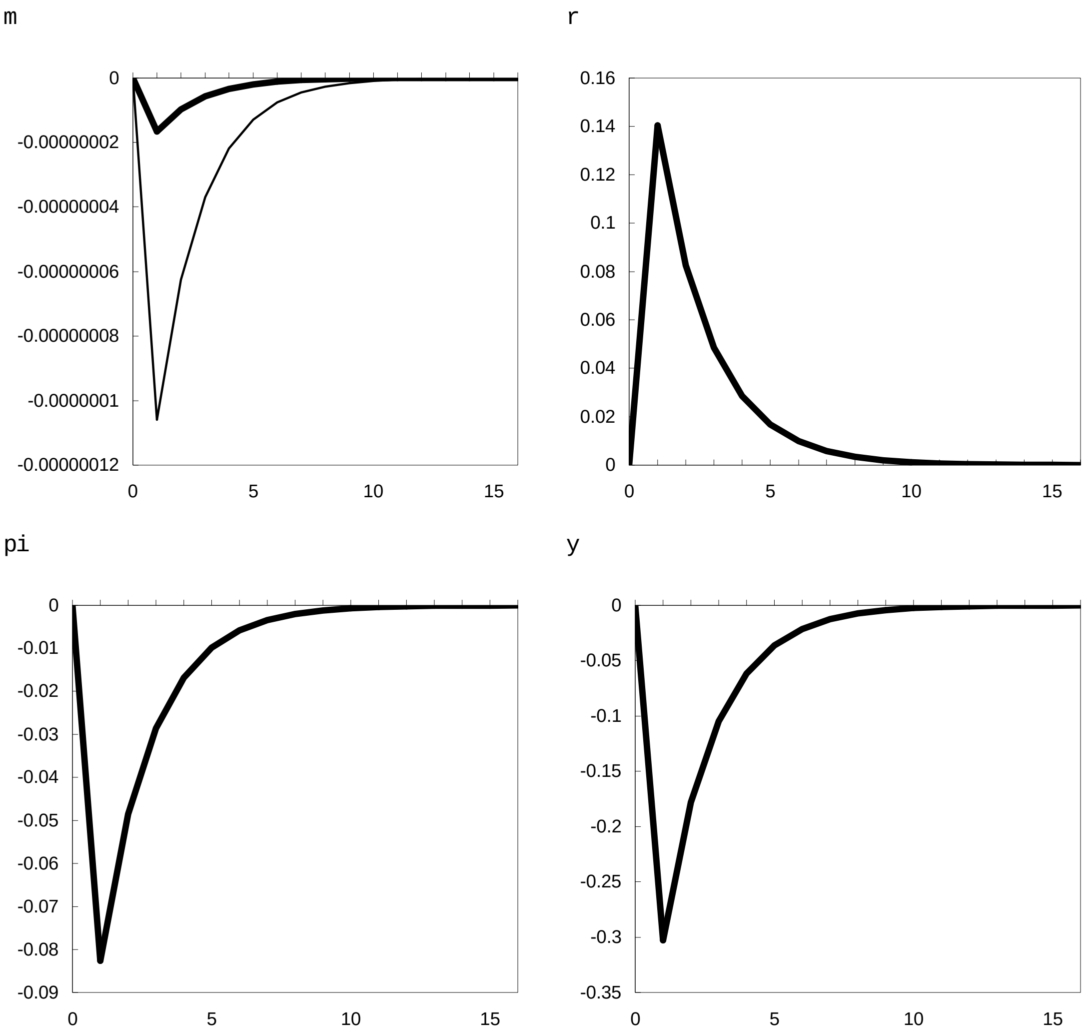


Figure 2: Simulated Autocorrelation