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Output Composition of Monetary Policy Transmission Mechanism in Japan

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Abstract

In this paper, I investigate the output composition of monetary policy transmission mechanism in Japan. It is usually thought that the investment channel, namely the process that a change in interest rate alters the cost of capital and therefore investment, is more predominant in Japan. Yet, in the United States, it is commonly argued that the consumption channel through intertemporal substitution is more prevalent than the investment channel.

The aim of this paper is twofold; 1) to understand which of the two channels; the consumption channel and the investment channel, is more significantly predominant in the monetary transmission mechanism of Japan based on the analysis with VAR and DSGE models, and 2) to contribute the research concerning the "Output Composition Puzzle" advocated by Angeloni, Kashyap, Mojon and Terlizzese (2002) for the fact that the consumption channel is more prevalent in the United States but in Euro area investment channel is the predominant driver of output changes.

The results obtained from the Japanese models are consistent with our intuitive conclusion that the investment channel is more important.

JEL Classification: C33; E50.
Key words: VAR; DSGE; Monetary Policy Transmission; Output Composition Puzzle;

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1 Introduction

In this paper, I research on the output composition of monetary policy transmission mechanism in Japan. As conventionally known, raising of interest rates leads to the decrease in the output and eventually price level. However, channel to this end is not quite obvious, although it may be considered apparent from intuition based on our experiences. Usually, it is thought that the investment channel, namely the process that the interest rate change made by the central bank alters the cost of capital and therefore investment, is more predominant. Yet, in the United States, it is commonly argued that the consumption channel through intertemporal substitution is more prevalent than investment channel. Recently, Angeloni, Kashyap, Mojon and Terlizzese (2002) concludes through the analysis from VAR (Vector AutoRegression), DSGE (Dynamic Stochastic General Equilibrium) and Large Macroeconometric Models employed in central banks that in the United States the consumption channel is the main transmission channel, but on the other hand, in the Euro area, it is only playing a minor role in monetary transmission. With plausible parameter calibration, it states that the phenomenon in the United States cannot be explained theoretically by DSGE model and names these facts as the "Output Composition Puzzle."

The aim of this paper is twofold; 1) to understand which of the two channels; the consumption channel and investment channel, is more significantly predominant in the monetary transmission mechanism of Japan based on the analysis with VAR and DSGE models, and 2) to contribute the research concerning the "Output Composition Puzzle." The results are consistent with our intuitive conclusion that the investment channel is more significant in the monetary transmission mechanism in Japan.

This paper consists as follows. First, I construct four VAR models with different identification which can account for responses in consumption and investment respectively to nominal interest rate shock. Then, the results obtained from VAR models are compared with those from DSGE model, the parameter of which is estimated as well as calibrated so that it can explain the macroeconomic dynamics underlying in Japanese macroeconomic data. Finally, findings here are summarised in conclusion.

2 VAR Models

The research on monetary policy transmission mechanism using VAR is quite vast. Indeed, the seminal paper on identified VAR of Sims (1980), which is well-known for the "Sims critique" on traditional large macromodels for their implausible identifications, is also on monetary transmission. Since then, quite a large number of researches with various identification schemes have been published. Among them, it is popular to identify the system for contemporaneous relationships between macroeconomic variables. For example, some such as Christiano, Eichenbaum and Evans (1999) use Choleski decomposition, which is called as the recursive framework for identification, and others such as Leeper, Sims and Zha (1996) employ non-recursive framework for identifying monetary policy shocks.

As for the research on Japanese monetary policy, Iwabuchi (1990) is the first attempt to investigate monetary transmission mechanism in Japan using identified VAR, which employs non-recursive structure for the analysis. Since then, researches which are similar to Iwabuchi (1990) but slightly different in aim have been published with various identification. Miyao (2000), Kimura, Kobayashi, Muranaga and Ugai (2002), and Fujiwara (2003a) examine the stability of monetary transmission mechanism with identified VAR on monetary policy transmission. Kasa and Popper (1997) and Shioji (2000) construct monetary VAR models with reserve market so that they could embed the actual implementing scheme of monetary policy. Sugihara, Mihira, Takahashi and Takeda (2000) tries to find out robust conclusions on monetary transmission mechanism by constructing VAR models with various identification scheme such as recursive, non recursive and long-run restriction introduced by Blanchard and Quah (1989). Further it estimates the model with both non-differenced and differenced series. Overall, Teruyama (2001) surveys the recent developments in VAR on monetary transmission mechanism in Japan.

However, concerning the output composition of monetary transmission mechanism which is the central aim of investigation in this paper, prior researches have been paying little attention to the detailed structure of the transmission channel, that is, to understanding which transmission channel; consumption channel through intertemporal substitution or investment channel through cost of capital, is more predominant driver of output changes after monetary policy shocks. As prior researches on this field in Japan tend to include only one output variable, usually industrial production,[1] we have not yet been well-informed about whether changes in output level and price level is brought mainly through consumption or investment.

Even, considering the researches on the United States and the Euro area, there have not been many researches with VAR models which can account for the output composition. One example can be found in Christiano, Eichenbaum and Evans (2001). It estimates VAR with ten variables; consumption, investment, GDP, GDP deflator, real wage, labour productivity, corporate profit, federal funds rate, M2 and S&P 500 stock price index, so that it could judge whether DSGE with time-varying capital utilisation they create can reproduce realistic, in other words, very similar impulse responses to those obtained from VAR models. However, its main aim lies not on understanding the output composition of monetary transmission mechanism.

The seminal research which induces attention on the importance of understanding output composition is recent research conducted by Angeloni, Kashyap, Mojon and Terlizzese (2002). It estimates four VAR models each for the United States and the Euro area in order that the difference in the monetary transmission mechanism between them could be scrutinised. For the United States,

[1] This may be due to the fact that the VAR on monetary policy transmission is normally estimated on monthly data so that the more information could be extracted.

they construct VAR models based on Christiano, Eichenbaum and Evans (1999), Gorden and Leeper (1994), those with the extension made to include GDP components, further Christiano, Eichenbaum and Evans (2001) and Erceg and Levin (2002). Concerning the Euro area, the VAR models of Peersman and Smets (2003) with M3 and without M3, Gali (1992) with extension to include GDP components, and Christiano, Eichenbaum and Evans (2001) modified for the Euro data are examined. As has been mentioned, it concludes that the consumption channel is more prevalent in the United States but in the Euro area investment channel is the predominant driver of output changes and names this fact as the "Output Composition Puzzle."

As VAR model on monetary transmission mechanism with output decomposition is hardly found in researches on Japan,[2] I construct four VAR models based on (1) Gorden and Leeper (1994), (2) Christiano, Eichenbaum and Evans (2001), (3) Erceg and Levin (2002) and (4) Leeper, Sims and Zha (1996).[3] While the recursive structure of contemporaneous relation is assumed in the first three, the non-recursive structure, whose methodology is established by Bernanke (1996), Blanchard and Watson (1986) and Sims (1986), is applied to the last case. After brief explanation on VAR models examined here,[4] outlines of these models are described. Finally, we investigate output composition of monetary transmission in Japan from results obtained by the VAR models.

2.1 VAR Primer

VAR models here are estimated and identified as follows.

2.1.1 Estimation

The basic building block consists of a vector time series Z_t. The vector Z_t evolves over time according to:

$$Z_t = B_0 + B_1 Z_{t-1} + B_2 Z_{t-2} + ... + B_q Z_{t-q} + u_t$$

where $\mathrm{E}u_t u_t' = V$. The vector u_t is assumed to be uncorrelated with past values of Z_t.

[2]The only research I could find is Morsink and Bayoumi (2000), but it estimates the VAR separaterly for each GDP component.

[3]Detailed information on data employed in these VAR models are as follows; investment, consumption and rest of GDP components: seasonally adjusted series at 1995 price from SNA (Cabinet Office), CPI: seasonally adjusted Consumer Price Index at 2000 price (Ministry of Public Management, Home Affairs, Posts and Telecomunications) , commodity price: Nikkei Shohin Sisuu (Nikkei Shinbun), call rate: with collateral bases before 1995 and without collateral bases after 1995 (Bank of Japan), money supply: seasonally adjusted M2+CD, however disconnection due to the different difinition is solved by using quartely growth rate (Bank of Japan), stock price: TOPIX (Tokyo Stock Exchange), bond yield: newly issued 10 years government bonds (The Japan Bond Trading Co.), profit to revenue ratio: computed from "Financial Statements Statistics of Corporations by Industry, Quarterly" (Ministry of Finance), and labour productivity: computed from SNA and "Labour Force Survey" (Ministry of Public Management, Home Affairs, Posts and Telecommunications)

[4]I here refer to Vigfusson (2002).

Estimation of the VAR's coefficients $\{B_j\}_{j=0}^{q}$ can be done equation by equation by OLS. The matrix V can be estimated from the sample residuals $(1/T)\sum \hat{u}_t \hat{u}_t'$.

In this paper, VAR models are estimated for two periods. As concluded by Miyao (2000) and Fujiwara (2003a), the structural break has occurred around 1995 with quite high possibility. So, two estimated period from 1980/Q1 to 2002/Q3 and 1980/Q1 to 1996/Q1 are chosen to obtain the robust result on output composition of monetary transmission mechanism.

As for the lag length, the number of lags, q, is set at the optimal lag length suggested by two information criteria, Akaike Information Criteria (AIC) and Schwarz Bayesian Information Criteria (SBIC). It is always one according to SBIC while AIC suggests two at the most. Therefore, results from both one and two lags cases are shown. However, impulse responses of the longest lag length recommended either by SBIC or AIC are only demonstrated here because there are no major changes in impulse responses within the reasonable lag length.

2.1.2 Fundamental Shocks and The Structural VAR

The next step is to calculate the structural matrix A_0. The values of u_t are not the standard structural shocks as they are usually auto-correlated. Instead, we assume that the relationship between the VAR disturbances u_t and the fundamental economic shocks ε_t is given by

$$A_0 u_t = \varepsilon_t,$$

$$\begin{aligned} A_0 Z_t &= A_0 B_1 Z_{t-1} + A_0 B_2 Z_{t-2} + A_0 u_t \\ &= A_0 B_1 Z_{t-1} + A_0 B_2 Z_{t-2} + \varepsilon_t. \end{aligned}$$

We need to know the value of A_0 in order to calculate impulse responses. To find a unique A_0 however requires further assumptions. Many matrices might solve the equation

$$A_0^{-1} \left(A_0'\right)^{-1} = V.$$

In general, one can choose between two different approaches. The simpler and more common is the recursiveness assumption. One implements this assumption by defining the matrix A_0^{-1} to be the lower Choleski decomposition of V.

The other approach is to not to assume recursiveness but rather assume that enough entries are zero or otherwise constrained that only a unique A_0 solves the above equation and satisfies these further assumptions. Following the methodology established by Bernanke (1986), Blanchard and Watson (1986) and Sims (1986), the matrix A_0 is found as the matrix that maximize the likelihood function as below.[5]

[5]However, the uniqueness of this A_0 can be difficult to establish.

$$L(A_0, V) = -\frac{T}{2}\log(2\pi) + \frac{T}{2}\log|A_0|^2 - \frac{T}{2}\text{trace}(A_0 V A_o')$$

2.1.3 Impulse Responses

Having found the A_0 matrix, the next step is to calculate the impulse responses to a fundamental shock. The basic idea is the following. Suppose that the VAR has the following form.

$$Z_t = B_1 Z_{t-1} + B_2 Z_{t-2} + A_0^{-1}\varepsilon_t$$

We suppose that the $j-th$ fundamental errors take on the value one while the other fundamental errors are set equal to zero. The impulse response is how the variables in the VAR respond to this shock. The impulse response in the first period is

$$\Gamma_j(1) = A_0^{-1} e_j$$

where the j-th element of e_j is equal to one and all other elements are zero. The vector $\Gamma_j(1)$ has length being equal to the endogenous variables with the same ordering as Z_t. The second period impulse response is

$$\Gamma_j(2) = B_1 A_0^{-1} e_j.$$

The third is

$$\Gamma_j(3) = B_1 B_1 A_0^{-1} e_j + B_2 A_0^{-1} e_j.$$

Note that if the matrix A_0 were the identity matrix, then the impulse response functions for all shocks would be the moving average representation of the VAR.

2.1.4 Constructing Confidence Intervals for Impulse Responses

The procedures use simulation to calculate the confidence intervals around the impulse response functions. These confidence intervals are pointwise confidence intervals.

The confidence interval is constructed with the following steps. The first step is to generate the artificial data under the null hypothesis that the estimated model correctly represents the data. The artificial data is created by using the estimated coefficients along with error terms. These error terms are here generated by Bootstrapping method, where the error terms are generated by sampling randomly with replacement from the residuals of the original vector autoregression.

Having generated the artificial data, the next step is to estimate a VAR on this data. Using the estimated variance covariance matrix, a new A_0 matrix is estimated. The impulse response is calculated using these new estimates.

The above steps are repeated 100 times to generate a large sample of impulse responses. The procedure then calculates the confidence intervals with 5 and 95 percentile values of the sample for the lower and upper bounds.

2.2 VAR Based on Gordon and Leeper (1994)

The model consists of eight variables; consumption c, investment i, the rest of GDP components y, CPI p, commodity price com, bond yield rl, call rate r and M2+CD m. All variables except for interest rate are log of actual value.[6] Although original Gorden and Leeper (1994) restricts the information set available to central bank when setting the short-term interest rate by excluding contemporaneous data of output and its components as they should not be accessible, they can affect the decision of interest rate changing by central bank in the model examined here. Further, commodity price is added to avoid the price puzzle.[7]

When deriving the impulse responses, the order of the variables is set as above and simple recursive framework is employed for identification. The change in call rate can only have the contemporaneous effect on money supply and it is assumed that the central bank exploits all the information except for current money supply when determining call rate.

2.2.1 Impulse Responses to Nominal Interest Rate Shock

Chart 1 shows the impulse responses to nominal interest rate shock for estimated period from 1980/Q1 to 2002/Q3 and Chart 2 presents those for 1980/Q1 to 1996/Q1.[8]

Almost the same impulse responses are obtained in both cases. Raising the nominal interest rate by the central bank lowers the level of money supply and these altogether reduce consumption, investment and the rest of GDP components. Price level and commodity price also decrease eventually reflecting these developments although with temporally increase in price level initially. This is indeed the price puzzle. Notably, this price puzzle almost disappears in the case when the estimated period is 1980/Q1 to 1996/Q1.[9] As a result, long-term bond yield also become lower.

Concerning output composition, which will be analysed later, investment channel seems to be more predominant. As for the significance of the responses of each component, confidence intervals propose that the responses of consumption and investment are almost significantly negative in the case when estimation is conducted until 1996/Q1.

[6]VAR models are estimted with level in this paper. Sims, Stock and Watson (1992) claims that even if variables are non-stationary, the VAR should be estimated with levels as differencing throws away important information.

[7]Price puzzle is the symptom that the price level tends to rise after the positive interest rate shock. As for the discussion of price puzzle, see Hanson (2000).

[8]AIC suggest that the optimal lag length for the estimated period 1980/Q1 to 2002/Q3 is two. Therefore, in this case, impulse responses when number of lags is two are demonstrated.

[9]Fujiwara (2003a) implies that one of the causes of price puzzle may be the coexistence of equilibrium dynamics and dis-equilibrium dynamics in economic time series.

2.3 VAR Based on Christiano, Eichenbaum and Evans (2001)

The model consists of ten variables; consumption c, investment i, the rest of GDP components y, CPI p, real wage w, labour productivity q, call rate r, profit to revenue ratio π, M2+CD m and TOPIX s. All the variables except for r and π are log of actual value. The original Christiano, Eichenbaum and Evans (2001) employs the aggregate real corporate profit, however the profit ratio is employed in this model. This is due to the fact that the aggregate profit data is almost disconnected in Japan because of bankruptcy of large companies etc. in 1990s.

The order of the variables when deriving impulse responses is set as above and simple recursive framework is employed for identification. The change in call rate can only have effects on corporate profit, money supply and stock price contemporaneously and it is assumed that central bank knows all the current information on non-financial variables when determining call rate.

2.3.1 Impulse Responses to the Nominal Interest Rate Shock

Chart 3 shows the impulse responses to nominal interest rate shock for estimated period from 1980/Q1 to 2002/Q3 and Chart 4 presents those for 1980/Q1 to 1996/Q1.[10]

Both charts show that the impulse responses are almost the same. A positive shock on call rate reduces corporate profit and money supply, and therefore, stock price falls. These developments in financial variables bring lower level of consumption, investment and rest of GDP components. Price level and real wage initially increase but decrease soon after.[11] These developments result in lower labour productivity.

Again, concerning output composition, investment channel seems to be more important and confidence intervals imply that the responses of consumption and investment are almost significantly negative in cases where estimation is conducted until 1996/Q1.

2.4 VAR Based on Erceg and Levin (2002)

The model consists of six variables; consumption c, investment i, the rest of GDP components y, CPI p, commodity price com, and call rate r. All the variables except for r are log of actual value.

The order of the variables when deriving impulse responses is set as above and simple recursive framework is employed for identification. The change in call rate has no contemporaneous effect on other variables but current information of all the macroeconomic variables are used by the central bank to set the interest rate.

[10] In both cases, lag length is one.

[11] Degree of this price puzzle is less significant in the case when estimated period is 1980/Q1 to 1996/Q1

2.4.1 Impulse Responses to the Nominal Interest Rate Shock

Chart 5 shows the impulse responses to nominal interest rate shock for estimated period from 1980/Q1 to 2002/Q3 and Chart 6 presents those for 1980/Q1 to 1996/Q1.[12]

Here again, impulse responses obtained in both cases are nearly the same. A positive shock on call rate decreases consumption, investment and rest of GDP components and therefore, commodity price becomes lower. Although initially increasing, price level eventually decrease reflecting these developments.[13]

As for output composition, investment is likely to be more predominant driver in GDP changes. Their responses are almost significantly negative when estimation is conducted from 1980/Q1 until 1996/Q1.

2.5 VAR Based on Leeper, Sims and Zha (1996)

Leeper, Sims and Zha (1996)[14] claims that it is unrealistic to include the contemporaneous information about demand and price level into the information set which the central bank possesses at the time when changing nominal interest rate. Instead, they think it appropriate to restrict this information set to include only leading indicator of price level, commodity price in this case, and money supply. Further, consistent with the definition of leading indicator, it is assumed that all variables have contemporaneous effect on commodity price.

Based on this identification scheme, the model for Japanese data is constructed as follows. The model consists of seven variables; CPI p, consumption c, investment i, the rest of GDP components y, commodity price com, call rate r and M2+CD m. All the variables except for r are log of actual value.

Then, the structural matrix A_0 is constructed as follows.

$$A_0 = \begin{pmatrix} a_1 & a_2 & a_3 & a_4 & 0 & 0 & 0 \\ a_5 & a_6 & 0 & 0 & 0 & 0 & 0 \\ a_7 & o & a_8 & 0 & 0 & 0 & 0 \\ a_9 & a_{10} & a_{11} & a_{12} & 0 & 0 & 0 \\ a_{13} & a_{14} & a_{15} & a_{16} & a_{17} & a_{18} & a_{19} \\ 0 & 0 & 0 & 0 & a_{20} & a_{21} & a_{22} \\ a_{23} & a_{24} & a_{25} & a_{26} & 0 & a_{27} & a_{28} \end{pmatrix} \begin{matrix} u_p \\ u_c \\ u_i \\ u_y \\ u_{com} \\ u_r \\ u_m \end{matrix}$$

The matrix above is obtained by non-recursive identification. As for the parameters, no restriction has been made on the sign of components of the structural matrix.

[12]AIC suggest that the optimal lag length for both estimated periods is two. Therefore, impulse responses when number of lags is two are demonstrated.

[13]Price puzzle is more significant in the case when the estimated period is from 1980/Q1 to 2002/Q3.

[14]Largest model introduced in Leeper, Sims and Zha (1996) consists of thirteen variables. It includes consumption but not investment.

The concept behind this matrix is as follows. Top row shows that price level receives contemporaneous effects from GDP components. The second row to the fourth row show that while consumption and investment are affected only by current price level, the other GDP components have some effect from consumption and investment as well as price level. This is because other GDP components include imports and exports which should be highly correlated contemporaneously with consumption and investment. Fifth and sixth rows are as explained above. The last row is about money demand function. it shows that money demand function should have contemporaneous effects from price level, GDP and call rate.

The change in call rate can only have simultaneous effects on money supply and commodity price.

2.5.1 Impulse Responses to the Nominal Interest Rate Shock

Chart 7 shows the impulse responses to nominal interest rate shock for estimated period from 1980/Q1 to 2002/Q3 and Chart 8 presents those for 1980/Q1 to 1996/Q1.[15] Almost the same impulse responses are obtained in both charts.

A positive shock on call rate decreases consumption, investment, and money supply. Initial increase in rest of GDP components, price level and commodity price is somewhat puzzling, but they are eventually decreasing due to the restraining effect of tightening monetary policy.

Similar to the above three models, the investment channel looks to be playing a more important role in monetary transmission.

2.6 Output Composition in Monetary Transmission

In this subsection, results which have been just obtained above are first summarised in "contribution ratio" so that we could measure the output composition of monetary transmission mechanism in Japan. Contribution ratio is a measure advocated by Angeloni, Kashyap, Mojon and Terlizzese (2002), "the ratio of changes in the components of GDP to the overall movements in GDP." Since VAR models are estimated in logs for GDP components, this ratio is computed as the ratio of cumulative responses[16] of the components to GDP response, each relative to baseline, and then weigh the component movements by their shares in GDP. According to the historical average since 1980/Q1, each GDP components weight is set as follows; consumption: 0.55, investment: 0.15, rest of GDP components: 0.3.

Contribution ratios for consumption and investment in both lag one and lag two cases are demonstrated below.

[15] AIC suggest that the optimal lag length for the estimated period 1980/Q1 to 2002/Q3 is two. Therefore, in this case, impulse responses when number of lags is two are demonstrated.

[16] Cumulative responses are used so as to eliminate the distortion from temporal noise.

Consumption

- lag 1

	1980:2-2002:3				1980:2-1996:1			
	GL	CEE	EL	LSZ	GL	CEE	EL	LSZ
4q	0.14	0.43	0.15	0.50	0.10	0.50	0.27	0.57
8q	0.20	0.40	0.20	0.47	0.25	0.43	0.29	0.47
12q	0.24	0.36	0.24	0.47	0.28	0.39	0.30	0.43

- lag 2

	1980:2-2002:3				1980:2-1996:1			
	GL	CEE	EL	LSZ	GL	CEE	EL	LSZ
4q	0.20	0.40	0.06	-0.01	-0.16	0.46	0.24	0.18
8q	0.21	0.41	0.17	0.68	0.13	0.46	0.30	0.23
12q	0.21	0.36	0.22	0.44	0.17	0.42	0.31	0.21

Investment

- lag 1

	1980:2-2002:3				1980:2-1996:1			
	GL	CEE	EL	LSZ	GL	CEE	EL	LSZ
4q	0.53	0.18	0.67	0.62	0.58	-0.11	0.56	0.49
8q	0.69	0.54	0.72	0.57	0.64	0.35	0.61	0.49
12q	0.70	0.67	0.71	0.54	0.65	0.51	0.64	0.53

- lag 2

	1980:2-2002:3				1980:2-1996:1			
	GL	CEE	EL	LSZ	GL	CEE	EL	LSZ
4q	0.39	0.08	0.57	0.42	0.40	-0.12	0.35	0.29
8q	0.74	0.48	0.95	0.53	0.65	0.24	0.54	0.56
12q	0.88	0.61	0.94	0.58	0.76	0.38	0.60	0.70

Overall, as expected in the impulse response analysis, contribution ratio of investment is larger than that of consumption. The average of contribution ratio of consumption from 16 VAR models is 0.25 at the end of first year after the shock, 0.33 at the end of second year after and 0.32 at the end of third year after. On the other hand, those of investment are 0.37, 0.58 and 0.65. This is consistent with our intuition on the monetary transmission mechanism in Japan.

3 DSGE Model

Inspired by real business cycle (RBC) model such as Kydland and Prescott (1982) and King, Plosser and Rebello (1988), analysing macroeconomic phenomenon with small general equilibrium model has become very popular in the field of monetary economics. Usually, sticky prices as in Calvo (1982) and Taylor (1993) type policy rule are added to the standard RBC models as above so that we could investigate the role of monetary policy. This framework of analysis[17] is often called dynamic stochastic general equilibrium model (DSGE).[18] It would not be any exaggeration to say that DSGE is now the central analytical tool in modern macroeconomics.[19]

However, application of DSGE to Japan is not as popular as that of VAR. Only a small number of researches can be found on Japanese economy, such as Orphanides and Wieland (2000), Kimura and Kurozumi (2002), Fukunaga (2002), Hayashi and Prescott (2002), and Jung, Teranishi and Watanabe (2002). Furthermore, most of these models have paid no consideration to stock variables and therefore do not endogenise investment.[20] Hence, as they are not usually suitable to the analysis on output composition of monetary transmission, I here construct a DSGE model on Japanese economy by only slightly modifying and re-calibrating Nelson (2002). As the aim of constructing DSGE here is to judge whether the impulse responses obtained above VAR models can be considered realistic from theoretical model, it should be based on standard macroeconomic theory.[21] Nelson (2002) takes very standard approach to modelling. It incorporates equations derived from the utility maximisation of consumers and profit maximisation of firms with habit formation, capital adjustment cost, estimated policy rule as in Rotemberg and Woodford (1997) and New Keynesian Phillips curve as in Calvo (1983) and Fuhrer and Moore (1995).

3.1 The Model

The DSGE model examined in this paper consists of thirteen equations below. All equations are expressed as the log deviation from the steady state.[22]

[17]Goodfriedn and King (1997) names this analytical framework as "New Neo-Classical Synthesis".

[18]Several solution methods are now available such as Uhlig (1999) and Klein (2002). All are based on the seminal research by Blanchard and Kahn (1981).

[19]Taylor (1999) collects the research with this technique in its early stage.

[20]Fukunaga (2002) includes investment in the system. However, the focus in Fukunaga (2002) is rather on the effect of imcomplete financial market than to obtain just impulse responses per se of Japanese economy.

[21]It may not be appropriate to use the word standard in economics. The word standard here means the robust theory which is employed in many researches. For example, such researches as the financial accelerator model of Bernanke, Gertler and Gilchrist (1999), the credit cycle of Kiyotaki and Moore (1997), the limited participation model of Christiano and Eichenbaum (1995), and search and matching in labour market as Mortensen and Pissarides (1994) are excluded from candidates as they are more specific in topic.

[22]As for the detailed explanation for the derivation of equations here by solving agents' optimising problem and their log-linearisation are demonstrated in Fujiwara (2003b). This will be distributed upon request.

3.1.1 Structural Equations From Optimising Behaviour

Consumption

$$\frac{\beta h(\sigma-1)}{\sigma(1-\beta h)}E_t c_{t+1} = \frac{\beta h^2\sigma - \beta h^2 + \sigma\beta h - 1}{\sigma(1-\beta h)}c_t - \frac{h(\sigma-1)}{\sigma(1-\beta h)}c_{t-1} - \psi_t + \frac{1-\beta h\rho_\lambda}{1-\beta h}\lambda_t$$

variables; c: consumption, ψ: Lagrange multiplier on consumer budget constraint, λ: demand shock[23]

parameters; β: subjective discount rate, h: parameter for habit formation, σ: intertemporal elasticity of substitution for consumption, ρ_λ: AR(1) parameter on demand shock

Labour Market Equilibrium

$$0 = (1-\chi)\,y_t - (1-\chi)\,n_t - \mu_t + \psi_t$$

variables; y: GDP, n: labour, μ: gross markup

parameters; χ: Elasticity of substitution between labour and capital stock

Money Demand

$$0 = -\frac{1}{\varepsilon}\psi_t - rm_t - \frac{1}{\varepsilon R^{SS}}R_t$$

variables; rm: real money balance, R: net nominal interest rate[24]

parameter; ε: reciprocal of intertemporal elasticity of substitution for real money balance

Euler Equation

$$\mathrm{E}_t\psi_{t+1} = \psi_t - r_t$$

variable; r: net real interest rate

Fisher Equation

$$R_t = r_t + E_t\pi_{t+1}$$

variable; π: inflation rate

Quasi-Investment

$$\beta(1-\delta)\,\mathrm{E}_t x_{t+1} + \beta\frac{\rho(1-\alpha)\frac{Y^{SS}}{K^{SS}}}{(\eta-1)\,\beta\phi\eta\,(X^{SS})^{\eta-1}}\mathrm{E}_t\left[(1-\chi)\,y_{t+1} - (1-\chi)\,k_{t+1} - \mu_{t+1}\right]$$
$$= x_t + \frac{1}{(\eta-1)\,\phi\eta\,(X^{SS})^{\eta-1}}r_t$$

[23] To be exact, this is a shock to conumer preference.

[24] Capital letters with superscript SS denotes the steady state level of the variables.

variables: x: quasi investment,[25] k: capital stock

parameters: δ: depreciation rate, α: labour share, ρ: reciprocal of steady state markup, ϕ, η: parameters for capital adjustment cost[26]

Law of Motion for Capital

$$k_{t+1} = \delta x_t + (1-\delta)\, k_t$$

Resource Constraint

$$y_t = \frac{C^{SS}}{Y^{SS}} c_t + \frac{X^{SS} + \eta\phi \left(X^{SS}\right)^{\eta}}{Y^{SS}} x_t$$

Production Function

$$\begin{aligned} y_t = {} & \alpha \left(\frac{A^{SS} N^{SS}}{Y^{SS}}\right)^{\chi} a_t + \alpha \left(\frac{A^{SS} N^{SS}}{Y^{SS}}\right)^{\chi} n_t \\ & + (1-\alpha) \left(\frac{K^{SS}}{Y^{SS}}\right)^{\chi} k_t \end{aligned}$$

variable; a: technology shock

3.1.2 AR Shocks

Aside from the structural equation above, AR(1) process is assumed to the disturbances mentioned above

Demand Shock

$$\lambda_t = \rho_\lambda \lambda_{t-1} + e_{\lambda t}$$

innovation; e_λ: white noise innovation for demand shock

Technology Shock

$$a_t = \rho_a a_{t-1} + e_{at}$$

innovation; e_a: white noise innovation for technology shock

3.1.3 Policy Rule

Although several formulas are available such as Taylor rule, here the estimation method introduced in Rotemberg and Woodford (1997)[27] is applied to estimate the Bank of Japan's empirical policy rule.

[25] Quasi investment is the investment excluding capital adjustment cost.

[26] In this paper, capital adjustment cost is defined as ϕX_t^{η}.

[27] Rotemberg and Woodford (1997) first estimates the VAR with R_t, π_{t+1} and y_{t+1} and derives monetary policy reaction function by assuming that the monetary policy shock has no contemporaneous effect on other variables.

$$
\begin{aligned}
R_t = &\ 1.2926 * R_{t-1} - 0.4728 * R_{t-2} + 0.0296 * R_{t-3} \\
&+ 0.0624 * \pi_t + 0.0179 * \pi_{t-1} + 0.1205 * \pi_{t-2} \\
&+ 0.3227/4 * y_t - 0.2132/4 * y_{t-1} - 0.0986/4 * y_{t-2} \\
&+ e_{Rt}
\end{aligned}
$$

innovation: e_R: white noise innovation for policy shock

3.1.4 Phillips Curve

Two pricing equations based on optimising behaviour is available in this paper. Their results will be shown later. The first one is the very popular in monetary economics, the New Keynesian Phillips curve in the terminology of Roberts (1995) based on staggered price setting advocated by Calvo (1983) where only a limited number of firms can have a chance to change the price. The other one, Hybrid New Keynesian Phillips curve, is based on Fuhrer and Moore (1995) which is similar setting to Calvo (1983) but past information of inflation is utilised additionally when setting the new price.

Calvo (1983) α_μ is the parameter determined by how frequently firms can change the price.

$$\beta \mathrm{E}_t \pi_{t+1} = \pi_t - \alpha_\mu \mu_t$$

Fuhrer and Moore (1995) The weight on the lead (namely lags) are set according to the estimation results on Japanese data by Kimura and Kurozumi (2002).[28]

$$0.65 * \mathrm{E}_t \pi_{t+1} = \pi_t - 0.35 * \pi_{t-1} + \alpha_\mu \mu_t$$

3.2 Setting Deep Parameters

The table below shows the model calibration.

Table: Model Calibration

[28]Note that the sum of the parameters for lead and lags is one. Therefore, implicitly it is assumed that the subjective discount rate is approximately one, which may contradict the assumption of the model explained so far. However, the effect from this approximation is minuscule.

Parameters	Description	Quarterly Value
α	labour share	0.650
β	subjective discount factor	0.990
σ	intertemporal elasticity of substitution for consumption	0.660
h	habit formation parameter	0.800
δ	rate of depreciation	0.021
$1/\sigma\epsilon$	steady state consumption elasticity of money demand	1.000
ϕ	capital adjustment cost parameter 1	0.750
η	capital adjustment cost parameter 2	2.000
$1/\rho$, μ	steady state markup	1.250
ρ_λ	AR(1) parameter for demand shock	0.220
ρ_a	AR(1) parameter for technology shock	0.870
α_μ	price stickiness	0.087
N^{SS}	steady state fraction of time in employment	0.330
Z^{SS}	steady state level of technology	1.000
π^{SS}	steady state inflation rate	0.025

The grounds for setting the calibrated parameters are as follows.

Labour Share Labour share is set according to Fukunaga (2002) which computes the historical average of nominal labour income against nominal GDP.

Discount Factor Subjective discount factor is the reciprocal of the gross equilibrium real interest rate[29] and equilibrium real interest rate is set at 1 % per year.

Intertemporal Elasticity of Substitution for Consumption Estimating the intertemporal elasticity of substitution σ is an intensively researched area, as seen in Hayashi and Sims (1983), Hall (1988), Patterson and Pesaran (1992), Atkeson and Ogaki (1996), and Ogaki and Reinhart (1998). However, even though sophisticated econometric techniques are used, the results are not necessarily sensible and stable. Here, I simply estimate it with GMM for the IS curve as shown in McCallum and Nelson (1999), derived from the same representative consumer's optimising problem as the model above.

$$y_t = b_0 + \mathrm{E}_t y_{t+1} - \sigma \frac{C^{SS}}{Y^{SS}} \left(R_t - \mathrm{E}_t \Delta p_{t+1}\right) + \frac{C^{SS}}{Y^{SS}} \nu_t$$

This equation is estimated for the period from 1980/Q1 to 1996/Q1.[30] Instrumental variables are time trend, constant, one and two lags of government

[29] Note that since this model is not employing the overlapping generations model as in Yaari (1965), Blanchard (1985), Buiter (1988) and Weil (1989), which are well summarised in Frenkel and Razin (1992), steady state exists when the subjective discount factor equals to the reciprocal of the real steady state gross interest rate. Futher, when this is satisfied, any level of consumption can be the candidate of the steady state value as consumption Euler equation is alyways met.

[30] Fujiwara (2003a) hints that since the introduction of de-facto zero nominal interest rate in 1996 the Japanese economy may possibly be in a state that is difficult to explain using

expenditure. Estimated results are as follows; where the steady state ratio of consumption against GDP is just set at 0.55 which is the historical average since 1980.

	b_0	σ
Estimated Value	-0.360648	0.655399
(Standard Error)	(0.260995)	(0.484557)

The result above shows that the estimated value of intertenporal elasticity of substitution is about 0.66.

Habit Formation Parameter As it is difficult to find any preceding research which shows the degree of the habit formation in Japan, the parameter is initially set at the value obtained in Fuhrer (2000).[31] As this value does not have to be valid in the case of Japanese economy, results with quite different settings, namely very high habit formation case (h=0.99) and very low habit formation case (h=0.4) are also shown to guarantee the robustness of results.

Depreciation Rate Capital depreciation rate is set according to the preceding researches on Japan, i.e. Hayashi and Prescott (2002), and Fukunaga (2002).

Steady State Consumption Elasticity of Money Demand The unitary elasticity of substitution between consumption and real balance is assumed.

Capital Adjustment Cost Parameters ϕ and η are set based on Cassaras and McCallum (2000). Like the habit formation parameter, the parameter value for this particular capital adjustment cost function cannot be found for the case on Japanese economy and is very hard to be estimated. Therefore, results from quite different settings, namely very high adjustment cost case (ϕ=1.5) and very low adjustment cost case (η=0.25) are also shown so that the robustness of results are guaranteed.

Steady State Markup Steady state markup is set at around the historical average of markups computed from corporate profit in SNA statistics.

AR(1) Parameter for Demand Shock This is estimated from errors in IS curve estimation for obtaining intertemporal elasticity of substitution as above.

AR(1) Parameter for Technology Shock This is set at the value employed in Fukunaga (2002).

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standard macroeconomic theory. Hence, the estimation is conducted for the period before 1996.

[31] It would be possible to obtain the parameter for habit formation by employing the estimation method advocated by Fuhrer (2000).

Price Stickiness Price stickiness is set at the estimated result by Fuchi and Watanabe (2001), which is also used in Fukunaga (2002).

Steady state fraction of time in employment This is set so that each works for eight hours per day on average.

Steady State Level of Technology This determines the consumption/GDP ratio in steady state. Therefore, it is fixed at the value which makes this ratio almost equal to the historical average.

Steady State Inflation Rate One percent inflation annually is assumed reflecting the recent price developments in Japan.[32]

3.3 Impulse Responses to Nominal Interest Rate Shock

Chart 9 shows the impulse responses to nominal interest rate shock when New Keynesian Phillips is employed and chart 10 presents those when the model is set with Hybrid New Keynesian Phillips Curve.

Although there exist minor differences caused by differences in specification, the monetary policy transmission mechanisms are all alike. A positive shock to call rate lowers investment[33] through a rise in cost of capital, consumption through intertemporal substitution and therefore aggregate GDP. In response to these developments in demand side, inflation rate becomes lower.

3.4 Output composition in Monetary Transmission

Contribution ratio defined above are also used here to measure the output composition of monetary transmission in Japan depicted as a DSGE model.

Consumption

	Calvo				
	BASE	High AC	Low AC	High H	Low H
4q	0.25	0.32	0.07	0.07	0.28
8q	0.29	0.36	0.13	0.14	0.30
12q	0.32	0.38	0.18	0.18	0.33

	Fuhrer-Moore				
	BASE	High AC	Low AC	High H	Low H
4q	0.14	0.20	0.07	0.04	0.17
8q	0.20	0.25	0.14	0.09	0.22
12q	0.24	0.28	0.20	0.14	0.25

[32] This setting has only marginal effects on results, just alters the steady state nominal interest rate.

[33] Note that investment here is quasi-investment. Contribution ratio is also calculated for quasi-investment.

Investment

	Calvo				
	BASE	High AC	Low AC	High H	Low H
4q	0.39	0.27	0.67	0.53	0.36
8q	0.35	0.25	0.61	0.48	0.34
12q	0.33	0.24	0.54	0.44	0.32

	Fuhrer-Moore				
	BASE	High AC	Low AC	High H	Low H
4q	0.55	0.46	0.67	0.65	0.52
8q	0.49	0.41	0.59	0.59	0.47
12q	0.45	0.38	0.53	0.55	0.44
AC	0.75	1.5	0.25	0.75	0.75
H	0.80	0.80	0.80	0.99	0.40

Results suggest that the investment channel is more predominant driver of GDP changes. The average of contribution ratio of consumption from 10 DSGE models is 0.18 at the end of first year after the shock, 0.22 at the end of second year after and 0.23 at the end of third year after. On the other hand, those of investment are 0.45, 0.42 and 0.41.

Angeloni, Kashyap, Mojon and Terlizzese (2002) concludes that the high response of consumption to nominal interest rate shock in the United States cannot be explained by theoretical model with reasonable calibration. Contrary to this result, without major caveats, the output composition obtained from VAR models with various identification can be considered as being within the range of explanation by the theoretical DSGE model albeit somewhat smaller responses of investment in DSGE.[34]

4 Conclusion

Up to this point, I have shown empirically from VAR models that investment channel is more important in monetary transmission mechanism. Then, we have viewed that the same results are also obtained from theoretical DSGE model of Japanese economy. Therefore, it would be appropriate to conclude that the output composition against the shock to nominal interest rate in Japan is not puzzling yet reasonable since the VAR result on output composition is almost consistent with that of DSGE model.

So, what makes the output composition between Japan and the United States so different? Angeloni, Kashyap, Mojon and Terlizzese (2002) points out three possible explanations for the consumption reaction difference between

[34]This may be due to the fact that investment is here quasi-investment which excludes adjustment cost. Furtheremore, It is not very easy to obtain such a hump-shaped response of investment as in VAR impulse responses from DSGE model because capital adjustment cost is only valid for capital stock not for investment.

the Euro area and the US: 1) lower adjustment cost in Euro area due to higher labour adjustment cost, 2) More sensitive response of US consumers against interest rate changes due to the difference in financial asset composition, and 3) government insurance mechanisms which cushions income against interest rate shock. These explanations are naturally valid for explaining the difference between Japan and the US. However, two other explanations would be possible; high relative risk aversion[35] and saving behaviour of Japanese consumers. As for the former, this directly means low intertemporal elasticity of substitution. Concerning the latter, the amount outstanding of financial assets owned by households are much larger in Japan than in the US. This implies that the downward pressure caused by substitution effect from interest rate rise is lessened by upward pressure from income effect to some extent, although substitution effect surpasses overall.

Probably, these five points altogether make the consumption response to nominal interest rate shock in Japan less critical. However, the grounds for some of these points may become less certain in the prospecting future. Prolonged recession since the beginning of 1990s has been changing the labour market in Japan. The conventional life-time employment cannot be fully guaranteed any longer and this may result in lower labour adjustment cost. Government debt has been increasing significantly and therefore future cuts in government spending is expected. Noteworthy ageing occurring in Japan will see the rise of the propensity to consume and this would result in the decrease of financial assets. Therefore, it might be possible that the output composition in Japan is getting closer to that of the US in the near future.

Thus, checking the output composition against the nominal interest rate shock is useful not only to understand the transmission mechanism so we could find out what kind of policy mix is effective to stimulate the economy, but also to be always aware of the possibility of structural breaks. Although the formal test to possibly explain the difference in output composition between in Japan and in the US is left for future research,[36] it is always of importance for the central bank to understand the detailed monetary transmission mechanism.

Last but not least, consistent with the results in Miyao (2000), Kimura, Kobayashi, Muranaga and Ugai (2002) and Fujiwara (2003a), results from VAR models seem to imply that monetary policy has become less effective since the introduction of de-facto zero nominal interest rate in 1996. For the VAR estimated from 1980/Q1 to 2002/Q3 which includes the periods for de-facto zero nominal interest rate, upper bounds of confidence intervals for investment and consumption tend to be above zero. This is suggesting that the effects of monetary policy is weakening recently.

[35] Estimated value of intertemporal elasticity of substitution is not siginificantly lower compared to the conventional value of that in the U.S. However, as far as we concentrate on the difference of the impulse responses, it could be deduced that the intertemporal elasticity of substitution might be higher in the U.S. than in Japan.

[36] In this paper, I show the results from the quite different settings of capital adjustment cost and habit formation in order to keep the robustness of the result. However to obtain the convincing values for these parameters would also enhance the credibility of the outcomes from the DSGE model.

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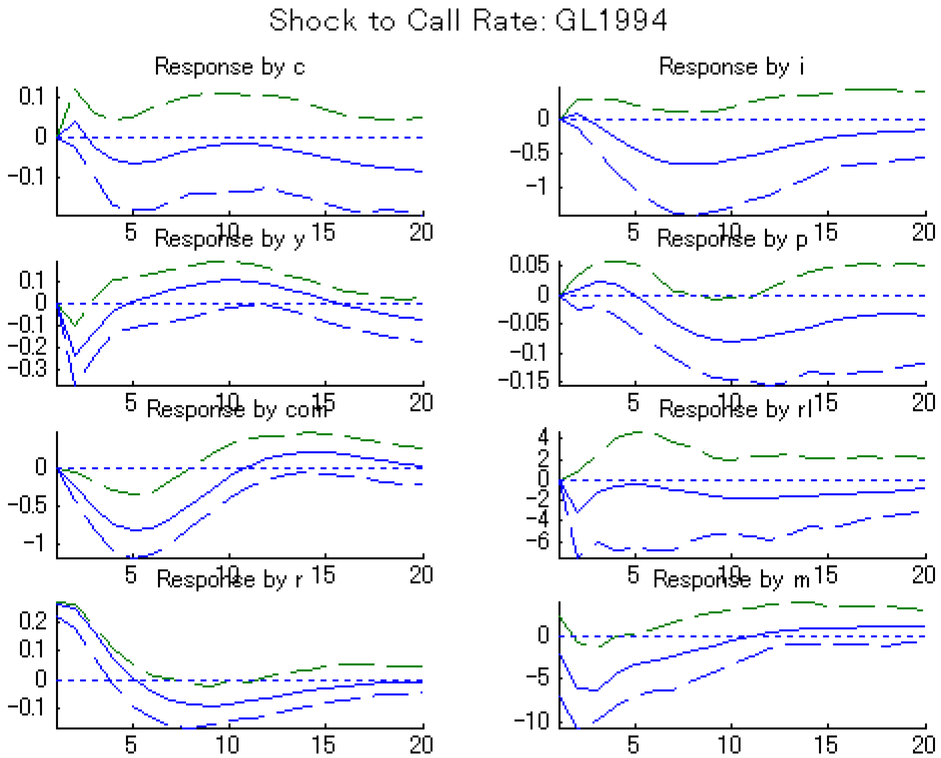
Chart 1



Shock to Call Rate: GL1994
Response by c
Response by i
Response by y
Response by p
Response by com
Response by rl
Response by r
Response by m

Chart 2

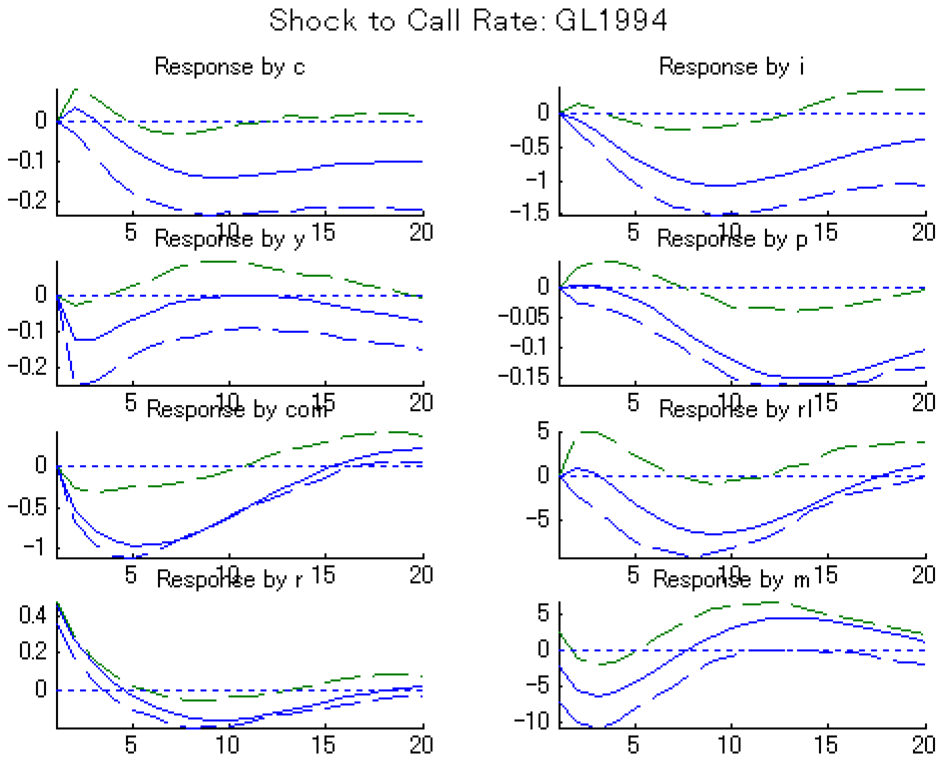
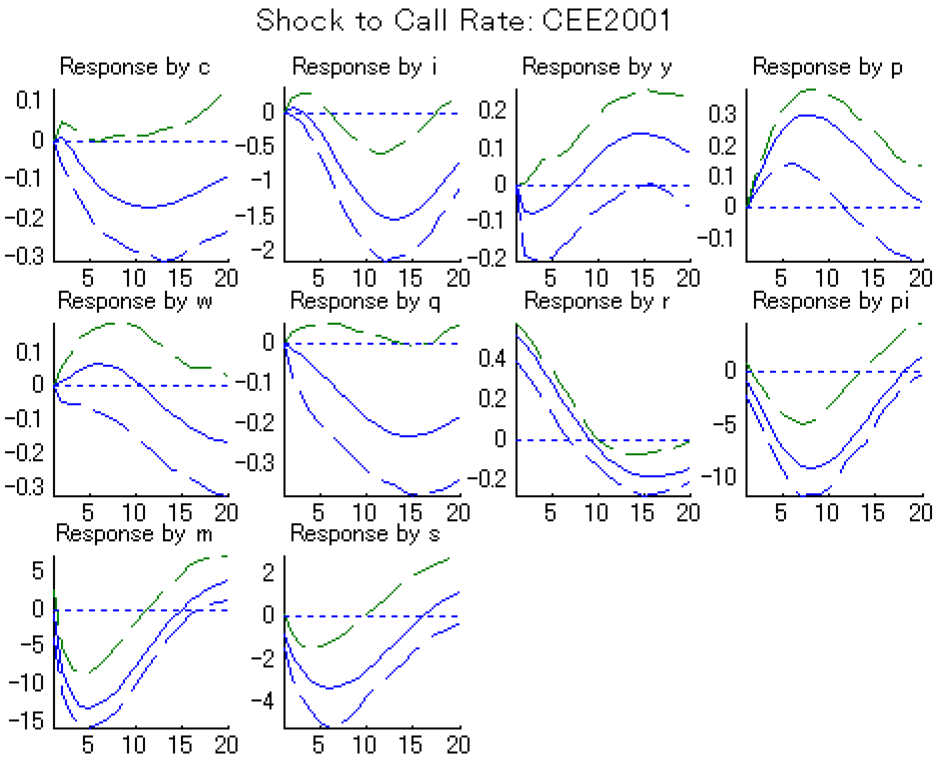

Shock to Call Rate: GL1994
Response by c
Response by i
Response by y
Response by p
Response by com
Response by rl
Response by r
Response by m
0
-0.1
-0.2
-0.5
-1
-1.5
-0.05
-0.15
5
-5
0.4
0.2
-10
10
15
20

Chart 3



Shock to Call Rate: CEE2001
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Response by y
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Response by r
Response by pi
Response by m
Response by s

Chart 4

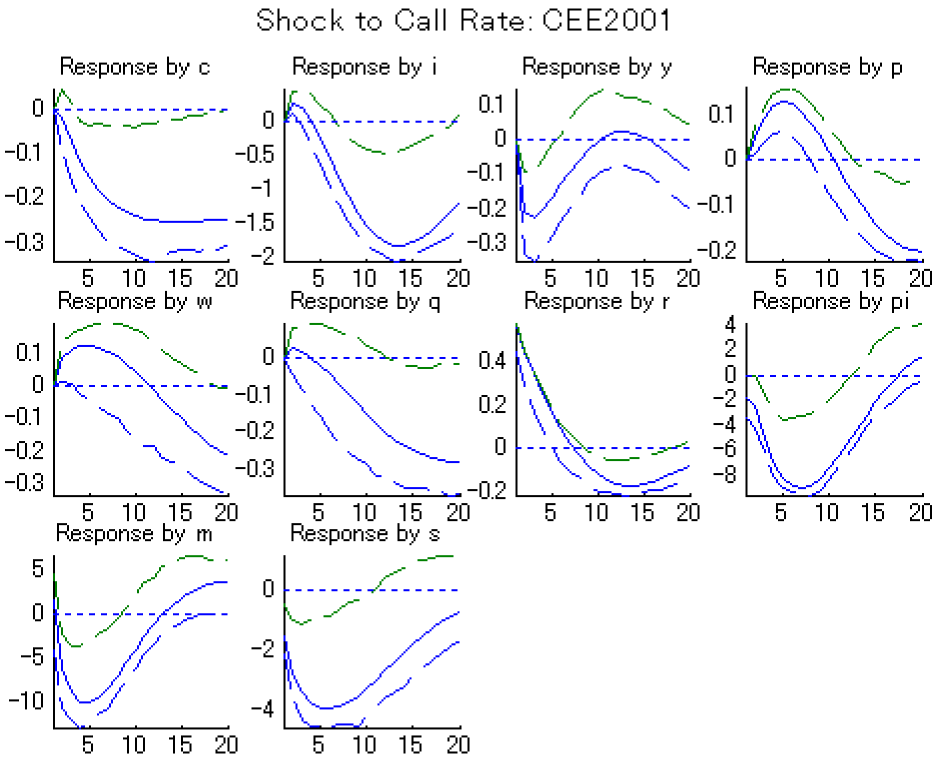
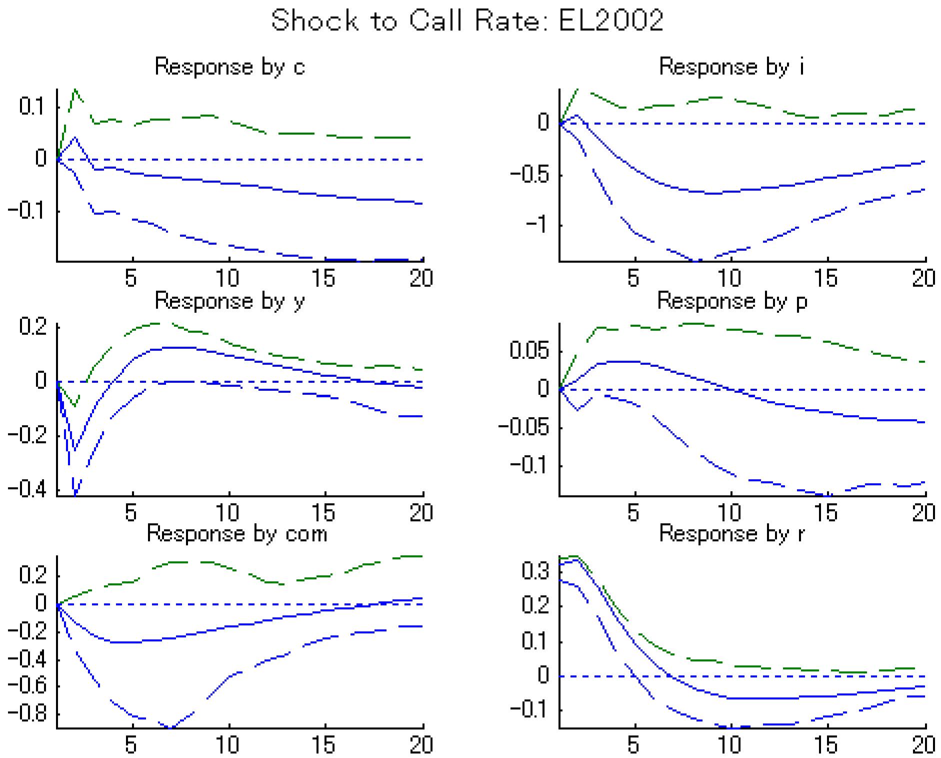

Shock to Call Rate: CEE2001
Response by c
Response by i
Response by y
Response by p
Response by w
Response by q
Response by r
Response by pi
Response by m
Response by s

Chart 5



Shock to Call Rate: EL2002
Response by c
Response by i
Response by y
Response by p
Response by com
Response by r

Chart 6

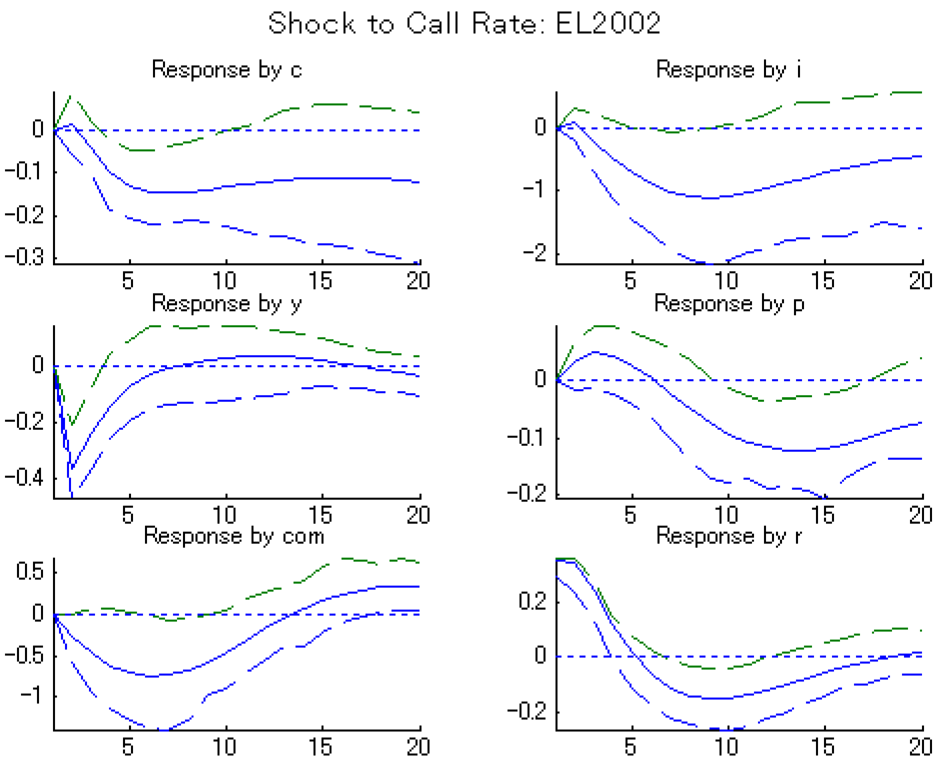
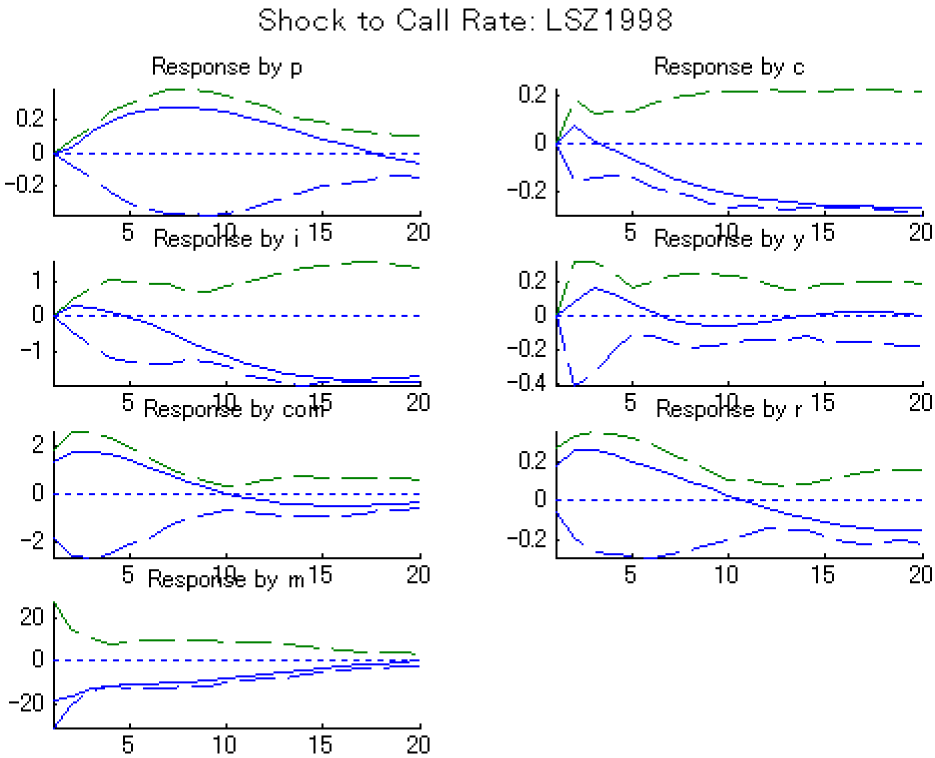
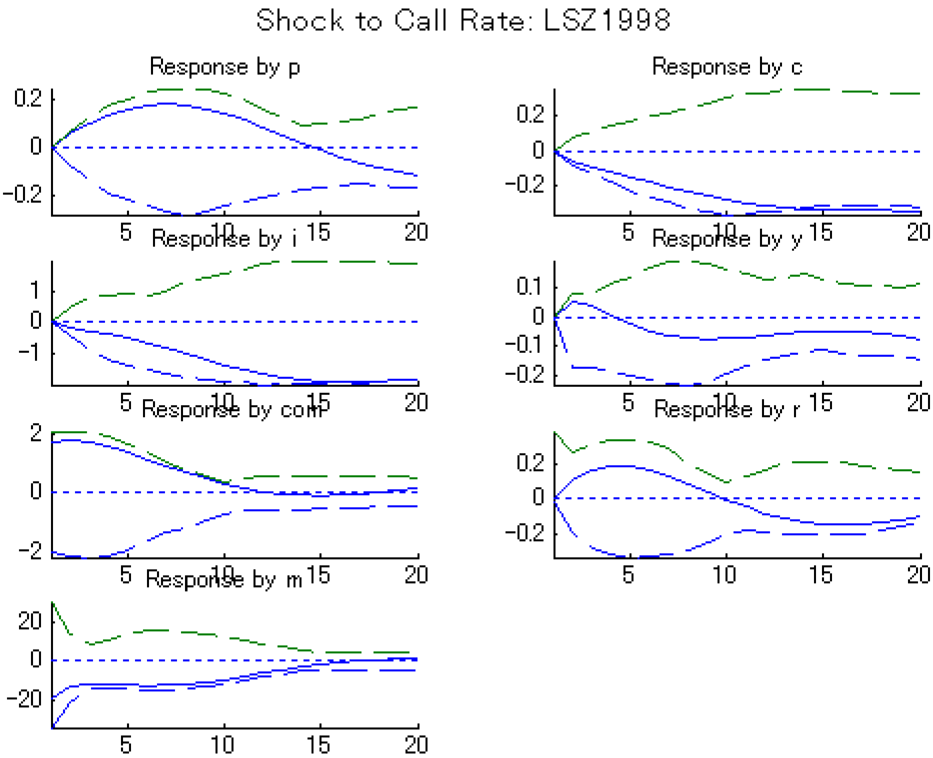

Shock to Call Rate: EL2002
Response by c
Response by i
Response by y
Response by p
Response by com
Response by r
0
-0.1
-0.2
-0.3
-1
-2
-0.4
0.5
-0.5
0.2
5
10
15
20

Chart 7



Shock to Call Rate: LSZ1998
Response by p
Response by c
Response by i
Response by y
Response by com
Response by r
Response by m

Chart 8



Shock to Call Rate: LSZ1998
Response by p
Response by c
Response by i
Response by y
Response by com
Response by r
Response by m
0.2
0
-0.2
1
0
-1
2
0
-2
20
0
-20
0.1
-0.1
5
10
15
20

Chart 9

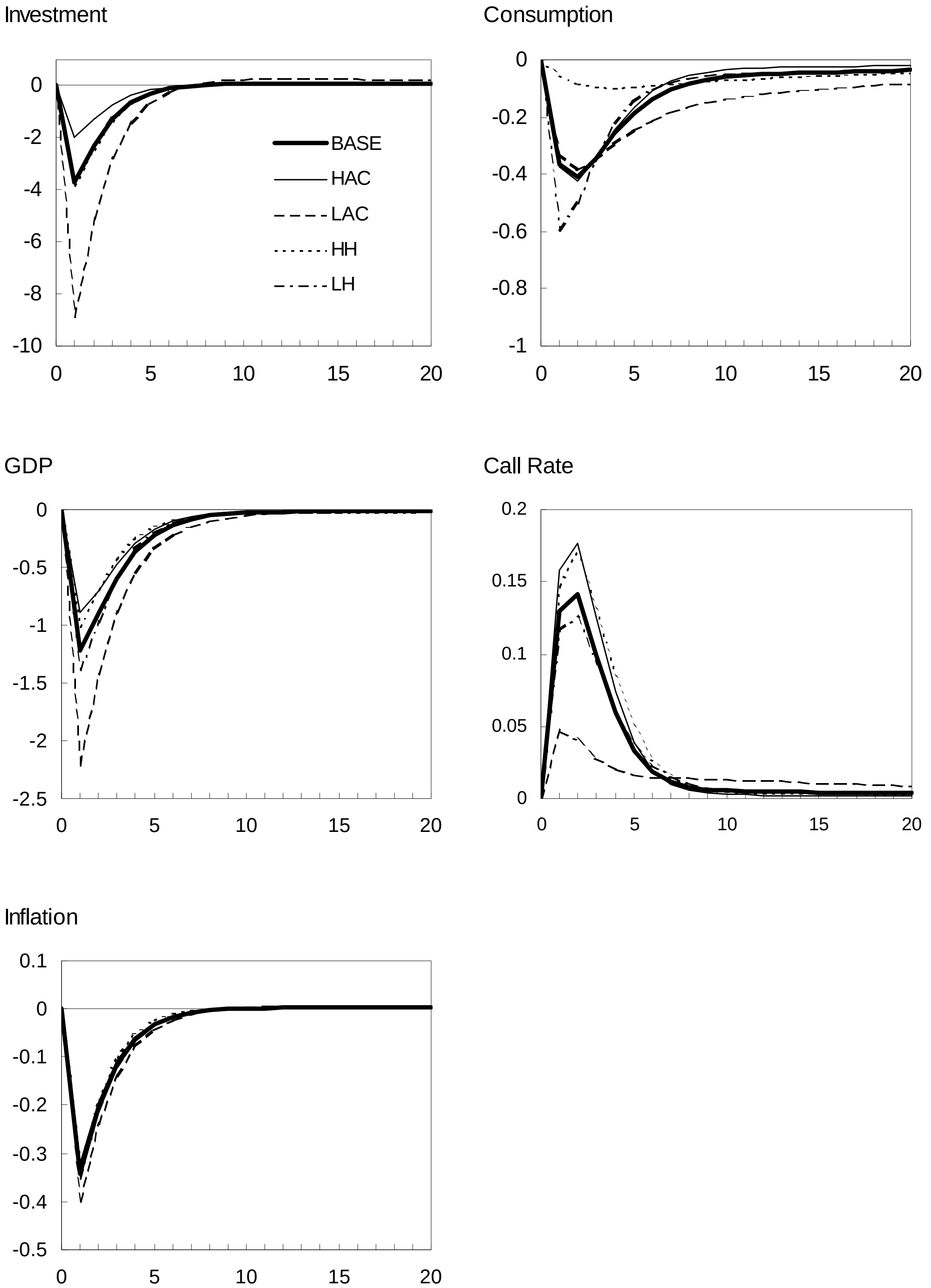
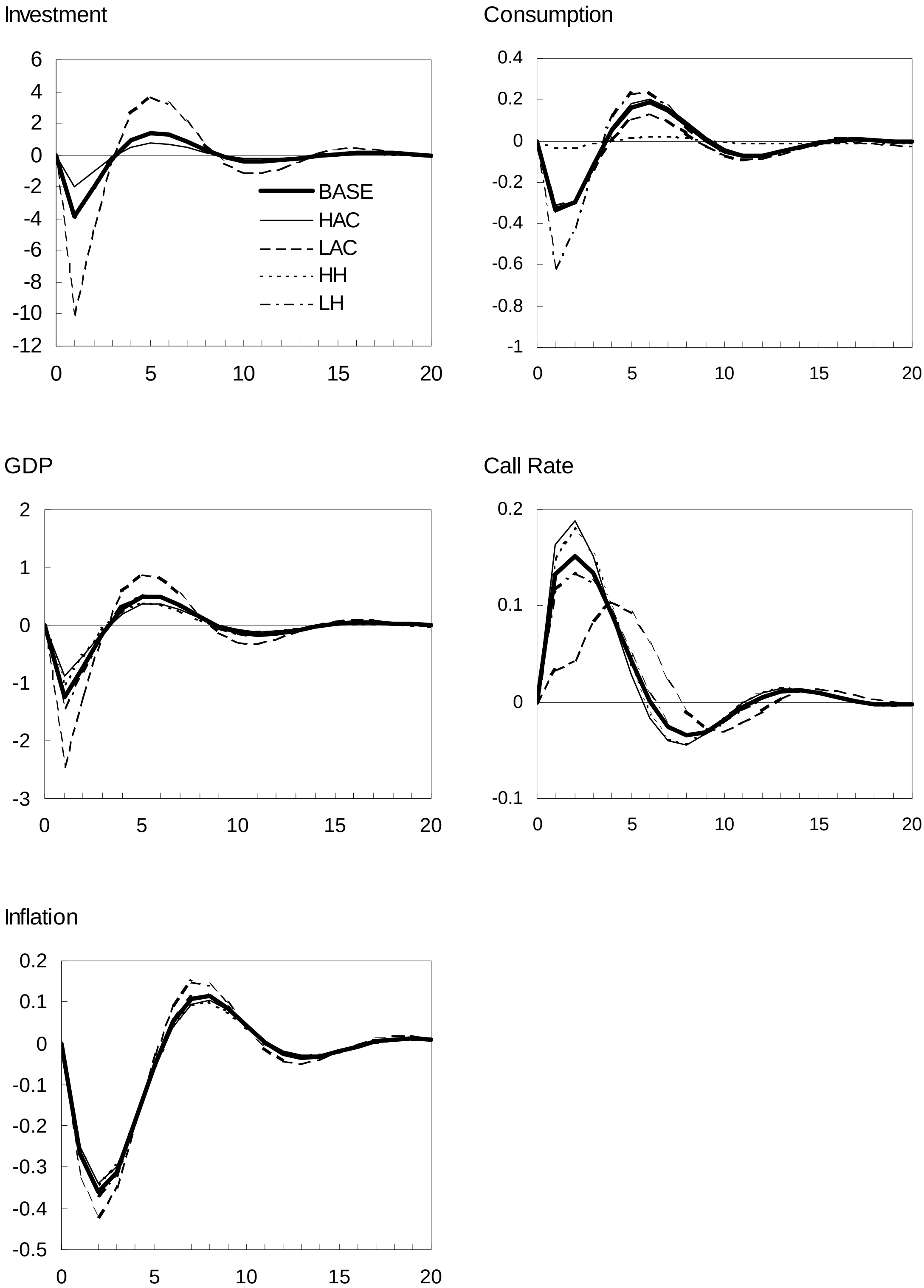

Investment
0
-2
-4
-6
-8
-10
0 5 10 15 20
BASE
HAC
LAC
HH
LH
Consumption
0
-0.2
-0.4
-0.6
-0.8
-1
0 5 10 15 20
GDP
0
-0.5
-1
-1.5
-2
-2.5
0 5 10 15 20
Call Rate
0.2
0.15
0.1
0.05
0
0 5 10 15 20
Inflation
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0 5 10 15 20

Chart 10



Investment
6
4
2
0
-2
-4
-6
-8
-10
-12
0
5
10
15
20
BASE
HAC
LAC
HH
LH
Consumption
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
5
10
15
20
GDP
2
1
0
-1
-2
-3
0
5
10
15
20
Call Rate
0.2
0.1
0
-0.1
0
5
10
15
20
Inflation
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
5
10
15
20