The Japanese Quantitative Easing Policy under Scrutiny: A Time-Varying Parameter Factor-Augmented VAR Model

Moussa, Zakaria
GREQAM

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Zakraria Moussa*

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Abstract

Interest rates in several countries have recently been decreased to exceptionally low levels and a Quantitative Easing Monetary Policy (QEMP) has been adopted by most major central banks. In this context this paper is very actual, as it sheds some light on the effectiveness of the Japanese use of QEMP, which is the only experience we can learn from. This paper employs a Time Varying Parameters Factor-Augmented VAR (TVP-FAVAR) model to analyse monetary policy shocks in Japan. This model allows us to explore the effect of QEMP on a large number of variables. Our analysis delivers four main results. First, unsurprisingly, our results suggest that the best model to specify the Japanese monetary policy during the two last decades is a model where all of parameters vary over time. Second, the effect of QEMP on activity and prices is stronger than previously found. In particular, we find a significant price reaction to a monetary policy shock. Third, in contrast to previous work, there is a detectable efficiency of the portfolio-rebalancing channel, which could have a role in transmitting the monetary policy shocks. Fourth, while the policy commitment succeeds in controlling private and business expectations, these effects are not transmitted to the long-end of the yield curve.

Key words: Time varying parameters; Factor-Augmented VAR; Japan; Quantitative Easing; Transmission channels

JEL Classification : C32; E52

*Université de la Méditerranée and GREQAM, Centre de la Vieille Charité, 2 rue de la Charité, 13002 Marseille, France.
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1 Introduction

The effectiveness of the quantitative easing monetary policy (QEMP) remains a much debated issue. Since this strategy is adopted by most major central banks, namely the Fed, the Bank of England and the European Central Bank, it is crucial to know whether this strategy can be used as an active tool to stimulate prices and foster growth, and, if so, through which transmission channel it works. The problem of quantifying the empirical relevance of the different channels of transmissions through which QEMP exerts its influence on output and prices has received wide and increasing attention in recent years. A growing body of empirical macroeconomic literature using VAR methodology has tried to gauge the effects of the Japanese monetary policy either in the very low interest period from 1995 or more specifically for the QEMP period. This Japanese use of QEMP, the only experience we can learn from, still requires exploration.

Earlier VAR studies have often been concerned with measuring monetary policy and its macroeconomic effects. See e.g.Christiano *et al.* (1999), Leeper *et al.* (1996), and Bernanke and Mihov (1998) for studies of the U.S., and Teruyama (2001) for the research on the Japanese monetary policy transmission mechanisms. Moreover, many researchers have investigated possible structural breaks which can characterize the monetary transmission mechanisms. More particularly, in the study of Japanese monetary policy all empirical studies are fairly consensual on the fact that examining the impact of such a policy should take into account the instability in the transmission mechanism. Structural breaks have been treated either exogenously, by including dummy variables or by using subsample analysis (e.g Miyao (2000)), or endogenously, by using Markov Switching VAR (MS-VAR) (e.g. Fujiwara (2006), Inoue and Okimoto (2008) and *chapter 1* above) or Time-Varying-Parameters VAR (TVP-VAR) model (e. g. Kimura *et al.* (2003), Nakajima *et al.* (2009)).

Miyao (2000) estimates a recursive VAR model and concludes, by using χ^2 testing procedure, that the effect of the monetary policy weakens from 1990 onwards. On the other hand, Kimura *et al.* (2003) employ a time-varying VAR model for the period between 1971-2002 and detect a structural change point in 1985 after which the inflation rate is less responsive to an expansion in the monetary base. More recently, Fujiwara (2006), Inoue and Okimoto (2008) and Mehrotra (2009) estimate an MS-VAR model where the regime states are considered as stochastic events. All the parameters of the models are stochastic and switch according to a hidden Markov chain. Both Fujiwara (2006) and Inoue and Okimoto (2008) conclude that the monetary policy is effective until around 1995-1996, when the call rate approaches the zero boundary and subsequently weakens. In addition, the period between 1995 and 1996 is considered as a transition period. The only work that covers the total period of QEMP is that of

Nakajima *et al.* (2009). To estimate the TVP-VAR they use quarterly data, namely the call rate, industrial production, the consumer price index and the monetary base, for the period between 1981 and 2008. Despite the existence of puzzles, their findings confirm to a certain extent those of Fujiwara (2006) and Inoue and Okimoto (2008) and show a change in the effect of monetary policy on activity and prices when interest rates become very low.

Usually, the overall effects of QEMP are examined for a single channel or a subset of channels[1]; typically, one or a subset of the following channels are considered: portfolio-rebalancing channel; signaling effect; policy-duration effect and also exchange rate channel. All empirical studies are relatively consensual on the fact that the portfolio-rebalancing channel does not work. Empirical studies dealing with the effectiveness of such a transmission channel, for instance Oda and Ueda (2007) and Kimura *et al.* (2003), show that the effect of a portfolio-rebalancing channel is insignificant or too small considering the huge amount of current account balances (CABs) expansion and the Japanese Government Bond (JGB) purchased by the Bank of Japan (BOJ). Referring to the signaling effect, Oda and Ueda (2007) detect a significant effect of this channel from the increase in CABs but no effect from the increase in long-term JGB purchases. The empirical studies dealing with the policy-duration effect find that it significantly lowers long-term interest rates. Among these studies we can quote Baba *et al.* (2005), Oda and Ueda (2007), Okina and Shiratsuka (2004) and more recently Nakajima *et al.* (2010). The later work uses a TVP-VAR model and shows that the significant effect of the policy-duration on the yield curve and market expectations is not transmitted to the real economy. On the other hand, Svensson (2003) offers what he calls a "foolproof way" of escaping from a liquidity trap. The author mostly focuses on alternative policies in a liquidity trap to affect private-sector expectations of the future price level via the exchange rate channel. However, Ito and Mishkin (2006) and Ito and Yabu (2007) argue that this channel can work if the BOJ neither sterilizes the intervention in the foreign exchange market ordained by the Ministry of Finance, nor announces an exchange rate target, sending a signal that the main objective remains the price level. On the other hand, Girardin and Lyons (2008) show some effects of this channel even though the BOJ/MOF intervention is technically fully sterilized.

All these empirical works use models with a small number of variables either to examine the existence of structural change or to quantify the possible transmission channels of the QEMP. However, for the reasons explained in Bernanke *et al.* (2005) and Stock and Watson (2005), using limited information can lead to a biased policy shock measurement. In other words, when information related to the central bank and the private sector is omitted, the measurement of the unsystematic part of monetary policy may be incorrect. This problem can be illustrated by the "puzzles" that characterize VAR results as obtained in most of the papers cited above. Moreover, the limited information means that transition channels are examined separately, and hence the possible interaction between channels is not considered. Of course,

[1] For more detail about the transmission channels suggested by the QEMP the reader is referred to the paper of Ugai (2007).

the challenge in assessing the strength of any particular channel of monetary transmission comes from the concurrent operation of multiple channels. For example, it is hard to tell how much of the long-term interest rate decline to attribute to a decline in stock prices (portfolio-rebalancing channel) and how much to the reduction in private sector expectations about the path of future short-term interest rates (policy-duration effect). However, a complete model in which a maximum of information will be taken into account will allow us to capture most of the structure underlying the economy and will reliably reveal what are the mechanisms through which the QEMP could affect the economy.

In this chapter, following Bernanke *et al.* (2005) and Stock and Watson (2005) we use the factor augmented VAR (FAVAR) model in order to complement the empirical works on Japanese monetary policy cited above, specifically with introducing further variables to the VAR data set. To our Knowledge, only one study so far has been conducted on the Japanese economy using the FAVAR model. Shibamoto (2007) was the first to employ a FAVAR model on Japanese data. However, since he uses data from January 1985 to March 2001, he does not examine the QEMP period. In addition, his results should be interpreted with great care since, as mentioned above, examining Japanese monetary policy without taking into account structural breaks could be misleading. In the previous chapter we combine MS-VAR methodology and factor analysis in what we call MS-FAVAR to examine Japanese monetary policy. The MS methodology allows us to detect discrete jumps for all parameters simultaneously; it permits us to date breaks and assess whether a new regime appears. Our findings on regime change timing are similar to those of Fujiwara (2006) and of Inoue and Okimoto (2008) ; the second regime corresponds to the adoption of the Zero Interest Rate Policy (ZIRP) and QEMP. In this chapter our objective is twofold. First, we use TVP-VAR methodology to allow for more flexible and independent variation in FAVAR parameters and to detect permanent and even gradual variations. Given the confirmation of regime changes in *chapter 1*, to go one step further, TVP-VAR methodology allows us to examine the evolution of Japanese monetary policy at each point in time, more particularly inside the second regime detected in *chapter 1*. Therefore, we will be able to focus precisely on the QEMP period and more reliably examine the effectiveness of this strategy. Second, it is true that the MS-FAVAR allows us to derive impulse responses for structural factors, since they are identified, representing clear economic concepts namely, activity , prices and interest rates. However, we cannot examine the dynamics of all the variables explained by the factors. Therefore, we employ here the Bayesian Markov chain Monte Carlo approach (MCMC) to the estimation of time-varying parameters in the FAVAR model (TVP-FAVAR), developed by Koop and Korobilis (2009). With these motivations and considerations in mind, we aim to use this complete model in order to endogenously treat the possible structural changes in the Japanese economy and provide a more complete and detailed analysis on how monetary policy shocks in Japan affect a large range of macroeconomic time series.

After analyzing a period ranging between 1978:1 and 2008:4 we obtain four main results. First, the best model to specify the monetary policy during the last two decades is a model where all of parameters vary over time. This corroborates our choice of a time varying parameters model. Second, the effect of QEMP on activity and prices is stronger than previously found. In particular, we find a significant price reaction to a monetary policy shock. Third, in contrast with previous work, there is a detectable effectiveness of the portfolio-rebalancing channel, which could have a role in transmitting the monetary policy shocks. Finally, even though the effect on expectation channel is short-lived, the policy commitment might prevent a downward spiral of expectations but were not able to generate an inflationary pressure to escape from the deflationary spiral and to revive the economie.

The remainder of this chapter proceeds as follows. In section two the TVP-FAVAR model is described. Section 3 contains the data description, specification tests and results. Section 4 concludes.

2 Methodology

In the previous chapter we combined MS-VAR methodology and factor analysis in MS-FAVAR to examine the Japanese monetary policy. MS model allows for state shifts in the FAVAR parameters only when they are significant and permits detecting simultaneous discrete jumps for all parameters. This model not only enabled us to know whether a significant new monetary policy regime appeared, but also permitted to date regime changes. A second regime appeared in February 1999, covering both ZIRP and QEMP periods. The objective of this chapter is to complement the analysis in *chapter 1* by using TVP-FAVAR model, allowing state shifts in the FAVAR parameters at the different point of the sample and not for subsamples. By doing this, we will be able to analyse the Japanese monetary policy at each time in the sample and especially QEMP period.

2.1 TVP-FAVAR model

Following Koop and Korobilis (2009), this subsection shows the econometric framework of the TVP-FAVAR. This model is a generalization of the FAVAR model developed by Bernanke *et al.* (2005) and Stock and Watson (2005). Factor dynamics are given by the following time varying parameters FAVAR:

$$Y_t = \alpha_t + \sum_{p=1}^{P} \beta_{t,p} Y_{t-p} + \upsilon_t \tag{2.1}$$

where $Y_t = [F_t \;\; R_t]'$. This means that along with the unobserved factors, Y_t contains an observable factor R_t of dimension $(\nu \text{x} 1)$, which represents the monetary policy instrument. The $((K+\nu)\text{x}1)$ vector of error terms υ_t is mean 0 with covariance matrix Ω_t of dimension $((K+\nu)\text{x}(K+\nu))$. However, Equation 2.1 cannot be estimated directly because the factors are unobserved. We need, therefore, as a first step, to estimate factors using a singular value decomposition of data. Factors, becoming observable, are included in a second step in the equation. We assume that the X_t is $(N\text{x}1)$ economic variable vector can be decomposed into a $(K\text{x}1)$ unobservable factor vector F_t. The unobservable factors are reflected in a wide range of economic variables. We can think of unobservable factors in terms of concepts such as "economic activity" or "price pressures". Assume that X_t are related to the unobservable factors F_t and the observable factors R_t with drifting parameters, as follows :

$$X_t = \Lambda_t^f F_t + \Lambda_t^R R_t + e_t \tag{2.2}$$

where e_t are errors with mean zero and variance-covariance matrix $\Psi = diag(exp(\psi_{1,t}), \cdots, exp(\psi_{n,t}))$. The term error e_t are assumed to be either weakly correlated or uncorrelated; these can be interpreted as the idiosyncratic components. Λ^f and Λ^R are the $(N\text{x}K)$, $(N\text{x}\nu)$ matrices of factor loadings. The implication of the diagonality of the covariance matrix is that the parameters in equation (2.2) can be estimated equation-by-equation. This approach is needed for reasons that will be explained below.

A Choleski decomposition of the reduced form covariance matrix Ω_t can be used to orthogonalize the reduced form innovations and to identify the structural model:

$$\Omega_t = A_t^{-1} H_t \left(A_t^{-1}\right)' \tag{2.3}$$

The time-varying matrices H_t and A_t are defined as follows:

$$H_t \equiv \begin{bmatrix} h_{1,t} & 0 & \cdots & 0 \\ 0 & h_{2,t} & \cdots & 0 \\ \vdots & \cdots & \ddots & \vdots \\ 0 & 0 & \cdots & h_{(K+\nu),t} \end{bmatrix} \tag{2.4}$$

$$A_t \equiv \begin{bmatrix} 1 & 0 & \cdots & 0 \\ a_{21,t} & 1 & \ddots & \vdots \\ \vdots & \cdots & \ddots & 0 \\ a_{(K+\nu)1,t} & \ddots & a_{(K+\nu)k,t} & 1 \end{bmatrix} \tag{2.5}$$

As suggested by Primiceri (2005) and Koop and Korobilis (2009) we assume that all the parameters evolve as random walks[2] augmented with the mixture innovation specification of Giordani and Kohn

[2]As explained in Primiceri (2005) the random walk assumption has the advantages of focusing on permanent shifts and reducing the number of parameters in the estimation procedure. However, a random walk model is non-stationary and it is obviously "more explosive" than the number of observation increases. By choosing quarterly data for the period between 1978 Q1 and 2008 Q4 our sample contains no more than 120 time series observations. Using such a short period alleviates this problem.

(2008). Therefore, the innovations of the random walk evolution of the parameters is defined as a mixture of two normal components (see koop et al 2009 and Koop and Korobilis (2009)):

$$\begin{cases} \Lambda_t &= \Lambda_{t-1} + J^{\lambda}_{i,t}\eta^{\lambda}_t \\ \psi_{i,t} &= \psi_{i,t-1} + J^{\psi}_{i,t}\eta^{\psi}_t \\ \phi_t &= \phi_{t-1} + J^{\phi}_{i,t}\eta^{\phi}_t \\ a_t &= a_{t-1} + J^{a}_{i,t}\eta^{a}_t \\ lnh_{i,t} &= lnh_{i,t-1} + J^{h}_{i,t}\eta^{h}_t \end{cases} \tag{2.6}$$

where $\phi = [\alpha_t \;\; \beta_{t,p}]$ and $h_{i,t}$ evolve as geometric random walks and we assume that the innovation vectors are independent from each other and are distributed as

$$\begin{bmatrix} \eta^{\lambda}_t \\ \eta^{\psi}_t \\ \eta^{\phi}_t \\ \eta^{a}_t \\ \eta^{h}_t \end{bmatrix} \sim N(0,Q), \qquad \text{where } Q = \begin{bmatrix} Q_{\eta^{\lambda}_t} & 0 & \cdots & \cdots & 0 \\ 0 & Q_{\eta^{\psi}_t} & \ddots & \ddots & \vdots \\ \vdots & \ddots & Q_{\eta^{\phi}_t} & \ddots & \vdots \\ \vdots & \ddots & \ddots & Q_{\eta^{a}_t} & 0 \\ 0 & \cdots & \cdots & 0 & Q_{\eta^{h}_t} \end{bmatrix} \tag{2.7}$$

The error terms in equation (2.7) are allowed, to some extent, to be mutually correlated. However, we assume for parsimony that all error components in equations (1.1)-(1.8) are uncorrelated with each other.

Note that the monetary policy variables are ordered last in the FAVAR (equation (2.1)). Then by imposing some normalization as in (2.6) the unobservable factors do not respond to the monetary policy shocks contemporaneously, and the innovations in the equations of R_t are treated as the monetary policy shocks.

Suppose that J_t are binary random variables that control structural breaks in the respective error term of the time varying parameters. As in Koop and Korobilis (2009) we assume that $J_t \sim Bernoulli(\pi)$, where π is the probability[3] corresponding to each of the parameter vectors Λ, ψ, ϕ, a and lnh. Therefore, if $J_t = 0$ or $J_t = 1$ that means that the data indicated constant and time varying parameters specifications, respectively, for all $(t = 1, ..., T)$. Otherwise, data can also determine a time varying parameters specification for some subsamples only; $J_t = 1$ for some t. The choice of either specification is motivated by the Bayesian procedure selection model based on marginal likelihoods. Following Koop and Korobilis (2009), we choose the more flexible model allowing J^{λ}_t to be different for each row of λ in equation (2.2) such that $J^{\lambda}_{it} \neq J^{\lambda}_{jt}$. This is the reason why equation (2.2) is estimated equation-by-equation. We assume also that hyperparameters $Q_{\eta^{a}_t}$ are block diagonal in which each block corresponds to parameters

[3] Also we assume that (π) is distributed as a $Beta(\tau_0, \tau_1)$ and all probabilities have the same prior values $(\tau_0 = \tau_1)$ and they are common for all parameters.

belonging to separate equations[4].

A particular advantage of the factor-augmented framework is that we can derive impulse responses not only for the fundamental factors, but also for all the variables included in the factors. We provide impulse responses to a monetary policy shock for some of the most interesting variables. Equation (2.1) can be written as

$$\hat{\Gamma}(L)\hat{Y}_t = \gamma_t \tag{2.8}$$

where L is a lag operator of order p, $\hat{\Gamma}$ the coefficient matrix including α, $\hat{Y}_t = \begin{bmatrix}\hat{F}_t & R_t\end{bmatrix}'$ and γ_t is a $((K+\nu)\text{x}1)$ vector of structural innovations. As the estimator of X_t using (2.2) is $\hat{X}_t = \Lambda_t^f \hat{F}_t + \Lambda_t^R \hat{R}_t$, impulse response functions of $\hat{X}_t$ are obtained as follows:

$$\hat{X}_t = \begin{bmatrix}\Lambda_t^f & \Lambda_t^R\end{bmatrix} \begin{bmatrix}\hat{F}_t \\ R_t\end{bmatrix} = \begin{bmatrix}\Lambda_t^f & \Lambda_t^R\end{bmatrix} \hat{\zeta}(L)\gamma_t \tag{2.9}$$

where $\hat{\zeta}(L) = \left(\hat{\Gamma}(L)\right)^{-1}$.

2.2 Estimation

This section gives an overview of the estimation strategy and the algorithm used in estimation. The Bayesian methods described by Kim and Roubini (2000) is used to estimate the model in equations (2.1)-(2.7) for two reasons. First, if the variance of the time varying coefficients is small, then the maximum likelihood estimator (MLE) is biased towards a constant coefficients FAVAR. As a consequence, numerical optimization methods are very likely to get stuck in uninteresting regions of the likelihood (Stock and Watson (1996)). Second, multiple peaks are highly probable in a non-linear FAVAR model with highly dimensional parameters. This makes maximum likelihood estimation quite unreliable if in fact a peak is reached at all. Therefore, the Gibbs sampler is appropriate to deal with the problem of estimating a highly dimensional parameter model, by allowing to divide the task in smaller and simpler ones. In addition, given that Gibbs sampler is a stochastic algorithm, it is more likely to escape local maxima.

Before summarizing the basic algorithm we need to clarify the choice of the factor estimation method. If factors form a part of the unknown parameters of the TVP-FAVAR model we need additional restrictions to identify it. Nonetheless, factors cannot be directly identified since we cannot attribute a clear economic interpretation to them. On the other hand, the main advantage of the static representation of the dynamic factor model, described by equation 2.2, is that the factors can be estimated by the principal component method. However, as discussed by Belviso and Milani (2006), the factors estimated by principal component have unknown dynamic properties because principal components neither exploit

[4]We have then $(K+\nu)-1$ blocks, namely $a^{block1} = \{a_{21,t}\}$, $a^{block1} = \{a_{31,t}, a_{32,t}\}$, ..., $a^{block((K+\nu)-1)} = \{a_{(K+\nu)1,t}, \ldots, a_{(K+\nu)k,t}\}$

the factor nor the idiosyncratic component dynamics. There are two principal approaches that exploit these features to extract the static factors through principal components. The first is the tow-step approach situated in the frequency domain proposed by Forni *et al.* (2005) and employed in the *chapter 1*. The second approach is a two-step strategy in the parametric time domain introduced by Stock and Watson (2005). Therefore, we use Forni *et al.* (2005)'s[5] method to estimate the space spanned by the factors[6]. In order to choose the appropriate number of estimated factors, we consider the sensitivity of the results to the inclusion of a different number of factors. As explained in Bernanke *et al.* (2005), this ad hoc way is justified by the fact that the statistical identification determines the number of factors present in the data set but it does not determine the number of factors to use in the model.

2.2.1 Prior distribution and starting values

In the choice of prior distribution of unknown parameters, we follow the specifications of Primiceri (2005) and Koop and Korobilis (2009). Following the Bayesian literature, ϕ, H_t and A_t will be called "parameters" and the covariance matrices of the innovations, i.e. the elements of Q, and the break probabilities "hyperparameters".

All the hyperparameters Q_η except $Q_{\eta_t^\psi}$ are assumed to be distributed as independent inverse-Wishart random matrices. The Wishart distribution can be thought of as the multivariate analog of χ-square, and used to impose positive definiteness of the blocks of $Q_{\eta/-\psi}$. Finally, the diagonal elements ψ_i of $Q^0_{\eta^\psi}$ have univariate inverse Gamma distributions as each ψ_i is a scalar.

$$Q^0_\eta \sim IW(l_\eta.(1+m_\eta).V^{OLS}_\eta, 1+m_\eta).$$
$$Q^0_{\eta^\psi} \sim IG(l_\psi.(1+m_\psi).V^{OLS}_\psi, 1+m_\psi)$$

where V^{OLS}_ψ denotes the variance of the OLS estimate of ψ and l_ψ are tuning constants. In our case we do not use a training sample[7] to estimate V^{OLS}_h as in Primiceri (2005), hence V^{OLS}_h and V^{OLS}_η are assumed to be null matrices of dimension $(m_\psi \times m_\psi)$ and $(m_\eta \times m_\eta)$, respectively; m is the number of elements in the state vectors. $IW(Sc, df)$ and $IG(Sc, df)$ represent respectively the inverse-Wishart and the inverse-Gamma with scale matrix Sc and degrees of freedom df. As in Primiceri (2005), l_ψ and l_η are assumed to be equal to 0.07. For all the parameters governing the structural break probabilities we assume that (π_0) $\sim Beta(0.5, 0.5)$, which indicates that there is a 50%[8] chance of a break occurring in any time period. Using uninformative priors we do not impose any constraint on the number of breaks and we let the data speak for themselves.

[5]For details of the dynamic factor model the reader is referred to Forni *et al.* (2005).

[6]This method is, in addition, appropriate for samples with relatively small numbers of time observations. The choice of this method is therefore particularly appropriate since we use a quarterly data sample with no more than 150 observations.

[7]In this paper we do not use informative priors from training sample because our sample is already relatively short and we are not prepared to sacrifice observations.

[8]$E(\pi) = \frac{\tau_0}{\tau_1+\tau_1}$.

The priors for the initial states of the regression coefficients, the covariances and volatilities are assumed to be normally distributed, independent of each other and of the hyperparameters. Let $\Theta_0 = [\Lambda_0 \;\; \psi_{i,0} \;\; \phi_0 \;\; a_0 \;\; lnh_{i,0}]' \sim N(0, 4I)$, where I is the identity matrix with dimensions of each respective parameter and 0 is a vector of 0's. The choice of zero mean reflects a prior belief that our variables will show little persistence since they are used in first difference and are stationary. The variance scaling factor 4 is arbitrary but large relative to the mean 0.

2.2.2 Simulation method

Conditional on using the conjugate priors and a Kalman filter, the Gibbs sampler is repeated until convergence to the true posterior densities of the parameters. Note that at time $t = 1$ we do not need to choose an initial value of J_1^{Θ} since whether we assume all parameters are constant ($J_1^{\Theta} = 0$) or all are varying ($J_1^{\Theta} = 1$) does not affect the posterior results. The states in J_t^{Θ} are updated in the subsequent periods. Let a superscript T denote the complete history of the data (e.g. $\Theta^T = \Theta_1^{'}, \ldots, \Theta_T^{'}$). We summarize the applied Gibbs sampler involving the following steps:

1. Initialize the parameters (Θ_0) and the estimated factors.
2. Draw Θ^T from $p(\Theta^T | Y^T, \Theta_0)$ using Carter and Kohn (1994)'s algorithm, except for h and ψ which are simulated using Kim *et al.* (1998)(1998)'s algorithm.
3. Draw hyperparameters $Q_{\eta^{\psi}}^T$ using the inverse gamma distribution and the remaining Q_{η}^T hyperparameters are drawn from an inverse Wishart distribution.
4. Simulated the binary random variables J^{Θ} using the Gerlach *et al.* (2000) algorithm.
5. Simulate $\pi^{\Theta}(\overline{\tau}_0, \overline{\tau}_1)$, where $\overline{\tau}_0 = \tau_0 + \sum_{t=1}^{T} J_t^{\Theta}$ and $\overline{\tau}_1 = \tau_1 + T - \sum_{t=1}^{T} J_t^{\Theta}$.
6. Go to step 2[9]

Conditional on initial values for the parameters (Θ_0), except for $\psi_{i,0}$ and $lnh_{i,0}$, the estimated factors and the data Y^T, the state-space form given by (2.1) and (2.2) is linear and Gaussian. Therefore, the conditional posterior of Θ^T is a product of Gaussian densities and Θ^T can be drawn using a forward-backward sampling algorithm from Carter and Kohn (1994). Our objective is to characterize the marginal posterior densities of Θ^T. To obtain an empirical approximation to this density, the Gibbs sampler simulates Θ^T from the conditional density $p(\Theta^T | Y^T, \Theta_0, F^T)$. This consists first, in updating the parameters at time t conditional on data at time t (from $t = 1$ to T, each Θ_t is consecutively updated conditional on data

[9]Note that only factor loadings are considered as time-varying parameters. For this reason we do not need to go back to step 1 in the algorithm. As explained above, factors are considered as known parameters in the absence of theoretical justification of additional identification.

at time t). Then, the Kalman filter produces a trajectory of parameters by again updating the estimated Θ_t using information in the subsequent periods $(t+1)$. Finally, from the terminal state Θ^T, a backward recursion produces the required smoothed draws by updating Θ^t conditional on information in previous periods from $t = T-1$ up to $t = 1$, using the information from the whole sample.

However, drawing from the conditional posterior of $\psi_{i,0}$ and $lnh_{i,0}$ is different because the conditional state-space presentation for $\psi_{i,0}$ and $lnh_{i,0}$ is non-normal. A Gibbs sampling technique that extends the usual Gaussian Kalman filter, developed by Kim *et al.* (1998), consists of transforming the non-Gaussian state-space form into an approximately Gaussian one, so that the Carter-Kohn standard simulation smoother can be employed.

In this second step, drawing parameters proceeds as follows. First, factor loadings (Λ^T) are simulated conditional on prior distributions of estimated factors and data X^T $(p(\Lambda^T|X^T,F^T))$. Second, conditional on the sampled values of Λ^T, a set of values of ψ^T are drawn from the conditional distribution $p(\psi^T|X^T,F^T,\Lambda^T)$. Third, coefficients (ϕ^T) are simulated from the conditional density $p(\phi^T|Y^T,\phi_0,a_0,lnh_0)$. Fourth, the elements of A_t are drawn from $p(A_t|Y^T,\phi^T,a_0,lnh_0)$. Finally, the diagonal elements of H_t are drawn from $p(A_t|Y^T,\phi^T,a^T,lnh_0)$.

In step 3, conditional on Y^T, estimated factor and Θ^T, drawing from the conditional posterior of the hyperparameters $Q^T_{\eta/-\psi}$ is standard, since it is a product of independent inverse-Wishart distributions. However, since we have constrained the hyperparameter matrix $Q^T_{\eta^\psi}$ to be diagonal, its diagonal elements $Q^T_{\eta_i^\psi}$ have univariate inverse-Gamma distributions. For the structural break probability parameters, the independent sequence of Bernoulli variable J^Θ is simulated non-conditional on data using Gerlach *et al.* (2000) algorithm[10]. Finally, in step 5 the conditional posterior for the break probabilities π is sampled from Beta distributions.

Given these marginal posterior densities, estimates of parameters and hyperparameters can be obtained as the medians or means of these densities. The algorithm uses 60 000 sampling replications and discards the initial 40 000 as burn-in. When the posterior moments vary little over retained draws, this means that the Gibbs sampler does converge to the true posterior densities of the parameters.

3 Empirical results

3.1 Data and preliminary results

In our application of the TVP-FAVAR methodology, the set of information variables is of a balanced panel of 139 macroeconomic time series for Japan. The data are at quarterly frequency and span the

[10]The algorithm proposed by Carter and Kohn (1994) draws J conditional on states Y^T, but in the presence of structural breaks or additive outliers J and Y^T become highly correlated, making this sampler very inefficient. The Gerlach *et al.* (2000) algorithm retains a high degree of efficiency regardless of correlation between J and Y (Giordani and Kohn (2008)).

period from 1983:Q2 through 2008:Q4. The data set consists of variables related to the real activity, consumer and producer price indexes, financial markets, private and business anticipations and interest rates. As in Bernanke *et al.* (2005) our data are classified into two categories of variables: we distinguish between "slow-moving" variables which are predetermined in the current period and "fast moving" variables which react contemporaneously to the economic news or shocks. The series have been demeaned and standardized and seasonally adjusted when it is necessary and, as usual, the series are initially transformed to induce stationarity. Our data set with the complete list of variables, its sources and the relevant transformations applied, is presented in Table 1 in Appendix A.

As for the choice of monetary policy instrument for Japan, indicators vary from study to study. As discussed in Inoue and Okimoto (2008), this choice is between the call rate (Miyao (2000) and Nakajima *et al.* (2009))[11] and the monetary base (Shioji (2000)). Inoue and Okimoto (2008) argue that the best choice is jointly considering the call rate and the monetary base as policy indicators. This is because from 1995 onwards and particularly from the introduction of QEMP in March 2001 to March 2006, interest rates were almost zero and the monetary policy target was explicitly the monetary base. However, Inoue and Okimoto (2008) finally consider only data spanning the period between January 1975 and December 2002. This is because from October 2002 onwards the call rate was zero, in which case the normality assumption is invalidated. Here, since our objective is to focus on the QEMP period and for the reasons given in Inoue and Okimoto (2008) we assume that the monetary base is the only observable factor and then the only monetary policy instrument.

In the first step, we need to determine the number of factors that characterize our data set. Our results are not materially affected whether we choose three or four factors. Bernanke *et al.* (2005) and Stock and Watson (2005) argue that three factors perform well and since parsimonious modeling is always preferred, in our case we will also assume that the data set can be described by three factors.

3.2 Specification tests

To carry out subsequent model selection, we opted for the Deviance Information Criterion (DIC) statistic (Spiegelhalter *et al.* (2002)). The problem with the TVP-VARs is that it is not easy to use the marginal likelihood, which is a typical measure for the Bayesian model, as we have stochastic volatility which makes likelihood evaluations difficult and cumbersome. The problem becomes more severe for the TVP-FAVAR model which has an additional equation. The DIC takes into account two important features of the model: the complexity (based on the number of the parameters) and the fit (typically measured by a deviance statistic). DIC examines the two features together and gives a measure which balances between the two. Table 1 shows the values of DIC estimated on 20,000 posterior means draws for 5 different mod-

[11] Note that all of these studies use data from 1975 and 1977 to 1995 and 1998 and hence the period of zero interest rate policy and QEMP are excluded.

els with 3 factors and 2 lags: (i) a model with constant parameter (FAVAR), (ii) a model with only varying factor loadings (TVPL), (iii) a model with varying factor loadings and auto-regressive terms (TVPLB), (iv) a model in which factor loadings, auto-regression terms and covariance elements are assumed to vary (TVPLBA), (v) a model where factor loadings, auto-regression terms and Log volatilities are assumed to vary (TVPLBS) and (vi) a model in which all of the parameters are assumed to vary (TVPLBAS). Except FAVAR model all the other models are estimated for two kinds of priors: uninformative priors ($Beta(0.5, 0.5)$) and tightened priors ($Beta(0.01, 10)$) for the transition probabilities. With the latter priors we constrain the model to have few breaks (one or two breaks) while with the uninformative priors the number of breakpoints is determined by the data. Not surprisingly, the FAVAR model shows the

Table 1. Model comparison with Deviance Information Criterion (DIC)

FAVAR		TVPL(2)	TVPLB(2)	TVPLBA(2)	TVPLBS(2)	TVPLBAS(2)
- 10421.3	Few breaks	- 10528.3	- 10530.0	-10531.7	-10610.9	**-10651.3**[a]
	uninformative	-10529.1	-10530.4	10543.0	-10607.2	**-10654.1**

[a]Results are based on 60,000 iterations after a burn-in period of 40,000. The model with smaller DIC would better predict a replicate datasets of the same structure.

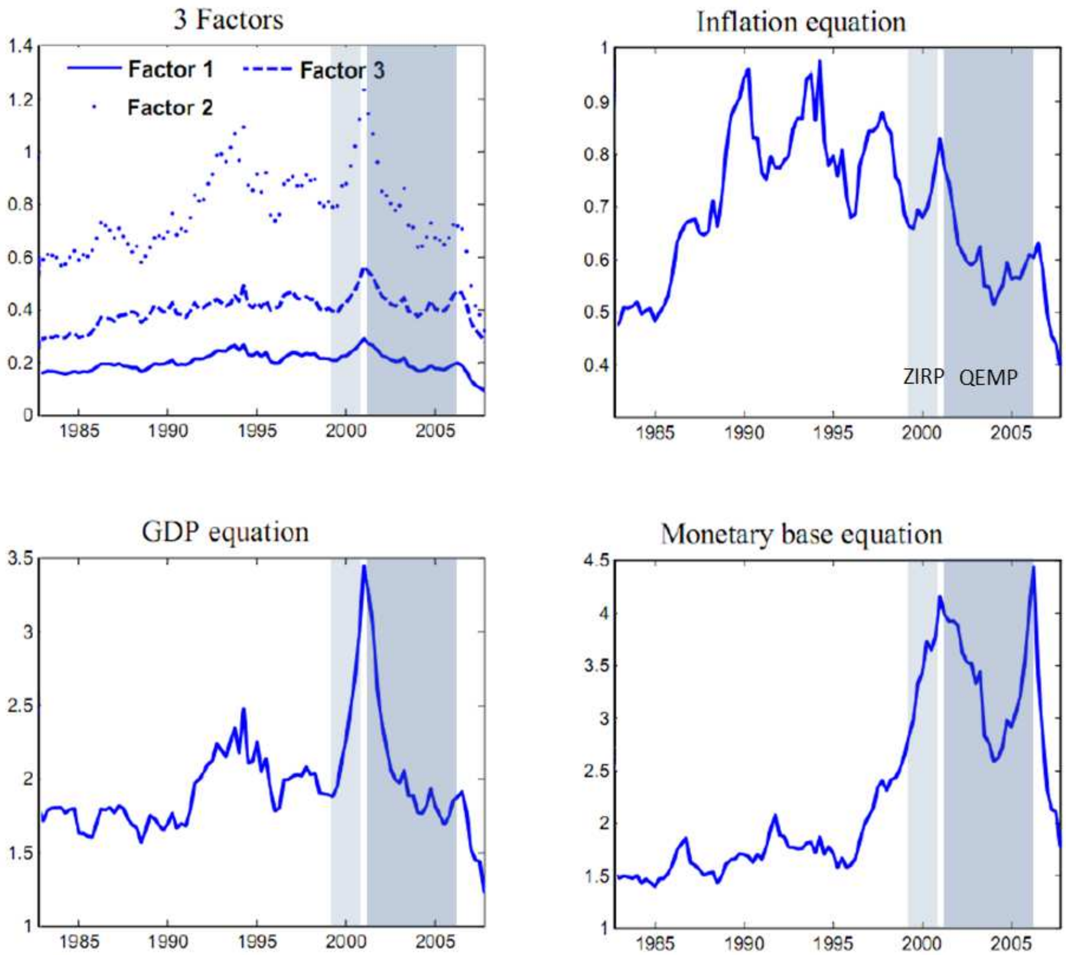
highest DIC value, indicating that we need to take into account breaks in the model. All the other models perform clearly better, corroborating the validity of a TVP approach. Then we test whether all parameters or few of them vary over time. The resulting DIC of the unconstrained model (TVPLBAS-FAVAR) is the lowest, hence all parameters do change over time. Next, we test whether the Japanese economy is characterized by only a small number of breaks (e.g., among others, Fujiwara (2006), Inoue and Okimoto (2008) and chapter 1 above). The comparison between models with uninformative and informative priors tend to confirm the existence of more than two breaks in the data (Nakajima *et al.* (2009)). Even with informative priors results still indicate a gradual evolution of the parameters. These outcomes tend to confirm our choice of uninformative priors where the number of breakpoints is determined in a data based fashion.

3.3 The evolution of the Japanese monetary policy

Before examining the effectiveness of QEMP and its transmission channels, we need to analyse the evolution of the Japanese monetary policy during the last three decades. In Figure 1 we present the time-varying standard deviations of the errors in the equations for the three factors, inflation, activity and the monetary base (i.e. the posterior means of the square roots of the diagonal element of Ω_t). Figure 1 shows that there is evidence of time variation in error variances in all equations.

The sharp increase in 1989 and in 1997 can be explained by the introduction of the consumption

Figure 1. Posterior mean of the standard deviation of equation residuals



The figures show the time-varying standard deviations of the errors in the equations for the three factors, inflation, activity and the monetary base.

tax (the consumption Tax Law took effect from 1 April 1989) and its increase from 3 to 5 percent in April 1997. However, after early 1998 and until 2005 the volatility is greatly reduced, reflecting the deflationary period experienced by the Japanese economy. The volatility of GDP keeps increasing from the mid-1990s until 2001. This confirms the findings of Nakajima *et al.* (2009) that the variance of real GDP becomes higher in the 1990s than it was in the 1980s. One possible explanation is the increased uncertainty that characterized the period after the burst of the asset price bubble and influenced the investment. We particularly note the sharp decline in GDP volatility after the implementation of the QEMP. In a similar way, we can think that during the QEMP period monetary policy was more widely understood, and reducing the volatility of investment, reinforced the perception that the business cycle had become less severe. Finally, the increase in monetary base volatility from the end of 1995 corresponds to the decrease in the call rate to a lower level in 1995 (0.5 %) and to nearly zero under the zero interest rate policy and

QEMP.

3.4 Impulse response analysis

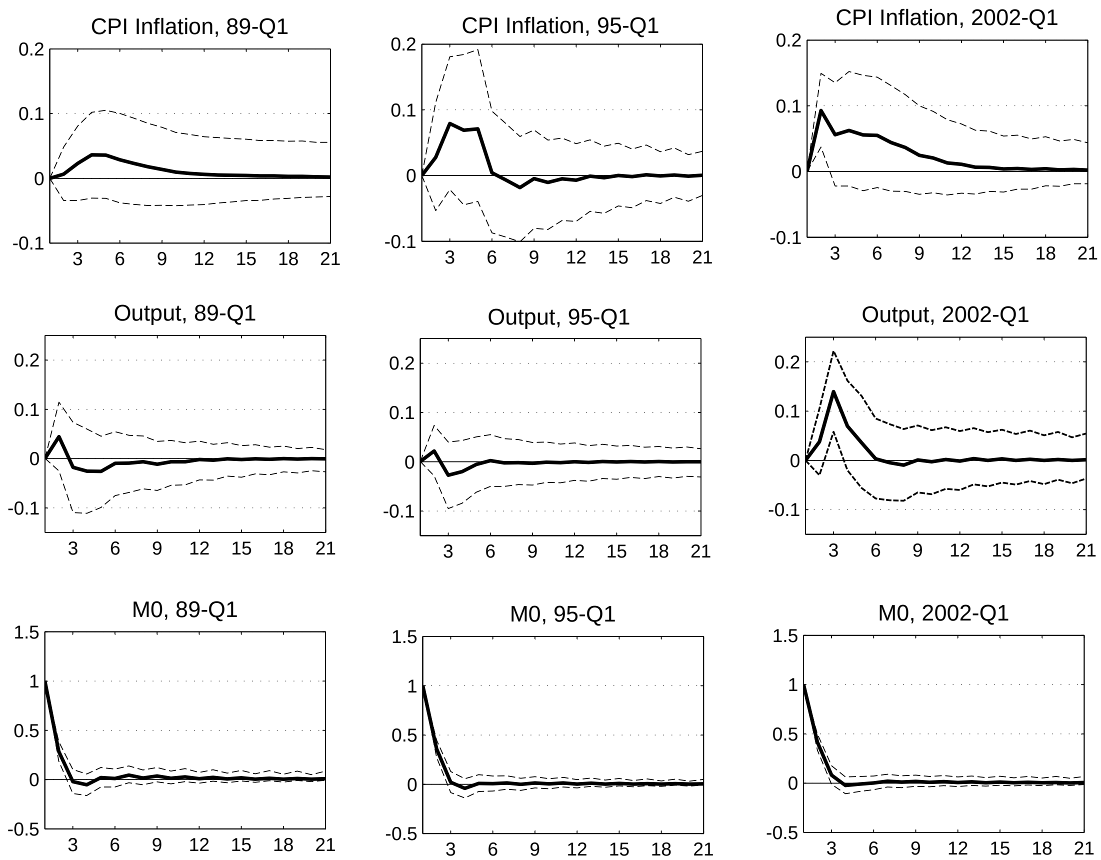
This section examines the dynamic relationships between variables through impulse response functions which can be implemented for all series included in our database. We conduct our analysis for three periods and dates are chosen in ad-hoc way: 1989 Q4, 1995 Q1 and 2002 Q1. The first date corresponds to the burst of the asset price bubble, the second date represents the end of the use of the call rate as a monetary policy instrument and the last date represents the beginning of the QEMP and the period when short-term interest rate reached zero. The shock is normalized so that it increases the monetary base by its standard deviation at all dates.

3.4.1 Was the QEMP effective?

Figure 2 displays impulse responses of key variables in the model to a monetary policy shock over different dates chosen arbitrary: (i) 1989 Q1, before the burst of the asset bubble and when interest rates were high, (ii) 1996 Q1, after the decline in the short term interest rates to 0.5% and (iii) 2002 Q1, over the QEMP period. The posterior median is the solid line and the broken lines are the 10th and 90th percentiles.

It is not surprising that the effect of the monetary base shock on inflation and GDP until 1995 is very weak and insignificant, indicating that monetary policy has been considered as interest rate policy. However, from the second half of 1995 (second row) the effect of the monetary base shock becomes positive but hardly significant. These results are consistent with the evolution of the monetary base stochastic volatility from the end of 1995. During this period the interest rates fell to 0.5 percent and then declined further to almost zero percent during the ZIRP period. It is then plausible to think that interest rates being extremely low, the monetary base began to be used as an alternative policy instrument. Interestingly, and in contrast with Fujiwara (2006) and Inoue and Okimoto (2008), during the QEMP period (third row) inflation displays a positive and significant response, which becomes statistically insignificant only after 3 quarters. This effect, though it is short-lived, shows that the QEMP has an inflationary effect. The effect of the monetary base shock on GDP is more pronounced. Production displays a temporary and not persistent positive response, which veers to be insignificant after one year. This positive effect on activity is unanimously detected in empirical studies. This temporary impact put together with the decline in the output volatility leads us to think that monetary policy might be the source of output fluctuations during the QEMP period. Note that the disconnection between traditional VAR results and the standard theory predictions, that is revealed by puzzles, price divergence and non-neutrality of money arising in Fujiwara (2006), Inoue and Okimoto (2008) and Nakajima *et al.* (2009), disappears under our rich-data model. As shown in Bernanke *et al.* (2005) and Forni and Gambetti (2010), our results corroborate the idea that

Figure 2. Impulse response functions



The figures show the reactions of inflation and GDP to a shock to M0 over 21 quarters for three different dates . The solid lines show the impulse responses implied by the time-varying FAVAR (posterior median) and dashed lines represent the 10^{th} and 90^{th} percentiles.

a FAVAR methodology, which exploits a large set of information, improves the accuracy of econometric models in predicting the effects of monetary policy, and, therefore, could address puzzling effects observed otherwise.

In order to go further in our analysis we exploit the advantage of using TVP-FAVAR, allowing us to observe the impulse responses to shocks for all the economic series included in the construction of the factors. In doing so, we are able to detect the origin of the QEMP effect. Figure 5 (in Appendix B) displays the reaction of disaggregated prices. Except for two producer price indexes the reaction of the remaining prices is significantly positive[12]. These results are in line with theory and are opposite to the so-called "price puzzle" observed by Nakajima *et al.* (2009) and Inoue and Okimoto (2008). An interesting result that emerges from Figure 5 is that the monetary base shock has a positive effect on house prices

[12] We do not report the confidence intervals for lack of space.

(CPIHWEGFH), which are strongly correlated to the land price. According to Kwon (1998), a large fraction[13] of business investment financed by bank loans is secured by land. It is therefore plausible to think that movements in land prices, whose values may serve as collateral, can improve financing conditions and may play a significant propagating role in the monetary transmission mechanism. As for disaggregated production, as shown in Figure 6 (in Appendix B), except mining, a positive shock to the monetary base increases all industrial production components, capacity utilization rates, shipments and to a lesser extent earnings and employment. The employment rate remains fairly unaffected.

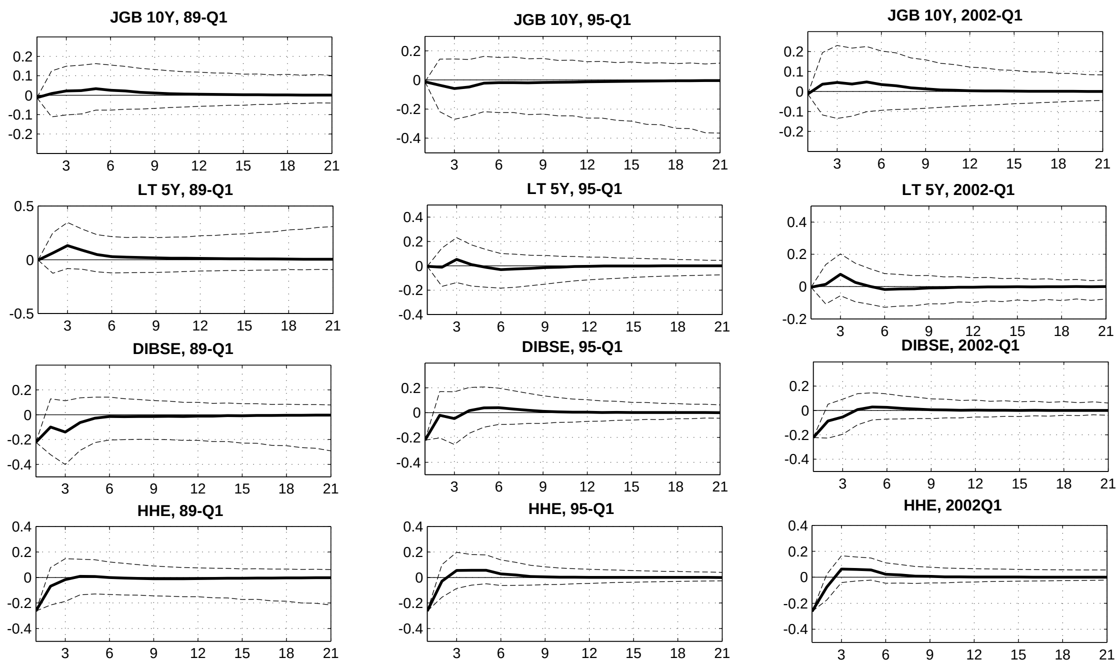
This result raises the question of the transmission mechanism through which the QEMP affected the output and inflation. The QEMP can work through either policy-duration channel or the portfolio-rebalancing channel, or both of them.

3.4.2 Policy-duration effect

The empirical validity of the policy-duration effect implied by theoretical studies is still an open question. As shown by Eggertsson and Woodford (2003) and Jung *et al.* (2005), a central bank can lower long-term interest rates by committing to the future zero interest rates in advance, and so lower the real interest rates thanks to the inflation expectation. Eggertsson and Woodford (2003) argue that this expectation channel is the only way to escape deflation and stimulate an economy under a liquidity trap situation. Note that lowering long-term interest rates is an intermediate objective and the ultimate objective of monetary policy is price stabilization, which will hopefully facilitate economic growth. Therefore, if this expectation channel is effective the economic recovery should increase expected inflation and thus future short-term interest rates, which, in turn, will raise long-term interest rates. From Figure 3, we see that during the period of QEMP the reaction of private-sector (HHE) and business-sector (DIBSE) expectations is significant but short-lived.

[13]Of total secured bank loans, about 45% have been collateralized by land, while only about 3% have been backed up by stocks and bonds. Thus, land prices might be closely related to real activities in Japan.

Figure 3. Impulse responses - Policy-duration effect



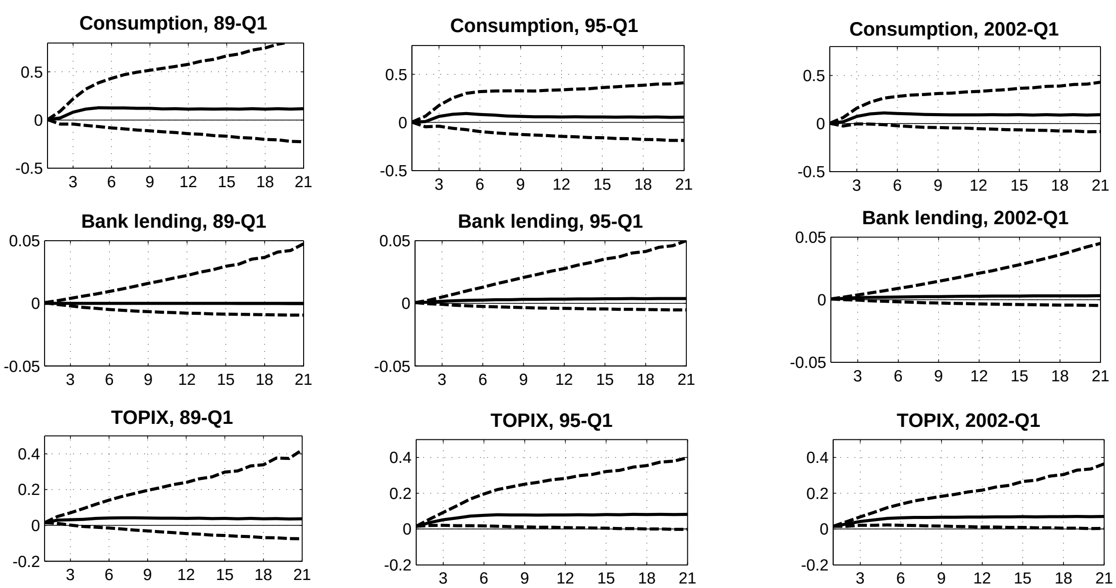
The figures show the reactions of five-year JGBs's yields (LT 5Y), long-term JGBs's yields (JGB 10 Y), private sector (HHE) and business-sector (DIBSE) expectations to a shock to M0 over 21 quarters for three different dates. The solid lines show the impulse responses implied by the time-varying FAVAR (posterior median) and dashed lines represent the 10^{th} and 90^{th} percentiles.

In contrast with Nakajima *et al.* (2009) and Kimura *et al.* (2003), the impulse responses of medium- (LT 5Y) and long-term (JGB 10 Y) interest rates are insignificant. However, these results need to be interpreted carefully and should not be taken as evidence against the expectation channel (neo-Wicksellian view). The positive effect on private and business sector expectations, even short-lived, can also be interpreted as a successful BOJ policy commitment in preventing a downward spiral of expectations. However, as argued in Nakajima *et al.* (2009), the policy commitment, alone, is not sufficient to generate significant inflationary pressure to escape from the trap of deflationary phase and to lead to upward shifts in the trend growth path. In order to better analyze the policy-duration effect, a more appropriate model examining the interactions between the macroeconomic variables and the yield curve is needed. This will be the subject of the next chapter.

3.4.3 Portfolio-rebalancing channel

The portfolio-rebalancing channel is supposed to be induced indirectly by the increase in the CAB or directly by the increase in BOJ's JGB purchases. As prices rise for JGBs their yields will fall relative to those of other assets. Households and companies may be encouraged to switch into other type of assets in search of higher returns. That would push up other asset prices as well. Similarly, households and companies use the additional money injected by the central bank to buy alternative non-monetary assets, increasing their prices. The stock price (TOPIX), which serves as a proxy for financial asset prices, increases in reaction to monetary base expansion but becomes insignificant only after around 6 quarters (Figure 4). As investors' demand for alternative assets such as equities increases, the ability of businesses to raise finance in capital markets improves and the cost falls. By contrast with Oda and Ueda (2007) and Kimura *et al.* (2003), these results show that the portfolio-rebalancing channel could have a role in transmitting monetary policy shocks. It is likely that the QMEP was effective through the stock price channel. As explained in *chapter 1*, there are four possible channels through which higher stock prices boost output: an increase in consumption through a rise in households' wealth (the wealth effect); an increase in investment through higher Tobin's q; an increase in bank lending through a decline in the external finance premium of borrowers (the balance sheet effect); and an increase in bank lending through an improvement in the banks' capital-to-asset ratios.

Figure 4. Impulse responses - Portfolio-rebalancing channel



The figures show the reactions of the consumption, the bank lending and asset prices (TOPIX) to a shock to M0 over 21 quarters for three different dates. Solid lines show the impulse responses implied by the time-varying FAVAR (posterior median) and dashed lines represent the 10^{th} and 90^{th} percentiles.

While bank lending does not react significantly to the monetary base shock, consumption[14] increases significantly during the QEMP period but this reaction is short-lived. Therefore, we suppose that

[14]This correponds to the total consumption for 2 or more persons (variable number 49 in the list of variables in Appendice A.)

the stock price channel is driven mainly by the wealth effect and investment[15]. The increase in the stock price may have helped Japanese firms restore their balance sheets, which were destroyed after the asset price bubble burst and land prices collapsed in the early 1990s[16]. Companies therefore started investing their profits instead of using them to repay debts.

Our findings suggest that QEMP is effective and works through both monetary policy commitment and portfolio-rebalancing channel. This is in line with Bernanke and Reinhart (2004)'s suggestions that the neo-Wicksellian policy commitment needs to be complemented with more aggressive use of monetarist approaches to monetary policy. The authors also argue that the BOJ should not have to limit changes to the composition of its balance sheet to only focus mainly on purchases of government securities but that it should extend its open market purshases to a wide range of securities. The recommendations addressed by Bernanke and Reinhart (2004) to the BOJ were put into practice by Ben Bernanke, as chairman of the Federal Reserve System, in order to combat the current financial crisis. The non-conventional monetary policy strategy adopted by the Fed called credit easing, is similar to QEMP in its explicit commitment to maintaining the nominal short-term interest rate at low levels. However, the main difference between the two strategies is that the Fed, through its Credit Easing, focuses on the change in the composition of its balance sheet by purchasing a wide range of securities[17], yet the size of the balance sheet remains a secondary objective. Moreover, Gagnon *et al.* (2010) show that credit easing mainly worked through the portfolio-rebalancing channel, the decline in long-term interest rates being attributed to the decline in term premia and not to the expectation of low future short-term interest rates. The authors argue that the large-scale asset purshases (LSAPs) implemented by the Fed not only reduced longer-term yields on the assets being purshased (agency MBS and Treasury securities), but also reduced yields on other assets (corporate bonds and equities).

This complementarity between the portfolio-rebalacing channel and the expectation channel is, moreover, corroborated by the fact that the BOJ, building on its past experience with QEMP, recently implemented "Comprehensive Monetary Easing" (CME). This strategy focuses more on changes in balance sheet composition and on the extension of open market purchases to a wide range of securities[18].

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[15]The data for private investments are available only from 1994

[16]As argued in Koo (2008), the corporate sector was busy repaying debt until 2004; net debt repayments fell to zero by the end of 2005.

[17]The Fed's experience of credit easing comprises two courses of action. First, there is an explicit commitment to maintaining the nominal short-term interest rate at low levels. Second, the Fed implements large-scale asset purchases (LSAPs), which range from housing agency debt and mortgage-backed securities (MBS) to long-term Treasury securities. However, the Bank of England and the ECB associated their operating procedure on a monetarist view of the transmission process. They began a programme of large-scale asset purchases in 2009 without any explicit commitment to maintaining their policy rates at low levels.

[18]In October 2010, the BOJ announced the adoption of the new monetary strategy called "Comprehensive Monetary Easing" in reference to its past experience of QEMP. This strategy approaches credit easing as implemented by the Fed, consisting of

4 Conclusion

Recent research has employed VAR models, accounting for regime changes, leading to advances in the measurement of the effect of Japanese quantitative easing. These models permit researchers to verify whether or not the Japanese monetary policy has undergone structural changes. This issue is particularly important for the Japanese economy in the last two decades. The main shortcoming of this literature has been the inability to incorporate larger and more realistic information sets related to central banks and the private sector. This chapter employed a time-varying parameters FAVAR (TVP-FAVAR) model to overcome these limitations. This model allowed us both to take into account regime changes and to measure the effects of monetary policy shocks on numerous variables.

Our analysis delivers four main results. First, unsurprisingly, our results suggest that the best model to specify Japanese monetary policy during the two last decades is a model where all parameters vary over time. This corroborates our choice of a time varying parameters model. Second, the effect of QEMP on activity and prices is stronger than previously found. In particular, we find a significant price reaction to a monetary policy shock. Moreover, the problem related to the price puzzle, the price divergence and the non-neutrality of money that arises in previous works disappears under our data-rich model. Third, by contrast with previous work, there is a detectable effectiveness of the portfolio-rebalancing channel, which could have a role in transmitting monetary policy shocks. The weak reaction of bank lending and the significant increase in consumption, even short-lived, lead to think that the positive and significant asset price reaction generates two main effects: it means lower yields, reducing the cost of borrowing for households and companies, leading to higher consumption and investment spending. It also means that the wealth of the asset holders increases, which should boost their spending. Fourth, while the policy commitment succeeds in controlling private and business expectations, the reaction of medium to long-end of the yield curve remains insignificant.

Moreover, one interesting result that emerges from the price reaction is that the monetary base shock has a positive effect on house prices, which are strongly correlated to the land price. A large fraction of business investment financed by bank loans is secured by land. It is therefore plausible to think that movements in land prices, whose values may serve as collateral, can improve financing conditions and may play a significant propagating role in the monetary transmission mechanism.

These results shoud not be taken as evidence in favor of portfolio-rebalancing channel against the

the following two principal courses of action. First, as in QEMP, the BOJ commits to maintaining short-term interest rates at around 0 to 0.1 percent. Second, the BOJ increases the amount of outright purchases not only of government securities, but also of commercial paper, corporate bonds, exchange-traded funds and Japanese real estate investment trusts. Note that in contrast to QEMP, CME puts the emphasis on the composition of the BOJ's balance sheet without any explicit reserve level target.

expectation channel. The positive but short-lived effect on private and business sector expectations may not be sufficient to restore the previous trends in prices and output, but might prevent downward spiral of expectations. Therefore, the two channels are complementary rather than exclusive. On the other hand, since the expectations hypothesis of the term structure of interest rates is a necessary condition for the effectiveness of the expectation channel, we think that a macro-finance model is more appropriate to better analyse the effectiveness of the policy-duration effect. This will be the issue of the next chapter.

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Appendix A: Data and transformations

Table 2. **Variable list**

Data are extracted from Reuters EcoWin database. The transformation codes (T) are: 1 – no transformation; 2 – first difference; 4 – logarithm; 5 – first difference of logarithm. In this database VRAI means seasonally adjusted.

#	Mnemonic	T	Description
			Slow moving
1	IPT	5	Industrial Production Total Index
2	IPSCP	5	Production, Ceramics, stone and clay products, Index
3	IPCH	5	Production, Chemicals, Index
4	IPVEH	5	Production, Industrial vehicle, Index
5	IPDVEH	5	Production, Domestic vehicle, total
6	IPFM	5	Production, Fabricated metals, Index
7	IPFT	5	Production, Food and tobacco, Index
8	IPGM	5	Production, General machinery, SA, Index
9	IPIS	5	Production, Iron and steel, Index
10	IPMANUF	5	Production, Manufacturing, Index
11	IPMMANUF	5	Production, Mining and manufacturing, Index
12	IPNFM	5	Production, Non-ferrous metals, Index
13	IPOMUNUF	5	Production, Other manufacturing, Index
14	IPPCP	5	Production, Petroleum and coal products, Index
15	IPPP	5	Production, Plastic products, Index
16	IPPI	5	Production, Precision instruments, Index
17	IPIP	5	Production, By industry, paper, Index
18	IPCE	5	Production, Communication Equipment, Index
19	IPSD	5	Production, Semiconductor devices, Index
20	IPTEXT	5	Production, Textiles, Index
21	IPTRANSPE	5	Production, Transport equipment, Index
22	SHIPMCGEXTE	5	Shipments, Capital goods excl transport equipment,, Index
23	SHIPMAG	5	Shipments, Capital goods, SA, Index
24	SHIPMCE	5	Shipments, Communication Equipment , Index
25	SHIPMCONSTG	5	Shipments, Construction goods,Index
26	SHIPMCONSUMG	5	Shipments, Consumer goods, Index
27	SHIPMDCG	5	Shipments, Durable consumer goods, Index
28	SHIPMING	5	Shipments, Investment goods , Index
29	SHIPMMANUF	5	Shipments, manufacturing, Index
30	SHIPMMMANUF	5	Shipments, Mining and manufacturing, Index
31	SHIPMNDCG	5	Shipments, Non-durable consumer goods, Index
32	SHIPMPG	5	Shipments, Producer goods total, Index
33	SHIPMPGMMANUF	5	Shipments, Producer goods, for mining and manufacturing, Ind
34	SHIPMPGOTHERS	5	Shipments, Producer goods, for others,, Index
35	CAPUORCH	5	Capacity Utilization, Operation Ratio,Chimicals
36	CAPUORFM	5	Capacity Utilization, Operation Ratio, Fabricated metals
37	CAPUORGM	5	Capacity Utilization, Operation Ratio, General machinery
38	CAPUORIS	5	Capacity Utilization, Operation Ratio, Iron and steel
39	CAPUORMINDUS	5	Capacity Utilization, Operation Ratio, Machinery industry
40	CAPUORMNUF	5	Capacity Utilization, Operation Ratio, Manufacturing
41	CAPUORPC	5	Capacity Utilization, Operation Ratio, Petroleum and coal
42	CAPUORPPP	5	Capacity Utilization, Operation Ratio, Pulp, paper and pap

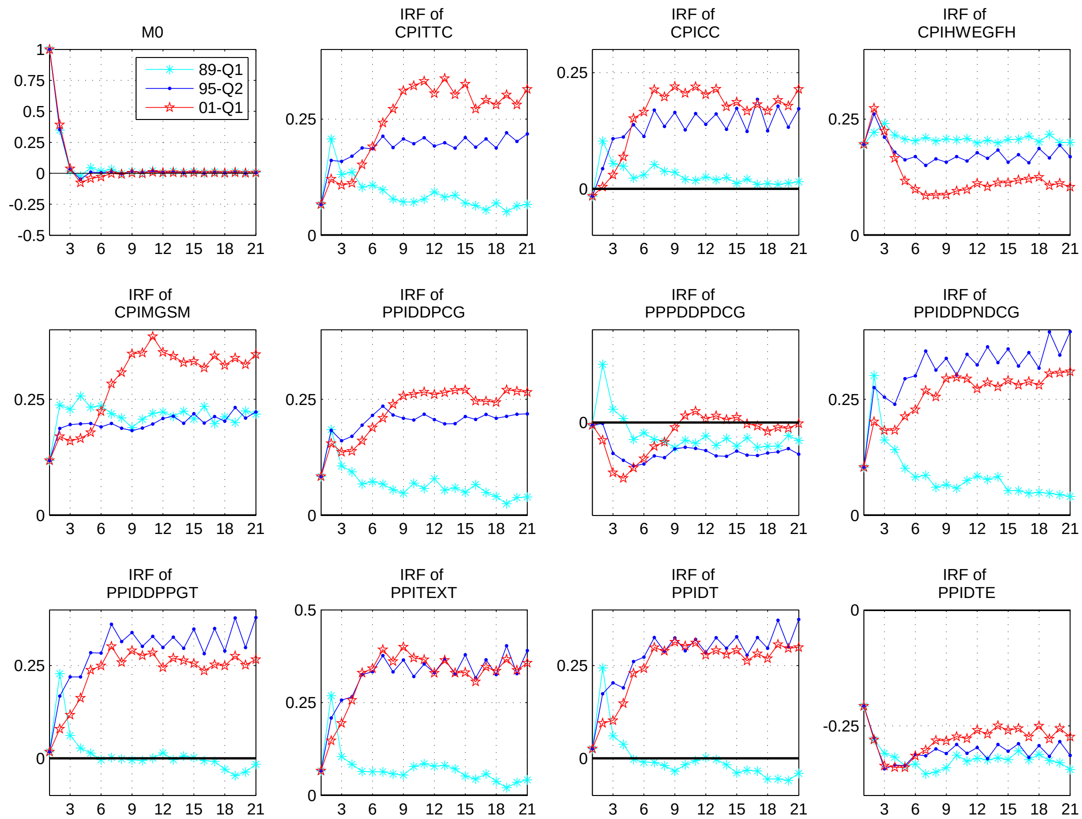
43	CAPUORTEXT	5	Capacity Utilization, Operation Ratio, Textiles
44	CAPUORTE	5	Capacity Utilization, Operation Ratio, Transport equipment
45	HWAVGC	5	Hours Worked, Average Per Month, Construction
46	HWAVGMANUF	5	Hours Worked, Average Per Month, Manufacturing
47	HWAVGMIN	5	Hours Worked, Average Per Month, Mining
48	CONSGENEXCLHA	5	Japan, Index of Consumption Expenditure Level, 2 or more persons, general excl housing, automobiles, money gifts & remittance, Vrai, Index, JPY, 2000=100
49	CONSGENERAL	5	Japan, Consumer Surveys, Index of Consumption Expenditure Level, 2 or more persons, general, Vrai, Index, JPY, 2000=100
50	CONSHOUSING	5	Japan, Consumer Surveys, Index of Consumption Expenditure Level, 2 or more persons, housing, Vrai, Index, JPY, 2000=100
51	CONSTRANSCOM	5	Japan, Consumer Surveys, Index of Consumption Expenditure Level, 2 or more persons, transportation & communication, Vrai, Index, JPY, 2000=100
52	UNEMP	5	Unemployment, Rate, SA
53	EMPTRATE	5	Employment, Overall, Total
54	EMPCONST	5	Employment, By Industry, Construction, Index
55	EMPGOV	5	Employment, By Industry, Government
56	EMPMANUF	5	Employment, By Industry, Manufacturing
57	EMPALLINDUST	5	Employment, By Status, Regular employees, all industries
58	JALFT	5	Japan, Activity, Labour Force, Total
59	SDST	5	Sales at Deapartement Stores, Total, Index
60	CPIALL	5	Japan, Consumer Prices, Industrial products,All, Index, JPY, 2000=100
61	CPIINDP	5	Japan, Consumer Prices, Industrial products,Textile, Index, JPY, 2000=100
62	CPIINDT	5	Japan, Consumer Prices, Electricity, gas & water charges , Index, JPY, 2000=100
63	CPIEGW	5	Japan, Consumer Prices, Services , Index, JPY, 2000=100
64	CPISERV	5	Japan, Consumer Prices, Durable goods , Index, JPY, 2000=100
65	CPIDG	5	Japan, Consumer Prices, Non Durable goods , Index, JPY, 2000=100
66	CPINDG	5	Japan, Consumer Prices, Food , Index, JPY, 2000=100
67	CPIFOOD	5	Japan, Consumer Prices, Reading and Recreation , Index, JPY, 2000=100
68	CPIRR	5	Japan, Consumer Prices, Nationwide, Miscellaneous Goods and Services, Durable goods, Index, JPY, 2000=100
69	CPIGSDG	5	Japan, Consumer Prices, Nationwide, Transport, Private transportation, Index, JPY, 2000=100
70	CPITPT	5	Japan, Consumer Prices, Nationwide, Transport, Public transportation, Index, JPY, 2000=100
71	CPITPUBT	5	Japan, Consumer Prices, Nationwide, Communication, Communication, Index, JPY, 2000=100
72	CPICC	5	Japan, Consumer Prices, Nationwide, Housing, Water, Electricity, Gas and Other Fuels, Electricity, Index, JPY, 2000=100
73	CPIWEG	5	Japan, Consumer Prices, Nationwide, Health, Medical treatment, Index, JPY, 2000=100
74	CPIHMT	5	Japan, Consumer Prices, Nationwide, Health, Medical care, Index, JPY, 2000=100
75	CPIHMC	5	Japan, Corporate Goods Prices, Domestic demand products, consumer goods, Index, JPY, 2000=100
76	PPIDDPCG	5	Japan, Corporate Goods Prices, Domestic demand products, final goods, Index, JPY, 2000=100
77	PPIDDPFG	5	Japan, Corporate Goods Prices, Domestic demand products, nondurable consumer goods, Index, JPY, 2000=100
78	PPIDDPNCG	5	Japan, Corporate Goods Prices, Domestic demand products, total, Index, JPY, 2000=100
79	PPIDDPT	5	Japan, Corporate Goods Prices, Domestic, capital goods, Index, JPY, 2000=100
80	PPIDCG	5	Japan, Corporate Goods Prices, Domestic, chemicals, Index, JPY, 2000=100
81	PPIDCH	5	Japan, Corporate Goods Prices, Domestic, consumer goods, Index, JPY, 2000=100
82	PPIDT	5	Japan, Corporate Goods Prices, Domestic, total, Index, JPY, 2000=100
83	PPISERVALL	5	Japan, Corporate Service Prices, All items, Index, JPY, 2000=100
84	PPISERVT	5	Japan, Corporate Service Prices, Transportation, Index, JPY, 2000=100
85	PPIFINS	5	Japan, Corporate Service Prices, Finance and insurance, Index, JPY, 2000=100
86	EXPORT	5	Japan, Exports, Volume, Total, Index, JPY, 2000=100
87	IMPORT	5	Japan, Imports, Volume, Total, Index, JPY, 2000=100

Fast moving			
88	CONSTSTARTEDP	4	Japan, construction started, Private
89	CONSTSTARTEDPUB	4	Japan, construction started, Public
90	CONSTSTARTEDT	4	Japan, construction started, Total
91	HSBS	4	Housing Starts, Housing built for sale
92	HSRH	4	Housing Starts, Rental homes
93	HST	4	Housing Starts, Total
94	NEWORDCONSP	5	Japan, New Orders, Construction, Private sector, JPY
95	NEWORDCONST	5	New Orders, Construction, Total, Big 50 constructors, JPY
96	NEWORDIM	5	Japan, New Orders, Machine Tools, By industry, machine and equipment industries, industrial machinery, JPY
97	NEWORDMTT	5	Japan, New Orders, Machine Tools, By industry, machine and equipment industries, total, JPY
98	NEWORDCMANUF	5	Japan, New Orders, Construction, Manufacturing, JPY
99	JDFFTSET	5	Japan, Daiwa, Free float, TSE, Total Index, JPY
100	JDFFTSETU	5	Japan, Daiwa, Free float, TSE, Transportation & Utilities Index, JPY
101	TOPIX	5	Japan, Tokyo SE, Topix Index, Price Return, End of Period, JPY
102	DOLLARYEN	5	US.Dollar/Yen Spot Rate, Average in the Month, Tokyo Market
103	EFFEXCHANGE	5	Japan, BIS, Nominal Narrow Effective Exchange Rate Index, Average, JPY
104	M1	5	Japan, M1, outstanding at end of period, Vrai, JPY
105	M2CDs	5	$M2+CDs$/Average Amounts Outstanding/(Reference) Money Stock
106	M3	5	Japan, M3, outstanding at end of period, JPY
107	BOJAAL	5	Japan, BOJ accounts, assets, loans, JPY
108	BOJAAT	5	Japan, BOJ accounts, assets, total, JPY
109	DLBABD	5	Japan, Domestically Licensed Banks, Assets, bills discounted, JPY
110	DLBACL	5	Japan, Domestically Licensed Banks, Assets, call loans, JPY
111	DLBACLBD	5	Japan, Domestically Licensed Banks, Assets, loans and bills discounted, JPY
112	DLBCBALBD	5	Japan, Domestically Licensed Banks, City banks, assets, loans and bills discounted, JPY
113	DLBRBALBD	5	Japan, Domestically Licensed Banks, Regional banks, assets, loans and bills discounted, JPY
114	DLBAL	5	Japan, Domestically Licensed Banks, Assets, loans, JPY
115	DLBCBAL	5	Japan, Domestically Licensed Banks, City banks, assets, loans, JPY
116	DLBRBAL	5	Japan, Domestically Licensed Banks, Regional banks, assets, loans, JPY
117	INVINVG	5	Inventory Investment goods, Index
118	INVMMANUF	5	Inventory Mining and manufacturing, Index
119	INVFM	5	Inventory Fabricated metals, Index
120	INVCG	5	Inventory Construction goods, Index
121	INVCAPG	5	Inventory Capital goods, Index
122	INVNDCG	5	Inventory Non-durable consumer goods, Index
123	INVCONSUMG	5	Inventory Consumer goods, SA, Index
124	INVPG	5	Inventory Producer goods, Index
125	PLRLT	1	Japan, Prime Rates, Prime Lending Rate, Long Term, End of Period, JPY
126	PLRST	1	Japan, Prime Rates, Prime Lending Rate, Short Term, End of Period, JPY
127	TB3M	1	Japan, Treasury Bills, Bid, 3 Month, Yield, End of Period, JPY
128	TIOR3M	1	Tokyo interbank offered rates (3 months)
129	JGB10	1	Yield of Government Bonds (10 Y)
130	SP10TIOR3M	1	Spread rate: Yield of Government Bonds (10 Y) - Tokyo Interbank Offered Rate (3 M)
131	IBGB10	1	10-year interest-bearing Government Bonds
132	LGB10	1	10-year Local Government Bonds
133	GGB10	1	10-year Government Guaranteed Bonds
134	IBBD5	1	5-year interest-bearing Bank debentures
135	CALLRATE	1	Japan, Interbank Rates, Uncollateralized, O/N, Average, JPY
136	SPIBBD5TIOR3M	1	Spread between the Yield on long-term and short-term: Yield of Government Bonds (5 Years) - Tokyo Interbank Offred Rate (3 months)

137	SPGGB10TIOR3M	1	Spread between the Yield on long-term and short-term: Yield of Government Guaranteed Bonds (10 Years) - Tokyo Interbank Offred Rate (3 months)
138	DIBSE	1	DI/Business Conditions/All industries/Forecast
139	HHE	1	Consumer Surveys, Consumer Confidence, Including one-person households, total

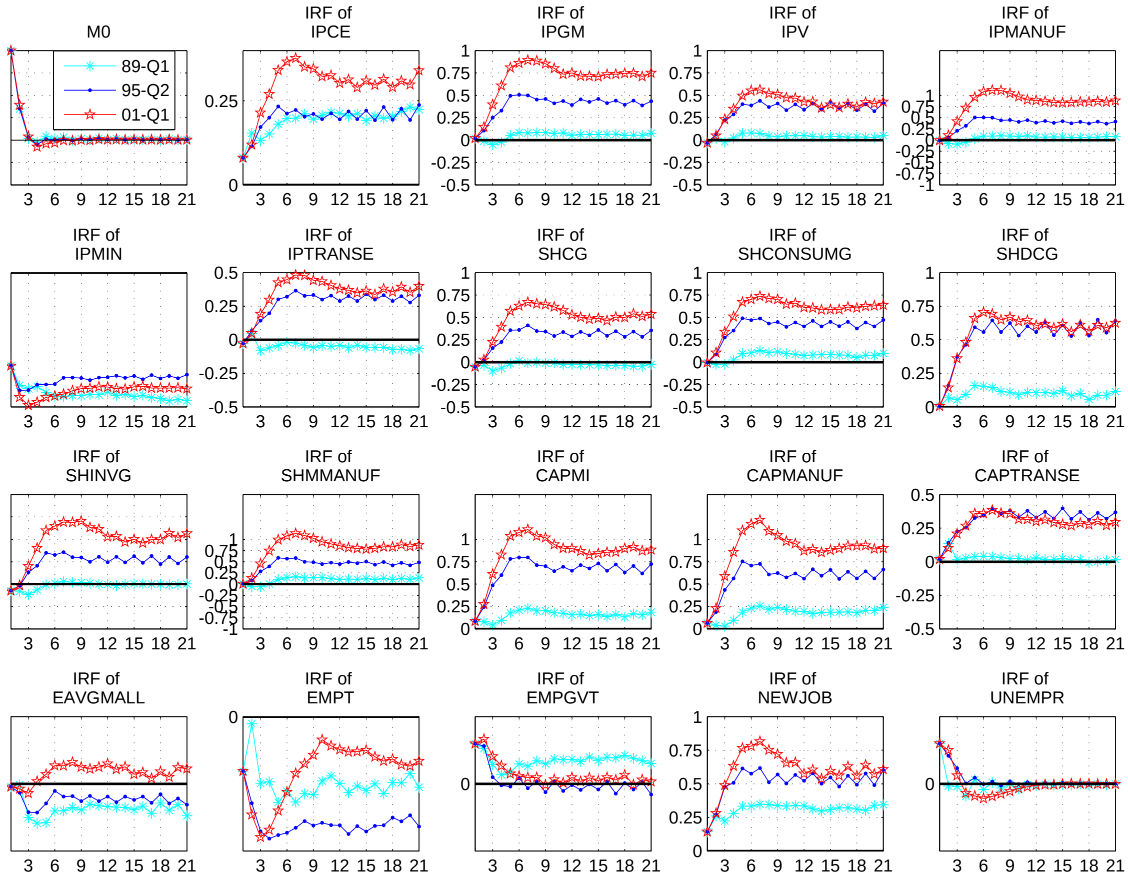
Appendix B: Impulse response functions for price and activity variables

Figure 5. Impulse responses - Disaggregated price



The figures show the reactions of some selected prices to a shock to M0 over 21 quarters for three different dates . The solid lines show the impulse responses implied by the time-varying FAVAR (posterior median) and dashed lines represent the 10^{th} and 90^{th} percentiles. Details on nomenclatures are given in Appendice A.

Figure 6. Impulse responses - Disaggregated production



The figures show the reactions of some selected variables related to activity to a shock to M0 over 21 quarters for three different dates . The solid lines show the impulse responses implied by the time-varying FAVAR (posterior median) and dashed lines represent the 10^{th} and 90^{th} percentiles.Details on nomenclatures are given in Appendice A.