Quantitative easing works: Lessons from the unique experience in Japan 2001-2006

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Abstract

The current financial crisis has now led most major central banks to rely covertly or overtly on quantitative easing. The unique Japanese experience of quantitative easing is the only experience which enables us to judge this therapy's effectiveness and the timing of the exit strategy. This paper provides a new empirical framework to examine the effectiveness of Japanese monetary policy during the "lost" decade and quantify the effect of quantitative easing on Japan's activity and prices. We combine advantages of Markov-Switching VAR methodology with those of factor analysis to establish two major findings. First, we show that the decisive change in regime occurred in two steps: it crept out from late 1995 and established itself durably in February 1999. Second, we show for the first time that quantitative easing was able not only to prevent further recession and deflation but also to provide considerable stimulation to both output and prices. If Japanese experience is any guide the quantitative easing policy must be seen as a symptomatic treatment; it must be accompanied with a dramatic restructuring in the financial framework. The exit from quantitative easing must be postponed and decided within a clear program and according to clear numerical objectives.

JEL Classification: C32; E52

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1. Introduction

The current financial crisis has now led most major central banks to rely covertly or overtly on quantitative easing. The unique Japanese experience of quantitative easing is the only experience which enables us to judge this therapy's effectiveness and determine the appropriate timing of the exit strategy. It is widely believed that during the "lost" decade in Japan, characterized both by stagnation and by deflation, monetary policy was all but impotent. Available academic work concludes that quantitative easing, based on flooding banks with base money, did not manage to stimulate activity or revive inflation. The empirical study of output and price effects of monetary policy using the workhorse in macroeconomic time series analysis, i.e. VARs (vector auto-regressive models), has been a very intensive area of research over the last decade (Sims *et al.* (1990), Sims and Zha (1998); Bagliano and Favero (1998)). Such work has usually put a lot of emphasis on the interest rate and the money transmission channel. However, in the case of Japan, since this traditional channel of monetary policy did not work any more, the transmission channels used by the QEMP to affect those macroeconomic variables need to be specified. Two transmission channels for the quantitative easing policy have been suggested. The first is the expectation channel, consisting of " policy duration" and "signaling effects", and the second is the portfolio rebalancing channel. On the other hand, instabilities in the transmission mechanism of monetary policy are very likely, particularly in the case of Japan. In a standard stochastic model, Orphanides and Wieland (2000) show that, when inflation is lower than one per cent, non-linearities in the transmission process of monetary policy arise solely from the presence of the zero bound on nominal interest rates. Indeed, these effects become increasingly important for determining the outcome of monetary policy in circumstances with such low inflation rates. On an empirical level, accounting for regime shifts should be a major concern when examining the transmission mechanisms of monetary policy. Our aim is to investigate the potential structural changes in transmission mechanisms of Japanese monetary policy. We will therefore allow for stochastic regime switching within a vector-autoregressive model.

Moreover, to conserve degrees of freedom, standard VARs rarely employ more than six to eight variables. This fact is particularly important in the case of a Markov-Switching (MS) VAR model when the number of estimated parameters rises very quickly if the number of variables is large or the lag length is long. Moreover, in reality policymakers work with an information set which contains many data series. Bernanke *et al.* (2005) show that lack of information in the VAR model leads to two related problems : (i) the less the central bank and private sector related information is reflected by the analysis the more the policy shock measure is biased. This leads to puzzles which characterize the traditional VAR model. (ii) impulse response functions are not sufficient to analyze the effects of monetary policy on general economic concepts like real economic activity or investment, which cannot be represented by one variable only. Factor analysis consists in summarizing a large number of data series to produce a small number of estimated factors. We suggest that a combination of factor-augmented and Markov Switching VAR models could be powerful since it enables us at the same time to introduce a realistic amount of information, keep the statistical advantages of using a parsimonious system, and take into account possible structural changes. Moreover, following Belviso and Milani (2006), we also attribute a clear economic interpretation to the factors, in a structural FAVAR (SFAVAR). Each estimated factor will represent one economic concept namely 'Real activity', 'Inflation' and 'Interest rates'.

The combination of these methodologies in a so-called MS-SFAVAR model allows us to establish two major findings. First we propose new empirical evidence supporting the ability of quantitative easing to provide stimulation to both output and prices. Given the uncertainties surrounding the measurement of output and prices during the great stagnation, using factor analysis to characterize these two macroeconomic concepts by summarizing a large number of variables errs on the side of caution. Second, proposing the first Markov-switching analysis of a SFAVAR, we are able to show that the decisive change in regime occurred in two steps: it crept out in late 1995 and established itself durably in 1999 around the time when the BOJ implemented QEMP. The impulse responses in the second regime should thus describe precisely the effect of this non-conventional strategy on output and prices. In addition, by contrast with previous work using MS-VARs (Fujiwara (2006)) non-neutrality of money and price divergence disappear with the MS-SFAVAR model. However, according to the Japanese experience, if the quantitative easing can affect the symptoms it cannot affect the causes of the Japanese disease such as the financial distress in the banking system and the excessive indebness of the corporate sector.

To conduct this analysis we will proceed as follows. Section 2 discusses the related literature. Section 3 presents some stylized facts on the Japanese economy and a brief review of the main transmission channels of QEMP. Next, the MS-SFAVAR model is described in section 4. The following two sections examine data and estimation results and conduct a range of robustness tests. Then Section 7 develops the implications of the paper's main results for management by the Fed of the global financial crisis generated by the burst of the United States housing bubble. Finally, section 8 concludes.

2. Related literature

Conclusions on the existence and the timing of the structural changes in Japanese monetary policy appear to be particularly sensitive to : i) the methodology employed, ii) the variables taken into account, especially the choice of the monetary policy instrument and iii) the period considered.

Kamada and Sugo (2006) adopt the VAR methodology to identify monetary policy shocks by imposing sign restriction on the impulse response functions. They use five variables, namely the CPI, industrial production, the nominal exchange rate, 10-year JGB yields, and a monetary policy proxy. On the other hand the authors use the Markov Chain Monte Carlo (MCMC) method to detect dates of possible structural changes between February 1978 and April 2005. The detected structural change point corresponds to the peak of the asset price bubble in 1990 and results from a change in VAR parameters. These authors show that during the post-bubble period the effect of monetary policy on prices and production weakened. Miyao (2000) estimates a four-variable VAR. His monthly data for the call rate, industrial production, the monetary base and the nominal effective exchange rates span the period between 1975 and 1998. The structural change point is imposed exogenously in 1995 by including dummy variables. Such a treatment of structural change is criticized by Sims and Zha (2006) who argue that structural changes must be treated endogenously where regimes are considered as stochastic events.

Fujiwara (2006) uses the Markov-switching methodology within a VAR framework (MS-VAR) with regime-dependent impulse response functions (Ehrmann *et al.* (2003)). He examines the period between 1985 and 2003 by including three and then four macroeconomic variables (industrial production, CPI, the monetary base and the 10-year JGB yield). This model represents the advantage of detecting regime changes without imposing a priori constraints on the timing of such changes. However, this analysis suffers from the non-neutrality of money and price divergence in the pre-stagnation regime. Moreover it does not uncover any output or price effect of base money shocks during the Great stagnation.

In the spirit of Fujiwara (2006), Inoue and Okimoto (2008) employ a MSVAR model with five variables, namely industrial production, the consumer price index, the monetary base, the call rate and the nominal effective exchange rate. The data span the period between 1975 and 2002. The monetary base and the call rate both account for the monetary policy instruments. Two regimes are identified. In the first regime the classical monetary instrument was effective until late 1995. In the second regime which started in 1996, after the interest rate fell almost to zero, the effectiveness of interest rate shocks collapsed. However, the monetary base in this regime has a positive and significant effect on output but a weak effect on prices. Mehrotra (2009) uses three variables in the estimation of an MSVAR, specifically output, inflation rate and call rate as a monetary instrument. Using data for the period between 1980 and 2003, he detects structural change in 1994. Mehrotra (2009) finds that monetary policy still has a moderate impact on output in the second regime but the inflation response displays a price puzzle and remains insignificant.

The common point of all these studies is that a limited set of variables is used in the analysis. In the present paper we apply the same methodology as Fujiwara (2006) and Inoue and Okimoto (2008) combined with factor analysis. The MS-SFAVAR represents an improvement with respect to the standard MS-VAR model since it does not suffer from the omitted-variable bias and allows a parsimonious system.

3. Quantitative Easing and its Transmission Channels

3.1. The Quantitative Easing Strategy

Since the beginning of the 1990s Japan has experienced a long slump in addition to a deflation activated by the burst of the financial bubble. In order to try and get out of this crisis, the bank of Japan (BOJ) began to cut rates, reducing the uncollateralized overnight call rate from 6 % in 1990 to 0.5 % in September 1995 and then maintained this rate at such level up to September 1998. Despite several short recovery phases the economy began to deteriorate again in 1998. The BOJ then successively decreased the call rate to a level very close to zero in 1999 and implemented the so-called Zero Interest Rate Policy (henceforth ZIRP) between April 1999 and August 2000. This policy seemed to generate the expected results ; the economy was recovering in mid-2000 and prices were stable. Therefore, the BOJ decided to stop the ZIRP in August 2000. However, the economy weakened in late 2000; output began to decline and deflation worsened in 2001.

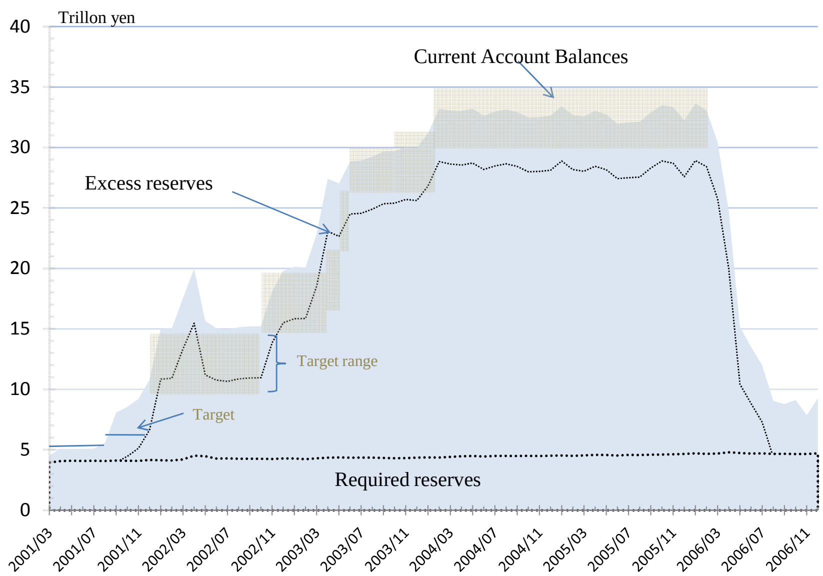
Under this economic environment the BOJ was pressured to adopt more aggressive monetary easing. The classical monetary policy instrument (the overnight call rate) did not work any more because it was almost equal to zero and subject to the non-negativity constraint on nominal short-term interest rates. Therefore, the BOJ decided to implement the so-called Quantitative Monetary Easing Policy (henceforth QMEP) in March 2001. The monetary policy instrument was thus changed to Current Account Balances (henceforth CAB) held by commercial banks with the Bank of Japan. The QMEP consisted in providing ample liquidity using the CAB as the main operating policy target. Figure 1 shows that at the introduction of QMEP the CAB increased to 5 trillion yen; a level 25% higher than the required reserve. The BOJ gradually raised the target nine more times between March 2001 and December 2004 to 35 trillion yen which is the upper target range. Over its five years of existence of the QMEP, excess reserves, which is the amount exceeding the required reserves of around 5 trillion yen, averaged 26 trillion yen. Long-term government bonds were the main category of assets bought to reach the quantitative target concerning current accounts[1]. Between August 2001 and October 2005 the amount of outright purchases of JGB was raised from 200 billion yen to 1.2 trillion yen per month, to reach 63 trillion yen. The range of assets bought by the BOJ was afterward widened to cover private assets held by private banks, asset-backed securities and asset-backed commercial paper. The purchase of the latter implied that the central bank granted credit directly to small and medium-sized firms.

3.2. Transmission Mechanisms of QEPM

Several factors limited the number of monetary policy transmission channels in Japan. First, because nominal interest rates were almost zero, real interest rates could only be affected by expected inflation. Consequently monetary policy using the traditional channel of the short-term interest rate was inoperative. Second, the collapse of the Japanese banking system prevented the activation of the credit channel. Indeed, bank lending declined during the period between 1999 and 2005 in spite of the ample liquidity provided to the banking system (Ito and Mishkin (2004)). Third, monetary policy could influence prices through changes in the value of the domestic currency in the foreign exchange market. This strategy, supported especially by Svensson (2003) was called the "foolproof way" to exit the deflation spiral. Monetary authorities were skeptical about this strategy which was criticized by Ito and Mishkin (2004) with respect to its implementation. Indeed, due to the prevalence of floating exchange rates it was not easy for Japanese authorities to follow Svensson's

[1] Maeda *et al.* (2005) provide an overview of the open market operations under the QEPM focusing on technical aspects.

Figure 1. Current Account Balance Targets



Source: Bank of Japan
Note: The monetary authorities had a target of about 5 trillion yen when quantitative easing began in March 2001, and a target of 6 trillion yen from August to December 2001. Such an increase in target corresponds to 20%. They raised it by about 100% to 10-15 trillion yen range in December 2001. They then lifted it to the 15–20 trillion yen range in March 2003 (40%) and the 30–35 trillion yen range in 2004 (11%). The legally required reserves during this period were on the order of 5 trillion yen.

suggestion. On the other hand, the implementation of an exchange rate peg could be a source of confusion between the nominal anchor, which is the price level, and the exchange rate. However, Ito and Mishkin (2004) and Ito and Yabu (2007) suggest that the BOJ can intervene in the foreign exchange market without announcing an exchange rate target. This intervention, being unsterilized, could help monetary authorities to gain credibility, sending a signal that the main objective remains the price level. Moreover, Girardin and Lyons (2008) show that the intervention of the BOJ, even thought it is fully sterilized through the issue of bonds, works through indirect channels. By means of a microstructure-based intervention model they document that BOJ interventions worked indirectly both by coordinating private trades in the same direction and damping the price impact of private traders. Therefore the hypothesis of exchange rate channel is valid but it is beyond the scope of our study. The transmission channels of QMEP are usually classified in two groups[2]: expectation effects, which consists of policy-duration and signaling effects, and portfolio-rebalancing effects. The expectation channel is strictly connected to the commitment to maintain a zero interest rate until core CPI inflation becomes zero or positive year-on-year. The policy-duration effect was suggested by Krugman (2000) and Eggertsson and Woodford (2003) in spite of the fact that their two points of view differ on operational measures. Several empirical studies[3] detect a significant effect of policy-duration through a flattening of the yeild curve. Nonetheless, more recently Nakajima *et al.* (2009) show that there is no evidence that this effect is transmitted to the real economy. Signaling effects are suggested by all of the three courses of action included in the QEMP. However, the most pronounced signal sent by the BOJ to the private sector is when it purchases long-term JGB's. In other words, the BOJ makes the commitment constraining because it will incur a capital loss when long-term interest rates increase. Surprisingly, Oda and Ueda (2007) detect a significant effect of this channel

[2]There are several possible way to classify transmission channels. See also Ugai (2007)
[3]See Oda and Ueda (2007) and Okina and Shiratsuka (2004)

from the increase in CABs but no effect from the increase in the long-term JGB purchases. The potfolio-rebalancing channel can work directly when the BOJ alters its asset composition or indirectly through the mechanism whereby the monetary base excess would lead the private sector to adjust its portfolio by buying financial non-monetary assets. Therefore, these asset prices rise and yields accordingly decrease. Kimura and Ugai (2003) and Oda and Ueda (2007) show that the effect of the rebalancing portfolio channel is insignificant or too small considering the extensive amount of the CAB expansion and the JGB purchases.

The BOJ committed itself to maintaining this policy until inflation (measured by the CPI excluding perishables) is stably positive. It predicted in March 2006 that inflation would remain positive and judged that the objective was reached and that it was time to exit the QEMP. Consequently, the BOJ returned to the traditional instrument, the overnight interest rate, as the operating target. Nevertheless, the efficacy of QEMP has not been definitively established empirically. We suggest below to evaluate the effects of such a policy on the real economy through the channels just cited.

4. Methodology

Several criticisms addressed to the VAR approach concerning the identification of the effects of monetary policy focus on the use of a restricted quantity of information. In order to conserve the degree of freedom, it is rare to use more than eight variables in a classical VAR model.

Bernanke *et al.* (2005) show that the lack of information, from which the VAR approach traditionally suffers, leads at least to two problems. First, taking into account only a small number of variables in the analysis biases the measures of the monetary policy shocks. The best illustrations of this problem are the price, interest rate, liquidity and exchange rate puzzles. Second, the impulse response functions are observed only for variables included in the model. The analysis thus cannot be done on global economic concepts like economic activity or productivity, which cannot be represented by a single variable. To remedy these problems, the authors proposed a combination between factor and VAR analysis. This approach allows us to summarize a large amount of information in a limited number of factors which will be used in the VAR model. Moreover, it avoids imprecision and possible biases in the estimates that arise from the fact that any one observable may be a poor measure of the relevant underlying concept.

However, in Bernanke *et al.* (2005)'s paper the factors do not have an immediate economic interpretation. Following Belviso and Milani (2006) we provide a structural interpretation to these factors. We seek to identify each factor as a basic force that governs the economy as 'real activity', 'price pressure', 'interest rates' and so on. We follow this literature and attempt to go a step further, seeking to take into account the possible existence of structural change in the monetary transmission mechanism. We therefore propose a Markov switching vector autoregression augmented with economically interpretable factors: we label this novel approach Markov Switching Structural Factor-Augmented VAR (MS-SFAVAR).

4.1. MS-SFAVAR

Let X_t and Y_t be two vectors of economic variables, with dimensions (Nx1) and (Mx1), where $t = 1, 2, ...T$ is a time index. X_t denotes the large dataset of economic variables and Y_t denotes the monetary policy instrument controlled by the central bank. We assume that variables in X_t are related to a vector F_t with (Kx1) unobservable factors, as follows :

$$X_t = BF_t + e_t \tag{4.1}$$

where e_t are errors with mean zero assumed to be either weakly correlated or uncorrelated; these can be interpreted as the idiosyncratic components. The $(N\text{x}K)$ vector Λ represents the factor loadings.

We can think of unobservable factors in terms of concepts such as "economic activity" or "price pressure". But here, following Belviso and Milani (2006) we divide X_t into various categories X_t^1, X_t^2, ... X_t^I which represent various economic concepts, where X_t^i is a $(N_i \text{X} 1)$ vector and $\sum_i N_i = N$. Each category of X_t^i is thus assumed to be represented by only one element of F_t^i which is a $(K_i \text{X} 1)$ vector ($\sum_i K_i = K$). That means that each variable in the vector X_t^i is influenced by the state of the economy only through the corresponding factors. Therefore, compared to the FAVAR model, the factors have more meaningful structural interpretations. Hence we obtain :

$$\begin{bmatrix} X_t^1 \\ X_t^2 \\ \dots \\ X_t^I \end{bmatrix} = \begin{bmatrix} \Lambda_1^f & 0 & \dots & 0 \\ 0 & \Lambda_2^f & \dots & 0 \\ \dots & \dots & \dots & \dots \\ 0 & 0 & 0 & \Lambda_I^f \end{bmatrix} \begin{bmatrix} F_t^1 \\ F_t^2 \\ \dots \\ F_t^I \end{bmatrix} + \begin{bmatrix} e_t^1 \\ e_t^2 \\ \dots \\ e_t^I \end{bmatrix} \tag{4.2}$$

In this analysis we assume that each segment of X_t^i can be explained by exactly one factor, that is $K_i = 1$ for all i. Also assume that the dynamics of $(Y_t, F_t^1, F_t^2, ..., F_t^I)$ is given by a factor-augmented autoregression (FAVAR):

$$\begin{bmatrix} F_t^1 \\ F_t^2 \\ \dots \\ F_t^I \\ Y_t \end{bmatrix} = \Phi(L) \begin{bmatrix} F_{t-1}^1 \\ F_{t-1}^2 \\ \dots \\ F_{t-1}^I \\ Y_{t-1} \end{bmatrix} + \nu_t \tag{4.3}$$

Consider the $(M+I)\text{X}1$ dimensional vector Z_t:

$$Z_t \begin{bmatrix} F_t^1 & F_t^2 & \dots & F_t^I & Y_t \end{bmatrix} \text{T} \tag{4.4}$$

A Markov-Switching structural factor-augmented VAR is represented by system (4.5). In its most popular version (Krolzig (1997)), which we will use here, the regime-switching model is based on the assumption that the process s_t is a first-order Markov process. Hamilton (1989), in his original specification, assumed that a change in regime corresponds to an immediate one-time jump in the process mean. We rather consider the possibility that the mean would smoothly approach a new level after the transition from one regime to another. We do it in an extension of Hamilton's approach to a regime-switching VAR system (Krolzig (1997)).

$$Z_t = \begin{cases} \alpha_1 + B_{11} Z_{t-1} + \dots + B_{p1} Z_{t-p} + A_1 u_t & if \quad s_t = 1 \\ \vdots \\ \alpha_m + B_{1m} Z_{t-1} + \dots + B_{pm} Z_{t-p} + A_m u_t & if \quad s_t = m \end{cases} \tag{4.5}$$

Each regime is characterized by an intercept α_i, autoregressive terms $B_{1i}, \dots, B_{pi}$ and a variance-covariance matrix A_i. We assume that m, the number of regimes, is equal to two. In this general specification all parameters are allowed to switch between regimes according to a hidden Markov chain[4]. With Markov-switching heteroscedasticity, the variance of errors can also differ between the two regimes. After the change in regime there is thus an immediate one-time jump in the variance of errors. This model is based on the assumption of varying processes according to the state of the economy controlled by the unobserved variable s_t. Here $s_t = \{1, 2\}$ is assumed to follow the discrete time and discrete state stochastic process of a hidden Markov chain and governed by transition probabilities $p_{i,j} = Pr(s_{t+1} = j | s_t = i)$, and $\sum_{j=1}^{2} p_{ij} = 1 \forall i, j \in (1, 2)$. The conditional probabilities are collected into a transition matrix P as follows:.

$$p = \begin{pmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{pmatrix} \tag{4.6}$$

[4]In the terminology of Krolzig (1997) this specification is an MSIAH(m)-VAR(p) model.

For a given parametric specification of the model, probabilities are assigned to the unobserved regimes conditional on the available information set which constitutes an optimal inference on the latent state of the economy. We thus obtain the probability of staying in a given regime when starting from that regime, as well as the probability of shifting to another regime. The classification of regimes and the dating algorithm used imply that every observation in the sample is assigned to one of the two regimes. We assign an observation to a specific regime when the smoothed probability of being in that regime is higher than one half. The smoothed probability of being in a given regime is computed by using all the observations in the sample.

4.2. Estimation

Our MS-SFAVAR approach retains the advantages of a FAVAR model over a simple VAR. Moreover, it allows us to take into account the instability of the monetary transmission mechanism. Factors estimated from the subset databases are the unobserved variables that, with the policy instrument, enter the MS-VAR (equation 4.5). To estimate the factors, the variables must be transformed to induce stationarity. By contrast the variables used in a VAR analysis do not need to be stationary. In the tradition of Sims *et al.* (1990), the specification of a VAR system that we use considers variables in levels[5]. In the case of such VARs with polynomial functions of time and one or more unit roots, Sims *et al.* (1990) show that, independently of the order of integration of the variables, one can get a consistent estimation of coefficients. An alternative route would consist in focusing on target variables such as the output gap rather than the level of output, and inflation rather than the price level. However, both would raise problems. In the case of Japan, the output gap is a loosely defined concept since there is much uncertainty as to the level of potential output (Kamada and Masuda (2001); and Bayoumi (2001)). Similarly, focusing on the rate of inflation would not seem adequate when examining a period of overall price stability. Mehrotra (2009) examines whether price-or inflation-targeting would be more adequate in the deflationary environment experienced by the Japanese economy. As Mehrotra (2007) and (2009) argue, movements in the price level seem to be the relevant variable of interest. All the more so, since the BOJ promised to keep its interest rate at zero until the CPI stabilizes at zero, in which case there is neither inflation nor deflation. Moreover, Fujiwara (2006) provides a succinct argument in support of a VAR estimation in level. He argues that the main purpose of a VAR analysis is to examine the inter-relationship among variable rather than to determine parameter estimates. Differencing, therefore, could miss important information about co-movement in the data. Consequently, we estimate model in levels using cumulated factors[6].

In this paper we consider a two-step approach to estimating 4.2-4.5. The first step consists in the estimation of the factors and factor loadings. The second step is the estimation of the MS-VAR using the factors.

4.2.1. Factor estimation

The main approach used for the estimation of factors consists in principal component analysis. However, as discussed by Belviso and Milani (2006), the factors thus estimated have unknown dynamic properties because principal components do not exploit the dynamics of the factors or the dynamics of the idiosyncratic component. Two standard principal approaches exploit these features to extract the static factors through dynamic principal components: the static principal components method proposed by Stock and Watson (2002) and the Generalized Dynamic Factor Model (GDFM) of Forni *et al.* (2005) that is a two-step approach based on dynamic principal components. The first approach is situated in

[5]Of course the cointegration relationship between variables was explored. Results of the VECM model in Appendix F show that there is no evidence supporting the existence of long term relationships between production, price, long term interest rate and monetary base. This can be explained by the fact that the money multiplier was no longer stable after 1990 and, as mentioned by Fujiwara (2006), there is a lack of evidence to support the presence of a M2 velocity cointegrating relationship after 1985.

[6]Examine the graphs of MS-VAR residuals to find out whether the residuals are well behaved seems reasonable. Non-stationarity of variables therefore does not impose problem with the estimation. In addition, by the means of bootstrap techniques we are able to have an interpretable statistic tests on regression parameters.

the time domain while the second is situated in the frequency domain. Both differ from static principal component analysis in that they allow for a possibility of autocorrelation between idiosyncratic components. Nonetheless, there are two main differences between Stock and Watson's (2002) method and that of FHLR in the way they estimate the space spanned by the factors. First, Stock and Watson's (2002) approach estimates the factors using the standard principal components based on a one-sided filter of the variables. But in the FHLR approach the common factors are estimated by exploiting information about the degree of commonality between all variables, obtained from covariance matrices of common and idiosyncratic components, estimated in a first step. Indeed, the variables are weighted according to their common and idiosyncratic variances. The variables having the highest common/idiosyncratic variance ratio (commonality) are selected. Since the weights are inversely proportional to the variance of the idiosyncratic components, this method provides more efficient estimates of common factors.

For the MS-SFAVAR approach employed in this paper, static factors are estimated by using the GDFM of Forni *et al.* (2005). Under the GDFM each variable can be written as the sum of two unobservable components:

$$x_{it} = \chi_{it} + \varepsilon it = b_{i1}(L)f_{1t} + b_{i2}(L)f_{2t} + \cdots + b_{iq}(L)f_{qt} + \varepsilon_{it} \tag{4.7}$$

where χ_{it} is the common component and $\varepsilon_t it$ the idiosyncratic component; $b_{i1}(L), \cdots, b_{iq}(L)$ $(i = 0, \cdots, s)$ represent the dynamic loadings of order s; $f_{1t}, \cdots, f_{qt}$ are the q dynamic factors. Equation 4.7 can be written in vector notation:

$$x_{it} = \chi_{it} + \varepsilon t = B(L)f_{qt} + \varepsilon it = BF_t + \varepsilon t \tag{4.8}$$

where $F_t = (f_t', \cdots, f_{t-s}')$ an $B = B(L)$. The number of static factors is equal to $r = q(s+1)$.

As noted above, this approach is a two-step process[7]. First, it uses a frequency representation of the time series proposed by Forni et al (2000a) to estimate the spectral density matrices of the common part ($\sum_n^\chi(\theta), -\pi \leq \theta < \pi$) and of the idiosyncratic part ($\sum_n^\varepsilon(\theta)$). Then, the covariance matrices of common and idiosyncratic components ($\widehat{\Gamma}_{n0}^\chi$ *and* $\widehat{\Gamma}_{n0}^\varepsilon$ respectively) are obtained by using the inverse Fourier transforms of the respective spectral density matrices. Second, by using estimated covariance matrices, eigenvalues and eigenvectors are estimated by solving the generalized principal components problem:

$$\begin{array}{c} \Gamma_{n0}^\chi V_{nj} = \widehat{\Gamma}_{n0}^\varepsilon V_{nj}\mu_{nj} \\ s.t. V_{nj}'\widehat{\Gamma}_{n0}^\varepsilon V_{nj} = I_r \end{array} \tag{4.9}$$

where the columns of the $(n\ x\ r)$ matrix V_{nj} correspond to the eigenvectors and μ_{nj} is a diagonal matrix containing the first largest eigenvalues of $\widehat{\Gamma}_{n0}^\chi$ *and* $\widehat{\Gamma}_{n0}^\varepsilon$ on its diagonal. The first generalized principal components are estimated as follows:

$$\widehat{F}_{nt}^j = V_{nj}'x_{nt} \tag{4.10}$$

The static factor loadings are defined as:

$$\left[(V_{nj}'\widehat{\Gamma}_{n0}^T)^{-1}\right]' V_{nj}'(\widehat{\Gamma}_{n0}^\chi)' \tag{4.11}$$

where $\widehat{\Gamma}_{n0}^T = \widehat{\Gamma}_{n0}^\chi + \widehat{\Gamma}_{n0}^\varepsilon$.

$\widehat{F}_{nt}^j$ are consistent estimates of the unknown common factors in equation 4.1.

4.2.2. MS-SFAVAR estimation

In the second step the model is estimated with the EM[8] (Expectation–Maximization) algorithm. Estimated factors are introduced in 4.5 instead of simple variables in a classical MS-VAR model.

[7]The representation theory of the dynamic factor model can be found in Forni *et al.* (2005)

[8]The estimation method, identification and impulse response are detailed in Ehrmann *et al.* (2003)

In a Markov-switching VAR, with regime-dependence in the mean, variance and autoregressive parameters, a large number of parameters can potentially switch between regimes. It is therefore often difficult to interpret the results of the estimation of such systems. Such a problem of interpretation is similar to the interpretation of parameters in simple VAR systems. Since the seminal work of Sims (1980), econometricians have traditionally imposed identifying restrictions on the parameters estimates. They then derive a structural form of the model based on economic intuition. This approach uses impulse response analysis in order to trace out how fundamental disturbances affect variables in the model. Ehrmann *et al.* (2003) suggested imposing similar identifying restrictions on Markov-switching models. They propose using regime-dependent impulse response functions in order to trace out how fundamental disturbances affect the variables in the model, dependent on the regime. As a result, there is a set of impulse response functions for each regime. Such response functions are conditional on a given regime prevailing at the time of the shock and throughout the duration of the response[9]. They facilitate the interpretation of switching parameters by providing a convenient way to summarize the information contained in the autoregressive parameters, variances and covariances of each regime. This approach combines Markov-switching and identification in a two-stage procedure of estimation and identification. First, a Markov-switching unrestricted VAR model is estimated, allowing means, intercepts, autoregressive parameters, variances and covariances to switch. Second, in order to identify the system, one can impose restrictions on the parameter estimates to derive a separate structural form for each regime, from which it is possible to compute the regime-dependent impulse response functions. Identification uses the Cholesky decomposition of the variance-covariance matrix. The confidence intervals around the impulse responses are computed by bootstrapping techniques (Ehrmann *et al.* (2003)).

5. Empirical Analysis

In the following, we report the results from the estimation of a MS-SFAVAR model on a data set including 3 sub-groups of factors, representing 3 economic concepts, and a monetary policy instrument. Our vector X_t contains 135 variables. Since we focus our empirical analysis on the quantitative easing period our sample spans the period between 1985 : 3 and 2006 : 03 at a monthly frequency. A full description of the database is provided in appendix B. The standard method to evaluate monetary policy through a VAR model is to consider the uncollateralized overnight call interest rate as the monetary policy instrument. In the special case of Japan, where interest rates were almost zero, this method cannot be applied, because interest rates contained no more information concerning monetary policy. Theoretical work investigated alternative variables, so-called intermediate variables, which are not directly controlled by the central bank. These variables can be the long-term interest rate, the exchange rate, the interest rate spread and a monetary policy proxy (Kamada and Sugo (2006)). Nevertheless, intermediate variables can be inconvenient as far as they can react to their own shocks, thereby complicating the identification of monetary policy shocks. In this paper, we use the monetary base[10] as the monetary policy instrument to measure the effects of the quantitative easing policy in Japan. The monetary base thus represents the only observed factor included in Y_t.

5.1. Estimated Structural Factors

Since subsets of similar variables are considered to extract factors, the comovement observed in these macroeconomic time series should be strong. A small number of factors therefore account for a relevant percentage of

[9]As shown by Ehrmann *et al.* (2003) regimes predicted by the transmission matrix must be highly persistent in order to have useful regime dependent impulse functions.

[10]The seasonally adjusted M0 was corrected for the Y2K effect related to the temporary surge in liquidity demand in December 1999 and January 2000. As argued in Juselius (2006) transitory shocks in the model generate residual autocorrelations and violate the independence assumption of the VAR model. As the Y2K effect appears as additive outliers we removed it by estimating an ARMA model with transitory intervention dummies (see figure A.2 in appendix A.)

Table 1. Eigenvalues and percent of variance of first four factors

Activity factors				
	F1[a]	F2	F3	F4
Eigenvalue	1.73	1.12	0.23	0.14
Percent variance	34.04	8.44	4.87	4.02
Price factors				
Eigenvalue	2.04	0.87	0.57	.34
Percent variance	59.39	21.52	9.63	5.85
Interest rate factors				
Eigenvalue	2.37	0.76	0.43	0.32
Percent variance	97.18	1.36	0.62	0.27

[a] $F_i, (i = 1...4)$ denotes i –th factor.

the overall panel variance. The first obvious check of the fit of our factor model is to see how well each factor represents each sub-group of data series. In particular we examine the assumption according to which every sub-group is represented by only one factor. Following Bernanke *et al.* (2005)and Belviso and Milani (2006), the number of static and dynamic factors are determined in an ad hoc way. The statistic criterion, using the percentage of the variance of the panel accounted for by common factors, describes comovements among series but does not determine the number of factors to include in the MS-FAVAR model. In addition, the number of parameters to estimate in the models depends on the number of variables, lags and states and can quickly be explosive. We then extract one factor from each sub-group in order to employ the more parsimonious system. Table 1 gives the results on the relative importance of the first four factors in explaining the variance of all variables. The first factor explains about 34, 59 and 97 percent of the data variability respectively for activity, prices, and interest rates. Even when an additional factor is added, there is relatively little gain in the share of variance explained. This confirms the robustness of our assumption considering only one factor for each sub-group. Figure A.1 illustrates the estimated loadings plotted as bar charts for each factor. The numbers on the horizontal axis refer to the ordering of the series of each subgroup and the factor loadings are on the vertical axis. The interest rate factor loadings are high (0.6 or higher), while price and activity factor loadings have a lower level for some variables. This is due to the fact that activity and price variables are more heterogeneous than interest rates. Nonetheless, it appears that all variables are involved in constructing the factors since loadings are spread across all series. Furthermore, Figures C.1, C.2 and C.3 in Appendix C show that cumulative factors clearly represent the corresponding variables in level.

5.2. *Traditional MS-VAR*

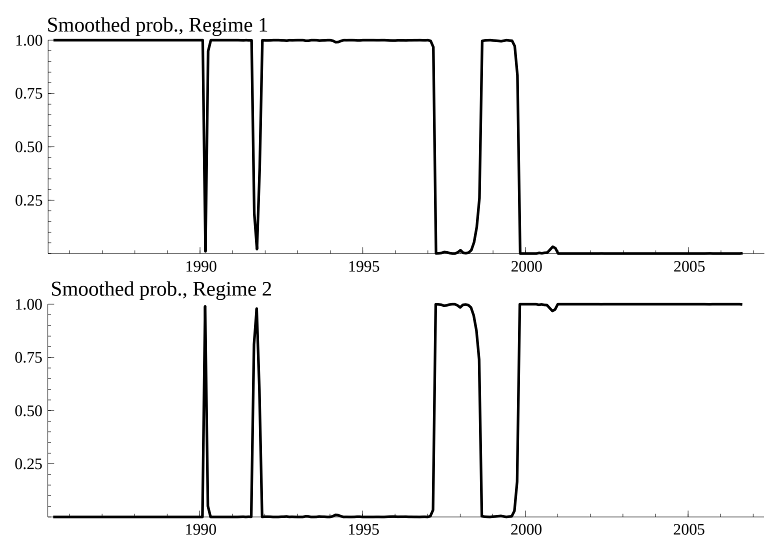
We first evaluate Japanese monetary policy using the MS-VAR model following Fujiwara (2006) with four observed variables namely output y, the price level p, the money stock m and the 10-years JGB yields l, but using a longer sample. First and foremost, we need to determine the optimum number of regimes to characterize the behavior of the time series studied. Second, the best specification among various MS-VAR models has to be determined.

We tested for linearity by taking the linear model as the null hypothesis (there is a single regime) and the two-regime-switching model as the alternative. In this case the usual tests, namely LR tests, LM and Walds tests, cannot be conducted since the nuisance parameter is identified only under the alternative. The problem of statistical inference when the nuisance parameters are unidentified under the null hypothesis has frequently been addressed. Hansen (1992) and Garcia (1998) propose a non-standard likelihood ratio test (NSLR) which is calculated as a correction on the p-value of a standard likelihood ratio test. However, this method does not give exact critical values but only a lower bound for the limiting distribution of a standard LR statistic and is not developed for VAR models but for a univariate process. Since the null parameter space contains only two subsets, Cho and White (2007) show that the NSLR test is not valid if boundary conditions are ignored. Moreover, Cho and White (2007)'s test (QLR) is only applicable on specific models which do not include the MSVAR. In this paper we therefore use other tests like the Log-likelihood or information criteria. The null hypothesis can easily be rejected as shown in Table D.1 in Appendix D. Moreover, the plots[11] of the nonlinear model estimation residuals indicate the absence of residual autoregression and almost all of the standardized residuals fall within two standard deviations of a zero mean. The two-regime model is therefore supported.

Next, the best specification among various MS-VAR models has to be identified. In this case the LR test suggested by Krolzig (1997) can be performed without causing problems. The alternative hypothesis MSIAH-VAR specification, where all parameters switch between regimes, is tested against the other possible specifications. We then test the hypothesis of no regime dependence in the variance–covariance matrix (MSIA-VAR), in autoregressive terms (MSIH-VAR) and in both the variance–covariance matrix and autoregressive terms (MSI-VAR) for different lags.

The likelihood ratio test (Appendix D, TableD.2) suggests that an MSIAH-VAR model better fits the data than other MSI-VAR specifications for two and three lags. Consequently, this study applies the Markov switching MSIAH-VAR model in which intercepts, autoregressive terms and variance-covariance matrices are allowed to switch between regimes. The lag length of two is chosen in order to have serially-uncorrelated residuals. This lag length is supported by AIC and HQ criteria (Appendix D, TableD.3). Moreover, according to Table D.4 in Appendix D, showing the transition matrix, the two-regimes are highly persistent. Regime dependent impulse responses are therefore an useful tool to analyze the monetary policy of Japan. Figure 2 plots smoothed regime probabilities. The Japanese economy was in regime one up to

Figure 2. Regime probabilities for MSIAH-VAR



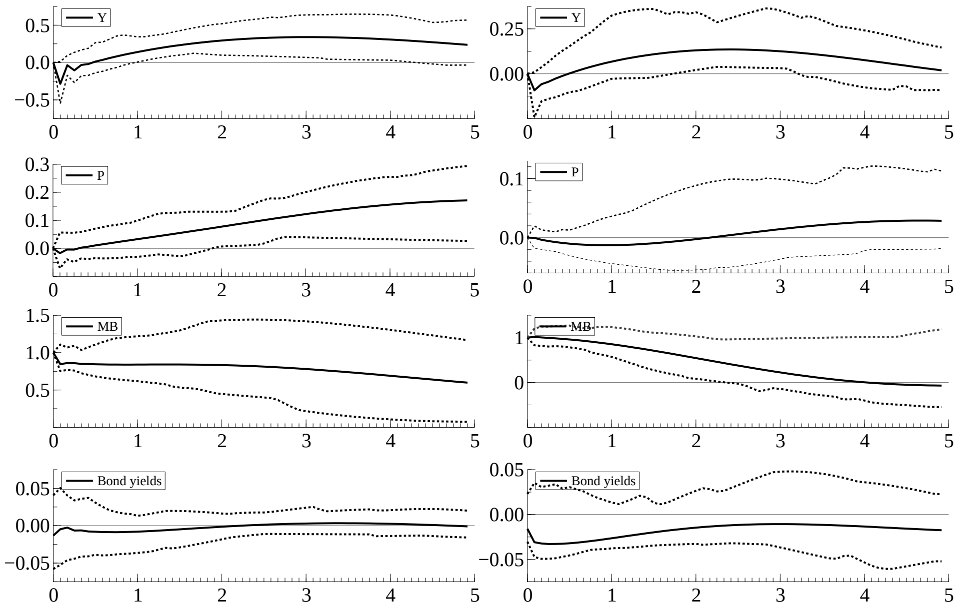
1997 and has been in regime two since then, with an advanced warning in 1997 and early 1998. This result is similar to that of Fujiwara (2006); the 2000 break date coincides neither with the beginning of ZIRP or QEMP, but lies in-between..

The stylized facts on the effects of an expansionary monetary base shock were established by Christiano *et al.* (1998), using impulse response functions. They conclude that plausible models of the transmission mechanism of a monetary

[11]Plots are not reported here in order to conserve space and are available upon request from authors.

expansion should be consistent at least with the following evidence on price, output and interest rate : *i*) the aggregate price level initially responds very little, *ii*) output initially rises, with an inverted j-shaped response, with a zero long-run effect of the monetary impulse, and *iii*) interest rates initially fall. Figure 3 presents the impulse response functions to a positive

Figure 3. Response to a monetary base shock in MS-VAR, regime 1 (left) and regime 2 (right).



Note: The impulse reaction period is chosen to be 5 years. Solid lines show impulse responses, while dotted lines represent confidence intervals using the 10th and 90th percentile values calculated on the basis of 999 bootstrap replications. We refer to Davidson and MacKinnon (2001) who considered the problem of choosing the number of bootstrap replications.

shock on the monetary base. Over the 1985-2000 period points *i*) and *iii*) are almost matched, while understandably, *ii*) does not hold. The non-neutrality of money and the divergence of prices after a shock on the monetary base are striking. Indeed, output responds immediately in a persistent way, while adjustment in prices takes more than twice as long. The 2000-2006 regime is characterized by insignificant effects of monetary base shocks on output and no price response. Evaluating the reaction of interest rates reveals important results. In regime one the response of the interest rate is negative but insignificant. In the regime two the reaction of bond yields is more substantial but remains insignificant. A look at the interest-rates reaction reveals that policy-duration and signaling effects could affect prices in the expected way, even though they remain weak. There is thus little evidence that the transmission mechanism of Japanese monetary policy at a time of near-zero interest rates would work essentially through the effects on the term-structure of interest rates.

5.3. MS-SFAVAR

In the following, we present the estimated effects of the QEMP within the aforementioned specifications of model 4.5. Since we identify monetary shocks by using the Cholesky decomposition, the factor ordering must be determined carefully. The interest rate factor includes several long-term rates that contain expectations on the economy. Because the monetary authorities can react only to the current state of the economy, the interest rate factor is ordered after the monetary base. We consider therefore the following ordering of factors : real activity factor, prices factor, monetary base and interest rate factors. Information criteria (Appendix E, TableE.1) suggest that the model is non-linear.

From table E.2 and table E.3 in Appendix E, an MSIAH-SFAVAR specification is suggested by the LR test and the lag length supported by two information criteria is two. The transition matrix (Appendix E, Table E.4) implies that the regimes are highly persistent. As shown in Figure 4, the change in regime occurred in two steps: it first appeared in May 1996 and established itself durably in February 1999. Regime two thus corresponds precisely with the beginning of the non-conventional monetary policy strategy namely the ZIRP consolidated by the QEMP.

Figure 4. Regime probabilities for MS-SFAVAR

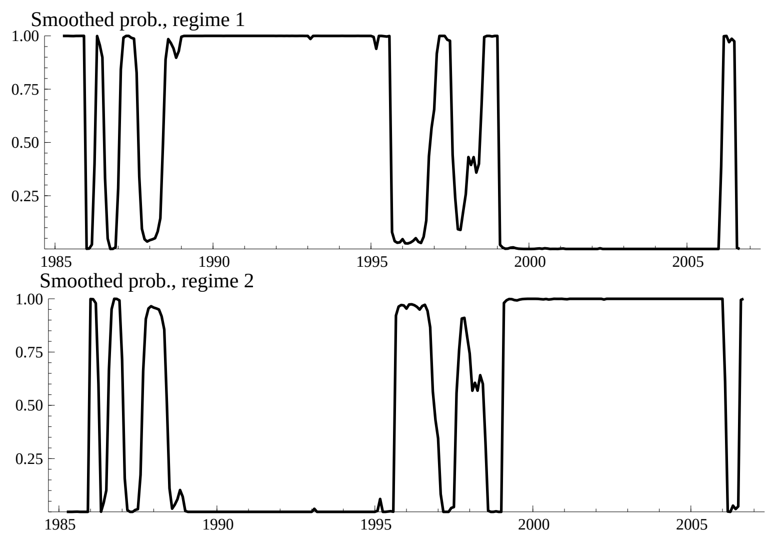
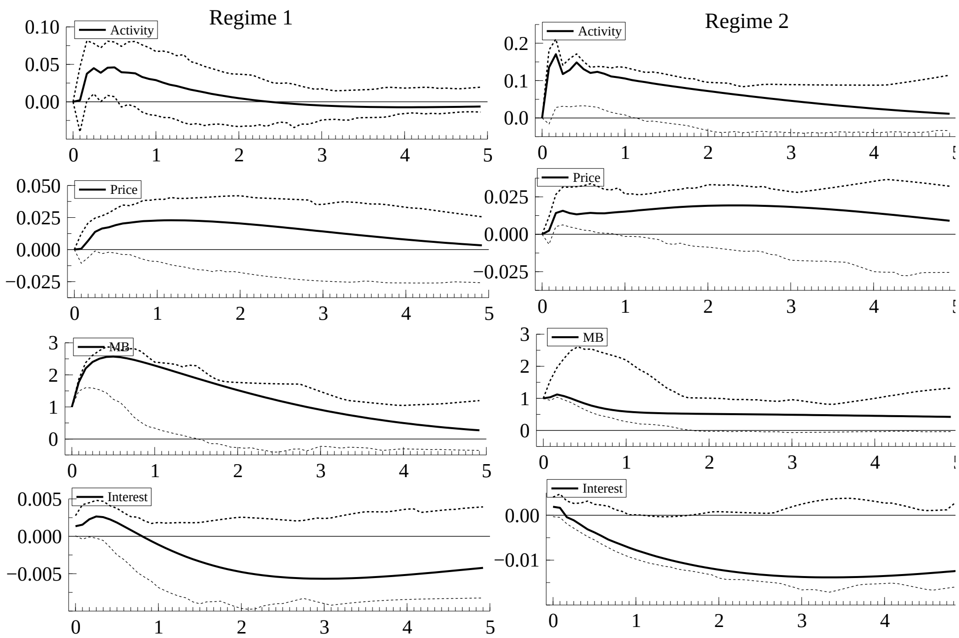


Figure 5 shows that, unlike in a classical MS-VAR, the stylized facts aforementioned are verified in all points in both regimes. By contrast with Fujiwara (2006), Kamada and Sugo (2006) and Kimura, Kobayashi, Muranaga and Ugai (2003) we detect a positive and significant effect on real activity even in the second regime under QEMP. In the pre-1996 regime, the response of the output factor is moderate and short lived, while the response of the price factor is half as large, as quick, but hardly significant. Under the second regime, after its initial rise the monetary base subsequently falls smoothly towards its initial level; within eight months approximately half of the initial innovation has disappeared. The response of the output factor is three times as large as under the first regime, and fifty percent longer-lived. The 90% confidence interval indicates that the effect lasts significantly for thirteen months. The peak increase is found within 6 months. The monetary shock is equivalent to a 1% increase in the monetary base. For reference, the total stock of CABs was about 4.6 trillion yen in the beginning of regime two, so an increase of 1% would represent 46 billion yen. It leads to an increase of real activity by about 0.15%, 0.1% after six months and one year, respectively. Even though this effect becomes insignificant at the end of the first year it shows that a passive monetary policy would make the recession more severe. Therefore, the quantitative easing would have at least prevented a further fall in output. Moreover, The magnitude and duration of this estimated effect seem small in absolute terms. However, the considerable successive increases in CABs, by 25%, 20%, 100% and so on, would have caused a sizable rise in Japan's activity respectively by about 3.75%, 3% and 15% after six months. However, the response of output remains short-lived, it veers to be insignificant from the end of the first year. The response of the price factor, while slightly smaller is much longer-lived (up to nine months) than under the pre-1996 regime. The impulse responses indicate that a 1% increase in the monetary base results in a cumulative 0.05% rise in prices over 5 years. As compared to the standard MS-VAR, it is possible to see the contribution of the information contained in the factors and it

Figure 5. Response to a monetary base shock in MS-SFAVAR



Note: The impulse reaction period is chosen to be 5 years. Solid lines show impulse responses, while dotted lines represent confidence intervals using the 10th and 90th percentile values calculated on the basis of 999 bootstrap replications.

is then noteworthy that the non-neutrality of money and the price divergence in the pre-1996 regime, which characterized the MS-VAR model, disappear with the MS-FAVAR. From the viewpoint of the liquidity premium, the significance of the output effect tends to imply that, at near-zero interest rates, base money and financial assets are not perfect substitutes. Portfolio rebalancing could therefore stimulate the economy. In other words, an increase in the monetary base reduces the liquidity premium and leads economic agents to adjust their portfolios away from the monetary base to financial assets, stimulating investment. The positive effect on prices is more substantial in regime one than in regime two. Policy-duration and signaling effects seem to be stronger on short to medium-term interest rates in regime two than under regime one. The decline in the interest rate factor becomes significant with a delay of one year. However, the positive effect of this expectation channel remains small since the response of the interest rate factor veers to be insignificant from the beginning of the second year.

In summary, our results indicate that the quantitative easing policy not only prevented further recession and deflation but also had a relevant role stimulating real activity and prices in the short to medium run.

6. Robustness

Our results are based on the four variables which are arranged in order of output, price, monetary base and long term interest rate. To check the robustness of the reported results, we estimated two additional types of models, price-output–monetary base–bond yields and output–price–monetary base. The three variables model was previously estimated by Fujiwara (2006). Neither the change in the ordering of variables (and factors) nor the exclusion of bond yields change the dominance of the MSIAH-VAR specification. The timing of regime change in the model price-output–monetary base–bond yields is similar to that found in the model reported here. However, the exclusion of bond yields (and interest rate factor) changed the timing of regimes for both the MS-VAR and MS-SFAVAR but not in a significant way. The results obtained from all models are qualitatively similar to the results presented in the previous section. Under the traditional MS-VAR all models indicate that the output and price reactions to a positive shock on the monetary base are positive and significant during regime one. The effectiveness of monetary base shocks greatly diminishes during the second regime. In the MS-SFAVAR the additional models confirm our basic finding that monetary base shocks still have a positive effect on output and price even during the second regime. Moreover, we applied the method proposed by Stock and Watson (2002) to estimate static factors. The results obtained from the MS-SFAVAR using these factors are very similar to those of using Forni *et al.* (2005) methodology. Thus, our basic findings remain unaltered even if we include static factors in the estimation.

7. Implications and Discussion

The attempt to fight the effects of the global crisis generated by a credit boom built around the subprime-bubble has led most major central banks to rely covertly or overtly on quantitative easing. In January 2009[12] the Fed explicitly announced the adoption of quantitative easing. In order to draw lessons from the unique experience of quantitative easing in Japan, a comparison between the quantitative easing programs implemented by the Fed and the BOJ is useful. Differences between the two experiences can be classified into two categories: those that are related to the preconditions for implementation and those that are related to the implementation of the quantitative easing itself.

With respect to preconditions, the Japanese experience demonstrates that quantitative easing should be seen as a symptomatic treatment which stimulates activity and prices. It was preceded by a treatment that addressed the cause of the problems of the Japanese economy and it is note-worthy that the quantitative easing policy was adopted in Japan after a dramatic change in the financial framework dealing with financial distress. Cargill *et al.* (2000) investigate changes in the Japanese financial system and the BOJ's evolution since the early nineties. They argue that the smooth implementation of the big-bang announcements succeeded in establishing an infrastructure[13] for the resolution of bank failures. These change in the regulatory environment were combined by a commitment of 60 trillion yens (roughly 460 billion US$) to clean up banks' balance sheets. This has not been completely achieved yet for the American and European financial systems. In addition, the US Department of Treasury announced only 30 billion US$ to remove 'toxic' assets from banks' balance sheets, an intervention which seems insufficient, considering the size of the current crisis and the Japanese experience.

As regards the implementation itself, the BOJ and the Fed used different approaches. One principal difference is related to the timing; it took 10 years after the bubble burst in Japan to take on quantitative easing, while the Fed rapidly adopted this strategy, just one year after the USA entered into financial crisis in 2007. The Fed therefore was more reactive. The second difference concerns the total amount of CABs devoted to this strategy. After only one year the increase in the reserves held by banks with the Fed, roughly 8% of GDP, now exceeds the level reached by those with the BOJ during the five years of quantitative easing, between 2001 and 2006 (6% of GDP). The BOJ had also a commitment to a clear numerical target for inflation and a fixed 5-year timetable. In contrast, the Fed prefered flexibility. This left out the advantage of a clear commitment which reduces uncertainties and allows for better control of inflation expectations.

To continue the comparison, the US and Japanese experiences have one aspect in common: the currency carry trade. The carry trade strategies consist of investing at short-term horizons by borrowing funds from banks in a low-interest rate currency and investing it in a currency with higher interest rate. The foreign offices of American global banks account for

[12] The Fed has boosted its balance sheet to US$ 2.04 trillion from US$ 946 billion in September 2008. For more details see "Credit and Liquidity Programs and the Balance Sheet".

[13] The establishment of the Financial Supervisory Agency and the Financial Reconstruction committee in June and October 1998 respectively should provide more transparent reporting of nonperforming loans and more direct control over managing the financial crisis.

most of the yen carry trade (Hattori and Shin (2007)). Between 2004 and 2006, when the Fed raised its interest rates, the Japan branches of foreign banks lent yens to their branches outside Japan to take advantage of low Japanese interest rates and thus higher returns. During the current crisis, the Fed has encountered the dollar carry trade. This carry strategy might have an impact on the transmission mechanism of quantitative easing.

This comparison is even more important now that the Fed is discussing exit strategies. One issue involves choosing between increasing either short-term or long term interest rates. Assuming the fed raises short-term rates, it would face the decision of whether or not to reduce the excess reserves in the banking system. If the decision were taken to reduce excess reserves, the magnitude and timing of such a reduction would need to be considered. A similar debate occurred within the BOJ in late 2004, at the end of the series of increases in the CABs. The BOJ chose raising short-term rate in the end of quantitative program while CABs were being sharply reduced prior to this.

Moreover, the Japanese experience suggests that efforts to clean up bank's balance sheets significantly improved the effectiveness of quantitative easing. However, this effect, although considerable, is short-lived; it turns insignificant after one year. The short duration of this effect should be borne in mind by the fed, which has already been conducting its quantitative easing for one year. Indeed, the benefits of quantitative easing could still be exploited although they might not last long, motivating a continuation of liquidity creation by the Fed, possibly with caution. In the light of the Japanese experience, we argue that, in spite of the immediate reaction and the huge amount of CABs employed, which may help solve short-term liquidity pressures in the financial system, the Fed would be better off postponing its exit from quantitative easing. This should be decided according to a clear timetable and clear numerical objectives, not only about GDP's growth rate but also related to the preconditions discussed above. Quantitative easing is no substitute for efforts to restore the financial system to health. This would allow the Fed to better control the private sector inflation expectations and deal with the origin of this crisis.

8. Conclusion

During the Great Stagnation in Japan, academic economists almost unanimously recommended that, under a liquidity trap, the only way for monetary authorities to try to revive the economy was to force-feed banks with base money. In this paper we propose an SFAVAR approach combined with a Markov-Switching method in order to analyze the effectiveness of this Japanese monetary policy. We implement a two-step approach. First, structural factors are estimated from subset databases representing different economic concepts. Second, a Markov-switching model is estimated.

Two main conclusions can be drawn from this work. First, we show for the first time that when the Bank of Japan did start to follow this advice, through its quantitative easing policy, this strategy was effective in reviving output and price inflation. However, the effect of quantitative easing is short-lived: it lasts only one year. This transient effect, even when sizable, bears out the hypothesis that quantitative easing must be seen as a symptomatic treatment. Recession and deflation are the symptoms and not the sources of the disease of the Japanese economy. Therefore quantitative easing needs to be coupled with the necessary restructuring in the financial system. Our results contrast with almost all available empirical evidence on the effects of this policy. The contrast does not stem from our use of regime-switching analysis, but rather from our use of factor analysis in order to account for the myriad of variables which may have been interacting under this new monetary policy of the BOJ. Second, in contrast to the MS-VAR approach, our MS-SFAVAR allowed us to detect changes in monetary policy mechanisms in a reliable way; structural change occurred in February 1999 after a period of transition starting in May 1995. In addition, our results show that the non-neutrality of money and the price divergence in the pre-1995 regime, which characterized the MS-VAR model, disappear with the MS-SFAVAR. Results presented here thus confirm the idea that exploiting a larger and more realistic information set proves a more reliable way to model monetary policy behavior. Our conclusion is that quantitative easing, coupled with financial reforms could have positive effects on the economy. However, the Japanese experience suggests that we should not expect quantitative easing to deal with this serious crisis in the short term, since it takes time to prove its effectiveness.

In future work, we plan to use this approach to investigate in detail the transmission mechanisms of Japanese monetary policy. The Interest rate factor seems to be operative and responsible for monetary policy influence. However, this factor can be affected both by=the expectation and the portfolio rebalancing channels suggested by the QEMP. It will therefore be interesting to determine to what degree each factor affects every transmission channel. On the other hand, we did not consider the international mechanism of monetary policy transmission. Our future research will also focus on examining the implication of the currency carry trade strategies on the effectiveness of quantitative easing.

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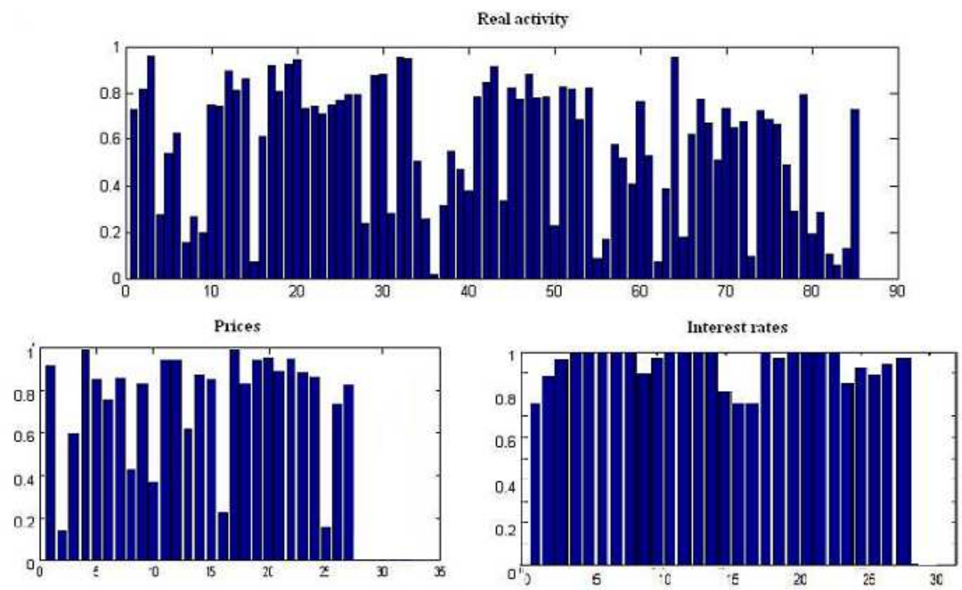
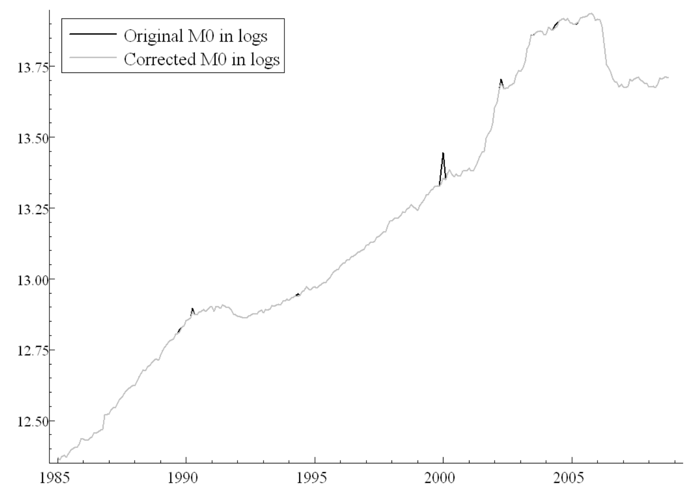
A. - Factor loadings

Figure A.1. Estimated factor loadings



Note: The loadings are spread across many series. The numbers on the horizontal axis refer to the ordering of the series of each subgroup and correlations between the variables and the first factors (factor loadings) are on the vertical axis.

Figure A.2. The original and corrected M0



Source: Bank of Japan
Note: The monetary base (M0) is corrected for the Y2K effect when the BOJ had provided an exceptionally large amount of funds in the market.

B. - Data description

Table B.1. **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.

N°	Description	T
	Real activity factor	
1	Industrial Production Total Index	5
2	Production, Capital goods, SA, Index	5
3	Production, Ceramics, stone and clay products, SA, Index	5
4	Production, Chemicals, SA, Index	5
5	Production, Construction goods, SA, Index	5
6	Production, Consumer goods, SA, Index	5
7	Production, Domestic vehicle, total	5
8	Production, Durable consumer goods, SA, Index	5
9	Production, Fabricated metals, SA, Index	5
10	Production, Food and tobacco, SA, Index	5
11	Production, General machinery, SA, Index	5
12	Production, Iron and steel, SA, Index	5
13	Production, Manufacturing, SA, Index	5
14	Production, Mining and manufacturing, SA, Index	5
15	Production, Non-durable consumer goods, SA, Index	5
16	Production, Non-ferrous metals, SA, Index	5

17	Production, Other manufacturing, SA, Index	5
18	Production, Petroleum and coal products, SA, Index	5
19	Production, Plastic products, SA, Index	5
20	Production, Precision instruments, SA, Index	5
21	Production, Producer goods, SA, Index	5
22	Production, Pulp, paper and paper products, SA, Index	5
23	Production, Semiconductor devices, SA, Index	5
24	Production, Textiles, SA, Index	5
25	Production, Transport equipment, SA, Index	5
26	Shipments, Capital goods excl transport equipment, SA, Index	5
27	Shipments, Capital goods, SA, Index	5
28	Shipments, Construction goods, SA, Index	5
29	Shipments, Consumer goods, SA, Index	5
30	Shipments, Durable consumer goods, SA, Index	5
31	Shipments, Mining and manufacturing, Index	5
32	Shipments, Mining and manufacturing, Index	5
33	Shipments, Non-durable consumer goods, Index	5
34	Shipments, Producer goods total, Index	5
35	Shipments, Producer goods, for mining and manufacturing, Index	5
36	Shipments, Producer goods, for others, Index	5
37	Capacity Utilization, Operation Ratio, Fabricated metals, Index	5
38	Capacity Utilization, Operation Ratio, General machinery, Index	5
39	Capacity Utilization, Operation Ratio, Iron and steel, Index	5
40	Capacity Utilization, Operation Ratio, Machinery industry, Index	5
41	Capacity Utilization, Operation Ratio, Manufacturing excluding machinery industry, Index	5
42	Capacity Utilization, Operation Ratio, Manufacturing, Index	5
43	Capacity Utilization, Operation Ratio, Petroleum and coal products, Index	5
44	Capacity Utilization, Operation Ratio, Pulp, paper and paper products, Index	5
45	Capacity Utilization, Operation Ratio, Textiles, Index	5
46	Capacity Utilization, Operation Ratio, Petroleum chemicals products, Index	5
47	Capacity Utilization, Operation Ratio, Rubber products, Index	5
48	Capacity Utilization, Operation Ratio, Transport equipment, Index	5
49	Hours Worked, Average Per Month, Electricity, gas, heat and water	1
50	Hours Worked, Average Per Month, Manufacturing	1
51	Hours Worked, Average Per Month, Mining	1
52	Unemployment, Rate	1
53	Labour Productivity, Foodstuff and tobacco (30 employees or more), Index	5
54	Labour Productivity, Furniture (30 employees or more), Index	5
55	Labour Productivity, Manufacturing (30 employees or more), Index	5
56	Labour Productivity, Textiles (30 employees or more), Index	5
57	Employment, Overall, Total	5
58	Sales at Deapartement Stores (Total)	5

59	Wholesale Trade, Food and beverages, JPY	5
60	Wholesale Trade, Furniture and house furnishing, JPY	5
61	Wholesale Trade, General merchandise, JPY	5
62	Wholesale Trade, Machinery and equipment, JPY	5
63	Wholesale Trade, Minerals and metals, JPY	5
64	Wholesale Trade, Others, JPY	5
65	Wholesale Trade, Textiles, JPY	5
66	Wholesale Trade, Total, JPY	5
67	Housing Starts, Housing built for sale	4
68	Housing Starts, Private homes	4
69	Housing Starts, Rental homes	4
70	Housing Starts, Total	4
71	Inventory Mining and manufacturing, Index, JPY, 2000=100	5
72	Inventory Construction goods, Index, JPY, 2000=100	5
73	Inventory Capital goods, Index, JPY, 2000=100	5
74	Inventory Durable consumer goods, Index, JPY, 2000=100	5
75	Inventory Non-durable consumer goods, Index, JPY, 2000=100	5
76	Inventory Consumer goods, Index, JPY, 2000=100	5
77	Inventory Producer goods, Index	5
78	New Orders, Construction, State organizations	5
79	New Orders, Construction, Total, big 50 constructors	5
80	New Orders, Construction, Works abroad	5
81	New Orders, Construction, Works executed	5
82	New Orders, Construction, Works yet to be executed	5
83	New Orders, Machine Tools, Total demand	5

Price factor

84	Japan, Consumer Prices, Nationwide, All Items, General, Index, JPY, 2000=100	5
85	Japan, Consumer Prices, Industrial products,All, Index, JPY, 2000=100	5
86	Japan, Consumer Prices, Industrial products,Textile, Index, JPY, 2000=100	5
87	Japan, Consumer Prices, Electricity, gas & water charges , Index, JPY, 2000=100	5
88	Japan, Consumer Prices, Services , Index, JPY, 2000=100	5
89	Japan, Consumer Prices, Durable goods , Index, JPY, 2000=100	5
90	Japan, Consumer Prices, Non Durable goods , Index, JPY, 2000=100	5
91	Japan, Consumer Prices, Food , Index, JPY, 2000=100	5
92	Japan, Consumer Prices, Reading and Recreation , Index, JPY, 2000=100	5
93	Japan, Consumer Prices, Reading and Recreation, Recreational durables , Index, JPY, 2000=100	5
94	Japan, Consumer Prices, Reading and Recreation, Recreational goods , Index, JPY, 2000=100	5
95	Japan, Consumer Prices, Reading and Recreation, Recreational Services , Index, JPY, 2000=100	5
96	Japan, Consumer Prices, Nationwide, Clothing and Footwear, Hats and caps, Index, JPY, 2000=100	5
97	Japan, Consumer Prices, Nationwide, All Items, General excluding imputed rent, Index, JPY, 2000=100	5
98	Japan, Consumer Prices, Nationwide, Miscellaneous Goods and Services, Durable goods, Index, JPY, 2000=100	5
99	Japan, Consumer Prices, Nationwide, Transport, Private transportation, Index, JPY, 2000=100	5

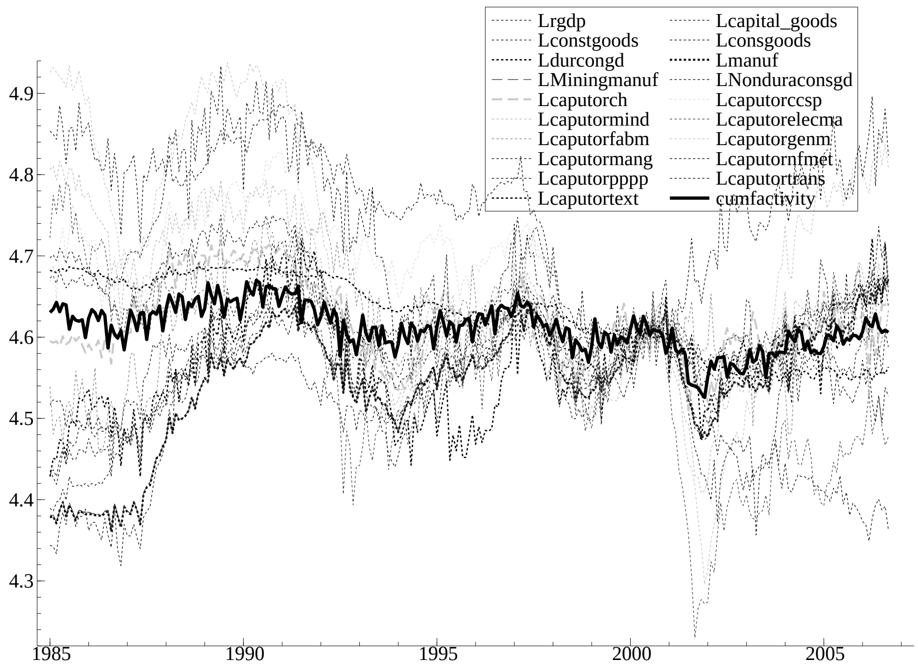
100	Japan, Consumer Prices, Nationwide, Transport, Public transportation, Index, JPY, 2000=100	5
101	Japan, Consumer Prices, Nationwide, Communication, Communication, Index, JPY, 2000=100	5
102	Japan, Corporate Goods Prices, Domestic demand products, nondurable consumer goods, Index, JPY, 2000=100	5
103	Japan, Corporate Goods Prices, Domestic demand products, total, Index, JPY, 2000=100	5
104	Japan, Corporate Goods Prices, Domestic, capital goods, Index, JPY, 2000=100	5
105	Japan, Corporate Goods Prices, Domestic, chemicals, Index, JPY, 2000=100	5
106	Japan, Corporate Goods Prices, Domestic, consumer goods, Index, JPY, 2000=100	5
107	Japan, Corporate Goods Prices, Domestic, total, Index, JPY, 2000=100	5
108	Japan, Corporate Service Prices, All items, Index, JPY, 2000=100	5
109	Japan, Corporate Service Prices, Transportation, Index, JPY, 2000=100	5
110	Japan, Corporate Service Prices, Finance and insurance, Index, JPY, 2000=100	5

Interest rate factor

111	Call Rates, Collateralized Overnight (a)/Average(b)	1
112	Average Contracted Interest Rates on Loans and Discounts of Domestically Licensed Banks,Stock/Short-term Loans/City Banks	1
113	Average Contracted Interest Rates on Loans and Discounts of Domestically Licensed Banks, Stock/Short-term Loans/Regional Banks	1
114	Average Contracted Interest Rates on Loans and Discounts of Domestically Licensed Banks, Stock/Short-term Loans/Regional Banks II	1
115	Average Contracted Interest Rates on Loans and Discounts of Domestically Licensed Banks, Stock/Long-term Loans/City Banks	1
116	Average Contracted Interest Rates on Loans and Discounts of Domestically Licensed Banks, Stock/Long-term Loans/Regional Banks	1
117	Average Contracted Interest Rates on Loans and Discounts of Domestically Licensed Banks, Stock/Long-term Loans/Regional Banks II	1
118	Average Contracted Interest Rates on Loans and Discounts of Domestically Licensed Banks, Loans/Regional Banks II	1
119	Average Contracted Interest Rates on Loans and Discounts of Domestically Licensed Banks, Discounts/Shinkin Banks	1
120	Average Contracted Interest Rates on Loans and Discounts of Domestically Licensed Banks, Stock/Total/Shinkin Banks	1
121	(Discontinued)Average Interest Rates on Certificates of Deposit (New Issues)/Total (through February 2000)	1
122	(Discontinued)Average Interest Rates on Certificates of Deposit (New Issues)/60 days - 89 days (through February 2000)	1
123	Japan, Interbank Rates, BBA LIBOR, 3 Month, End of Period, JPY	1
124	Japan, Interbank Rates, Collateralized Overnight, Average, JPY	1
125	Japan, Treasury Bills, Bid, 3 Month, Yield, End of Period, JPY	1
126	Japan, Prime Rates, Discounts, Regional Banks II, End of Period, JPY	1
127	Japan, Prime Rates, Discounts, Regional Banks, End of Period, JPY	1
128	Japan, Prime Rates, Discounts, Shinkin Banks, End of Period, JPY	1
129	Japan, Prime Rates, Finance Corporations, Key Lending Rates, - 5 Year, End of Period, JPY	1
130	Japan, Prime Rates, Loans, City Banks, End of Period, JPY	1
131	Japan, Prime Rates, Prime Lending Rate, Long Term, End of Period, JPY	1
132	Japan, Prime Rates, Prime Lending Rate, Short Term, End of Period, JPY	1
133	Japan - Benchmark bond - Japan 10-year Government Benchmark bond yield - Yield, average of observations through period - Japanese yen	1
134	Government Bond Yield, 10 Year, Average	1
135	10-year interest-bearing Government Bonds	1
136	10-year Local Government Bonds	1
137	10-year Government Guaranteed Bonds	1
138	5-year interest-bearing Bank debentures	1

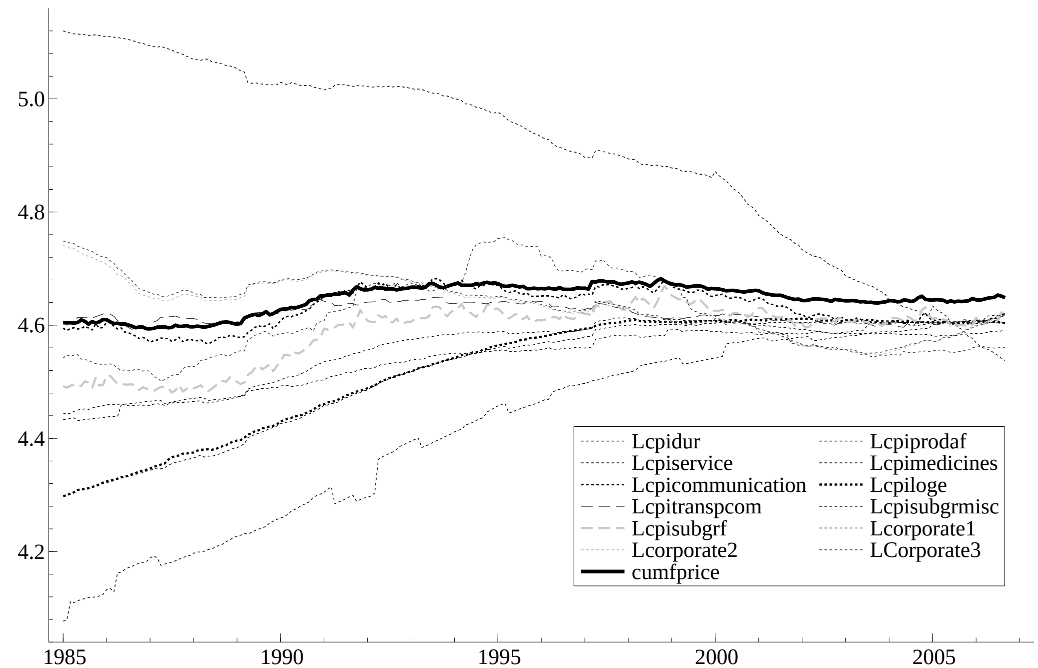
C. - Estimated factors

Figure C.1. Activity factor



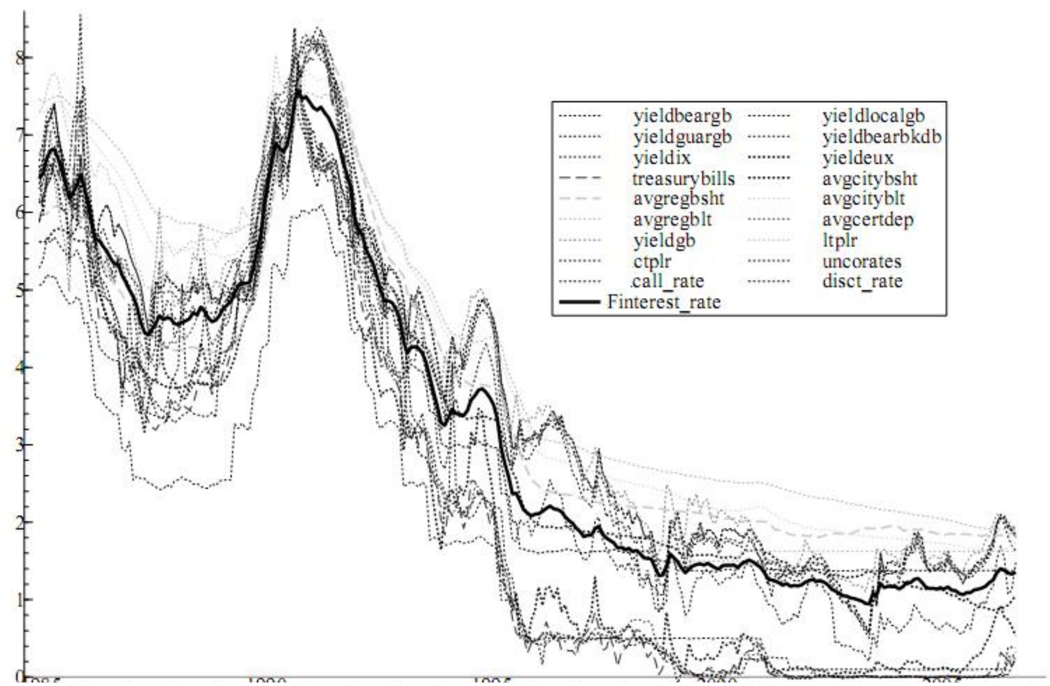
Note: The real activity factor is estimated from the vector of all the 83 the real activity related variables. The bold line shows the cumulative activity factor, while the doted lines represent simple variables in log level related to the real activity outlined in table 2.

Figure C.2. Price factor



Note: The price factor is estimated from the vector of all the 27 price related variables. The bold line shows the cumulative price factor, while the doted lines represent price related variables, expressed in log level, described in table 2.

Figure C.3. Interest rate factor



Note: The interest rate factor is estimated from the vector of all the 28 interest rate related variables. The bold line shows the cumulative interest rate factor, while the doted lines represent some interest rate related variables outlined in table 2.

D. - MS-VAR estimation results

Table D.1. Linearity test:VAR model

Lags	IC	Two regimes[a]	single regime
Lag1	AIC	**-20.4985**	-20.2435
	HQ	**-20.3584**	-20.0434
	SC	**-19.7938**	-19.6435
Lag2	AIC	**-20.4987**	-20.2834
	HQ	**-20.3402**	-20.0345
	SC	**-19.7058**	-19.7003
Lag3	AIC	**-20.2358**	-20.1348
	HQ	**-19.8345**	-19.7905
	SC	**-19.3345**	-19.3104

[a]Four variable MSVAR with output, price level, monetary base and bond yield. All information criterion (values in bold font) for all number of lags support the presence of regime shifts.

Table D.2. MS specifications among various MS-VAR models

	IC	MSI[a](2)	MSIA(2)	MSIH(2)	MSIAH(2)
Lag1	Log-L	2675.3495	2702.3459	2833.4954	2843.8345
	Parameters	36	52	46	62
	LR test[b]	336.97	282.9772	**20.6782**	-
	$\chi^2(R)$	38.885	18.307	26.296	-
Lag2	Log-L	2683.8454	2738.3245	2826,3455	2860.3432
	Parameters	52	84	62	94
	LR test	353.9894	244.0374	67.9954	-
	$\chi^2(R)$	58.124	18.307	46.194	-
Lag3	Log-L	2686.3485	2740.3428	2846.4328	2888.2394
	Parameters	68	116	78	126
	LR test	403.7818	295.7932	83.6132	-
	$\chi^2(R)$	76.778	18.307	65.171	-

[a] According to Krolzig's notation, MSI means that only intercepts are assumed to switch between regimes, MSIA means that intercepts and coefficients are assumed to switch, MSIH means that intercepts and variance covariance matrices are assumed to switch and MSIAH means that all the parameters are assumed to switch.

[b]All the calculated values of Likelihood Ratio test, except for $lag = 2$, are greater than Chi2 tabulated values. All the specifications are thus outperformed by the MSIAH.

Table D.3. Lag length test:MSIAH-VAR model

	AIC[a]	HQ	BC
Lag = 1	-21.3490	-20.5238	**-20.3475**
Lag = 2	**-21.2348**	**-20.2398**	-19.5379
Lag = 3	-21.4473	-20.4384	-19.4348

[a]The lag length supported by AIC and HQ (values in bold font) is two.

Table D.4. Transition matrix

	Regime 1[a]	Regime 2
Regime 1	0.9227	0.0773
Regime 2	0.0563	0.9437

[a]Note that $p_{i,j} = Pr(s_{t+1} = j|s_t = i)$

E. - MS-FAVAR estimation results

Table E.1. Linearity test: MS-FAVAR

Lags	IC	Two regimes[a]	Linear FAVAR[b]
Lag1	AIC	**-24.2349**	-23.5437
	HQ	**-23.8645**	-23.5889
	SC	**-23.5984**	-23.4787
Lag2	AIC	**-24.4375**	-24.4048
	HQ	**-24.1653**	-24.1648
	SC	-23.7375	**-23.7861**
Lag3	AIC	**-24.4348**	-24.3904
	HQ	**-24.0849**	-24.0394
	SC	**-23.5103**	-23.4938

[a]The presence of two regimes is supported by all the information criterion for all number of lags except SC criteria for two lags.

[b]The four variables MS-FAVAR consist of real activity, price and interest rate factors and monetary base.

Table E.2. MS specifications among various MS-FAVAR model

	IC	MSI(2)	MSIA	MSIH	MSIAH
Lag1	Log-L	3123.5672	3145.2763	3239.2340	3254.1346
	Parameters	36	52	46	62
	LR test[a]	261.1348	217.7166	29,8012	-
	$\chi^2(R)$	38.885	18.307	26.296	-
Lag2	Log-L	3167.3458	3243.5745	3345.9074	3354.3409
	Parameters	52	84	62	94
	LR test	304.2359	256.4347	57.4375	-
	$\chi^2(R)$	58.124	18.307	46.194	-
Lag3	Log-L	3164.3341	3222.7817	3328.0644	3372.5083
	Parameters	68	116	78	126
	LR test	416.3484	299.4532	88.8878	-
	$\chi^2(R)$	76.778	18.307	65.171	-

[a]Since Likelihood Ratio statistic values are greater than Chi2 tabulated values, the null hypothesis of linearity is rejected. MSIAH FAVAR specification is thus supported to perform better the data.

Table E.3. Lag length test:MSIAH-FAVAR model

	AIC	HQ	BC
Lag = 1	-25.2042	-24.3240	-24.2305
Lag = 2	-25.4534	**-25.3941**	**-24.4375**
Lag = 3[a]	**-25.4649**	-24.3485	-23.3458

[a]This lag length is supported by only AIC.

Table E.4. Transition matrix

	Regime 1[a]	Regime 2
Regime 1	0.9517	0.0483
Regime 2	0.0671	0.9329

[a]Note that $p_{i,j} = Pr(s_{t+1} = j | s_t = i)$

F. - VECM estimation results

Before estimating a VAR in level, we explored the possibility of using a VECM[14]. We started by testing for the number of cointegrating relationships in the system and estimating the long run relations. Juselius (2004) recommends that the stationarity tests on any single time series should be conducted with a chi-square-distributed likelihood ratio statistic. This should be done within a modeled system that is restricted for rank. Juselius cautions against using univariate tests such as the Dickey-Fuller tests, because she argues that the (non)stationarity of a series is not independent of the rank of the error-correction terms.

Following Nielsen (2004) and Juselius (2004) we first examined the plotted[15] logged levels, except for the interest rate, and first difference of the data. There is no mean reversion and the examination of first-differenced data suggests that there are a number of observation-specific non-normal “outliers” effects. Therefore the specification includes a linear trend, and a number of various appropriately specified observation-specific dummy variables to account for outliers. Then the unrestricted VAR in levels, denoting a VAR model in logged levels, was estimated with a restricted trend and three lags. The standard misspecification tests showed that the residuals were not well behaved. The multivariate normality test strongly rejected the null hypothesis of normality.

We followed a procedure for the examination and analysis of potential outliers recommended by Juselius (2004) and Nielsen (2004). An observation is considered an “outlier” if it generates a standardized residual with an absolute value which should be larger than 3.6 given our sample size. Looking at the standardized residuals there are no outliers in the industrial production variable. Outliers in the consumer price index are present on: **1989:04** (+3.7), 1989:11 (-3,2) and **1997:04** (+6.8). In the monetary base variable the outliers are on: 1999:12, 2000:01, 2000:02 and **2006:04** . The government bond yields show outliers on 1998:10 (-3.7), **1998:12** (+4.5), 2003:06 and 2003:08. Outliers which can be explained by economic events are:

- 1989:04 : the consumption tax and the consumption Tax Law took effect from 1 April 1989. There is a dramatic change in slope of the price variable starting on this date. We can consider this outlier as permanent. Specification considerations include a permanent shift variable for the post 1998:04 part of the sample.

[14] OxMetrics and the econometrics package CATS in Rats are used the VECM analysis.
[15]Plots are not reported here in order to conserve space

- 1997:04 : Prime Minister Hashimoto decided to increase the consumption tax from 3 to 5 percent and to put an end to temporary income tax cuts. Specification considerations include an impulse dummy variable to allow for the shock caused by this intervention.

- 1998:10 : corresponds to a sharp decline in 10-year yields generated by the Russian crisis which led to flight to quality and pulled down the term premium. This event seems to have been temporary and a blip dummy variable included in the short run deterministic component is specified for this event.

- 1998:12 : the sharp increase in 10-year yields reflects an increase in the public debt; Moody's reduced Japan's debt rating from its highest Aaa to Aa1 on November 17, 1998. This increase can also be explained by the announcement by the Trust Fund Bureau that it would stop outright purchases of government bonds in December 1998.

- In **2001:9** there is a permanent shift asociated with an important decision taken by the BOJ: a change in the guideline for monetary market operations; CAB rose from 5 to 6 trillion yen. At the same date there was an increase in outright purchases of long-term government bonds, from 400 billion to 600 billion yen per month.

- Outliers which are present on 1999:12, 2001:01 and 2000:2 correspond to the provision of extra liquidity by the BOJ to deal with the potential Year 2000-related problems. As such outliers are of opposite signs they are considered as transitory effects of a shock ($+4$, $+3$ and -7).

- 2006:04 corresponds to the end of QEPM (the effect seems to start here rather than in 2006:03).

Permanent shift dummies were restricted to the cointegrating space to allow for the possibility that the events may have had a permanent effect. However, outliers which do not correspond to an economic event and which seem to be due to transitory effects of shocks or simple mistakes, are likely to be additive and should therefore not be modeled. Following Nielsen (2004) we chose to leave the additive outliers in the data set. The inclusion of the shift, blip and transitory dummies in an unrestricted VECM does improve the misspecification tests significantly but the multivariate normality test still rejects the null hypothesis of normality. This is caused by the non-normality of the residuals of the monetary-base equation in spite of major attempts to improve the specification (multivariate normality test value falling from a highly untenable 240.6 initial value to 11.8). In the next step, to calculate the rank test statistics we used a simulated Bartlett test. This is because the 95 percent fractile values are adjusted for the restriction of permanent shift dummies included in the cointegration space (Juselius 2004). The null hypothesis corrected for the shift dummies suggest that the null hypothesis of at least $r = 0$ is accepted. Hence the rank test statistics suggest that the system has no cointegrating relation and the four variables do not share common trends. The same analysis was conducted for cumulated factors. Since the factors are estimated from different subsets of variables they are not orthogonal to each other and can be cointegrated. In spite of the ability of factor analysis to eliminate idiosyncratic shocks and therefore outliers from simple variables we cannot detect any long term relationship between the factors and the monetary base.