The effectiveness of quantitative easing in Japan : New evidence from a structural factor-augmented VAR

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Abstract

This paper provides a new empirical framework to examine the effectiveness of Japanese monetary policy during the "lost" decade characterized both by stagnation and deflation. We combine advantages of Markov-Switching VAR methodology with those of structural factor analysis in a so-called the MS-Factor-augmented VAR model to establish three major findings. First we propose new empirical evidence supporting the ability of quantitative easing to provide stimulation to both output and prices. Second, we show that the decisive change in regime occurred in two steps: it crept out in May 1995 and established itself durably in February 1999. Third, 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-FAVAR.

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Keywords: Markov-switching; Factor-Augmented VAR; Japan; Monetary policy; Transmission channels

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Introduction

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 conjunction between the prolonged stagnation and the deflation that followed the financial burst in the early 1990s in Japan induced several authors to investigate and to recommend different strategies to monetary authorities to get out of this situation. In order to stop the deflationist spiral the Bank of Japan (BOJ) gradually cut the nominal interest rates to zero. Under the non-negative constraint on nominal short-term interest rates several authors recommended that the BOJ should dramatically reverse deflation expectations of private agents. This would require a credible accommodation commitment and an increase of the current and future monetary base by flooding the yen market (Krugman (2000) ; Bernanke (2000); McCallum (2000) ; Svensson (2000) and Svensson (2003)). In March 2001 the BOJ thus decided to implement a quantitative easing monetary policy (henceforth QEMP) which comprises three courses of action: (i) to increase the monetary base by setting a quantitative target for current account balances (CAB) at the BOJ; (ii) to make a public commitment to maintain an accommodative monetary policy until inflation (measured by the consumer price index less perishables) registers in a stable manner a zero or positive rate; (iii) to support the quantitative objective related to current account balances by purchasing Japan Government Bonds (JGB). This policy was in effect until March 2005 and since then the short-term interest rate has been the operational target.

This paper provides a new empirical framework to examine the effectiveness of such a strategy. contrary to previous academic work, we find that QEMP had some effects on output and prices. In the case of Japan, since the traditional channel of monetary policy, namely the short-term interest rate, did not work any more, the transmission channels used by the QEMP to affect those macroeconomic variables need to be clear. 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. Indeed, the commitment to maintain a zero interest rate and the expansion of CAB at BOJ provide a signal to the private sector that the easing policy would be maintained and induce the private sector to alter its expectations about the future path of short-term interest rates, thus lowering long-term interest rates. In addition to this "policy duration effect", the increase in the BOJ's purchases of JGBs can be perceived as a strong signal since the central bank would bear a great capital loss if interest rates increased. This "signaling effect" strengthens the credibility of the BOJ to maintain its commitment. The second transmission mechanism is the portfolio rebalancing channel whereby the expansion of the CABs at the BOJ and the increase in BOJ's purchases of JGBs seems to lead the private agents to alter the composition of their portfolios, lowering yields on non-monetary assets.

When examining the transmission mechanism of monetary policy one issue which needs to be dealt with, particularly in the case of Japan, is the identification of instability in such a transmission process. 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 channels of Japanese monetary policy on economic activity and prices. We will therefore allow for stochastic regime switching within a vector-autoregressive model.

Representative recent works of Kamada and Sugo (2006), Kimura and Ugai (2003) or Fujiwara (2006)[1] are among several empirical studies which evaluate the transmission channels of monetary policy in Japan, many of them dealing explicitly with instability. These works admit that examining monetary policy in a country where interest rates have come down to almost zero, without taking into account possible structural changes would be misleading.

Kamada and Sugo (2006) adopt the VAR methodology and use the Markov Chain Monte Carlo (MCMC) method to detect dates of possible structural changes in the Japanese economy 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. Kimura and Ugai (2003) show that transmission channel efficiency is highly uncertain and poor. Their empirical study, based on VAR methodology with time-varying parameters, allows them to take into account the possible changes of heterocedasticity of money demand and of transmission mechanism when interest rates are almost zero. Even though this methodology allows them to capture changes in economic structure and to obtain time-varying impulse function responses, it does not solve the price puzzle (which characterizes VAR model) and assumes that a single financial variable is the best indicator of the monetary policy.

[1] see Ugai (2007) for a survey.

Only Fujiwara (2006) uses Markov-switching methods within a VAR framework (MS-VAR) with regime-dependent impulse functions (Ehrmann *et al.* (2003)). The author examines the period between 1985 and 2004 by including three and then four macroeconomic variables (industrial production, CPI, monetary base, 10 year JGB yield). This model is able to detect regime changes without imposing a priori constraints on the time of such changes. However, this work 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 and is not able to identify in a credible way the date of regime change.

In the present paper MS-VAR methodology is employed according to Fujiwara (2006). However, in above quoted work only a few macroeconomic variables were taken into account when examining monetary policy. 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 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. But 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 analysis 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 can not be represented by one variable only. Factor analysis consists in summarizing a large number of data to produce a small number of estimated factors. In order to introduce a realistic amount of information and to keep the statistical advantages of using a restricted number of variables in term of degrees of freedom, some authors combine VAR methodology and factor analysis.

The Factor-Augmented VAR (FAVAR) model gained in popularity with the work of Bernanke *et al.* (2005) and Stock and Watson (2005). However the FAVAR model shortcomings are that factor identification is often problematic and that factors do not have an immediate economic interpretation[2]. In addition, the FAVAR model ignores one fundamental econometric modeling issue which is a possible change in monetary policy transmission discussed below.

The main goal of this paper is therefore to develop a new empirical framework that combines the advantages of MS-VAR methodology with those of FAVAR in a so-called MS-FAVAR model to establish two major findings. First we propose new empirical evidence supporting the

[2]see Belviso and Milani (2006).

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. Moreover, following Belviso and Milani (2006), we also attribute a clear economic interpretation of the factors. Each estimated factor will represent one economic concept namely 'real activity', 'Inflation' and 'Interest rates'. Second, proposing the first Markov-switching analysis of a FAVAR, we are able to show that the decisive change in regime occurred in two steps: it crept out in May 1995 and established itself durably in February 1999. In contrast to previous work (Fujiwara (2006)) non-neutrality of money and price divergence disappear with the MS-SFAVAR model.

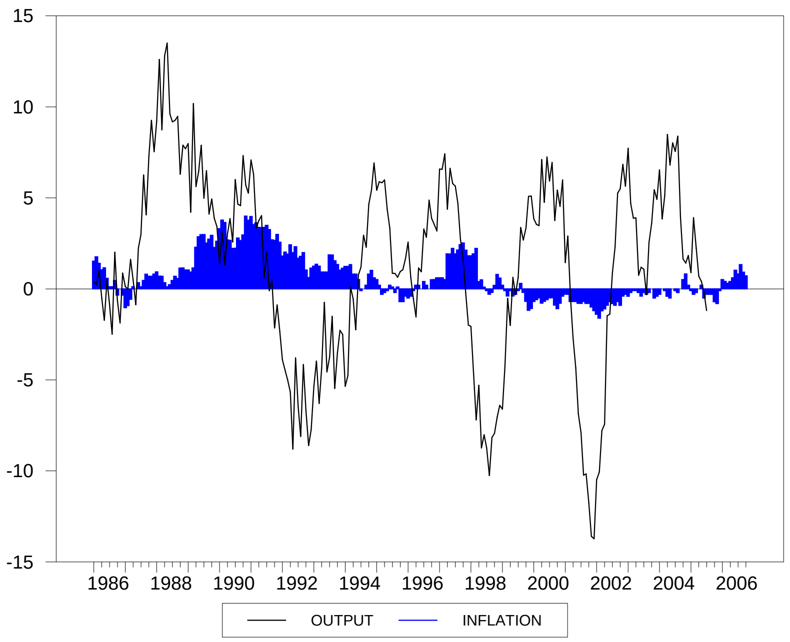
To conduct this analysis we will proceed as follows. Section 1 presents some stylized facts on the Japanese economy. Section 2 describes the used MS-SFAVAR model. Section 3 examines data and estimation results . Section 4 concludes.

1 The Great Stagnation and transmission mechanisms of monetary policy

1.1 The Great Stagnation

Since the beginning of the 1990s Japan has been experiencing a long economic 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 1995 and then maintained this rate at such level from September 1995 to September 1998, as shown by Figure1. Despite several short

Figure 1. CPI inflation and GDP growth rate

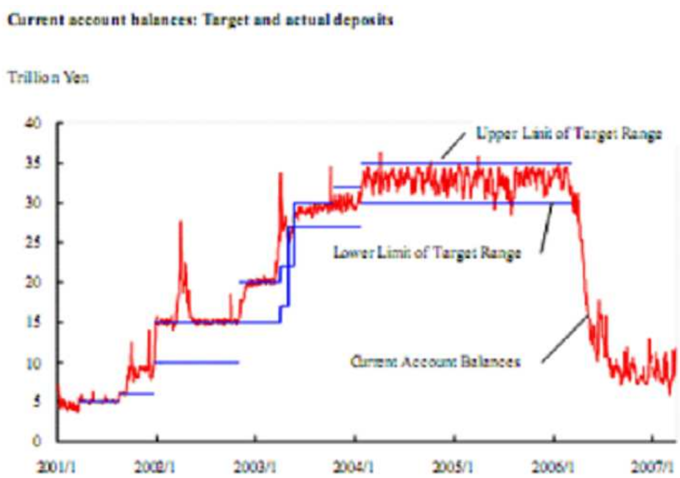


recovery phases the economy began to deteriorate again in 1998. The BOJ then successively decreased the call rate to a level very close to zero in 1999 and implemented the so-called Zero Interest Rate Policy (henceforth ZIRP) between April 1999 and August 2000. The ZIRP was defined as a commitment to maintain the uncollateralized overnight call rate at zero as long as the economy is in deflation. This policy seemed to generate the expected results ; as shown by Figure 1 the economy was recovering in mid-2000 and prices were at least 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-negative 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 the Current Account Balances (henceforth CAB) at the bank of Japan. The QMEP consisted in providing ample liquidity using the CAB as the main operating policy target. Figure2 shows that at the introduction of QMEP the CAB increased to 5 trillion Yen ; a level higher than the required reserve level of 4 trillion Yen. The BOJ gradually raised the target to 35 trillion Yen in 2004. The long-term government bonds were the main category of assets bought

Figure 2. Current Account Balance Targets



to reach the quantitative target concerning current accounts. 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, assets-backed securities and assets-backed commercial paper. The purchase of the latter means that the central bank granted credit directly to small and medium-sized firms.

1.2 Transmission Mechanisms of QEPM

Several factors limited the number of monetary policy transmission channels in Japan. First, because the nominal interest rates were almost zero the real interest rate could only be affected by expected inflation. Consequently the conventional monetary policy using the traditional channel of the short-term interest rate is inoperative. Second, the Japanese banking system collapse made the credit channel inefficient. 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, another transmission channel through which monetary policy could influence prices is the change of the value of domestic currency in the foreign exchange market. This strategy was supported especially by Svensson (2003) and called the "foolproof way" to exit the deflation spiral. Monetary authorities were skeptical about this strategy which was criticized by Ito and Mishkin (2004) concerning its implementation. Indeed, after the adoption of floating exchange rates as a rule of the international monetary system it became impossible to Japanese authorities to follow Svenson's suggestion. On the other hand, the implementation of exchange rate peg could be a source of confusion between the nominal anchor, which is price level, and exchange rate. However, Ito and Mishkin (2004) suggest that the Ministry of Finance and 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 in credibility sending a signal that the main objective remains the price level. Ito and Yabu (2007) showed that the amount of intervention during the period between 1999 and 2004 has became large but the effect of such intervention weakened. The conjunction of these factors induces monetary authorities and economists to look for other possible channels. By the implementation of QEMP the economy could be affected through other transmission mechanisms. We classify[3] these transmission channels in two groups: expectation effects and portfolio rebalancing effects.

1.2.1 Expectation effects

This transmission channel is strictly connected to the commitment to maintain a zero interest rate until the rate of change of core CPI inflation becomes zero or positive year-on-year.

- **Policy duration effect** : although short interest rates are almost zero the QEMP allowed

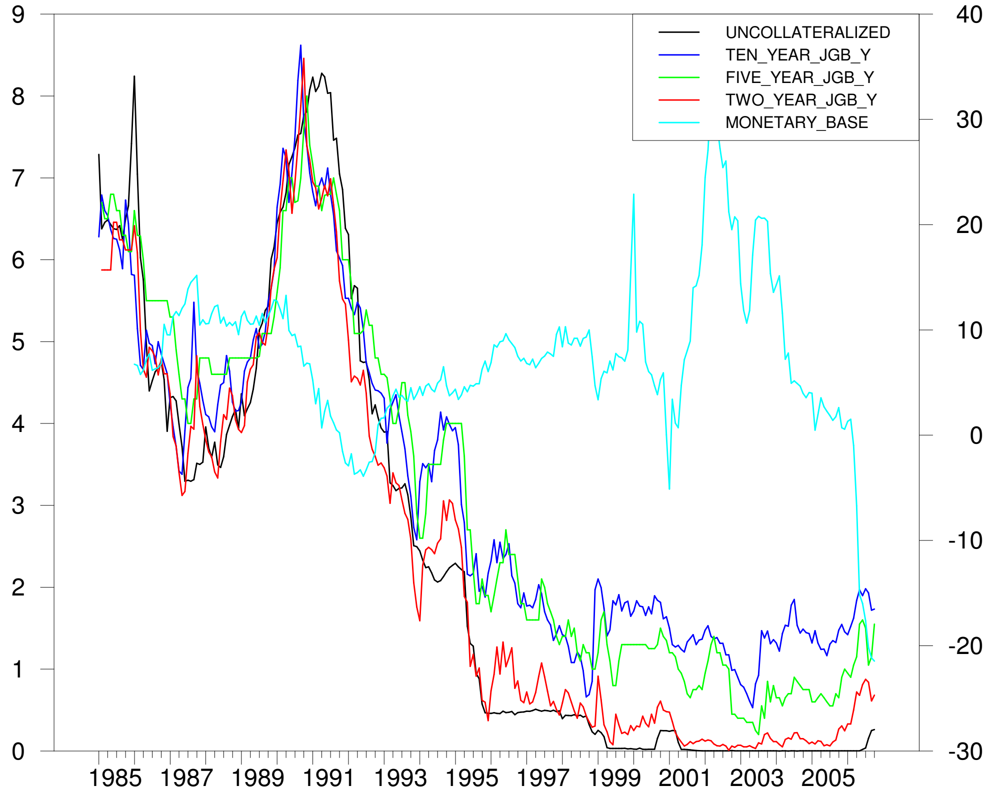
[3] There are several possible way to classify transmission channels. See also Ugai (2007)

to cut these rates further . The overnight call rate reached an extremely low level (0,001 %) ; below the 0.02-0.03% that was realized under the ZIRP. Nevertheless, this traditionnel channel depends on the real interest rate, rather than the nominal one, which affects the decisions of consumers and firms. Besides, it is the real long-term interest rate, and not short-term, that is often considered as having a major incidence on the economy. The relationship between short and long term real interest rates is explained by rational expectations. This expectation is possible only if the BOJ commits itself to maintaining a permanent increase in the monetary base. This increase in the monetary base could raise inflation expectations and afterwards could lead to a rise in spending (Krugman 2000) and a fall in the long term real interest rate stimulating agregate demand. Moreover, commitment would decrease the long term nominal interest rate when the private sector expects that the nominal interest rate would be zero until the conditions of the commitment are fullfilled. This so-called policy duration effect is reflected in the yield curve as shown by Figure 3 The yield curves gradually flattened till the end of year 2005, reflecting the effect of the credibility of the commitment of the BOJ on the anticipations of private agents.

- **Signaling effect** : signaling, in the Japanese monetary policy context, refers to the BOJ providing ample information on the intended state of monetary conditions, both now and into the future. All of the three pillars of QEMP may have a signaling effect. However, the most important signal of the QEMP is the purchase of long-term JGBs. If private agents suspects authorities renouncing on their commitment the objective of the inflation becomes inefficient[4]. In this case the BOJ needed to send a more pronounced signal to the private sector, making the commitment constraining. Indeed, when the BOJ increases its purchases of long-term government bonds the credibility of maintaining its commitment of zero interest rates increases. In other words, an increase on long-term interest rates would generate capital losses for central bank. However, the private sector could also anticipate that the BOJ would incur a capital loss, even if the commitment is maintained, when the long-term JGB interest rate increases following an economic recovery and when the central bank tries to absorb liquidity once the deflation process is stopped by selling JGB.

[4]Eggertsson and Woodford (2003) shows that the increase of monetary base does not influence the expected future conduct of the monetary policy.

Figure 3. Short- to long-term interest rates and monetary base



1.2.2 Portfolio rebalancing effect

The portfolio-rebalancing strategy involves a trade-off between risk and return. When interest rates are almost zero the efficiency of this channel is motivated by a specific theoretical analysis. According to Eggertsson and Woodford (2003) this transmission channel cannot work since the marginal utility for the representative household of additional income does not depend on the variance in financial asset prices but depends on household's consumption. This implies that in case the BOJ reduces the interest rate variance by buying financial assets, the representative household will not rebalance its portfolio. In addition, when interest rates are zero the opportunity cost of holding liquidity and the marginal utility gained from liquidity services become zero. Accordingly, an increase in the monetary base has no effect on household's utility.

Nonetheless, an other point of view is to consider that Eggertsson and Woodford (2003)'s assumption does not hold and thus marginal utility for the representative household depends on the variance in financial asset prices with an imperfect substitutability of financial assets. Therefore, following an increase of monetary base the marginal value of liquidity service reduces. Because the representative household starts to adjust his portfolio by buying financial assets with higher marginal values, these asset prices rise.

Besides, the resumption of inflation since November 2005 (Figure1) is a sign that the QEMP may have been successful. 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 the 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 empirically the effects of such a policy on the real economy through the channels just cited.

2 Methodology

Several criticisms adressed to the VAR approach concerning the identification of the monetary policy concentrate on the use of a restricted quantity of information. To optimize the degree of freedom, it is rare to use more than eight variables in a classical VAR model.

Bernanke *et al.* (2005) showed that the lack 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 shocks of monetary policy. The best illustrations of this problem are price, interest rate, liquidity and exchange rate puzzles. Second, the impulse response functions are observed only for variables included in the model. The analysis cannot thus 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 the factor analysis and the 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. This method, FAVAR, has the advantage of introducing the maximum quantity of information which is taken into account by central banks and private agents, while respecting the constraint of degrees of freedom of the 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', 'credit sector', 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).

2.1 MS-FAVAR

Let X_t and Y_t be two vectors of economic variables, with dimensions (NX1) and (MX1). and 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 X_t are related to a vector F_t with (KX1) unobservable factors, as follows :

$$X_t = BF_t + e_t \tag{2.1}$$

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 of the variables 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 :

$$\begin{bmatrix} X_t^1 \\ X_t^2 \\ \cdots \\ X_t^I \end{bmatrix} = \begin{bmatrix} \Lambda_1^f & 0 & \dots & 0 \\ 0 & \Lambda_2^f & \dots & 0 \\ \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & 0 & \Lambda_I^f \end{bmatrix} \begin{bmatrix} F_t^1 \\ F_t^2 \\ \cdots \\ F_t^I \end{bmatrix} + \begin{bmatrix} e_t^1 \\ e_t^2 \\ \cdots \\ e_t^I \end{bmatrix} \tag{2.2}$$

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 $(Y_t, F_t^1, F_t^2, ..., F_t^I)$ are given by a factor-augmented autoregression (FAVAR):

$$\begin{bmatrix} F_t^1 \\ F_t^2 \\ \dots \\ F_t^I \\ Y_t \end{bmatrix} = \Phi(L) \begin{bmatrix} F_{t-1}^1 \\ F_{t-1}^2 \\ \dots \\ F_{t-1}^I \\ Y_{t-1} \end{bmatrix} + v_t \tag{2.3}$$

Consider the $(M+I)$X1 dimensional vector Z_t:

$$Z_t \begin{bmatrix} F_t^1 & F_t^2 & \dots & F_t^I & Y_t \end{bmatrix} \mathrm{T} \tag{2.4}$$

A Markov-Switching structural factor-augmented VAR is described by equation 2.5. In its most popular version (Krolzig (1997)), which we will use here, the regime-switching model assumes that the process s_t is a first-order Markov process. Hamilton (1989)'s 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)).

$$Z_t = \begin{cases} \alpha_1 + B_{11} Z_{t-1} + \ \dots \ + B_{p1} Z_{t-p} + A_1 u_t & if \quad s_t = 1 \\ \vdots \\ \alpha_m + B_{1m} Z_{t-1} + \dots + B_{pm} Z_{t-p} + A_m u_t & if \quad s_t = m \end{cases} \tag{2.5}$$

Each regime is characterized by an intercept α_i, autoregressive terms $B_{1i}, \dots, B_{pi}$ and a 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 hidden Markov chain[5]. 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 t. When $m = 2$, $s_t = \{1,2\}$ is assumed to follow the discrete time and discrete state stochastic process of a hidden Markov chain and is characterized by transition probabilities p between the different states of the system. The probability may be written

$$p_{i,j} = Pr(s_{t+1} = j | s_t = i), \qquad \sum_{j=1}^{2} p_{ij} = 1 \forall i, j \in (1,2). \tag{2.6}$$

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

This stochastic process is defined by the transition matrix P as follows:

$$p = \begin{pmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{pmatrix} \tag{2.7}$$

For a given parametric specification of the model, probabilities are assigned to the unobserved economic 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 of Japanese economy periods imply that every observation in the sample is assigned to one of the two regimes. The rule followed to assign an observation at time t to a specific regime depends on the highest smoothed probability. The smoothed probability of being in a given regime is computed by using all the observations in the sample. We assign an observation to a specific regime when the smoothed probability of being in that regime is higher than one half.

2.2 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 in the MS-VAR (equation 2.5). To estimate the factors, the variables must be transformed to induce stationarity. It is important to note that the variables used in 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. In the case of such VARs with polynomial functions of time and one or more unit roots, Sims *et al.* (1990) showed 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. Movements in the price level then seem to be the relevant variable of interest. Consequently, we estimate model in levels using cumulative factors.

In this paper we consider a two-step approach to estimating 2.2-2.5. The first step consists of the estimation of the factors and factor loadings. The second step is the estimation of the MS-VAR using the factors.

2.2.1 Factor estimation

The main approach used for the estimation of factors consist of principal component analysis. However, As discussed by Eliatsz (2002) and Belviso and Milani (2006), the factors estimated by principal component have unknown dynamic properties because principal components do not exploit the dynamics of the factors or the dynamic of the idiosyncratic component. Two standard principal approaches that exploit these features to extract the static factors through dynamic principal components: 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 in dynamic principal components. the first approach is situated in time domain while the second is situated frequency domain. Both differ from static principal components in that these allow for a possibility of autocorrelation between idiosyncratic components. Nonetheless, there are two main differences between Stock and Watson (2002)' method and that of FHLR in the way they estimate the space spanned by the factors. First, Stock and Watson (2002)' approach estimates the factors using the standard principal components based on a one-sided filter of the variables. But in FHLR approach consisting of two steps; the common factors are estimated by exploiting information about the degree of commonality of each variable, 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 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:

$$x_{it} = \chi_{it} + \varepsilon it = b_{i1}(L)f_{1t} + b_{i2}(L)f_{2t} + \cdots + b_{iq}(L)f_{qt} + \varepsilon it \tag{2.8}$$

where χ_{it} is the common component and εit is 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 2.8 can be written in vector notation:

$$x_{it} = \chi_{it} + \varepsilon t = B(L)f_{qt} + \varepsilon it = BF_t + \varepsilon t \tag{2.9}$$

where $F_t = (f_t', \cdots, f_{t-s}')$ an $B = B(L)$. Equation 2.9 is similar to the equation 2.1 but the static factors here are driven by those dynamic. The number of static factor is equal to $r = q(s+1)$.
As noted, this approach is a two-step process[6]. First, it uses frequency representation of the time series proposed by Forni et al (2000a) to estimate the spectral density matrices of common part ($\sum_n^{\chi}(\theta), -\pi \leq \theta < \pi$) and of 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 to the respective spectral density matrices. Second, by using estimated covariance matrices the r static factors can be computed by mean of minimizing the fraction of idiosyncratic variance. Thus, the eigenvalues and eigenvectors are estimated by solving the generalized principal components problem:

$$\begin{aligned} &\Gamma_{n0}^{\chi} V_{nj} = \widehat{\Gamma}_{n0}^{\varepsilon} V_{nj} \mu_{nj} \\ &s.t. V_{nj}' \widehat{\Gamma}_{n0}^{\varepsilon} V_{nj} = I_r \end{aligned} \tag{2.10}$$

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

$$\widehat{F}_{nt}^{j} = V_{nj}' x_{nt} \tag{2.11}$$

The static factor loadings are defined as:

$$\left[(V_{nj}' \widehat{\Gamma}_{n0}^{T})^{-1} \right]' V_{nj}' (\widehat{\Gamma}_{n0}^{\chi})' \tag{2.12}$$

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

2.2.2 MS-FAVAR estimation

In the second step the model is estimated through the EM[7] (Expectation–Maximization) algorithm. Estimated factors are introduced in 2.5 instead of variables in a classical MS-VAR model.
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

[6]The representation theory of the dynamic factor model can be found in Forni *et al.* (2005)
[7]The estimation method, identification and impulse response are detailed in Ehrmann *et al.* (2003)

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. Recently 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[8]. 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. Estimation of the Markov-switching model uses expected maximum likelihood (Hamilton (1989) and Hamilton (1994)) because the recursive nature of the likelihood, stemming from the hidden Markov Chain, precludes likelihood maximization with standard techniques. 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. The latter involve the creation of artificial histories for the variables and submitting such histories to the same estimation procedure as the data Ehrmann *et al.* (2003).

3 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 sample X_t contains 143 variables and spans from 1985 : 3 to 2006 : 10 at a monthly frequency. The standard method to evaluate monetary policy through a VAR model is to consider the uncollateralized overnight call interest rate as monetary policy instrument. In the

[8] 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.

special case of Japan, where interest rates are almost equal to zero and where the BOJ cannot control them this method cannot be applied, because interest rates contain no more information concerning the behavior of 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 the monetary policy proxy (Kamada and Sugo (2006))[9]. Nevertheless, intermediate variables can be inconvenient as far as they can react to their own shocks, thereby complicating the identification of the shocks of the monetary policy. In this paper, we use the monetary base[10] as the monetary policy instrument to measure the effect of the quantitative easing policy in Japan. The monetary base thus represents the only observed factor included in Y_t.

3.1 Estimated Structural Factors

The first obvious check of the fit of our factors 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. Table 1 gives the results for the relative importance of the first four factors in explaining the variance of all variables. As can be seen, the first factor captures the major share of the variance; the first activity factor explains about 32 percent of the data variability, the first price factor explains 37 percent and the interest rate factor explains about 41 percent. Even when an additionel factor is added, there is relatively little gain in variance explained. This confirms the robustness of our assumption considering only one factor for each sub-group. Second, for every variable of each sub-group we estimate the R^2 by regressing each series onto the first and the second corresponding factors. The results[11] show that there is a large difference between the first factor and the second in each group in terms of variance explained. Therefore, in each sub-group the first factor corresponds to the largest variance explained. Figure 3.1 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 sufficiently high (loadings are 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 those of interest rates. Nonetheless, it appears that all of the variables are involved in

[9]The monetary policy proxy was constructed by combining two intermediate variables namely lending rates and the lending attitude of financial institutions.

[10]Kimura and Ugai (2003) and Fujiwara (2006)

[11]The results are available upon request.

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

Activity factors				
	F1[a]	F2	F3	F4
Eigenvalue	27.16	7.09	4.1	3.38
Percent variance	32.34	8.44	4.87	4.02
Price factors				
Eigenvalue	16.96	4.38	2.57	2.30
Percent variance	37	9.52	5.6	5.05
Interest rate factors				
Eigenvalue	5.37	1.76	1.40	0.84
Percent variance	41.35	13.6	10.79	6.02

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

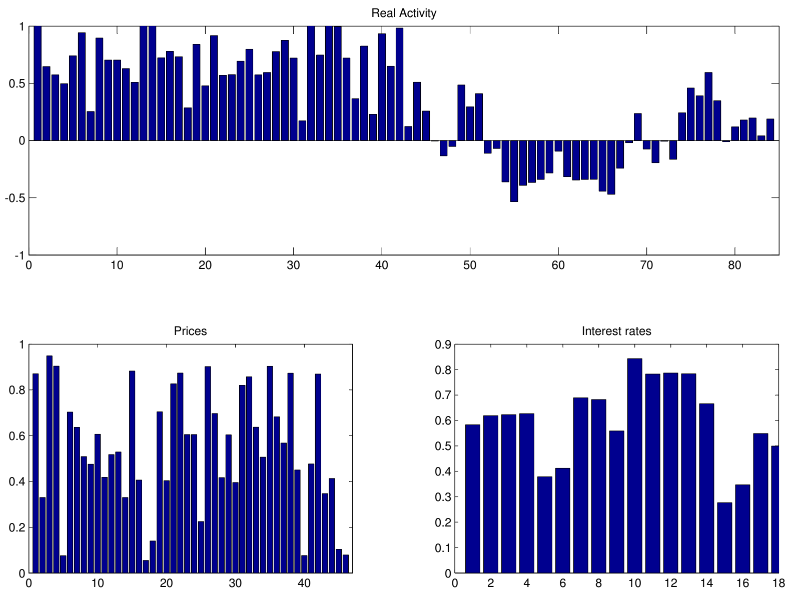


Figure 4. Factor Loadings

constructing the factors since loadings are spread across all of them. Furthermore, Figures 9, 10 and 11 in Appendix B show that cumulative factors clearly represent the corresponding variables in level.

3.2 Traditional MS-VAR

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

We tested for linearity by taking the linear model as the null hypothesis (there is a single regime) and the regime-switching model as the alternative. In these cases 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 non-identified under the null hypothesis has frequently been addressed. Hansen (1992) and Garcia (1998) proposed 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. Since the null parameter space contains only two subsets, Cho and White (2007) showed that the NSLR test is not valid if the boundary conditions are ignored. Moreover, Cho and White (2007)'s test (QLR) is applicable on specific models which do not include the MSVAR. In this paper we therefore perform other tests like Log-likelihood or information criterion. The null hypothesis was clearly rejected as shown in Table 3 in Appendix C. The two-regime model was therefore maintained.

Next, the best specification among various MS-VAR models was identified. In this case the LR test can performed without causing problems. The alternative hypothesis MSIAH-VAR specification is tested against the other possible specifications namely MSI, MSIA and MSIH models for different lags.

The likelihood ratio test (Appendix C, Table4) suggests that an MSIAH-VAR model better fits the data than other MSI-VAR specifications for two and three lags. Consequently, the 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 C, Table5). Moreover, according to Table 6 in Appendix C 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 4 plots smoothed[12]

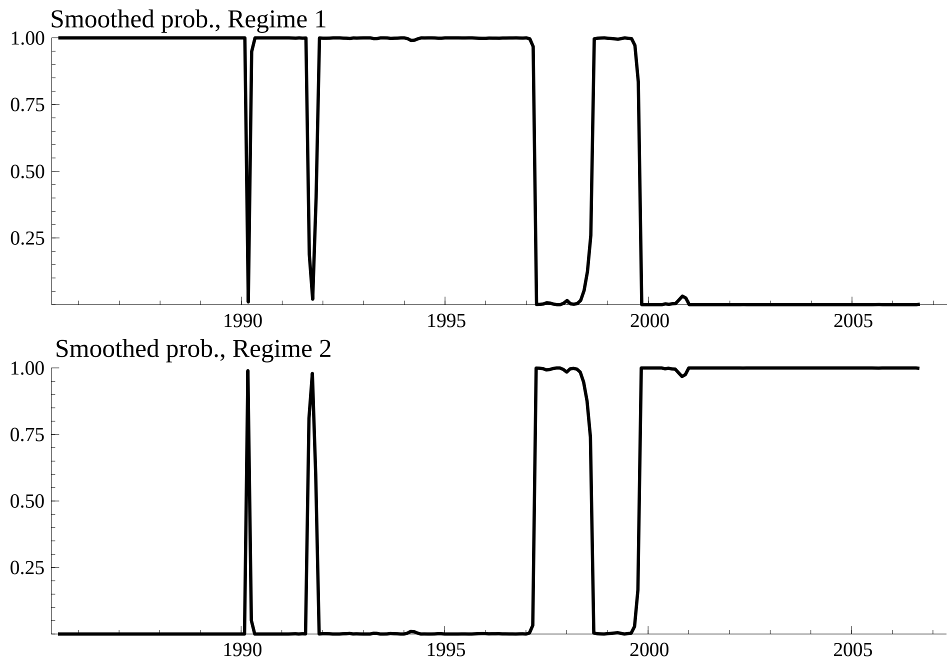


Figure 5. Regime probabilities for MSIAH-VAR

regime probabilities. As can be seen, the Japanese economy was in regime one up to 2000 and has been in regime two since then. We can consider that the Japanese economy experienced a transition period between 1997 and 2000. This result is similar to Fujiwara (2006)'s one ; this date coincides with the beginning of ZIRP and QEMP.

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

[12]The smoothed probabilities are calculated using the information of the entire sample, while the filtered probabilities are estimated using information contained only in the period before any given date for which the probabilities are estimated. We use therefore smoothed probabilities as indicator of which regime prevails at each date in the sample.

models of the transmission mechanism of a monetary expansion should be consistent at least with the following evidence on price, output and interest rates : *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.

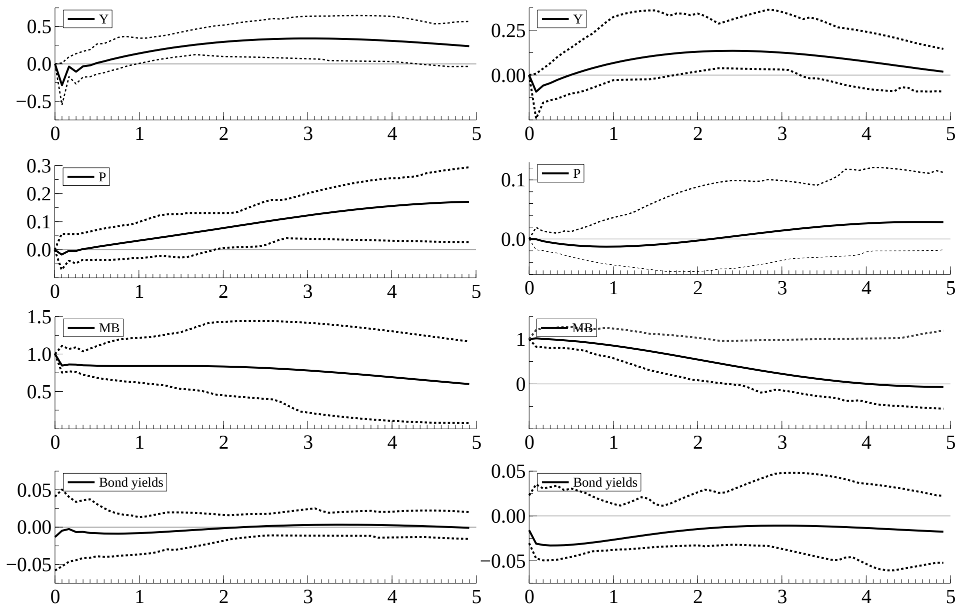


Figure 6. Impulse responses to a monetary shock for MS-VAR

Figure 5 presents the impulse response functions to a positive shock on monetary base. The impulse reaction period is chosen to be 5 years. Solid lines show the impulse responses, while the dotted lines represent confidence intervals using the 10th and 90th percentile values calculated on the basis of 1,000 bootstrap replications.

Over the 1985-1996 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 monetary base are striking. Indeed, output responds after nine months in a persistent way, while prices take more than twice as long to move, but subsequently explode. The 1997-2006 regime is characterized by little effect of monetary base shocks on output and no price response. Indeed, output does rise, but only after 18 months and for only a little more than a year. 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 contained in the expectation channel could have the expected effects on prices even though they remain weak.

3.3 MS-SFAVAR

In the following, we present the estimated effects of the QEMP within the aforementioned specifications of model 2.5. Since we identify monetary chocks 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 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 factor. Information criteria (Appendix D, Table7) suggest that the model is non-linear.

From table 8 and table 9 in Appendix D, an MSIAH-FAVAR specification is suggested by the LR test and the lag length supported by two information criteria is two. As can be seen from the transition matrix (Appendix D, Table 10), the regimes are highly persistent. We can easily see from Figure 6 that the change in regime occurred in two steps: it first appeared in May 1995 and established itself durably in February 1999. Regime two thus corresponds to the beginning of the non-conventional monetary policy strategies namely the ZIRP followed by the QEMP.

Figure 7 shows that, unlike in a classical MS-VAR, the stylized facts aforementioned are verified in all points in two 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-1995 regime, the response of the output factor is moderate and short lived, peaking at 0.05% from the second to the eighth month, while the response of the price factor is half as large, as quick, but hardly significant. Under the second regime, the response of the output factor is three times as large as under the first regime, and fifty percent longer-lived. The response of the price factor, while slightly smaller is much longer-lived (up to nine months) than under the pre-1995 regime. As compared to the standard MS-VAR, it is possible to see the contribution of the information contained in the factors and

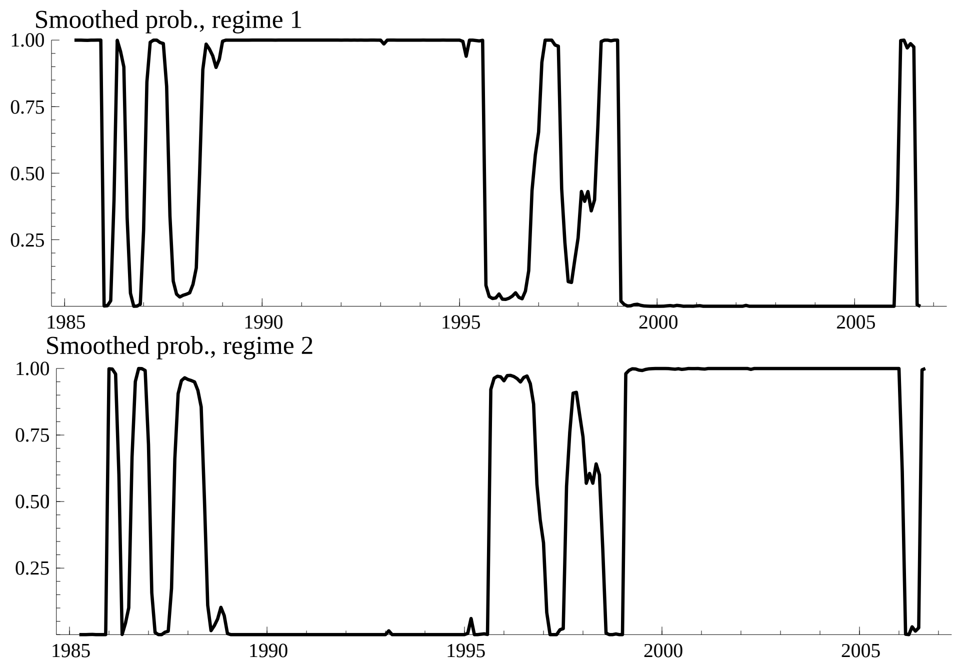


Figure 7. Regime probabilities for MS-FAVAR

it is then noteworthy that the non-neutrality of money and the price divergence in the pre-1995 regime, which characterized the MS-VAR model, are not present 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 have an effect to stimulate the economy. In other words, an increase in the monetary base reduces the liquidity premium and leads economic agents to adjust their portfolios from monetary base to financial assets to stimulating the 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 the 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. This lag means that the commitment was more efficient under QEMP than under ZIRP. However, the positive effect of this expectation channel remains small since the response

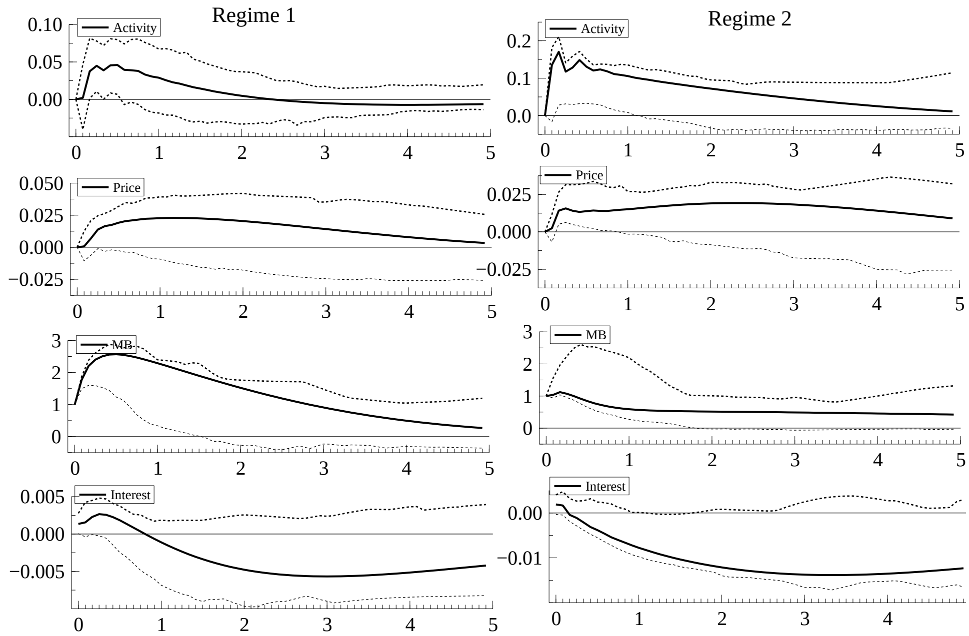


Figure 8. Impulse responses to a monetary shock for MS-FAVAR

of the interest rate factor veers to be insignificant from the beginning of the third year.

In summary, our results indicate that the monetary expansion weakly affect real activity and prices. The effectiveness of quantitative easing remains limited, considering the amount of liquidity injected into the economy and the effort made by the BOJ to gain in credibility and to guide private sector expectations and behavior.

4 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 a FAVAR 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 by the EM algorithm method.

Three 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 growth and price inflation. 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-FAVAR allowed us to detect changes in monetary policy mechanisms in a credible way; structural change occurred in February 1999 after a period of transition starting in May 1995. Third, 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-FAVAR.
Results presented here thus confirm the idea that exploiting a larger and more realistic information set proves a more reliable way to model the monetary policy behavior.

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 by both 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.

References

Bayoumi, Tamim. 2001. The morning after: explaining the slowdown in Japanese growth in the 1990s. *Journal of International Economics*, **53**(2), 241–259. http://ideas.repec.org/a/eee/inecon/v53y2001i2p241-259.html.

Belviso, Francesco, and Milani, Fabio. 2006. Structural Factor-Augmented VARs (SFAVARs) and the Effects of Monetary Policy. *Topics in Macroeconomics*, **6**(3), 1443–1443. http://ideas.repec.org/a/bep/mactop/v6y2006i3p1443-1443.html.

Bernanke, Ben, Boivin, Jean, and Eliasz, Piotr S. 2005. "Measuring the Effects of Monetary Policy: A Factor-augmented Vector Autoregressive (FAVAR) Approach". *The Quarterly Journal of Economics*, **120**(1), 387–422. http://ideas.repec.org/a/tpr/qjecon/v120y2005i1p387-422.html.

Bernanke, Ben S. 2000. Comment on America's Historical Experience with Low Inflation. *Journal of Money, Credit and Banking*, **32**(4), 994–97. http://ideas.repec.org/a/mcb/jmoncb/v32y2000i4p994-97.html.

Cho, Jin Seo, and White, Halbert. 2007. Testing for Regime Switching. *Econometrica*, **75**(6), 1671–1720. http://ideas.repec.org/a/ecm/emetrp/v75y2007i6p1671-1720.html.

Christiano, Lawrence J., Eichenbaum, Martin, and Evans, Charles L. 1998. Monetary Policy Shocks: What Have We Learned and to What End? Feb. http://ideas.repec.org/p/nbr/nberwo/6400.html.

Eggertsson, Gauti B., and Woodford, Michael. 2003. The Zero Bound on Interest Rates and Optimal Monetary Policy. *Brookings Papers on Economic Activity*, **34**(2003-1), 139–235. http://ideas.repec.org/a/bin/bpeajo/v34y2003i2003-1p139-235.html.

Ehrmann, Michael, Ellison, Martin, and Valla, Natacha. 2003. Regime-dependent impulse response functions in a Markov-switching vector autoregression model. *Economics Letters*, **78**(3), 295–299. http://ideas.repec.org/a/eee/ecolet/v78y2003i3p295-299.html.

Forni, M., Hallin, M., Lippi, M., and Reichlin, L. 2005. The generalized dynamic factor model: one-sided estimation and forecasting. *Journal of the American Statistical Association*, **100**.

Fujiwara, Ippei. 2006. Evaluating monetary policy when nominal interest rates are almost zero. *Journal of the Japanese and International Economies*, **20**(3), 434–453. `http://ideas.repec.org/a/eee/jjieco/v20y2006i3p434-453.html`.

Hamilton, James D. 1989. A New Approach to the Economic Analysis of Nonstationary Time Series and the Business Cycle. *Econometrica*, **57**(2), 357–84. `http://ideas.repec.org/a/ecm/emetrp/v57y1989i2p357-84.html`.

Hamilton, James D. 1994. Rational Expectations and the Economic Consequences of Changes in Regime. Nov. `http://ideas.repec.org/p/cdl/ucsdec/94-24.html`.

Ito, Takatoshi, and Mishkin, Frederic S. 2004. Two Decades of Japanese Monetary Policy and the Deflation Problem. Nov. `http://ideas.repec.org/p/nbr/nberwo/10878.html`.

Ito, Takatoshi, and Yabu, Tomoyoshi. 2007. What prompts Japan to intervene in the Forex market? A new approach to a reaction function. *Journal of International Money and Finance*, **26**(2), 193–212. `http://ideas.repec.org/a/eee/jimfin/v26y2007i2p193-212.html`.

Kamada, K., and Sugo, T. 2006. Evaluating the Japanese Monetary Policy under the Non-Negativity Constraint on Nominal Short-Term Interests Rates. Sep.

Kamada, Koichiro, and Masuda, Kazuto. 2001. Effects of Measurement Error on the Output Gap in Japan. *Monetary and Economic Studies*, **19**(2), 109–54. `http://ideas.repec.org/a/ime/imemes/v19y2001i2p109-54.html`.

Kimura, T., H. Kobayashi J. Muranaga, and Ugai, H. 2003. The Effect of the Increase in the Monetary Base on Japan's Economy at Zero Interest Rates: An Empirical Analysis. 276–312.

Krolzig, Hans-Martin. 1997. Markov-Switching Vector Autoregressions. Modeling, Statistical Inference and Application to Business Cycle Analysis.

Krugman, Paul. 2000. Thinking About the Liquidity Trap. *Journal of the Japanese and International Economies*, **14**(4), 221–237. `http://ideas.repec.org/a/eee/jjieco/v14y2000i4p221-237.html`.

McCallum, Bennett T. 2000. Theoretical Analysis Regarding a Zero Lower Bound on Nominal Interest Rates. `http://ideas.repec.org/p/nbr/nberwo/7677.html`.

Orphanides, Athanasios, and Wieland, Volker. 2000. Efficient Monetary Policy Design near Price Stability. *Journal of the Japanese and International Economies*, **14**(4), 327–365. http://ideas.repec.org/a/eee/jjieco/v14y2000i4p327-365.html.

Sims, Christopher A. 1980. Macroeconomics and Reality. *Econometrica*, **48**(1), 1–48. http://ideas.repec.org/a/ecm/emetrp/v48y1980i1p1-48.html.

Sims, Christopher A, Stock, James H, and Watson, Mark W. 1990. Inference in Linear Time Series Models with Some Unit Roots. *Econometrica*, **58**(1), 113–44. http://ideas.repec.org/a/ecm/emetrp/v58y1990i1p113-44.html.

Stock, James H, and Watson, Mark W. 2002. Macroeconomic Forecasting Using Diffusion Indexes. *Journal of Business & Economic Statistics*, **20**(2), 147–62. http://ideas.repec.org/a/bes/jnlbes/v20y2002i2p147-62.html.

Stock, James H., and Watson, Mark W. 2005. Implications of Dynamic Factor Models for VAR Analysis. July. http://ideas.repec.org/p/nbr/nberwo/11467.html.

Svensson, Lars E. O. 2000. The Zero Bound in an Open Economy: A Foolproof Way of Escaping from a Liquidity Trap. Aug. http://ideas.repec.org/p/hhs/iiessp/0687.html.

Svensson, Lars E. O. 2003. Escaping from a Liquidity Trap and Deflation: The Foolproof Way and Others. *Journal of Economic Perspectives*, **17**(4), 145–166. http://ideas.repec.org/a/aea/jecper/v17y2003i4p145-166.html.

Ugai, Hiroshi. 2007. Effects of the Quantitative Easing Policy: A Survey of Empirical Analyses. *Monetary and Economic Studies*, **25**(1), 1–48. http://ideas.repec.org/a/ime/imemes/v25y2007i1p1-48.html.

Appendix

Appendix A: The data set

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.

N°	Description	T
	Real activity factor	
1	Industrial Production Total Index (SA)	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, SA, Index	5
33	Shipments, Non-durable consumer goods, SA, Index	5
34	Shipments, Producer goods total, SA, Index	5
35	Shipments, Producer goods, for mining and manufacturing, SA, Ind	5
36	Shipments, Producer goods, for others, SA, Index	5
37	Capacity Utilization, Operation Ratio, Fabricated metals, SA	5
38	Capacity Utilization, Operation Ratio, General machinery, SA	5
39	Capacity Utilization, Operation Ratio, Iron and steel, SA	5
40	Capacity Utilization, Operation Ratio, Machinery industry, SA	5
41	Capacity Utilization, Operation Ratio, Manufacturing excl. machi	5
42	Capacity Utilization, Operation Ratio, Manufacturing, SA	5
43	Capacity Utilization, Operation Ratio, Petroleum and coal produc	5
44	Capacity Utilization, Operation Ratio, Pulp, paper and paper pro	5
45	Capacity Utilization, Operation Ratio, Textiles, SA	5
46	Capacity Utilization, Operation Ratio, Petroleum chemicals produ	5
47	Capacity Utilization, Operation Ratio, Rubber products	5
48	Capacity Utilization, Operation Ratio, Transport equipment	5
49	Hours Worked, Average Per Month, Electricity, gas, heat and wate	5
50	Hours Worked, Average Per Month, Manufacturing (SA)	5
51	Hours Worked, Average Per Month, Mining (SA)	5
52	Unemployment, Rate, SA	2
53	Labour Productivity, Foodstuff and tobacco (30 employees or more	5
54	Labour Productivity, Furniture (30 employees or more), Index (SA	5
55	Labour Productivity, Manufacturing (30 employees or more), Index	5
56	Labour Productivity, Textiles (30 employees or more), Index (SA)	5

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

Inflation factor

85	CPI all items	5
86	CPI durable	5
87	CPI privé de produit limentaires frais	5
88	CPI services	5
89	CPI medical care (soin)	5
90	CPI commodities	5
91	CPI logement	5
92	CPI transport et com	5
93	CPI, subgroup, miscellaneous, Index	5
94	CPI, subgroup, food, Index	5
95	Corporate Goods Prices, Domestic, minerals	5
96	Corporate Goods Prices, Domestic, manufacturing industry prod.	5
97	Corporate Goods Prices, Domestic, total	5
98	Nationwide, durable goods, Index	5
99	Nationwide, general excluding food and energy, Index	5
100	Nationwide, goods, agricultural & aquatic products, fresh, Index	5
101	Nationwide, goods, agricultural & aquatic products, Index	5
102	Nationwide, goods, agricultural & aquiatic products, rice, Index	5
103	Nationwide, goods, electricity, gas & water charges, Index	5
104	Nationwide, goods, excl fresh food, SA, Index	5
105	Nationwide, goods, industrial products, food products, Index	5
106	Nationwide, goods, industrial products, Index	5
107	Nationwide, goods, industrial products, large enterprises, Index	5
108	Nationwide, goods, industrial products, other, Index	5
109	Nationwide, goods, industrial products, petroleum products, Index	5
110	Nationwide, goods, industrial products, small & medium enterprises, Index	5
111	Nationwide, goods, industrial products, textiles, Index	5
112	Nationwide, goods, publications, Index	5
113	Nationwide, goods, SA, Index	5
114	Nationwide, public services & electiricy, gas & water charges, Index	5
115	Nationwide, semi-durable goods, Index	5

116	Nationwide, services, excl inputed rent, Index	5
117	Nationwide, services, general, eating out, Index	5
118	Nationwide, services, general, Index	5
119	Nationwide, services, general, private house rent, Index	5
120	Nationwide, services, general, related to domestic duties, Index	5
121	Nationwide, services, general, related to education, Index	5
122	Nationwide, services, general, related to medical care & welfare, Index	5
123	Nationwide, services, general, related to reading & recreation, Index	5
124	Nationwide, services, Index	5
125	Nationwide, services, public, house rent, public & public corp, Index	5
126	Nationwide, services, public, Index	5
127	Nationwide, services, public, related to domestic duties, Index	5
128	Nationwide, services, public, related to education, Index	5
129	Nationwide, services, public, related to forwarding & communication, Index	5
130	Nationwide, services, public, related to medical care & welfare, Index	5
131	Nationwide, services, public, related to reading & recreation, Index	5

Interest rate factor

132	Call rate (uncollateralized overnight, month average)	2
133	Discount Rate	2
134	Long terme prime lending rate	2
135	Short terme prime lending rate	2
136	Treasury Bills, 3 month, Yield, End of Period	2
137	10-year interest-bearing Government Bonds, unit:%	2
138	10-year Local Government Bonds, unit: %	2
139	10-year Government Guaranteed Bonds, unit:%	2
140	5-year interest-bearing Bank debentures	2
141	Government Benchmarks, 10 Year, Average	2
142	Government Benchmarks, 2 year, End of Period	2
143	Leading Index, Tokyo interbank offered rates (3 months)	2
144	Government Bond Futures Listed Yield on TSE (10 years)	2
145	Average Contracted Interest Rates on Loans and Discounts of Domestically Licensed Banks (New)	2
146	Average Contracted Interest Rates on Loans and Discounts of Domestically Licensed Banks, City Banks (short-term)	2

147	Average Contracted Interest Rates on Loans and Discounts of Domestically Licensed Banks, Regional Banks (short-term)	2
148	Average Contracted Interest Rates on Loans and Discounts of Domestically Licensed Banks, City Banks (Long-term)	2
149	Average Contracted Interest Rates on Loans and Discounts of Domestically Licensed Banks, Regional Banks (Long-term)	2
150	Average interest rate on certificate of deposit of all banks	2

Appendix B: Estimated factors

Figure 9. Activity factor

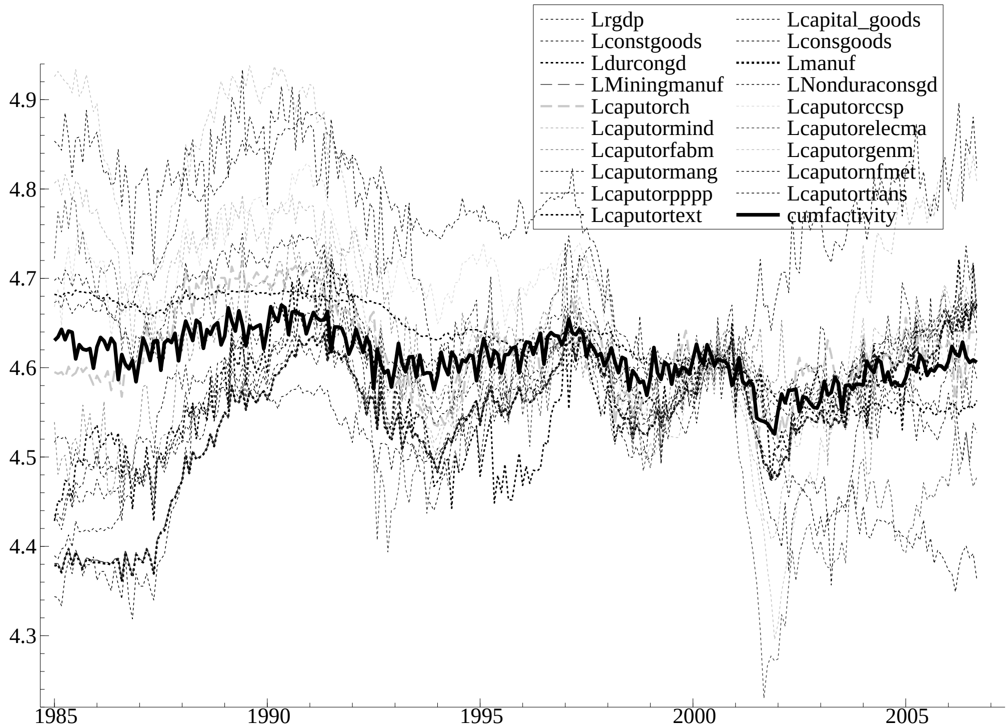


Figure 10. price factor

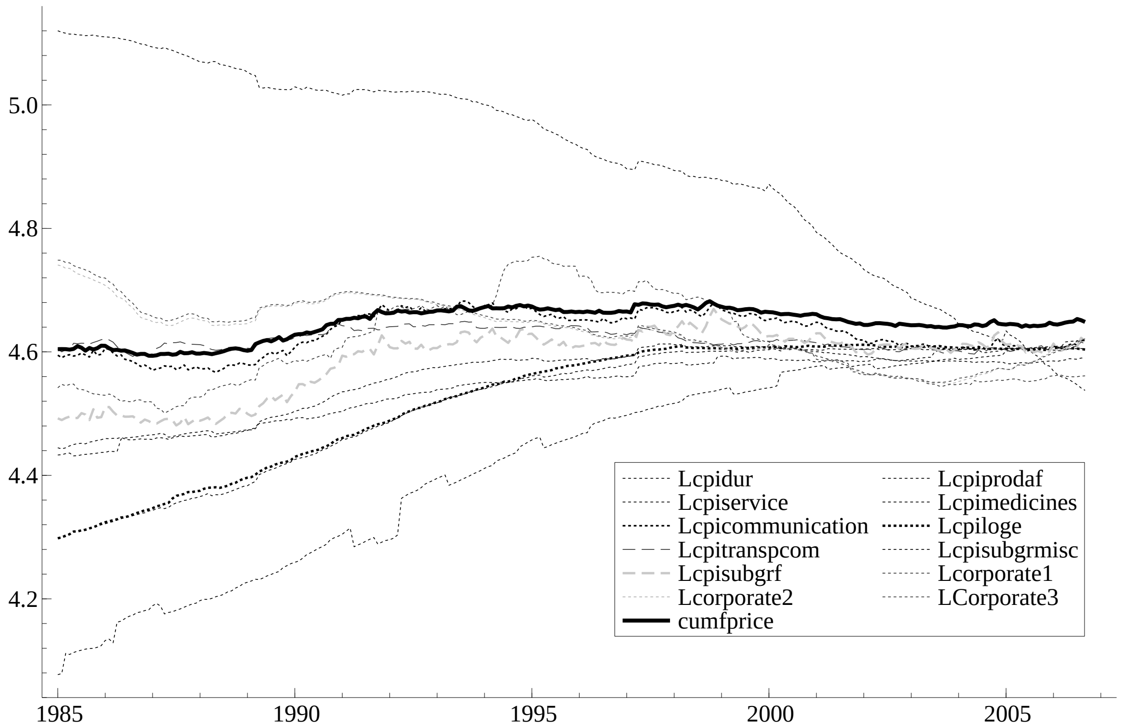
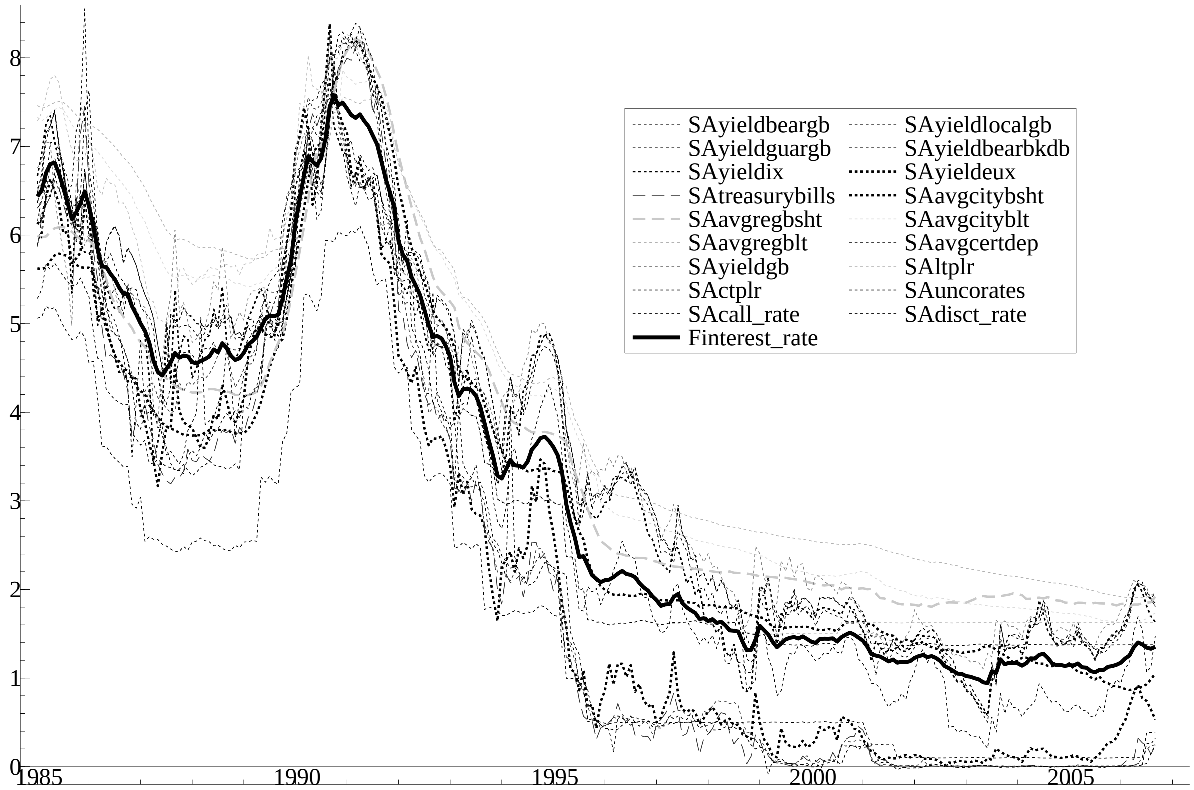


Figure 11. Interest rate factor



Appendix C: MS-VAR estimation results

Table 3. Linearity test:VAR model

Lags	IC	Two regimes[a]	single regime
Lag1	AIC	**-20.3016**	-20.1844
	HQ	**-20.1034**	-20.0198
	SC	**-19.8086**	-19.7741
Lag2	AIC	**-20.3240**	20.2545
	HQ	**-20.0369**	-20.0060
	SC	**-19.6499**	-19.6228
Lag3	AIC	**-20.2957**	-20.1835
	HQ	**-19.9192**	-19.8402
	SC	**-19.3593**	-19.3297

[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 4. MS specifications among various MS-VAR models

	IC	MSI[a](2)	MSIA(2)	MSIH(2)	MSIAH(2)
Lag1	Log-L	2675.2103	2702.7706	2833.0351	2843.9530
	Parameters	36	52	46	62
	LR test[b]	337.4854	282.3648	21.8358	-
	$\chi^2(R)$	26.509	3.940	7.962	-
Lag2	Log-L	2683.9581	2738.7488	2849.7266	2860.9429
	Parameters	52	84	62	94
	LR test	353.9696	244.3882	22.4326	-
	$\chi^2(R)$	29.051	3.940	18.493	-
Lag3	Log-L	2686.1478	2740.6982	2846.8515	2888.9669
	Parameters	68	116	78	126
	LR test	405.6382	296.5374	84.2308	-
	$\chi^2(R)$	43.188	3.940	34.764	-

[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 are bigger than Chi2 tabulated values. All the specifications are thus outperformed by the MSIAH.

Table 5. Lag length test:MSIAH-VAR model

	AIC[a]	HQ	BC
Lag = 1	-21.2236	-20.7082	**-20.3650**
Lag = 2	**-21.3729**	**-20.8783**	-19.9279
Lag = 3	-21.2333	-20.6670	-19.6182

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

Table 6. Transition matrix

	Regime 1[a]	Regime 2
Regime 1	0.9327	0.0673
Regime 2	0.0468	0.9532

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

Appendix D: MS-FAVAR estimation results

Table 7. Linearity test: MS-FAVAR

Lags	IC	Two regimes[a]	Linear FAVAR[b]
Lag1	AIC	**-24.1554**	-23.8491
	HQ	**-23.9572**	-23.6839
	SC	**-23.6624**	-23.4382
Lag2	AIC	**-24.4516**	-24.4178
	HQ	**-24.1645**	-24.1638
	SC	-23.7375	**-23.7861**
Lag3	AIC	**-24.4731**	-24.4001
	HQ	**-24.0966**	-24.0568
	SC	**-23.5367**	-23.5263

[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 factor, price factor, interest rate factor and monetary base.

Table 8. MS specifications among various MS-FAVAR model

	IC	MSI(2)	MSIA	MSIH	MSIAH
Lag1	Log-L	3116.5156	3164.5328	3247.7051	3262.4329
	Parameters	36	52	46	62
	LR test[a]	291.8346	195.8002	29.4556	-
	$\chi^2(R)$	15.3791	3.940	7.962	-
Lag2	Log-L	3198.2202	3223.5745	3323.3030	3351.9903
	Parameters	52	84	62	94
	LR test	307.5402	256.8316	57.3746	-
	$\chi^2(R)$	28.144	3.940	20.072	-
Lag3	Log-L	3164.3341	3222.7817	3328.0644	3372.5083
	Parameters	68	116	78	126
	LR test	416.3484	299.4532	88.8878	-
	$\chi^2(R)$	40.646	3.940	33.098	-

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

Table 9. Lag length test:MSIAH-FAVAR model

	AIC	HQ	BC
Lag = 1	-25.0694	-24.7280	-24.2203
Lag = 2	-25.6531	**-25.1341**	**-24.3622**
Lag = 3[a]	**-25.6778**	-24.9801	-23.9427

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

Table 10. Transition matrix

	Regime 1	Regime 2
Regime 1	0.9069	0.0333
Regime 2	0.0931	0.9667