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

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September 2008

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, are not present with the MS-FAVAR one.

JEL Classification : C32; E52

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 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 reverse sustainly private agents deflation expectations. This would need 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 consists in three pillars: (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 Bond (JGB). This policy took place until March 2005 and since then the short-term interest rate hase been the operational target.

This paper provides a new empirical framework to examine the effectiveness of such a strategy. By contrast 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, does not work any more, one may wonder through which transmission channels the QEMP could affect those macroeconomic variables . Two transmission channel for the quantitative easing policy were suggested. The first one is the expectation channel, consisting in the " policy duration" and the "signaling effects", and the second one 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 will be maintained and induce private sector to alter its expectations about the future path of short-term interest rate thus lowering the long-term interest rate. Beside 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 the deflation went on. 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 would lead the private sector to alter the composition of its portfolio, lowering yields on non-monetary assets.

When examining the transmission mechanism of monetary policy one issue which is to be treated, 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.

Among several empirical studies which evaluate the transmission channels of monetary policy in Japan, representative recent works are Kamada and Sugo (2006), Kimura and Ugai (2003) or Fujiwara (2006)[1], 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 weak. 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 if this methodology allows them to capture changes in economic structure and to get 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. Fujiwara

[1] see Ugai (2007) for a survey

(2006) is the only one to use 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 paper MS-VAR methodology is employed following Fujiwara (2006). However, in above quoted work only a few macroeconomic variables were taken into account when examining the monetary policy. To conserve degrees of freedom, standard VARs rarely employ more than six to eight variables. This matter is particularly important in the case of a MS-VAR model when the number of estimated parameters rises very quickly. But in reality policymakers care about 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 do not allow 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 in a small number of estimated factors. In order to introduce a realistic amount of information and to keep 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]. Besides, 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 ability of quantitative easing to provide stimulation to both output and prices. Given the un-

[2]see Belviso and Milani (2006)

certainties 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 rate'.
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. By contrast to previous work (Fujiwara (2006)) non-neutrality of money and price divergence are not present with the MS-SFAVAR model.

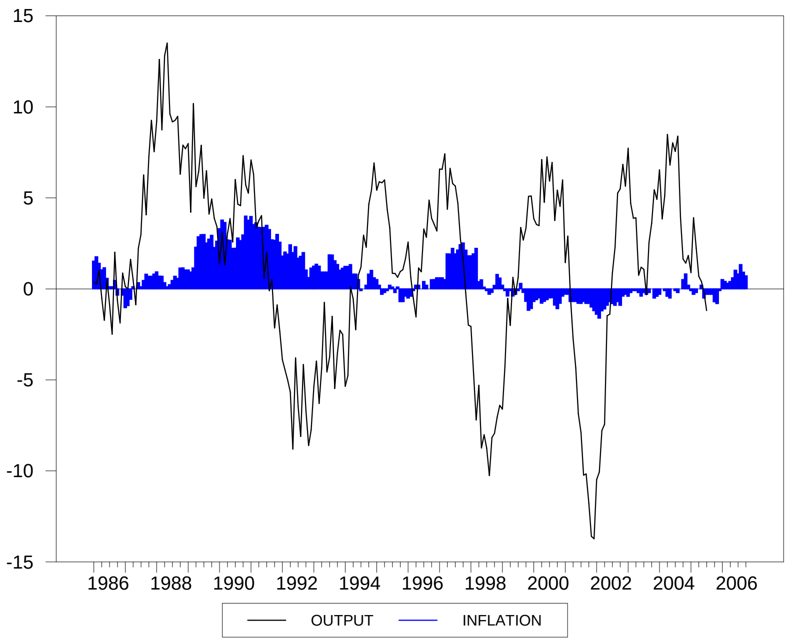
To conduct this analyze we will proceed as follows. Section 1 presents some stylized facts on the Japanese economy. Section 2 describes the used MS-SFAVAR model. Section 3 examines data and estimation results . Section 4 concludes.

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

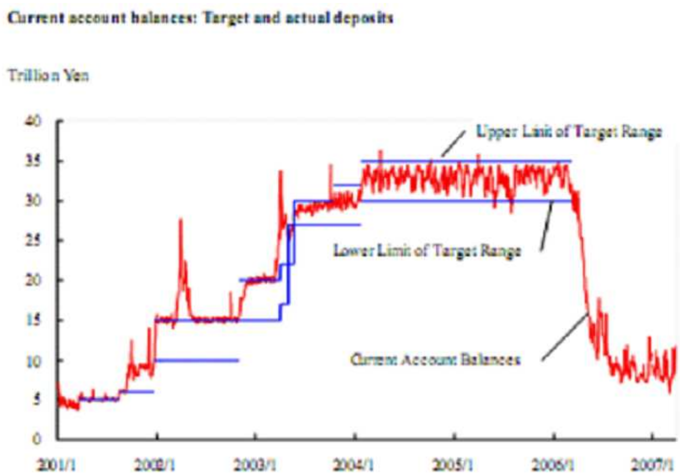


recovery phases the economy began to deteriorate again in 1998. The BOJ then successively decreased the call rate to a level very close to zero in 1999 and implemented the so-called Zero Interest Rate Policy (henceforth ZIRP) between April 1999 and August 2000. The ZIRP was defined as a commitment to 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

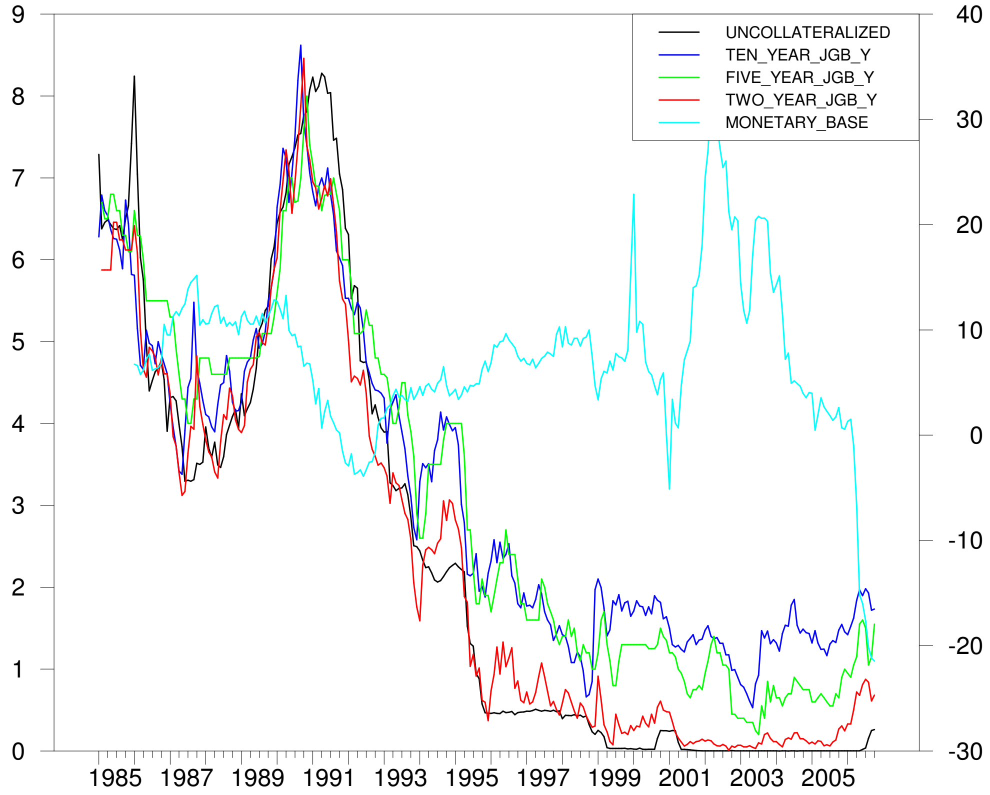
[3] There are several possible way to classify transmission channels. See also Ugai (2007)

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 increases. In other words, the continuation of deflation 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 S-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 :

$$X_t = \Lambda^f F_t + e_t \tag{2.1}$$

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.The main advantage of this static representation of the dynamic factor model, described by equation 2.1, is that factors can be estimated by the principal component method. 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):

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

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

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

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

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

probability may be written

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

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. There are two principal approaches that exploit these features to extract the static factors through principal components. The first is the two-step approach situated in the frequency domain proposed by Forni and Reichlin (2005). This approach exploits the cross-sectional heteroscedasticity of the idiosyncratic component and the dynamic properties of the data when extracting the common factors. A similar strategy has been proposed by Stock and Watson (2002). The second approach, a two-step strategy in the parametric time domain introduced by Giannone *et al.* (2005) and developed by Doz *et al.* (2006), uses principal components and the Kalman smoother to exploit both factor dynamics and idiosyncratic heteroscedasticity.

For the MS-SFAVAR approach employed in this paper, static factors are estimated by using the Doz *et al.* (2006) method. As explained above the two step estimator of approximate factor models outperforms the principal component method in a finite sample, but only if the sample size is large enough [6]. However Bernanke *et al.* (2005) and Belviso and Milani (2006) showed that the results under the two-step principal component approach are quite close to Bayesian joint estimation. Moreover, the two-step approach implies uncertainty surrounding the factor estimation. To obtain accurate confidence intervals on the impulse response functions, following Bernanke *et al.* (2005) we carry out a bootstrap procedure that accounts for the uncertainty in the factors. Bai and Ng (2002) provide some criteria to choose the number of factors, but no criterion has been developed to determine the optimal number of factors in a VAR framework. We assume only a single factor from each group in our MS-SFAVAR model in this paper. We divide X_t so that each sub-group is represented by only one of the following structural factors :

[6] According to Doz *et al.* (2006) 7O variables is a minimum.

- **Real Activity factor** : represents the general economic concept of “economic activity” instead of the single indicator of industrial production. It captures variances in the individual series such as industrial production, capacity utilization, employment / unemployment rates, new orders, housing starts,...
- **Inflation factor** : consists in the concept of ’inflation’. It is driven by the evolution of consumer prices, corporate goods and services prices.
- **Interest rate factor** : represents some interest rates of various maturity.

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 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 summarise 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

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

[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.

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 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.

[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)

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. To this end, for every variable of each sub-group we estimate the R^2 from regressing each series onto the first and the second corresponding factors. Results[11] show that there is a large difference between the first factor and the second one in each group in terms of variance explained. Therefore, in each sub-group the first factor corresponds to the biggest variance explained. The small gain in the percentage of the variance explained, when adding a second factor, confirms the robustness of our assumption considering only one factor for each sub-group. Figure 8, 9 and 10 reported in the Appendix B demonstrate that cumulative factors seem to sufficiently present the corresponding variables in level.

3.2 Traditional MS-VAR

We first evaluate Japanese monetary policy using the MS-VAR model following Fujiwara (2006) with four variables such as output y, the price level p,the money stock m and bond yields l with a longer sample. The main difficulty concerns the determination of the number of regimes which characterize better the behavior of the studied time series. In a second step the best specification among various MS-VAR model should be determined.

The test for linearity by taking the linear model as the null hypothesis (there is a single regime) and the regime-switching model as the alternative. The usual tests, namely LR tests, LM and Walds tests, cannot be conducted since the nuisance parameter is identified only under the alternative. Several works studied the problem of statistical inference when the nuisance parameters are non-identified under the null hypothesis. Hansen (1992) and Garcia (1998) proposed a non-standard likelihood ratio test (NSLR). This test is calculated as a correction on the p-value of a standard likelihood ratio test. 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 is clearly

[11]The results are available upon request.

rejected as shown in Table 2 in the Appendix C. The two regime model is therefore maintained.

In next step we identify the best specification among various MS-VAR models. In this case the LR test can performed without causing problem. 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, Table3) suggests that an MSIAH-VAR model fits better the data than others MSI-VAR specifications for two and three lags. Consequently, the study applies the Markov switching MSIAH-VAR model in which intercepts, parameters autoregressions and variance covariance matrices are allowed to switch between regimes. The lag length is chosen to be two in order to have serially uncorrelated residuals. This lag length is supported by AIC and HQ criterion (Appendix C, Table4). Next, according to Table 5 in the Appendix C that shows the transition matrix, the two regimes are highly persistent. Regime dependent impulse responses will then be an interesting tool to analyze the monetary policy of Japan. Figure 4 plots smoothed[12] regime probabilities. As can be seen, the Japanese economy was in regime one up to 2000 and 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 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 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

[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.

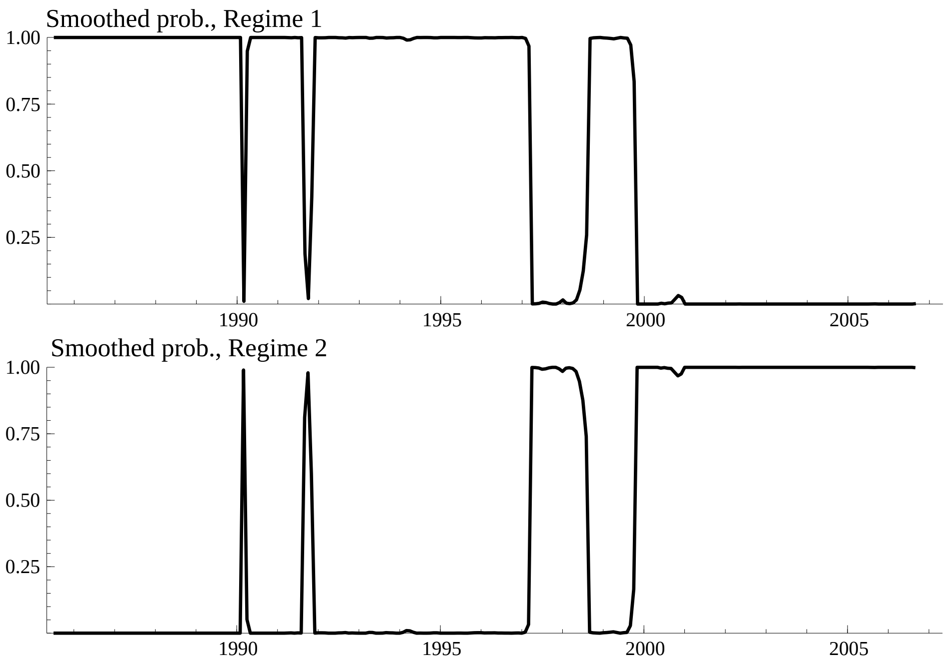


Figure 4. Regime probabilities for MSIAH-VAR

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

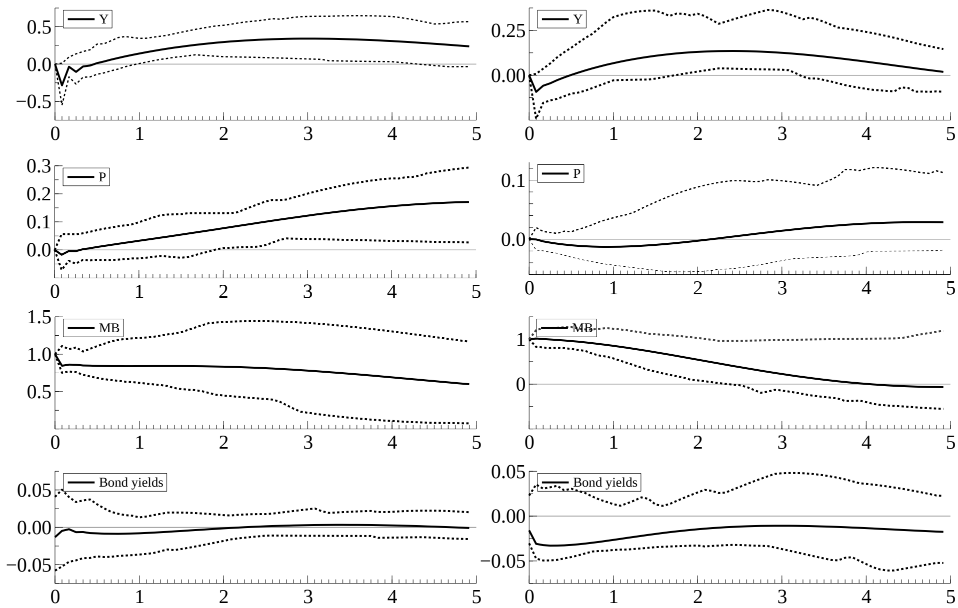


Figure 5. Impulse responses to a monetary shock for MS-VAR

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, Table6) suggest that the model is non-linear.

From table 7 and table 8 in the Appendix D, a 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 9), 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.

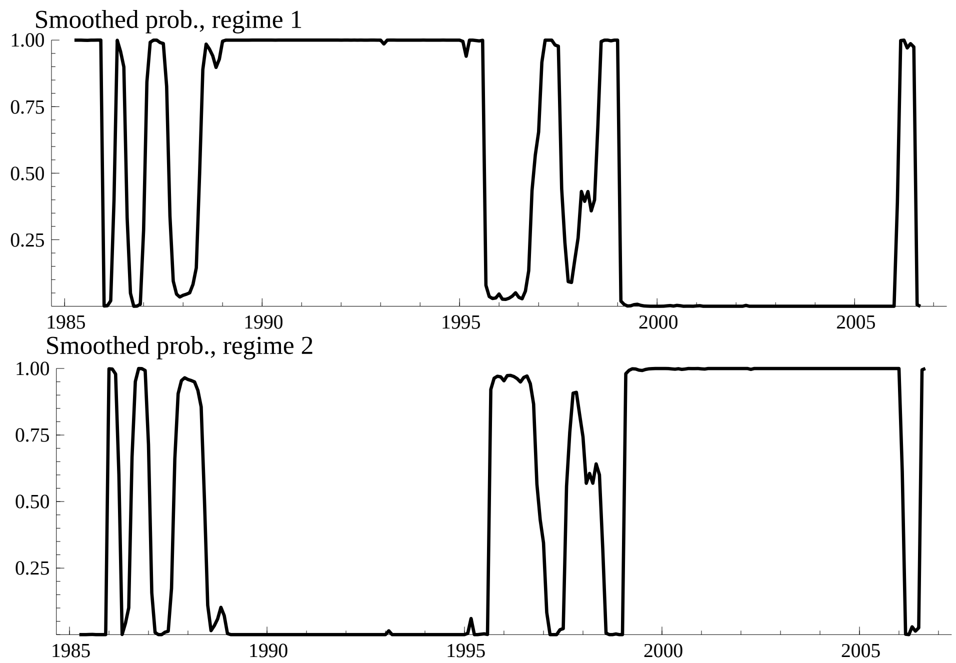


Figure 6. Regime probabilities for MS-FAVAR

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 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

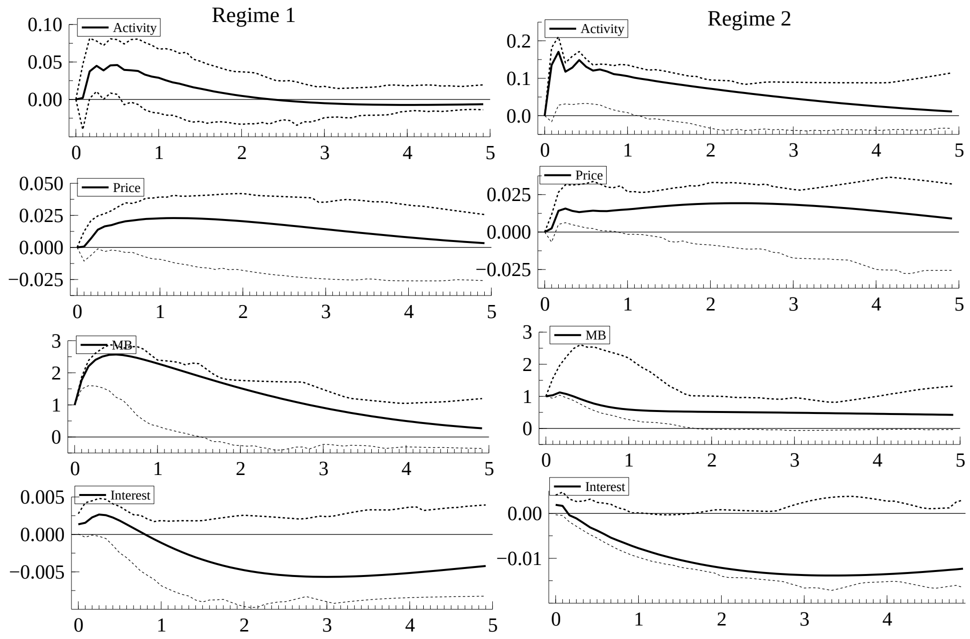


Figure 7. Impulse responses to a monetary shock for MS-FAVAR

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

As a whole, our results show that the monetary expansion seems to affect weakly real activity and prices. The effectiveness of quantitative easing remains limited, considering the amount of liquidity injected in the economy and the effort made by the BOJ to gain in credibility and to guide private sector expectation 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 and 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 Japanese monetary policy. We implemented a two-step approach. In a first step, structural factors are estimated from subset databases representing different economic concepts. In a second step, a Markov-switching model was estimated by EM algorithm method.

Three main conclusions can be drawn from this work. First, this paper is the first to show that when the Bank of Japan did start to follow such advice, through its quantitative easing policy, such a strategy did help revive output growth and price inflation. Such results contrast with almost all available empirical evidence on the effects of such policy. Such a 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 and propelled by this new monetary policy of the BOJ. Second, by contrast with the MS-VAR approach, our MS-FAVAR allowed us to detect changes in monetary policy mechanism 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, are not present with the MS-FAVAR.
Results presented here confirm thus the idea that exploiting a larger and more realistic information set reveals to be better to model the monetary policy behavior.

In future work, we plan to use this approach in order to investigate in detail the transmission mechanism of Japanese monetary policy. The Interest rate factor seems to be operative and responsible for the monetary policy influence. However, this factor can be affected by both the expectation and the portfolio rebalancing channels suggested by the QEMP. It will be thus interesting to determine the size of the effect of every transmission channel.

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Appendix

Appendix A: The data set

Table 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, SA.	5
2	Industrial Production, Capital goods, SA, Index	5
3	Industrial Production, Construction goods, SA, Index	5
4	Industrial Production, Consumer goods, SA, Index	5
5	Industrial Production, Durable consumer goods, SA, Index	5
6	Industrial Production, Manufacturing, SA, Index	5
7	Industrial Production, Mining and manufacturing, SA,Index	5
8	Industrial Production, Non-durable consumer goods,SA,Index	5
9	Shipments, Mining and manufacturing, SA, Index	5
10	Shipments, Construction goods, SA, Index	5
11	Shipments, Capital goods, SA, Index	5
12	Shipments, Durable consumer goods, SA, Index	5
13	Shipments, Non-durable consumer goods, SA, Index	5
14	Shipments, Consumer goods, SA, Index	5
15	Shipments, Producer goods total, SA, Index	5
16	Capacity Utilization, Operation Ratio, Chemicals, SA	5
17	Capacity Utilization, Operation Ratio, Ceramics, clay and stone products, SA	5
18	Capacity Utilization, Operation Ratio, Machinery industry, SA	5
19	Capacity Utilization, Operation Ratio, Electrical machinery, NSA	5
20	Capacity Utilization, Operation Ratio, Fabricated metals, SA	5
21	Capacity Utilization, Operation Ratio, General machinery, SA	5
22	Capacity Utilization, Operation Ratio, Manufacturing, SA	5
23	Capacity Utilization, Operation Ratio, Non-ferrous metal, SA	5

24	Capacity Utilization, Operation Ratio, Pulp, paper and paper products, SA	5
25	Capacity Utilization, Operation Ratio, Transport equipment, SA	5
26	Capacity Utilization, Operation Ratio, Textiles, SA	5
27	Value of exports, Total, SA, JPY	5
28	Import Volume, Total, Index	5
29	Export Volume, Total, Index	5
30	Export Value, USA, Total	5
31	Export Value, China, Total	5
32	Unemployment rate, SA	4
33	Employment, By Status, Regular employees, all industries, 30 or more employees, Index	5
34	New job offert	5
35	Employment, By Industry, Manufacturing	5
36	Employment, By Industry, Non-agricultural industries	5
37	Electric power consumed, big contracts	5
38	Hours Worked, Average Per Month, Construction	5
39	Hours Worked, Average Per Month, Electricity, gas, heat and water	5
40	Hours Worked, Average Per Month, Manufacturing	5
41	Hours Worked, Average Per Month, All industries	5
42	Hours Worked, Average Per Month, Mining	5
43	Construction Started, Private $(1,000m^2)$	5
44	Construction Started, Public $(1,000m^2)$	5
45	Housing Starts, Housing built for sale	5
46	Housing Starts (owned)	5
47	Housing Starts, Rental homes	5
48	Housing Starts, Total	5
49	Total Floor area of new housing construction started	5
50	New order machinery (less volatile order)	5
51	New order machinery (Total)	5
52	inventory Mining and manufacturing, SA, Index	5
53	inventory Construction goods, SA, Index	5
54	inventory Capital goods, SA, Index	5
55	inventory Durable consumer goods, SA, Index	5
56	inventory Non-durable consumer goods, SA, Index	5

57	inventory Consumer goods, SA, Index	5
58	inventory Producer goods, SA, Index	5

Inflation factor

59	CPI (all items)(2000=100)	5
60	CPI (Durables)(2000=100)	5
61	CPI (General, Exclude Fresh Food)(2000=100)	5
62	CPI (services)(2000=100)	5
63	CPI (medical care)(2000=100)	5
64	CPI (commodities)(2000=100)	5
65	CPI (Shelter)(2000=100)	5
66	CPI (Transportation and Communication) (2000=100)	5
67	CPI (subgroup, miscellaneous, Index)(2000=100)	5
68	CPI (subgroup, food, Index)(2000=100)	5
69	Corporate Goods Prices, Domestic, minerals	5
70	Corporate Goods Prices, Domestic, manufacturing industry prod	5
71	Corporate Goods Prices, Domestic, Total	5
72	Wholesale price index Total	5
73	Wage index Contractual Cash, Manufacturing, JPY	5
74	Real wage Contractual Cash, Manufacturing, 30 or more employees, Index	5
75	Wage index Contractual Cash, All industries, JPY	5
76	Wage, Contractual Cash, Manufacturing, 30 or more employees, JPY	5

Interest rate factor

77	Call rate (uncollateralized overnight, month average)	1
78	Discount Rate	1
79	Long terme prime lending rate	1
80	Short terme prime lending rate	1
81	Treasury Bills, 3 month, Yield, End of Period	1
82	10-year interest-bearing Government Bonds, unit:%	1
83	10-year Local Government Bonds, unit: %	1
84	10-year Government Guaranteed Bonds, unit:%	1
85	5-year interest-bearing Bank debentures	1

86	Government Benchmarks, 10 Year, Average	1
87	Government Benchmarks, 2 year, End of Period	1
88	Leading Index, Tokyo interbank offered rates (3 months)	1
89	Government Bond Futures Listed Yield on TSE (10 years)	1
90	Average Contracted Interest Rates on Loans and Discounts of Domestically Licensed Banks (New)	1
91	Average Contracted Interest Rates on Loans and Discounts of Domestically Licensed Banks, City Banks (short-term)	1
92	Average Contracted Interest Rates on Loans and Discounts of Domestically Licensed Banks, Regional Banks (short-term)	1
93	Average Contracted Interest Rates on Loans and Discounts of Domestically Licensed Banks, City Banks (Long-term)	1
94	Average Contracted Interest Rates on Loans and Discounts of Domestically Licensed Banks, Regional Banks (Long-term)	1
95	Average interest rate on certificate of deposit of all banks	1

Appendix B: Estimated factors

Figure 8. Activity factor

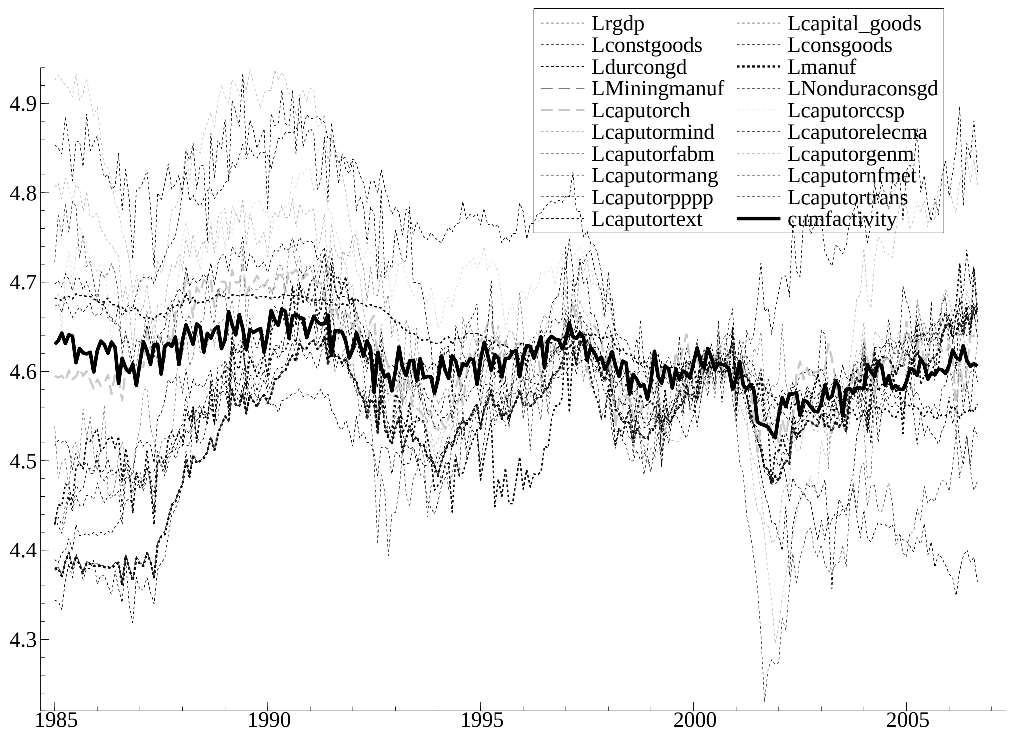


Figure 9. price factor

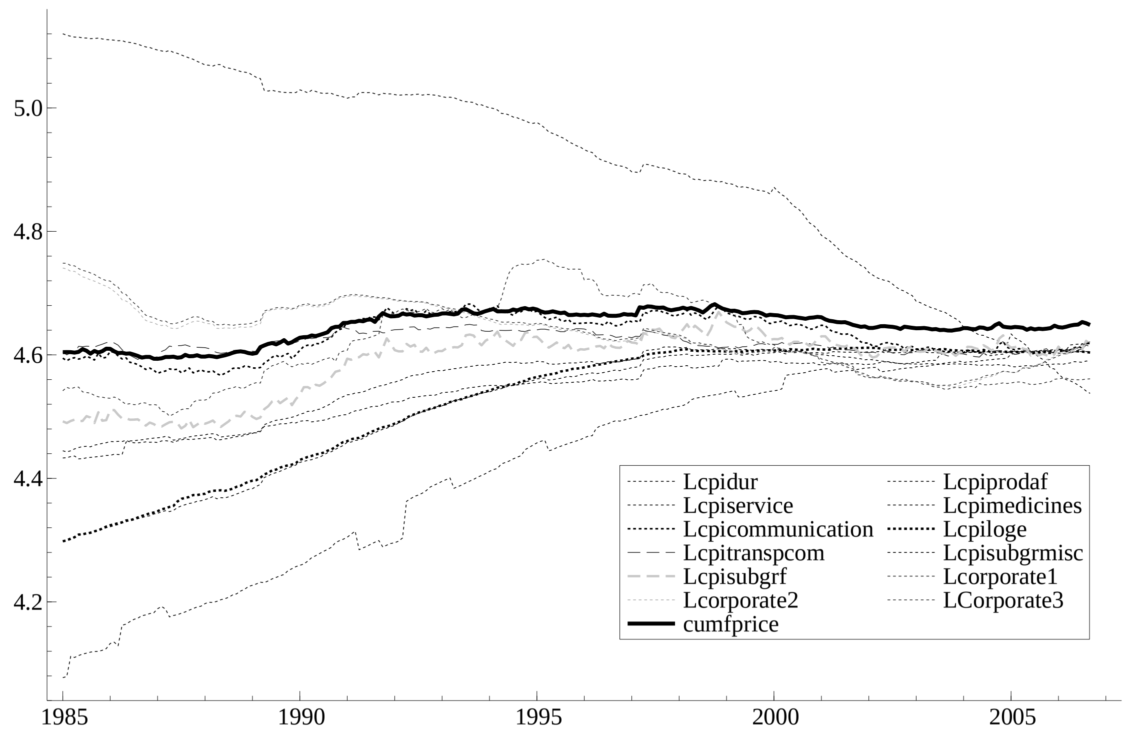
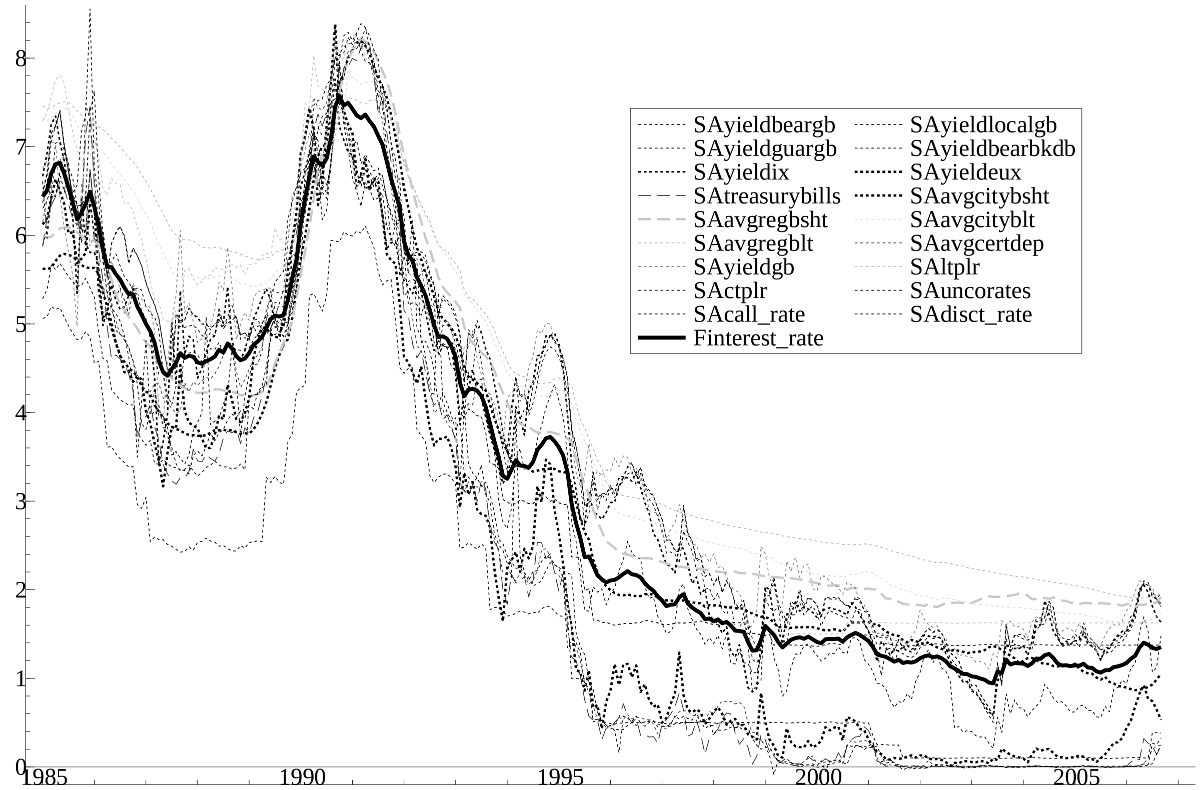


Figure 10. Interest rate factor



Appendix C: MS-VAR estimation results

Table 2. 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 3. 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 4. 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 5. 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 6. 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 7. 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 8. 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 9. Transition matrix

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