Forecasting Swedish Inflation with a Markov Switching VAR

by

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Abstract
Viewed over the whole available history of fiat money in Sweden, high levels of inflation have been present only over a short time span. It is only in the last two decades – the seventies and the eighties – that inflation has been high, at an average of eight percent on an annual basis. Based on consumer price data from 1830 to 1970, by contrast, the average inflation rate has been about two percent. In January 1993, the governing board of the Riksbank announced an inflation target of two percent as target for monetary policy. In the period after this announcment inflation has come down to its pre 1970 level. This poses difficulty for forecasting inflation, since the 1970-92 period represents a sizable part of the available and reliable macro data. In particular, forecasts based on linear models have the property that they tend to revert back to their unconditional means. Since the mean has been high, linear models thus tend to produce implausibly high forecasts that do not take into account the new monetary regime with an inflation target, nor the new legislative independence of the Riksbank. In this paper, I propose a VAR with Markov switching around two states, a high and a low inflation state. It is then possible to use data from 1970-1992 and yet produce plausible forecasts one to two years ahead. The forecasts incorporate the risk of switching back to high inflation, but are not dominated by this risk the way linear models are. Nor is this risk ignored altogether, such as with the introduction of a dummy variable for the shift in the level of inflation.

JEL Classification: C32, C53.

Keywords: VAR, Markov switching, forecasting, inflation.

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1 Introduction

Swedish inflation has been fairly high during the last two decades, on average eight-percent per year between 1970 to 1992. After 1992 by contrast, inflation has been on average two percent. Although contemporary history thus suggests that low inflation is a new regime, this is not the case. Based on approximate[1] consumer price data from 1830-1955 and thereafter CPI, the average level of inflation between 1830-1970 has been about two percent.[2] Thus, the low level of inflation since 1992 represents a *return* to a level of inflation that has been present for almost one-and-a-half centuries. It is not the regime of low inflation that stands out but rather the inflationistic period 1970-92.

With a few years of experience, it now appears that the Riksbank's inflation target of two percent has changed the inflation process after two decades of wage-price spirals coupled with devaluations. Surveys of inflation expectations[3] show a downward adjustment; union wage negotiations appear to take the lower levels of inflation into account; and forward rate curves, as discussed in Dillén and Hopkins (1998), no longer indicate high inflation risk premia.[4]

Given that the inflation process has changed, how can historical data – particularly from the last two decades – be used to forecast inflation? The problem with forecasts based on linear models is that they tend to revert back to their unconditional means. Since the mean of inflation has been high for contemporary data, linear models thus

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[1] The approximate series is published in Statistics Sweden (1994). For the period 1830-1931 it relies on the Myrdal-Bouvin (1933) index.

[2] Inflation rose gradually throughout the postwar period but then began to accelerate strongly after 1970. The specification of 1970 as a turning point is meant to emphasise the link to the available macro data rather than suggest a definite time for the switch to the high inflation regime.

[3] Surveys on inflation expectations are carried out by Aragon, Prospera Research and Statistics Sweden.

[4] For an early discussion of whether the inflation process has changed or not, see Berg and Lundkvist (1997).

tend to produce implausibly high forecasts that do not take into account the new monetary policy regime with an inflation target, nor the new legislative independence of the Riksbank.[5]

Some form of time-variation in the mean of inflation appears necesary in order to produce sensible forecasts. Probably the easiest way to do this is by use of a dummy variable, such as in Jacobson et al (1998). If we view the dummy as a parameter, and construct it to equal zero prior to 1992 and one afterwards, the shift in mean can be incorporated into the estimation. Apart from being simple and transparent, this approach has the advantage that we can also assess whether or not the shift is significant – an advantage shared by all dummies, such as for VAT changes or for other tax changes.

The disadvantages, even for simple hypothesis testing, are several. Although it is true that some dummy variables are exogenous to the data generating process in focus, such as if a person is male or female, or if the observation is made in December or June, many important shifts are not exogenous. In particular, the shift to inflation targeting in Sweden is clearly not independent of the high levels of past inflation: had inflation been low, there would have been no need for an inflation target. This dependence is likely to matter for constructing inflation forecasts since the shift to an inflation target is likely to be such that it affects many of the relationships in the inflation process. For example, it might affect the variance of inflation, since high levels of inflation have also been associated by high inflation volatility; it might affect the marginal propensity to demand nominal wage increases, and so on.

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[5]For the period 1995-1998 monetary policy has been guided by an inflation target, which was unilaterally announced by the governing board of the Riksbank in January 1993. On January 1, 1999 new legislation has come into effect that makes the Riksbank independent of – but accountable to – Swedish parliament via the governing board. The goal of price stability has been adopted into law as a formal goal for monetary policy. Interest rate decisions are decided by majority voting by an independent executive board of six directors.

We could, of course, introduce the same dummy parameter for each coefficient, but much of the simplicity and transparency is lost, and moreover, there is no reason why all coefficients should switch at the same time. Some may switch immediately, some only gradually, and others not at all.

In this paper, we propose a vector autoregression (VAR) with Markov switching for the Swedish inflation process. We assume that there are two regimes, a high inflation state and a low inflation state. Further, we assume that the regime is *unobservable* – and has to be inferred from the data. The statistical set-up is the same as that used in seminal work of Hamilton (1989) and has become fairly standard; the assumption of two inflation regimes has been used by Evans and Lewis (1995), Evans and Wachtel (1993), and Bleaney (1997), although their modeling of the states differ from that used here. The model is used to construct forecasts one to two years ahead – the horizon of interest for monetary policy - that take into account the shift to lower inflation, but *allow* for the risk that we may switch back to higher inflation. The risk of switching can be thought of as a *credibility* factor for monetary policy: the lower the risk of switching back to the high inflation regime, the higher is credibility.

The rest of the paper is outlined as follows. In the next section, we discuss the Markov switching model in more detail. In section 3 we discuss estimation issues, such as choice of variables and lag length. Section 4 shows how forecasts for Swedish inflation can be constructed in this framework. Section 5 concludes.

2 The model

The model is centered vector-autoregression (VAR) with p lag terms given by

(1) $$y_t - \mu_{s_t} = B^{(1)}\left(y_{t-1} - \mu_{s_{t-1}}\right) + \cdots + B^{(p)}\left(y_{t-p} - \mu_{s_{t-p}}\right) + \varepsilon_t \,,$$

where $\varepsilon_t \middle| s_t \equiv N(0,\Omega)$ and s_t follows a Markov chain with transition probabilities

(2) $$P = \begin{pmatrix} p_{11} & 1-p_{22} \\ 1-p_{11} & p_{22} \end{pmatrix},$$

y_t is a $n\times 1$ vector of observable variables, and μ_{s_t} is a state dependent vector of parameters. Notice that the variance of inflation is assumed to be state invariant.[6]

The model is discussed in Hamilton (1994), and has the feature that switches occur around a conditional mean term μ_{s_t}. The state is assumed to be unobservable, and has to be inferred from data; such an inference is denoted by $\text{pr}[s_t = \tau | \mathcal{Y}_t]$, where $\mathcal{Y}_t = \{y_t, y_{t-1}, \cdots\}$. The state probabilities are collected into the vector

(3) $$\xi_{\tau|t} = \begin{pmatrix} \text{pr}\left[s_\tau = 1 \middle| \mathcal{Y}_t\right] \\ \text{pr}\left[s_\tau = 2 \middle| \mathcal{Y}_t\right] \end{pmatrix}.$$

The Markov assumption implies that the probability of switching from one state to the other depends *only* on which is the past state. The advantage with this assumption is that estimation and forecasting is easy; the disadvantage is that it is likely that the current level – and indeed the whole inflation history – should affect the probability of switching to a given inflation regime. Switching models that deviate from the Markov assumption and allow the level variables to affect the transition probabilities have been discussed in Gray (1995), Ghysels (1994), and Diebold, Lee, and Weinbach (1994).

How might the risk of switching be interpreted? Let us without loss of generality define state one as the high inflation regime. The risk of switching from state two back to the high inflation regime, $1-p_{22}$, can then be considered as a measure of credibility for monetary policy.

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[6] This assumption may be relaxed in future work.

3 Estimation

In this section we will discuss issues concerning estimation of the VAR. The first question concerns which variables to include in the VAR, a question addressed using linear models in Nilsson & Nilsson (1994) and Baumgartner et al (1997) among others. Although the variables that performed best in a linear model need not do so in a non-linear specification, they at least provide a useful starting point. From the perspective of a small macro model, a measure of output, money, and interest rates are *sine qua non.*

Another important question concerns the choice of data frequency. Monthly data is available for all variables in the VAR, but for this frequency purely seasonal effects are strong. For a discussion of seasonality in Swedish CPI, see Borg (1996). Moreover, macro-models typically do not model seasonal fluctuations and are constructed for at most quarterly frequency – often yearly. Unless the seasonal component is explicitly modeled, as discussed in Hylleberg (1992), it seems reasonable to base empirical work that concerns monetary policy on quarterly frequency. Of course, seasonal fluctuations are present in quarterly data as well, and quarterly seasonal dummies are therefore included in the VAR.

In this paper we estimate and forecast quarterly growth rates. The focus on growth rates has some advantages for forecasting. First, the percentage growth of CPI (as proxied by changes in logarithms) is the measure of interest for monetary policy, and is thus the natural yardstick for model building. Second, and more important, as discussed in Hendry & Clements (1997), it is much more robust than levels-specifications to structural shifts that are not explicitly modeled.

The VAR in (1) is estimated with maxiumum likelihood (ML) via the EM algorithm, see Hamilton (1994). For the choice of lag length and specification of seasonality we have relied on finding the lowest parameterization possible where no misspecification appears present. The misspecification tests considered (but not displayed) are tests for residual autocorrelation, ARCH effects, and for the Markov assumption. These are F-versions of tests based on conditional scores from Newey (1985), Tauchen (1985), and White (1987) and suggested by Hamilton (1996) for a univariate model.

The variables included in the final specification are (the one quarter log growth of) CPI, M3, and industrial production.[7] Thus, the short-term interest rate has been excluded, essentially due to degrees of freedom problems[8]. The shortest lag-length consistent with data is four. In our preferred specification we have also imposed the linear restrictions that the two different means of inflation conditional on the state are given by 2 and 0.5 percent reflecting the high and the low inflation regime respectively. The restriction cannot be rejected by an LM test at conventional levels and is also consistent with simple time averages for 1970-92 and 1992-98. On an annual basis, this corresponds to 8 and 2 percent. Thus, the conditional mean of inflation in the low inflation regime is equal to the Riksbank's inflation target.

First, let

(4) $$y_t = \begin{pmatrix} \pi_t \\ \Delta y_t^* \\ \Delta \text{M3}_t \end{pmatrix}$$

where $\pi_t, \Delta y_t^*, \text{and} \, \Delta\text{M3H}_t$ is the (quarterly) log growth in prices, industrial production, and EU harmonized M3 respectively. The estimated Markov Switching VAR is then

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[7] The quarterly inflation series used is based on the shadow index discussed in the appendix.

[8] Including more variables soon gives degrees of freedom problems. The number of parameters estimated is $3n + n^2 p + nq + 0.5n(n+1) + q(q-1)$, so when $n = 3, p = 4$ there are 59 free parameters in the unconstrained model for slightly less than one-hundred data points. Adding one more variable (holding lag-length and number

$$y_t - \mu_{s_t} = \begin{pmatrix} \underset{(0.79)}{-0.42} & \underset{(0.94)}{1.04} & \underset{(0.88)}{0.24} \\ \underset{(2.16)}{-0.81} & \underset{(2.16)}{-1.67} & \underset{(2.16)}{-1.28} \\ \underset{(1.86)}{3.37} & \underset{(2.89)}{0.76} & \underset{(3.10)}{-0.73} \end{pmatrix} \begin{pmatrix} D^{(1)} \\ D^{(2)} \\ D^{(3)} \end{pmatrix}_t$$

$$(5) \qquad + \begin{pmatrix} \underset{(0.18)}{-0.07} & \underset{(0.07)}{0.03} & \underset{(0.08)}{0.13} \\ \underset{(0.57)}{-0.45} & \underset{(0.18)}{-0.23} & \underset{(0.18)}{0.12} \\ \underset{(0.86)}{-0.25} & \underset{(0.23)}{-0.07} & \underset{(0.19)}{-0.31} \end{pmatrix} \left(y_{t-1} - \mu_{s_{t-1}}\right) + \begin{pmatrix} \underset{(0.16)}{0.41} & \underset{(0.07)}{0.01} & \underset{(0.06)}{0.01} \\ \underset{(0.54)}{-0.72} & \underset{(0.19)}{0.24} & \underset{(0.16)}{0.11} \\ \underset{(0.69)}{-0.43} & \underset{(0.19)}{-0.08} & \underset{(0.20)}{0.09} \end{pmatrix} \left(y_{t-2} - \mu_{s_{t-2}}\right)$$

$$+ \begin{pmatrix} \underset{(0.23)}{0.13} & \underset{(0.08)}{0.02} & \underset{(0.06)}{0.01} \\ \underset{(0.67)}{0.24} & \underset{(0.19)}{0.23} & \underset{(0.18)}{0.02} \\ \underset{(0.61)}{0.04} & \underset{(0.19)}{0.02} & \underset{(0.22)}{-0.02} \end{pmatrix} \left(y_{t-3} - \mu_{s_{t-3}}\right) + \begin{pmatrix} \underset{(0.19)}{0.20} & \underset{(0.07)}{0.06} & \underset{(0.08)}{0.09} \\ \underset{(0.56)}{-0.04} & \underset{(0.23)}{-0.06} & \underset{(0.18)}{-0.08} \\ \underset{(0.78)}{0.54} & \underset{(0.15)}{0.01} & \underset{(0.20)}{0.44} \end{pmatrix} \left(y_{t-4} - \mu_{s_{t-4}}\right)$$

where $D^{(i)}$ are seasonal dummies,

$$(6) \qquad \mu_1 = \begin{pmatrix} 2.0^* \\ \underset{(0.63)}{0.26} \\ \underset{(0.78)}{2.46} \end{pmatrix}, \ \mu_2 = \begin{pmatrix} 0.5^* \\ \underset{(0.87)}{1.68} \\ \underset{(0.83)}{0.52} \end{pmatrix}, \ \mathrm{E}\left[y_t | s_t = 1\right] = \begin{pmatrix} 2.11 \\ 0.23 \\ 2.48 \end{pmatrix}, \ \mathrm{E}\left[y_t | s_t = 2\right] = \begin{pmatrix} 0.51 \\ 1.66 \\ 0.54 \end{pmatrix},$$

where the star denotes a linear restriction (discussed above), $\varepsilon_t | s_t \equiv N(0, \Omega)$ and

$$(7) \qquad P = \begin{pmatrix} \underset{(0.08)}{0.96} & \underset{(0.12)}{0.07} \\ \underset{(0.08)}{0.04} & \underset{(0.12)}{0.93} \end{pmatrix}, \ \Omega = \begin{pmatrix} \underset{(0.15)}{0.60} & \underset{(0.43)}{0.36} & \underset{(0.42)}{-0.24} \\ \underset{(0.43)}{0.36} & \underset{(1.97)}{5.24} & \underset{(1.03)}{0.04} \\ \underset{(0.42)}{-0.24} & \underset{(1.03)}{0.04} & \underset{(1.87)}{5.63} \end{pmatrix}.$$

Standard errors based on conditional scores are displayed in parentheses. Many parameters have large standard errors, and in particular several of the autoregressive terms.[9]

It is interesting to note that the conditional growth rate of industrial production given by μ_i is more than six times larger in the low inflation state than in the high inflation state. In other words, low inflation is associated with high growth of output in the data. This observation is of course useful from an economic perspective, but the

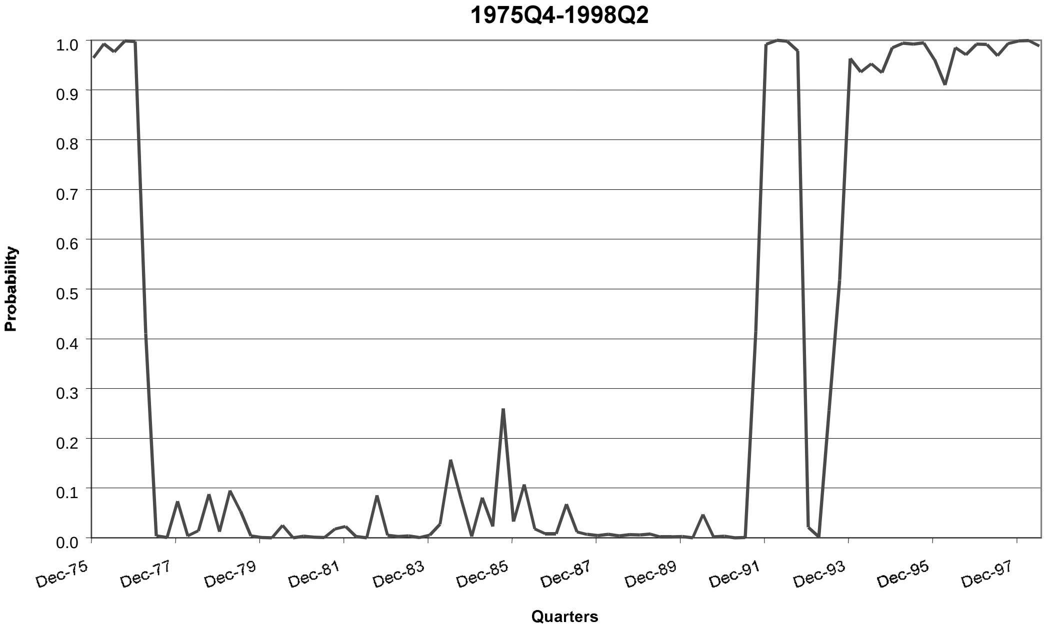
of regimes constant) yields 37 more parameters, which is infeasible.

[9] This might suggest using shorter lag length, but no such specification was found that was consistent with data.

difference in growth rates between the states is not statistically significant at conventional levels.[10]

In figure 1, we plot the probability of being in the low inflation regime, that is the filter[11] probabilities given by $\text{pr}[s_t = 2|\mathcal{Y}_t]$. These probabilities show that the Swedish economy was most likely in the low inflation regime in the early seventies, but then switched to the high inflation regime for most of seventies and the eighties, only switching back to the low inflation regime around 1992.

Figure 1. Probability of Low-Inflation Regime



To interpret these probabilities, it is helpful to superimpose them on the inflation rate. This is done in figure 2, which shows the quarterly change in CPI and the probability of being in the low inflation regime (minus two to make the plot easier to

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In particular, the EM iterations would not converge for lag lengths shorter than four.

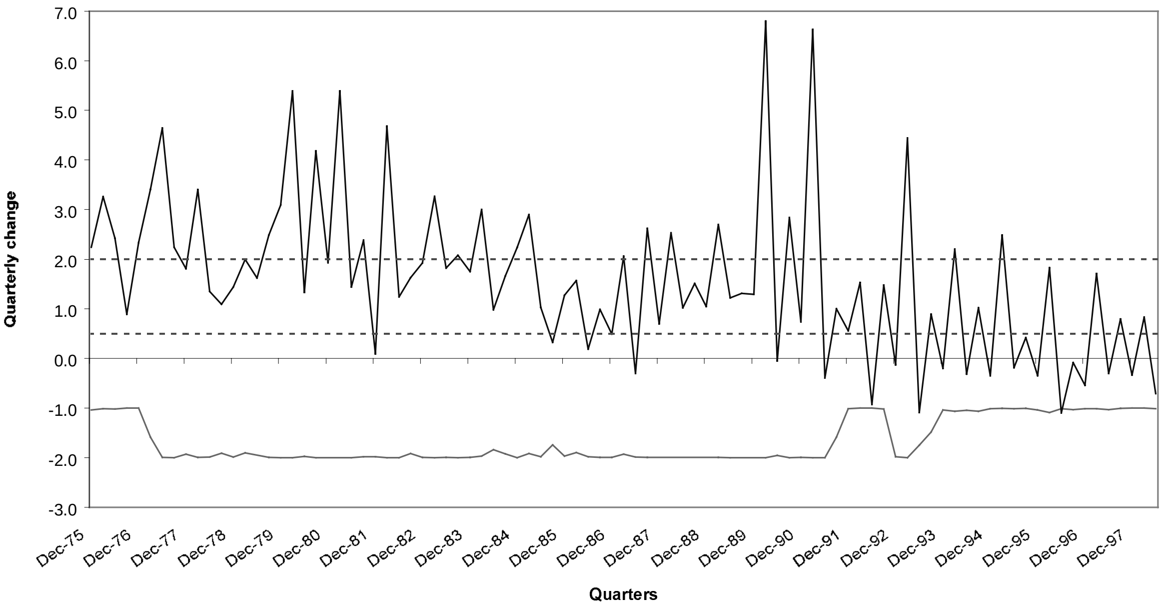
[10] Essentially the correlation between low inflation and high growth comes from a few post 1993 observations. To have firmer evidence for this relationship we would need more observations from the low inflation state, ideally observed over more than one business cycle.

[11] The smoothed probabilties, $\text{pr}[s_t = 2|\mathcal{Y}_T]$, are plotted in the appendix.

read). As can be seen, the episodes when switches seem to occur largely coincide with the movements in inflation.

Figure 2. Inflation and probabilities

1975Q4-1998Q2



4 Forecasting

As discussed in Hamilton (1994), and further in Blix (1997), forecasts j periods ahead in (1) are given by

(8) $$\mathrm{E}\left[y_{T+j} \middle| \mathcal{Y}_T\right] = aP^j \xi_{T|T} + JB^j \begin{bmatrix} y_T - a\xi_{T|T} \\ \vdots \\ y_{T-p+1} - a\xi_{T-p+1|T} \end{bmatrix},$$

where $a = (\mu_1 \quad \mu_2)$ and $J = (I_n \quad 0 \quad \cdots \quad 0)$ are $n \times q$ and $n \times np$ matrices respectively, and the $np \times np$ matrix

$$B = \begin{pmatrix} B^{(1)} & \cdots & & B^{(p)} \\ I_n & & & 0 \\ & \ddots & & \\ 0 & & I_n & 0 \end{pmatrix}$$

is in companion form VAR. Note that the forecasts from (8) are *not* conditional on unchanged repo rate over the forecast horizon.

Table 1 shows probabilities for staying in a given regime, i.e. the Markov transition probabilities p_{11} and p_{22}. The first column shows the maximum likelihood estimate (MLE). The second column illustrates a thought-experiment in which the probability of staying in the low inflation regime has been (arbitrarily) set equal to the probability of staying in the high inflation regime.[12] The final column is also a thought-experiment in which the probability of staying in the low inflation regime is set to 100%.

Table 1. Regime probabilities

	MLE	**Ad-hoc**	**100%**
p_{11}	0.96	0.96	NA
p_{22}	0.93	0.96	1

How might these three columns with transition probabilities be interpreted? For the MLE, the probability of staying in a given regime is proportional to the number of times the regime appears to have been realized. That the probability of staying in the low inflation regime is lower than staying in the high inflation regime is then only a reflection that for the data period used, most observations come from the high inflation regime. The second column can therefore be interpreted as the probability of staying in the low inflation regime that we *would have had if there were as many years of the low as the high inflation regime.* The last column corresponds to the effect of having a dummy-variable in the model and is interesting mainly for comparison to such models.

On what basis might we choose between the different transition probabilities for forecasting purposes? There are two reasons for interpreting the MLE as a *lower* bound for the probability of staying in the low inflation regime. First, it is probably not

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[12] Formally this restriction should be imposed when estimating the VAR. This has not been done, essentially

necessary to have twenty years of low inflation until the low inflation regime becomes as persistent as the high inflation regime has been in the seventies and eighties. Second, the probability of staying in the low inflation regime is likely to increase since the Riksbank has recently become independent (see footnote 5).

The ”ad-hoc” probability, on the other hand, might be interpreted as an *upper* bound since monetary policy – even with a more independent Riksbank – is unlikely to yield the same credibility as *twenty years of low inflation would have given.* Based on these arguments, it seems reasonable that the probability of staying in the low inflation regime should lie somewhere in the interval from 93 to 96 percent. In other words, the risk of switching to the high inflation regime is low, but not negligible.

Forecasts using data up to 1998Q2 and based on the different transition probabilities are displayed table 2. The highest forecast comes from using the MLE. Using the argument given above, this might be viewed as providing an upper bound for the forecast. By the same token, the ”ad-hoc” forecast might be viewed as providing a lower bound. So what is the best forecast? The methodology and arguments applied in this paper cannot (readily) be used as guidance: All outcomes between 2.2 and 3.2 percent as point forecasts for December 2000 are consistent with the Markov-switching VAR and with the informal arguments put forth in this paper. Thereby the interval highlights the *sensitivity* of the forecast on different views on the credibility of the low inflation-regime.[13]

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because the value added does not seem great enough to warrant the added computational cost.

[13] Finally, as with all forecasts it is desirable to examine the out of sample forecast performance. Such an exercise can provide indication of over-fitting and other failures. For example, over-parameterized models may provide good *within-sample* but poor *out-of-sample* fit. Although time-consuming, such an exercise can be performed for the MS-VAR. However, since there are few observations in the low inflation regime – both absolutely and in comparison to the high inflation regime - this will tend to increase the sample variance for those parameters to the point where the whole exercise may become misleading. In the future, with (hopefully!) more observations in the low-inflation regime, such an exercise may fruitfully be performed.

Table 2. Annual inflation forecasts

	MLE	Ad-hoc	100%
Sep-98	0.74	0.69	0.63
Dec-98	0.79	0.65	0.47
Mar-99	0.29	0.02	-0.34
Jun-99	1.28	0.84	0.26
Sep-99	1.00	0.42	-0.37
Dec-99	1.81	1.11	0.13
Mar-00	2.16	1.37	0.21
Jun-00	2.65	1.77	0.45
Sep-00	2.91	1.96	0.49
Dec-00	3.25	2.24	0.63

5 Conclusion

In this paper we have used a centered Markov switching VAR to estimate and forecast Swedish inflation. Linear models that do not attempt to model the downward shift in inflation typically tend to give too high forecasts, since linear models with mean-reversion tend to predict a return to the unconditional mean. For Swedish inflation forecasts this means the new legislation giving independence to the Riksbank and the track record of half a decade with low inflation have very little weight in the forecasts – although arguably they are crucial.

Simple remedies to the above difficulty, such as introducing dummy variables, help but pose new problems. For example, a shift dummy for the level of inflation in 1992 would probably be significant but would implicitly assume 100% credibility for the new level of inflation which does not seem reasonable.

By contrast, the approach with Markov switching allows for the downward shift without assuming full credibility, and is a parsimonious way to represent the data. It is also very easy to use for forecasting. Based on the MLE and on informal arguments we established a lower and an upper bound for the credibility of the low inflation regime and for the corresponding forecasts. The interval between the lower and the upper bound gives a range of model-consistent inflation forecasts. The interval shows how a given choice of the credibility factor – defined as the probability of remaining in the low inflation regime – affects the inflation forecast. Overall, the results in the paper indicate that the credibility for the inflation target is high, in the range of 93 to 96 percent. This means that the risk of switching back to high inflation is low – but not negligible.

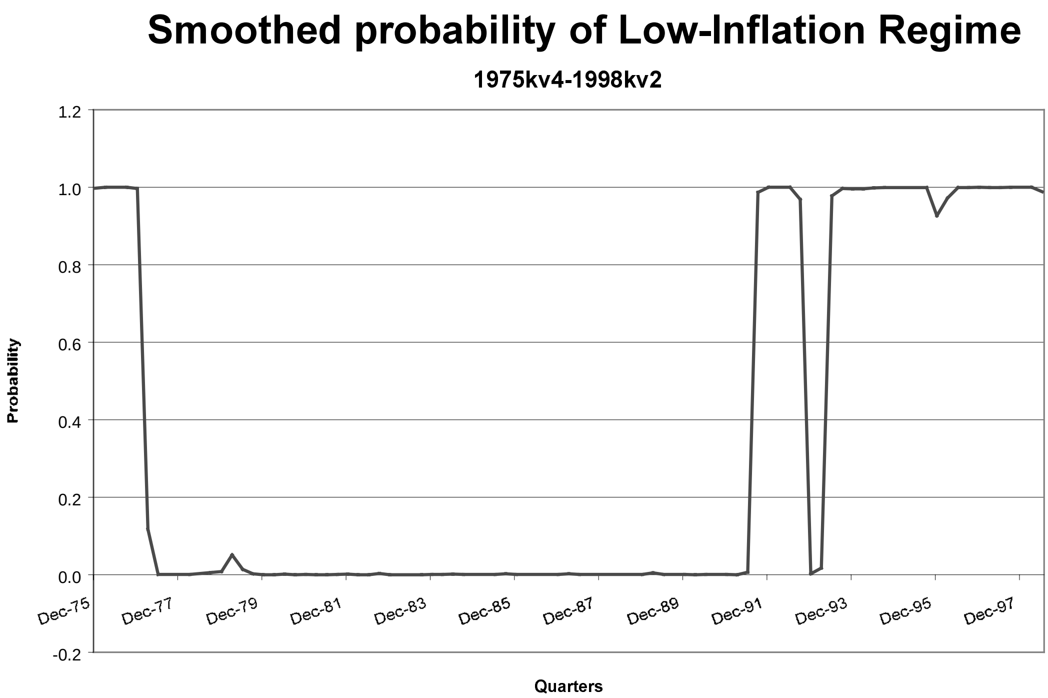
Future research might improve on the current method by allowing for time varying transition probabilities that depend on the *level* of the variables – and, ideally, in some (limited) way on the whole inflation history. In future research, it may also be possible to examine *out-of-sample* forecast performance and evaluate the merits of the MS-VAR approach.

Appendix: data

The data used are Swedish CPI from Statistics Sweden (SCB), EU harmonized broad Swedish money stock M3H (Sveriges riksbank), and industrial production NSA (SCB). The quarterly inflation rate used is based on a shadow index constructed by using the short term CPI index published by Statistics Sweden for a base year and then using the published yearly inflation rates to construct the rest of the series.[14] The data series used can be obtained from the author on request.

Appendix: smoothed probabilties

This figure shows the smoothed probabilties, $\mathrm{pr}[s_t = 2 | \mathcal{Y}_T]$, of being in the low inflation regime. See Hamilton (1994) for a discussion on estimation.



[14] The shadow series has been calculated by Göran Zettergren.

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