Do inflation expectations matter? The Great Moderation revisited

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This version, August 2007

Abstract

We examine the role of inflation expectations in the Great Moderation. We derive theoretical restrictions using a simple New-Keynesian model and test them using measures of inflation expectations obtained from survey data and bond markets. Expected inflation play a role in explaining the dynamics of inflation and of interest rates but this role is roughly unchanged over time. Systems with and without inflation expectations display similar reduced form characteristics. Including or excluding inflation expectations does not change the explanation of the Great Moderation. Results are robust to a number of variations of the empirical model.

JEL classification: C11, E12, E32, E62

Key Words: Indeterminacy, inflation expectations, term structure, Structural VARs.

*We thank Carlo Favero for sharing zero coupon rate term structure data for the US with us, Russell Cooper, Dale Henderson, Andrew Levin and David Lopez Salido for comments and suggestions. Both authors acknowledge the financial support of the Spanish Ministry of Education through the grant SEJ-2004-21682-E. Canova also acknowledges financial support from CREI.

1 Introduction

Many authors have recently examined the "Great Moderation" in the US (see Clarida, et. al. (2000), Blanchard and Simon (2001), Cogley and Sargent (2001) (2005), Stock and Watson (2002), Gambetti et. al. (2005), Gordon (2005) Primiceri (2005), Arias, et. al. (2006), Sims and Zha (2006) among others) and its international features are currently under study (see Stock and Watson (2004), Benati and Mumtaz (2006) or Canova, et. al. (2007)). Most analyses agree on the observation that the volatility and the persistence of output and inflation have declined since the late 1970s but explanations differ. The literature is mainly divided into two fronts - those who support the "bad policy" hypothesis (failure of the Fed to appropriately respond to inflation) and those who lean toward the "bad luck" hypothesis (shocks are drawn from a distribution with time varying features) - with a few authors claiming that changes in private sector may be responsible for the phenomenon (see e.g. McConnell and Perez Quiroz (2001), Canova (2005), Campbell and Herkovitz (2006)). The division appears to be linked to the type of empirical analysis one conducts: while narrative and reduced form approaches consistently point to "bad policy" as key to explain the facts, structural VARs favor the "bad luck" conclusion. Given the strong prior of many commentators, some have questioned the ability of structural VARs to detect the true sources of variations in the data (see Benati and Surico (2006)).

The most convincing formalization of the " bad policy" hypothesis appears in Lubik and Schorfheide (LS) (2004), who estimate a three equations New-Keynesian model with Bayesian methods over two subsamples, and find that estimated policy rule implies an indeterminate equilibrium in the first subsample (up to the end of the 1970s) but not in the second one (from the beginning of 1980s up today). Boivin and Giannoni (2006) confirm this finding with an alternative estimation technique. One important consequence of LS findings is that, by strengthening the reaction of the nominal rate to inflation, the Fed has effectively managed to anchor inflation expectations since the early 1980s. Hence, the dynamics of inflation expectations are crucial to understand the facts and to assess the credibility of the explanation. Despite of this, and as far as we know, no one has formally examined whether inflation expectations fit the role that the indeterminacy-determinacy story of the Great Moderation has given to them. Leduc et. al (2005) have studied how much the nominal rate moves in response to expected inflation shocks, when expected inflation is proxied by Livingstone Survey data, and whether there has been a change in the magnitude and the persistence of expected inflation shocks, but they do not directly examine the role of inflation expectations in the two regimes.

In this paper we study whether the restrictions imposed by the indeterminacy-determinacy story of the Great Moderation on inflation expectations are satisfied. To start with, we derive the population implications of a simple New-Keynesian model in the two regimes using a parameterization which replicates the most salient aspects of LS estimates. Since the dynamics of the variables of interest is not pinned down in the indeterminate regime, we examine two special cases - the continuity and the orthogonality solutions, see Lubik and Schorfheide (2003). We also examine what happens when shocks to expectations occur - in this case sunspot shocks are orthogonal to structural disturbances. Three basic implications emerge. First, expected inflation is a state variable in the indeterminate regime but not in the determinate one. Hence, expected inflation should Granger cause other endogenous variables in this sample and there should be a break in the significance of Granger causality tests as we move from the indeterminate to the determinate regime.

Second, variations in the coefficients of the policy rule, imply variations in both the impact coefficients and the lagged responses to shocks. This is true when changes imply switches from an indeterminate to a determinate regime and when they occur within a determinate regime. Hence, regimes can not be separated by examining the relative magnitude of the changes in the lagged dynamics and in the variance of the reduced form shocks.

Third, several explanations are "locally" indistinguishable from the indeterminacy-determinacy story. That is, it is possible to reproduce the population dynamics in response to structural shocks (in the continuity solution) of the indeterminacy regime with a specification where only a determinate equilibrium exists and structural parameters are appropriately adjusted. Interestingly, while the pure "bad luck" hypothesis, where only the variance of the structural shocks is adjusted, does not display this feature, alternative specifications, where changes in the parameters of the private sector and/or the policy rule are combined with particular variations in the variances of the shocks, have such a property.

Given the last two results, many of the counterfactuals performed in the literature are unlikely to be able to detect regime switches. In this paper we focus on the first implication role. To examine the role of inflation expectations in the two regimes we proceed as follows. We collect alternative measures of one year ahead inflation expectations: three based on survey data (Michigan, Professional Forecasts, Livingstone survey, Greenbook forecasts) and one backed out from the term structure of nominal interest rates. We, then, run several VARs which include output growth, inflation, the nominal interest rate, and a proxy measure of inflation expectations and examine (i) whether lagged inflation coefficients are significant and (ii) whether there is change in their significance over time. To complement this analysis we also examine whether omitting inflation expectations from the estimated system causes time varying biases in the variance of reduced form shocks. Finally, we study whether the presence of inflation expectations alters the interpretation of the Great Moderation. Since inflation expectations have been systematically excluded from the models designed to address the issue, we want to know whether the conclusions one reaches are robust to this omission.

Our results suggest that the role of inflation expectations differs from the one postulated by the indeterminacy-determinacy story. In particular, regardless of the specification of the empirical models and statistics used, we find (i) lags of expected inflation are either always significant or always insignificant and there is no clear switch over time in their importance in any equation of the system; (ii) reduced form variances estimated in systems with and without inflation expectations display similar features and little evidence of time varying biases; (iii) the economic interpretation of the Great Moderation episode is independent of the inclusion or the exclusion of inflation expectations from the empirical system. In particular, consistent with Gambetti et. al. (2005), supply and real demand shocks are crucial to understand the time profile of output growth volatility and persistence while monetary shocks are the most important driver of inflation persistence and volatility since the late 1970s; (iv) sunspot shocks seems to matter very little for output growth and inflation volatility and persistence and changes in their contribution do not line up well with the time variations in these statistics.

The rest of the paper is organized as follows. The next section examines the implications of a simple model. Section 3 describes our inflation expectation measures. Section 4 examines the empirical evidence. Section 5 discusses the causes of the Great Moderation. Section 6 measures the importance of sunspot shocks. Section 7 concludes.

2 What does theory tells us: a basic NK model

We consider a standard three-equation New-Keynesian model which includes a log-linearized Euler condition, a log-linearized Phillips curve, and a log-linearized policy rule describing how nominal interest rates react to real activity and inflation. We choose a simple structure to make the points of interest crystal clear. More complicated model, which allow for additional frictions and more shocks, deliver conclusions similar to those emphasized in this section. In deviation from a non-stochastic steady state, the equations are:

$$R_t = \phi_r R_{t-1} + (1-\phi_r)(\phi_\pi \pi_t + \phi_x(x_t - z_t)) + e_{R,t} \quad (1)$$

$$\pi_t = \beta\pi_{t+1|t} + \kappa(x_t - z_t) \quad (2)$$

$$x_t = x_{t+1|t} - \tau(R_t - \pi_{t+1|t}) + g_t \quad (3)$$

where $g_t = \rho_g g_{t-1} + e_{g,t}$, $z_t = \rho_z z_{t-1} + e_{z,t}$, x_t is the output gap, π_t the inflation rate, R_t the nominal rate, and the notation $t+1|t$ denotes conditional expectations. Here, g_t is a demand shifter, z_t exogenously shifts the marginal cost of production while $\beta, \kappa, \tau, \phi_r, \phi_\pi, \phi_x, \rho_g, \rho_x, \sigma_{eR}$, σ_g, σ_z and ρ_{gz}, the contemporaneous correlation between g_t and z_t, are parameters.

Table 1: Model Parameterization

Parameter	Regime 1 Indeterminate	Regime 2 Determinate	Regime 1 Determinate 1	Regime 1 Determinate2
β	0.99	0.99	0.99	0.99
τ	1.45^{-1}	1.45^{-1}	1.75^{-1}	1.45^{-1}
κ	0.77	0.77	0.58	0.77
ρ_g	0.68	0.68	0.74	0.74
ρ_z	0.82	0.82	0.74	0.77
σ_g	0.27	0.27	0.29	0.33
σ_z	1.13	1.13	1.05	1.31
σ_{eR}	0.23	0.23	0.15	0.15
ϕ_π	0.77	2.19	1.75	1.51
ϕ_x	0.17	0.30	0.82	0.87
ϕ_R	0.60	0.84	0.81	0.86
ρ_{gz}	0.14	0.14	0.14	0.14

To describe the population features of this model in different regimes we use a parametrization similar in spirit to the estimates of Lubik and Schorfheide (2004) (see table 1, columns 1 and 2), which were obtained with US data and Bayesian methods over the subsamples (1960:1-1979:2, 1982:4-1997:4), although none of the points we make depend on the exact parameter selection. Note that the only change in the first two columns of table 1 involves the coefficients of the policy rule. Given the nature of the model, when the reaction of the nominal rate to inflation is weak ($\phi_\pi < 1$) an indeterminate equilibrium obtains; when the reaction is strong ($\phi_\pi > 1$), a determinate equilibrium emerge.

The log-linearized decision rules for the nominal rate, the inflation rate and the output gap as a function of lagged values of the states and reduced form shocks are as follows. For the indeterminate regime, the continuity solution produces:

$$\begin{bmatrix} \widehat{R}_t \\ \widehat{\pi}_t \\ \widehat{x}_t \end{bmatrix} = \begin{bmatrix} -0.24 & -0.41 & -0.33 & -0.28 \\ 0.23 & -0.19 & -0.59 & -0.15 \\ 0.19 & -0.45 & 0.07 & 0.19 \end{bmatrix} \begin{bmatrix} \widehat{R}_{t-1} \\ \widehat{\pi}_{t-1} \\ \widehat{x}_{t-1} \\ \widehat{\pi}^e_{t-1} \end{bmatrix} + \begin{bmatrix} \widehat{u}_{1t} \\ \widehat{u}_{2t} \\ \widehat{u}_{3t} \end{bmatrix}, \Sigma_u = \begin{bmatrix} 0.31 & & \\ 0.96 & 3.39 & \\ -0.15 & -0.42 & 0.40 \end{bmatrix}$$

where π^e_t is expected inflation, while the orthogonality solution delivers:

$$\begin{bmatrix} \widehat{R}_t \\ \widehat{\pi}_t \\ \widehat{x}_t \end{bmatrix} = \begin{bmatrix} 0.62 & 0.03 & -0.17 & 0.01 \\ 0.27 & -0.18 & -0.58 & -0.14 \\ 0.13 & -0.48 & 0.06 & 0.17 \end{bmatrix} \begin{bmatrix} \widehat{R}_{t-1} \\ \widehat{\pi}_{t-1} \\ \widehat{x}_{t-1} \\ \widehat{\pi}^e_{t-1} \end{bmatrix} + \begin{bmatrix} \widehat{u}_{1t} \\ \widehat{u}_{2t} \\ \widehat{u}_{3t} \end{bmatrix}, \Sigma_u = \begin{bmatrix} 0.05 & & \\ 0.03 & 0.17 & \\ -0.08 & -0.41 & 0.98 \end{bmatrix}$$

On the other hand, in the determinate regime we have:

$$\begin{bmatrix} \widehat{R}_t \\ \widehat{\pi}_t \\ \widehat{x}_t \end{bmatrix} = \begin{bmatrix} -0.39 & -0.31 & 0.11 \\ -0.15 & 0.30 & -0.12 \\ -0.23 & -0.16 & 0.44 \end{bmatrix} \begin{bmatrix} \widehat{R}_{t-1} \\ \widehat{\pi}_{t-1} \\ \widehat{y}_{t-1} \end{bmatrix} + \begin{bmatrix} \widehat{u}_{1t} \\ \widehat{u}_{2t} \\ \widehat{u}_{3t} \end{bmatrix}, \Sigma_u = \begin{bmatrix} 0.09 & & \\ 0.24 & 0.98 & \\ -0.21 & -0.55 & 0.89 \end{bmatrix}$$

As these expressions show, expected inflation plays a crucial role under indeterminacy - it is a state variable and the choice of solution is unimportant - but not under determinacy. Moreover, if parameters would change within a regime, either of determinate or indeterminate type, the role of expected inflation would be unaltered. Omitting inflation expectations from an estimated system has therefore two implications. Reduced form errors in the indeterminate regime will combine structural shocks, forecast errors and lags of expected inflation. To the extent that expected inflation is correlated with actual inflation, standard techniques will give inconsistent estimates of the reduced form shocks and the estimated structural dynamics will be different from those obtained in the true system. Furthermore, the estimated variance of the reduced form shocks will be larger than the true one in the indeterminate regime but not in the determinate one.

Interestingly, while the structural model differs across regimes only in the coefficients of the policy equation, the solution is such that lag dynamics as well as the variance of the reduced form shocks change. Hence, standard counterfactuals exercises, conducted by switching the variance or the coefficients of two samples, can not be used to assess whether a regime change has occurred. In addition, since changes within regime imply changes in the lagged coefficients and in the variances of roughly the same magnitude as changes across regimes, it is impossible to use the relative magnitude of the variations in the reduced form (or structural) coefficients and in the variances to determine the nature of the regime in place and whether it has changed.

Figure 1 presents the conditional dynamics in response to shocks in the two regimes where, in the case of indeterminacy, we plot both the continuity and the orthogonality solutions. Three interesting features are present. First, the impact coefficients are quantitatively different in the two regimes - this mirrors the fact that reduced form variances change. Second, there are quantitative differences in the dynamics, but they die out relatively quickly - so that changes in lagged coefficients are smaller in magnitude than changes in the variances. Third, their qualitative features - in particular, the sign and the shape of the responses - are similar across regimes. Hence, when faced with a sample of data from this model, VAR methods, will find it hard to detect regime switches by looking at the dynamics induced by structural shocks.

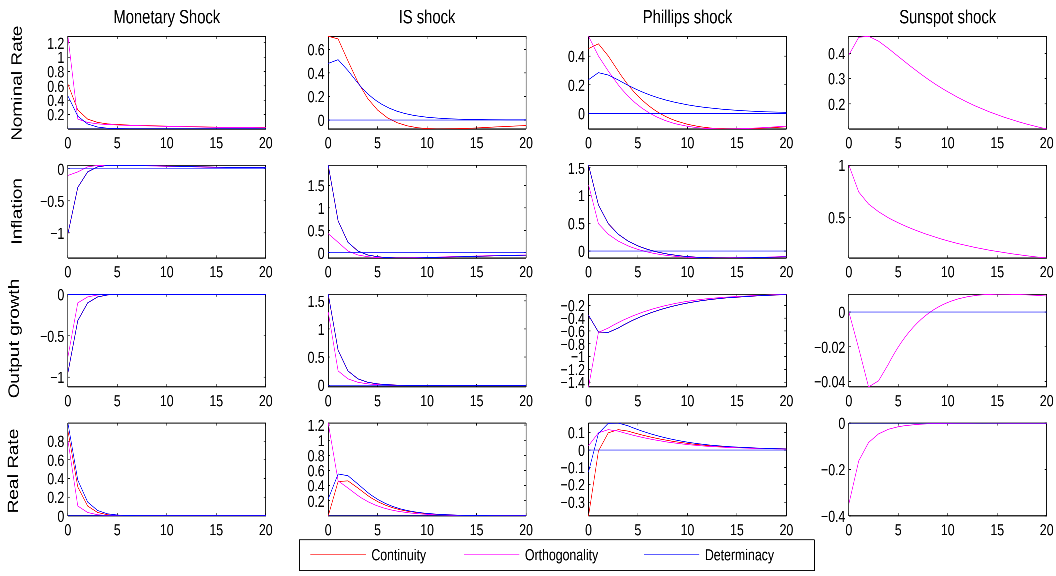

Figure 1: Impulse responses, Determinacy and Indeterminacy

It is often presumed that structural estimation methods have an edge in detecting regimes, because they take expectation formation into account. However, they are bound to fail if the model we consider were the DGP, precisely for the same reasons that structural VAR methods fail: the conditional autocorrelation function of the three endogenous variables is similar across regimes. To illustrate this point, we take the population dynamics generated by the model under indeterminacy (the continuity solution) as given and we ask: are there parameter values which make the dynamics of the model under determinacy "close" to those produced under indeterminacy? Figure 2 shows that the match is imperfect, but the serial correlation properties of nominal and real rates, output, inflation in response to the three structural shocks are closely reproduced. If rather than taking one parameterization, we take estimated uncertainty seriously and construct response bands for the indeterminate regime using Monte Carlo simulations, these bands would always include the point estimate of the responses under determinacy.

The parameters generating the responses in figure 2 are in the third column of table 1. Interestingly, it is impossible to simply change the variance of the shocks to match the dynamics of the indeterminate solution, that is, the "bad luck" hypothesis is not local to the indeterminacy/determinacy story. However, alternative explanations in which the private sector parameters change together with the structural variances or in which the parameters of the policy rule change together with the structural variance (keeping private sector parameters fixed, see last column of table 1) have this feature.

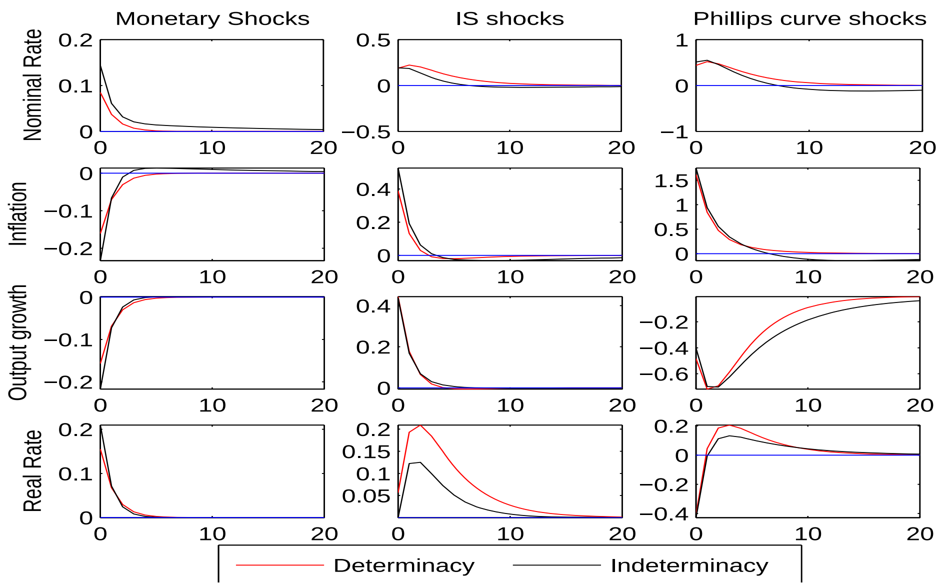

Figure 2: Alternative dynamics for regime 1

For completeness we also examine responses to a sunspot shock, when the orthogonality solution is chosen, even though their features depend on many details of the model. The last column of figure 1 shows that the dynamics induced by such a shock look, qualitatively, like those induced by a Phillips curve shock and only the sign of the response of the real rate after the impact period may allow us to separate them.

In sum, regime changes are hard to detect with standard methods. In particular, both structural VARs and impulse-response-matching structural methods are unlikely to succeed in separating indeterminate from determinate samples using the dynamics or the variances of reduced form shocks. However, the indeterminacy/determinacy story implies that expected inflation has a sharply different role in the two regimes. Hence, one must find that inflation expectations is a state variable up to the end of the 1970s but not afterwards, that is, lags of expected inflation matter for output, inflation, and interest rates up to the end of the 1970s but not afterwards and the change should be a permanent one. Furthermore, omitting expected inflation from the system should change the variance of reduced form shocks only for samples up to the end of the 1970s.

3 Measures of inflation expectations

Inflation expectations are not observable but there are a number of proxies which allow us to conduct our tests. Since in our empirical models we use yearly inflation rate (calculated year-on-year), we restrict attention to one year ahead expectations of inflation. Also, since available measures differ in the time coverage and in their reliability as predictor of future inflations, we dedicate this section to describe their properties and motivate our selection of proxy measures.

The Michigan survey reports average expected changes in consumer prices for the incoming year and is available quarterly since 1960:1. This survey has 100 respondent each period, primarily covers households, and is conducted before the inflation figures of the middle month of the quarter are available. We assign the forecast to the end of the quarter, giving the survey a bit more information than it actually has. We use the mean forecast as our measure, since median estimates are available only since 1978.

The Survey of Professional Forecasters, constructed by the Federal Reserve Bank of Philadelphia, presents data on forecasts of the implicit price deflator expected change over the next year and it is available since 1970:1 - CPI forecasts are available only since 1981. The number of respondents changes somewhat with the quarter and the year in which the survey is run, and respondents are primarily members of the business community. As the Michigan survey, it is conducted in the middle of each quarter, but we assign the reported value to the end of the quarter. In this case, we use median forecast as our measure.

The Livingstone survey is biannual - it is conducted in April and October since 1955:1 - and reports eight months ahead level of the non-seasonally adjusted CPI. The number of respondents is smaller than the other two surveys (it covers about 50 economists from industry, government and academia per time period) and this may produce larger or more persistent biases. To make it comparable to the other survey measures the 8 months expected rate of change is annualized. The median value of the survey is used as our estimate.

The Greenbook forecasts contains predictions of inflation at different horizons produced by the staff at the Federal Reserve Board for FOMC meetings. The projections contain annualized quarter-on-quarter changes of the implicit price deflation up to 1996 and of the chain-weighted price index after that date. One year ahead forecasts are available since 1975:1. Also since FOMC meetings do not occur regularly, quarterly data are constructed using the forecast produced by the report which is closest to the middle of each quarter. As with the other survey we assign this value at the end of the quarter.

Surveys are not the only potentially useful measures of inflation expectations available. The term structure of nominal interest rates also provides an implicit measure of inflation expectations. To obtain it we use a standard decomposition. Let $f_{t,4,k-4}$ be the forward rate quoted at t for one year maturity on a bond that has settlement period k. This rate, which can be computed using the returns on one year and any k years nominal bonds, can be decomposed as:

$$f_{t,4,k-4} \equiv \frac{R_{t,4}}{R_{t,k}} = r^e_{t,4,k-4} + \pi^e_{t,4,k-4} + [f_{t,4,k-4} - E_t \ln R_{4,t+k-4}] + [E_t \ln R_{4,t+k-4}] - r^e_{t,4,k-4} - \pi^e_{t,4,k-4}] \tag{4}$$

where the first term represents the expected one year real rate, the second the one year expected inflation, the third the nominal term premium (the difference between the forward rate and the expected future nominal rate) and the last the real excess return of the expected nominal rate over the expected real rate. While it is typical to assume that the first, the third and the fourth terms of the expression are roughly time invariant - this would allow us to identify the dynamics of expected inflation with those of the forward rate - such an assumption is too heroic for the sample we consider to be credible - if such an assumption is used the resulting expected inflation measure differs substantially from those contained in survey measures. As an alternative, we use the rational expectation assumption, regress realized inflation on a constant and the forward rate and take the predicted value as a measure of inflation expectations. This procedure is relatively common in the literature (see e.g. Svensson (1994), or Soderlin (1995)) and make the resulting expectations close to actual inflation. To take into account the different path of inflation the regression is actually run on two separate subsamples (up to 1980:2, after 1980:2). An alternative signal extraction approach, where expected inflation is treated as unobservable random walk while the other components in (4) have stationary AR(1) dynamics, produces similar results.

Data on the term structure of the nominal interest rates is available at the FRED databank of the Fed of Saint Louis. However, the data reports rates for non-zero coupon bonds. We have managed to recover comparable data set for zero coupon bonds but only for the period 1974:1-2001:4, which makes it too short for our purposes. It turns out that the forward rates implied by the two different term structure measures are very similar over the 1974-2001 sample (contemporaneous correlation 0.98) and the measures of expectations we obtain from the two different series are practically indistinguishable. To maximize the length of the sample, we work with inflation expectations obtained from non-zero coupon bonds even though the above decomposition is only approximately valid.

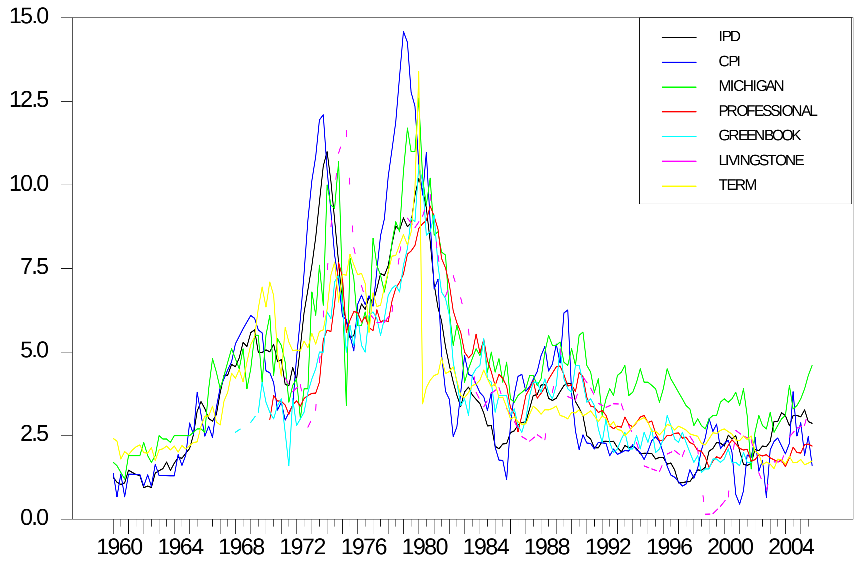

Figure 3: Actual and expected inflation.

While financial market data on inflation expectations are probably more reliable than survey data, the latter are publicly available and do not require any statistical model or possibly controversial assumption to back them out. To compare their properties, we plot in figure 3 the time path of these five series together with actual inflation computed using the implicit price deflator (IPD) and the CPI (measured here by the seasonally adjusted CPI for all items). Confirming Merha (2002), Michigan expectations are a good predictor of actual inflation up to 1980, but that its performance deteriorates somewhat over the 1980s, and over the 1990s the reported mean systematically overestimates actual inflation. Professional expectations are better if one looks over the whole sample. However, when we focus on particular episodes (for example, the beginning of the 1970s or of the 1980s), this measures is less reliable than the Michigan one. The Livingstone expectations appear to be free of large or persistent biases, except perhaps in the latest part of the sample. Nevertheless, their frequency and the fact that they are available only since 1971, prevents us from using them in our exercises. Greenbook forecasts appear to closely track IPD dynamics and are highly correlated with Professional forecasts. Inflation expectations backed out from the term structure of interest rates track actual inflation well, except for the early 1980s.

Table 2: Statistics and contemporaneous correlations

	Correlations						Statistics			
	Professional	Livingstone	Greenbook	Term	IPD	CPI	Mean	St. Err.	Min	Max
Michigan	0.78	0.50	0.77	0.79	0.86	0.82	4.66	2.20	1.2	12.60
Professional		0.63	0.88	0.70	0.73	0.69	4.05	1.97	1.54	9.37
Livingstone			0.54	0.47	0.50	0.46	4.12	2.66	0.15	11.62
Greenbook				0.60	0.75	0.71	4.04	2.03	1.40	10.60
Term					0.83	0.80	3.80	2.20	0.95	13.07
IPD							3.80	2.39	0.94	10.99
CPI							4.05	3.06	0.45	14.59

How are these measures related? Table 2 shows that Michigan and Term structure expectations are the ones which are most highly correlated with actual inflation (regardless if it is measured by IPD or CPI) and with each other. Despite the visual appearance of figure 3, and as in Merha (2002), the Livingstone survey poorly tracks the dynamics of realized inflation. In terms of moments of the empirical distribution, term expectations closely replicate those of actual inflation. Given these results, and since it is difficult to assess the relative magnitude of reporting and statistical biases, our exercises are conducted using both Michigan and term structure expectations [1].

4 The empirical evidence

We estimate fixed coefficient VAR models and examine whether lags of expected inflations matter in a system including real output growth (ΔGDP), the inflation rate (π), a short term nominal rate (R). Data is from the FRED data bank. Output growth is measures by the year-to-year change in GDP, inflation by the year to year change in CPI, all items and the interest rate by the Federal funds rate.

We use the traditional device of breaking the sample in two even if such approach is problematic for two reasons: since inflation and the nominal interest rate display inverted U-shaped pattern, it is not clear which date should be used to break the sample and whether a

[1] When comparing survey measures to actual inflation data one should be aware that they are not measuring the same thing. First, the reported expected rate is an average over quarters rather than an end of the period measure. Second, apart from profesional forecasts, it is not clear if agents forecast CPI levels/changes or headline CPI level/changes. Third, it is not clear if simple or compounded rates are used to construct yearly measures. Fourth, forecasts are typically for non-seasonally adjusted data, while seasonally adjusted data will be used in the exercise. Ang et. al. (2006) have shown that these measurement biases are small and account for none of their forecasting comparison results.

subset of the data (the 1979-1982 period) should be omitted or not; using subsamples forces a simultaneous break in all the relationships and this is inappropriate since the moments of these variables display breaks at different dates.

Table 3: F-tests, p-values

	With Michigan expectations							
sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
Δ GDP	0.73	0.70	0.81	0.91	0.70	0.55	0.99	0.92
π	0.00	0.01	0.01	0.00	0.02	0.00	0.04	0.05
R	0.12	0.00	0.11	0.24	0.00	0.01	0.10	0.05
	With term structure expectations							
sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
Δ GDP	0.69	0.82	0.52	0.29	0.02	0.03	0.10	0.67
π	0.58	0.51	0.10	0.00	0.00	0.00	0.59	0.24
R	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.02

Table 3 reports the p-value of an F-test for the exclusion of lags of expected inflation in the three equations for a number of subsamples when Michigan or Term expectations are used in a VAR with 4 lags. Two main results are evident. First, when Michigan expectations are used, lags of expected inflation are never important in the output growth equation, always important for the inflation equation and usually important for the nominal rate equation (the exceptions are the samples 1960:1-1981:2 and 1960:1-1982:1). Second, when Term structure expectations are used, lags of expected inflations are always significant for the nominal rate equation; significant in the output growth equation in the samples 1979-2005 and 1980-2005, and significant in the inflation equation if the years 1979-1980-1981 are jointly included in the sample.

Table 4, which reports the estimated variance of the reduced form residuals for various subsamples when the two proxies for expectations are used and when expected inflation is excluded from the system, confirms the outcomes of table 3. For appropriately selected samples, the variances of reduced form shocks in a system where expected inflation is included decreases over time and system which excludes expected inflation tends to have reduced form shocks with marginally higher variability. However, and perhaps more importantly, a system where expected inflation is excluded displays the same qualitative features as systems which include it: for appropriately chosen samples, the variance of all shocks declines.

Table 4: Variances of reduced form shocks

	With Michigan expectations							
sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
Δ GDP	0.80	0.81	0.86	1.06	0.60	0.58	0.56	0.34
π	0.07	0.08	0.09	0.10	0.05	0.04	0.03	0.03
R	0.50	0.75	1.47	1.96	0.93	0.92	0.46	0.15
	With term structure expectations							
sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
Δ GDP	0.80	0.81	0.83	1.00	0.55	0.53	0.51	0.34
π	0.10	0.10	0.10	0.10	0.04	0.04	0.04	0.03
R	0.43	0.52	1.03	1.35	0.64	0.64	0.46	0.15
	Without inflation expectations							
sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
Δ GDP	0.83	0.83	0.88	1.07	0.62	0.60	0.56	0.35
π	0.10	0.10	0.11	0.13	0.06	0.05	0.04	0.04
R	0.57	0.89	1.65	2.12	1.15	1.06	0.50	0.17

The evidence contained in tables 3 and 4 does not seem to support the main implication of the theory: in the model of section 2 expected inflation is initially relevant and later is irrelevant and the break in the relationships is permanent. The data tells us instead that if expected inflation matters, it matters for the whole sample and when it is not the case, changes are temporary in nature and primarily related to the Volker experiment of the end of the 1970as.

5 What can go wrong?

There are many reasons for why our analysis fails to conform with the prevailing theory. First, we may be unable to detect a permanent break in the importance of expected inflation because the lag length of the model is not appropriately chosen. Two opposing reasons may contribute to this fact. Given overlapping nature of all inflation expectations measures, a generous lag length is needed to make the residuals of the VAR a white noise..However, if the number of lags is too large, it is possible that lags of output growth, inflation and the nominal rate proxy for lags of inflation expectations making it impossible to detect regime changes. Since the model of section 2 produces a VAR(2) and since inflation expectation measures induce MA component of order three, a lag length of 4 seems to strike a balance between the two opposing force. In tables A.1 and A.2 we present results obtained varying the lag length from 2 to 8: while quantitatively results depend on the lag length, the general point we have made remain unaltered..Second, our tests may fail because the proxies for expected inflations we employ are plagued by measurement or estimation errors or fail to contain information relevant to distinguish the two regimes. Since Thomas (1999), Merha (2002), and Ang, et. al. (2006)) have shown that the proxies we employ capture important information about future developments of inflation, it is hard to believe that this is the case. Nevertheless. Faust and Wright (2006) have shown that Greenbook forecasts are superior to both Michigan and other survey measures of expectations, while Leduc et. al. (2005) claim that Livingstone expectations contain information which is relevant to capture shocks to expectations. Green book forecasts can not be used in our exercise since, as we have mentioned, a complete time series for one year ahead predictions is available only since 1975. We have repeated estimation using the same four variable system with data for output growth, inflation and the nominal rate sampled bi-annually, and with Livingstone survey data as proxy for inflation expectations. Tables A.3 and A.4 which contain the results of our tests show that the same conclusions obtain and, if anything, the evidence for a structural break is even weaker.

Third, one can easily argue that a four equation VAR is misspecified since many important variables are omitted from the system. What is the consequence of this misspecification? If a large scale model were the true data generating process for the data and the a four variable system was used, many important variables would be omitted and their presence in the residuals of the models in both regimes would make it hard to detect regime changes with our tests. We therefore repeated estimation using a eight variable VAR which include the previous four variables in addition to consumption growth, investment growth, hours and the growth rate of money. Consumption growth is measured by the year-to-year change in real nondurable private consumption, investment by the year to year change in fixed private investments, hours by total hours in the non-farm business sector and money growth by the year to year change in M2. The results for a VAR with two lags, which are in tables A.5 and A.6, indicate that in a larger system one has even harder time to give inflation expectations a predictive role in the first part of the sample and, as a consequence, to find a break in the importance of expected inflation over time.

Fourth, it may be that our F-tests and the informal comparison of variances we perform have low power in the particular situation we are interested. Despite the fact that we have tried to maximize the size of the sample, we have only about 80 data points on each side of the potential break date and this may be too short to be able to detect breaks. To check for this possibility, we have simulated data from each of the two regimes, parametrizing model to the posterior mean estimates of Lubik and Schorfheide (2004) in the two regimes and employing either the continuity and the orthogonality solution when generating data from the indeterminate regime. We then constructed two samples of 160 data points (one with 80 data from the continuity regime and 80 from the determinate regime, the other with 80 data from the orthogonality regime and 80 from the determinate regime) and applied our tests to simulated data. Tables A7 and A8 show that if this model were the true data generating process and about 40 years of quarterly data were available, we would be able to detect a change in importance of expected inflation in the system. In particular, expected inflation would be significant in some equations when up to the first 80 data points are used but not if either more data is included in the sample or estimation starts at a later date; the variance of the reduced form shocks in a system without expected inflation are larger than those in a system which includes expected inflation if the first 80 data points are used, but not if the last 80 data point are employed. Hence, our inability to find the role for expected inflation predicted by theory is not due to the fact that our testing technique displays severe small sample problems.

Fifth, as Orphanides (2004) has forcefully pointed out, policy decision are typically taken when preliminary estimates of the relevant quantities are available while empirical analysis is often conducted with revised or final estimates. This discrepancy may lead researchers astray when trying to understand how policymakers behaved in certain historical episodes. For our exercises this is a relevant concern since the presence of large measurement errors in variables other than inflation expectations in both samples, may make our procedure unable to detect breaks. To see whether this problem is relevant in practice we have simulated data from the model of section 2 assuming that private agents take decisions using the correct data while the central bank rule is

$$R_t = \phi_r R_{t-1} + (1-\phi_r)(\phi_\pi(\pi_t + u_{1t} + \phi_x(x_t - z_t + u_{2t})) + e_{R,t}$$

where u_{1t} and u_{2t} are measurement errors, assumed to be iid with variance σ_i^2. Using the same parametrization we have used in tables A7 and A8 we have then simulated two samples with 160 data points (one with 80 data from the continuity regime and 80 from the determinate regime, the other with 80 data from the orthogonality regime and 80 from the determinate regime) and applied our tests to the simulated data. Clearly, if measurement error is large anything can happen. Therefore, it is important to appropriately calibrate this error to make the simulation realistic. The size of the revision error between initial and final estimates of output growth and inflation over the last 40 years shows a small declining trend and its standard error around this trend it never exceeds 10 percent of the standard error of series. Therefore, it is conservative to assume that an upper bound for the standard error of the two measurement errors is 10 percent of the standard errors of the smallest structural shocks. Tables A9 and A10 show that, while important, a measurement error of this magnitude would not be able to cover up structural changes if they were present and our approach would be able to detect a change in importance of expected inflation over time.

Finally, arbitrarily splitting the sample and forcing the break to be common in all equations is less than ideal to examine the role of expected inflations over time. Time varying coefficient models are particularly suited for our purpose because they avoid strong restrictions on the nature of the breaks and allow us to track the evolution of the relationships of interest over time and detect, for example, U-shaped patterns. These patterns may be the reason for why depending on the chosen break date, one may find evidence which supports or contradicts the main hypothesis of interest. Finally, a specification with time varying coefficients allows us to examine the weaker hypothesis that the importance of expected inflation has declined as we move from the 1970s to the later part of the sample. The model we consider is

$$y_t = X_t' \theta_t + \varepsilon_t \tag{5}$$

where y_t is a $n \times 1$ vector, X_t' is a matrix including lags of the dependent variables and a constant, θ_t is a $n(np+1) \times 1$ vector, p is the number of lags and $\varepsilon_t \sim (0, \Sigma_t)$ We assume that θ_t evolves according to

$$\theta_t = \theta_{t-1} + u_t \tag{6}$$

where u_t is a $n(np+1) \times 1$ white noise with zero mean, covariance Ω, uncorrelated with ε_t and paths for θ_t which produce non-converging paths for y_t are discarded. We assume that $\Sigma_t = L\Omega_t L'$ where L is a lower triangular matrix, that $\Omega = diag\{\omega_{it}\}$ and that

$$\log \omega_{it} = \log \omega_{it-1} + \eta_{it}, \quad i = 1, \ldots, n$$

where $\eta_{it} \sim N(0, \sigma_\eta^2)$ and $\eta_{it}, u_t\ \varepsilon_t$ are independent.

We estimate such a model with Bayesian techniques and non-informative but proper priors. Since both θ_t and Σ_t are time varying and our estimation technique allows us to construct their exact posterior distribution at each t, rather than use classical F-tests at each date, we present the evolution of the median and of the 68% central posterior interval for the statistics of interest. For computational and expositional reasons, we report results for $p = 2$. As before, this choice is irrelevant for the conclusions we present.

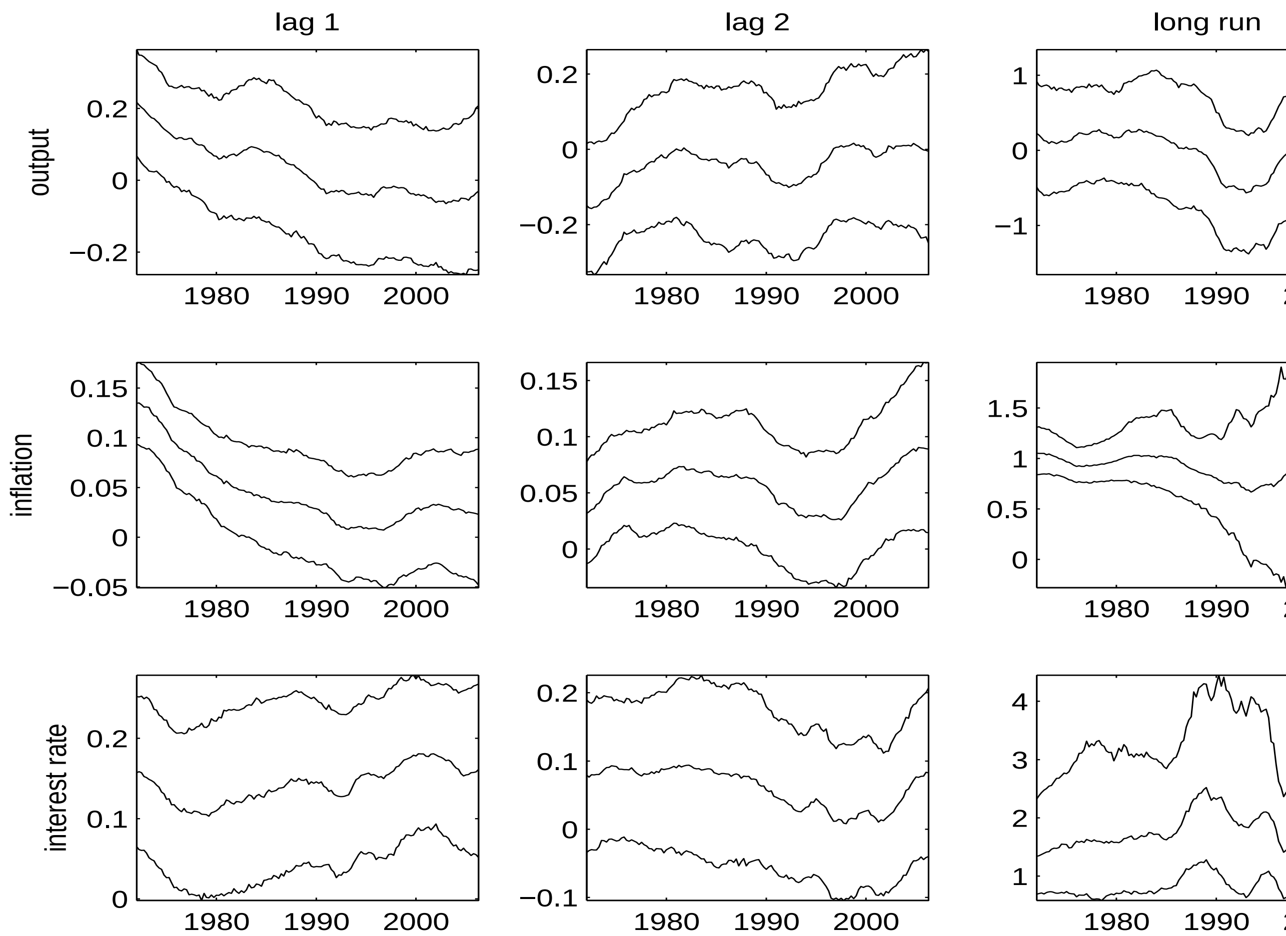

Figure 4: 68 percent posterior band for coefficients on lagged expected inflation, Michigan expectations.

Figures 4 and 5, which plot the evolution of the posterior intervals for the lags of expected inflation and for their long run value in each equation, when Michigan expectations and term expectations are used, respectively, broadly agree with table 3. When Michigan expectations are used, expected inflation is practically never significant in the output growth equation, and almost always significant in the inflation equation, at least in the long run. The significance of expected inflation in the interest rate equation depends on the sample, with the coefficient on the first lag becomes more significant since the early 1980s. In general, changes over time in the long run effects in all three variables are not statistically significant. When term expectations are used the evidence is a little more mixed. Nevertheless, it is still true that the importance of expected inflation in the output growth equation is small and somewhat increasing since the early 1980s while for the other two equations the effect is time varying but inconsistent with the hypothesis of interest. For example, decreases in the coefficient of the first lag of the expected inflation in the interest rate equation are compensated by increases in the coefficient of the second lag.

Overall, if there is a break in the importance of expected inflation in the system, it is not in line with the conventional wisdom: inflation expectations appear to become more important in the 1990s and 2000s than they were in the 1970s.

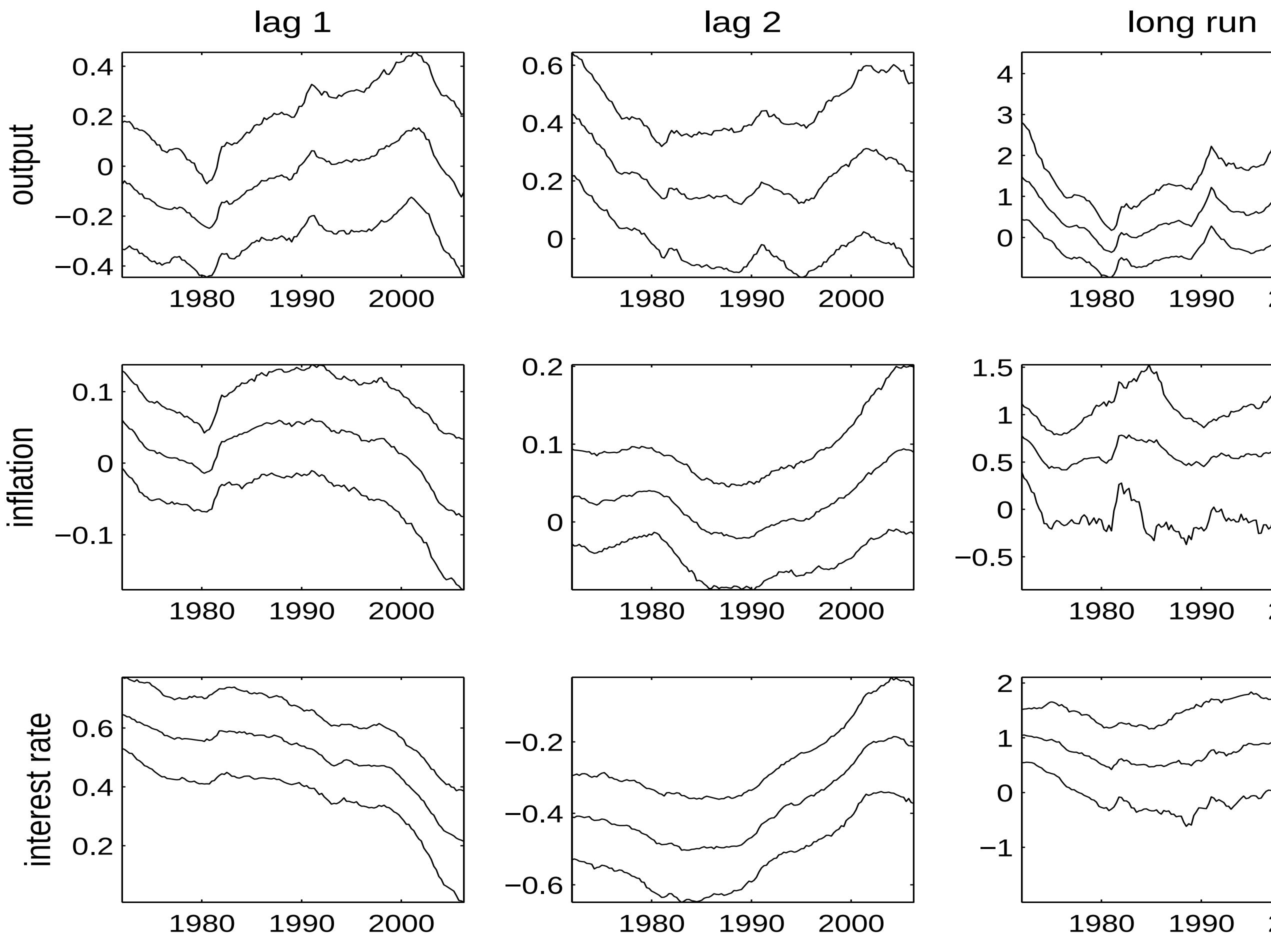

Figure 5: 68 percent posterior band for coefficients on lagged expected inflation, Term expectations.

Figure 6, which reports the mean of the posterior for the variance of the reduced form shocks with inflation expectations (Michigan solid line, Term dashed line) and without them (dotted line), also broadly agrees with table 4. For instance, there is a general decline in the variability over time of the reduced form shocks which is similar in magnitude and timing across measures of inflation expectations; and including or excluding inflation expectations from the system hardly changes the time path of the reduced form variances. Furthermore, given the considerable uncertainty associated with the point estimates, difference in the estimated variances in systems with and without inflation expectations are a-posteriori insignificant at any date in the sample.

To conclude, regardless of the measure of expectation employed, the specification of the VAR and the horizon where we measure the effect, the importance of expected inflation does not decline as we move from the 1970s to the end of the sample, neither in the sense of a structural break nor in the sense of a slow moving but continuous change. One interpretation of this result is that, once internally consistent but backward looking linear prediction of inflation are considered, the forward looking component present in expected inflation measures adds predictive power in certain equations only and, excluding Volker experiment, the predictive power is roughly constant over time.

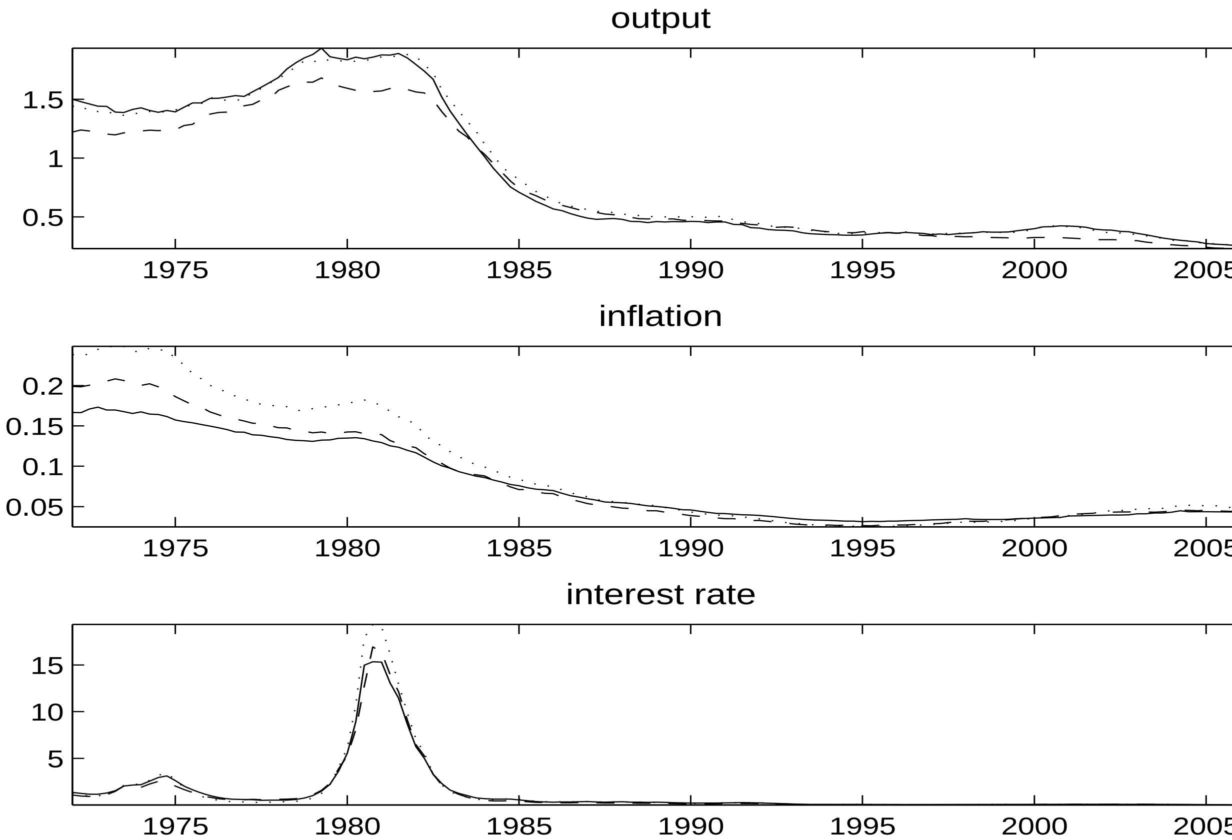

Figure 6: Variances of VAR shocks, solid Michigan, dashed Term, dotted no expectations.

6 Explaining the Great Moderation

The statistical analysis we have conducted appears to give sharp conclusions. Nevertheless, it is silent as to whether the absence of inflation expectations from an empirical model alters our understanding of the "Great Moderation" episode. Given that this economic relevance of expected inflation that its statistical one, we next study whether conclusions about the sources of the Great Moderation change if we exclude or include expected inflation. If expected inflation truly matter only up to a certain date, the majority of existing analyses of the Great Moderation, which systematically exclude them from the empirical system, are likely to be flawed.

To study the sources of the Great Moderation we need to identify structural shocks from the empirical model. The restrictions we use to obtain three behavioral shocks are in table 5. Gambetti et. al. (2005) have shown how they can be obtained from a DSGE model featuring monopolistic competitive firms, rational consumers and rules for monetary and fiscal policy, and that they are robust, in the sense that they hold as the structural parameters drift within a reasonable range. Note that these restrictions hold for the model used in section 2 as well.

Table 5: Identification restrictions

	GDP	π	R
Supply/sunspot	≥ 0	≤ 0	≤ 0
Real Demand	≥ 0	≥ 0	≥ 0
Monetary	≥ 0	≥ 0	≤ 0

Roughly speaking, supply/sunspot shocks move the aggregate supply of the economy along the aggregate demand curve, while demand shocks move the aggregate demand along the aggregate supply curve. To distinguish real demand from monetary shocks we use the restriction that in response to contractionary monetary shocks inflation falls. These restrictions are robust not only to the parameterization of the model but also to the horizon at which the analysis is conducted. Following Gambetti et. al. (2005) we impose restrictions at horizons zero and one.

In the introduction we have characterized the "Great Moderation" phenomena as a considerable fall in the volatility and the persistence of output and inflation. Here we measure persistence as the height of the structural spectrum of output growth and inflation at frequency zero and volatility as the area under the structural spectrum of the two variables. The statistics, which are reported as continuous lines in figure 7, when Michigan expectations are used, display two strong peaks, around 1974 and 1981, and a considerable decline after the second peak. Since 1985 the persistence and the volatility of both output and inflation have been stable and low relative to the 1970s. Figure 7 also presents the contribution of the three identified shocks: starred lines represent the contribution of supply/sunspot shocks, dotted lines the contribution of real demand shocks and dashed lines the contribution of monetary shocks. To understand what these measures mean note that at each t the local moving average of the structural system is $y_t = \sum_i C_{it}(\ell)\epsilon_{it}$, where ϵ_t are structural shocks and the local structural spectrum of y_t at frequency λ is $\mathcal{S}_y(\lambda, t) = \sum_i C_{it}(\lambda)\mathcal{S}_{\epsilon_i}(\lambda, t)$, where $\mathcal{S}_{\epsilon_i}(\lambda, t)$ is the local spectrum of ϵ_{it} at time t. Therefore, what we report are the persistence and volatility of output and inflation that would emerge if only one type of structural shocks were present at each date.

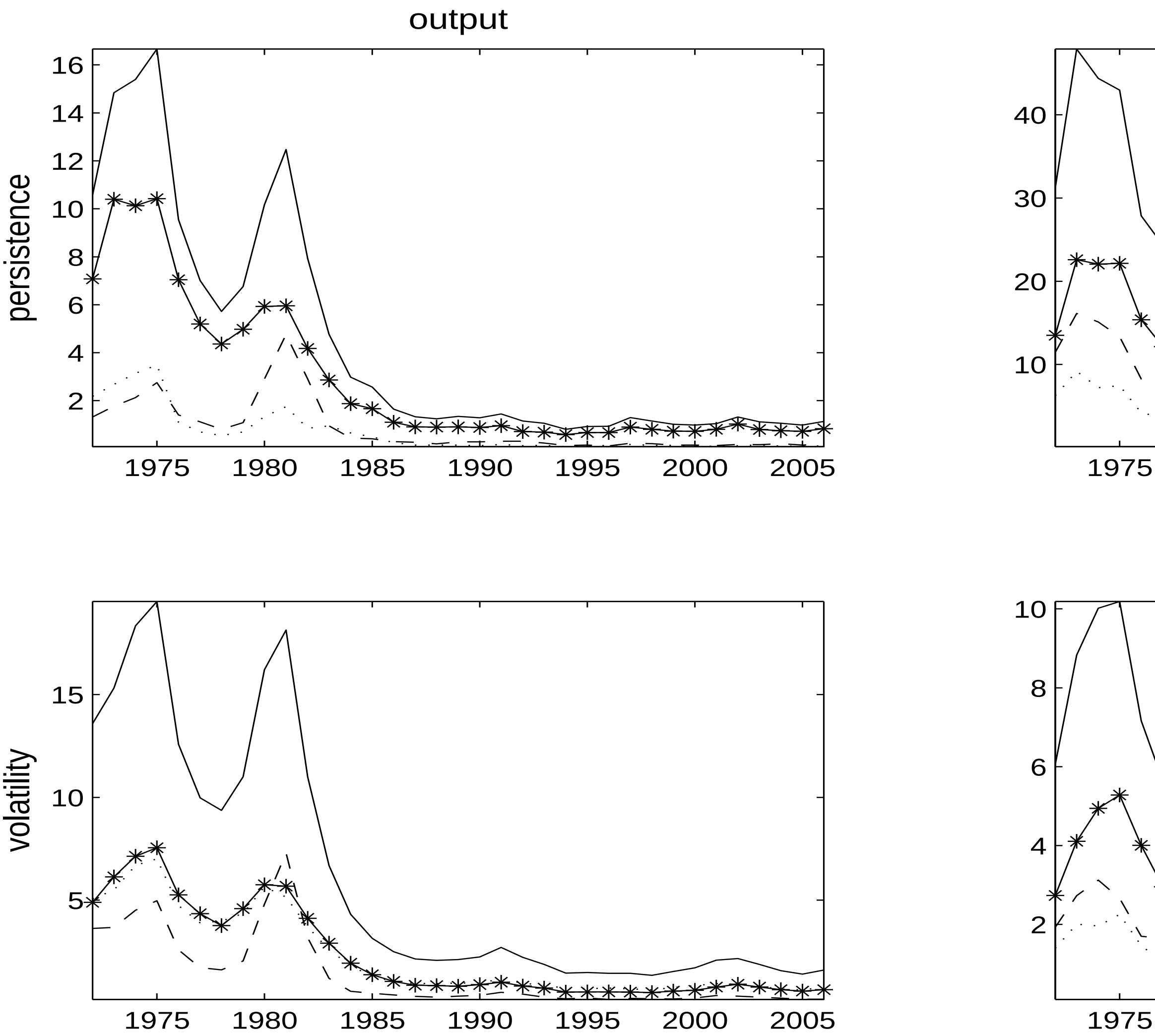

Figure 7: Overall statistics, contribution of supply (stars), real demand (dotted), and monetary (dashed) shocks.

Supply/sunspot shocks are the largest contributors to both the 1974 and 1981 peaks in the persistence and volatility in output growth. Monetary shocks contribute little to the 1974 peak, but become more important for the 1981 peak. Interestingly, these results square well with the increase in volatility of output growth shocks in the two episodes, and with the considerable increase in the volatility of interest rate shocks around 1981 (see figure 6) and are easily linked to the two oil shocks and the Volker experiment of the late 1970s. Supply/sunspot shocks contribute most to the peaks in inflation persistence and volatility in 1974, while monetary shocks are the sole contributor to the 1981 peak - the contributions of supply/sunspot and real demand shocks consistently decline since 1975 for both statistics. Hence, our structural analysis indicates that inflation volatility and persistence would have been lower since the mid 1970s, hadn't not been for the Volker experiment and that the fall in the volatility and persistence of inflation predates the adoption of a more aggressive monetary policy stance against inflation.

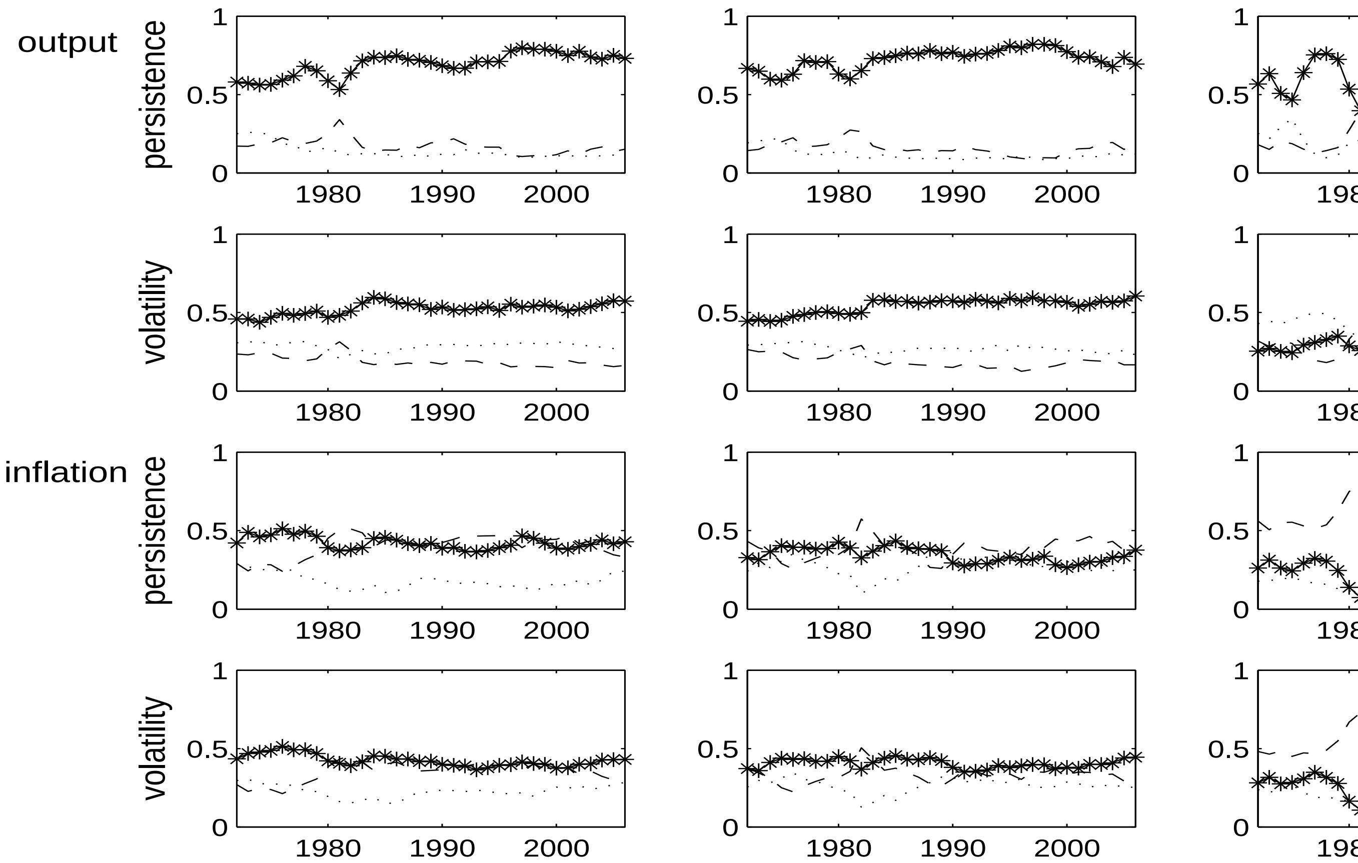

Figure 8: Share contribution of shocks: star supply shocks, dotted real demand shocks, dashed monetary shocks; colomn 1 Michigan, colomn 2 term, colomn 3 no expectations.

Would our conclusions change if we exclude inflation expectations from the VAR? Figure 8 reports the proportion of inflation and output growth volatility and persistence explained by the three identified shocks at each date in the sample in a VAR with Michigan expectations (first column), Term expectations (second column) and no expectations (third column). Several of our conclusions are maintained if we inflation expectations are excluded from the system. For example, supply and real demand shocks are crucial to characterize the time profile of output growth volatility and persistence while monetary shocks are important to understand only the 1981 peaks. However, when inflation expectations are excluded, monetary shocks become the most important driver of inflation persistence and volatility thought the sample, and their importance is slightly increasing over time. Notice also that the timing of the changes in the three columns is very similar. Hence, statistical and economic analyses agree in this case: inflation expectations fail to conform to the role that the indeterminacy/determinacy story has given to them.

7 Supply or sunspot shocks?

The results of the previous section are not entirely surprising. As we have emphasized in section 2, the dynamics induced by shocks in the determinate version of the model are qualitatively similar to those produced by its indeterminate versions. Since the structural spectrum of output growth and inflation is a continuous function of these dynamics, excluding or including inflation expectations can not make a huge qualitative difference for the conclusions one reaches.

Is it possible to find evidence that gives expected inflation a special role before 1980? As we have mentioned, the dynamics produced by the model in the determinate and the indeterminate regimes are similar if sunspots are ruled out. If they are allowed for, however, our identification scheme puts them together with supply shocks. One can therefore ask if the contribution of supply shocks to the statistics we have presented could give support to the hypothesis that inflation expectations matter up to a certain point in the sample but not afterwards. Figure 7 suggests that the time path of the volatility and persistence due to supply shocks is declining over time, but the proportions appearing in figure 8 are roughly constant.

Further evidence on the role of sunspots is difficult to obtain because small variations in the specification of the model may change the dynamics induced by these shocks. However, conditional on the model and its parameterization, one may try to separate supply from sunspot shocks if one looks at the dynamics of the real rate which converges to zero from below in response to sunspot shocks, but converges from above to zero in response to Phillips' curve shocks (see figure 1).

Given the above restrictions, we ask: what is the contribution of sunspot shocks to the statistics presented in figure 7? Figure 9 reproduces the path of the statistics due to the combined effect of supply and sunspot shocks reported in section 7 (line with stars) and shows the contribution of the two components when orthogonality is assumed (sunspot dotted, supply dashed). Output growth and inflation persistence would have been much lower in the 1970s and the change much more contained if only sunspot shocks where present. Also, the fall in output growth persistence would have occurred only in the mid-1980s. Similarly, output and inflation volatility would fail to display the two peaks in 1974 and 1981 had their been only sunspot shocks and the decline in the 1980s-1990s would have been minor relative to the 1970s.

Hence, while one can not deny that sunspot shocks matter - their contribution is roughly as important as the one of identified demand shocks, at least for inflation - the time path they induce fails to line up with the dynamics of persistence and volatility in output and

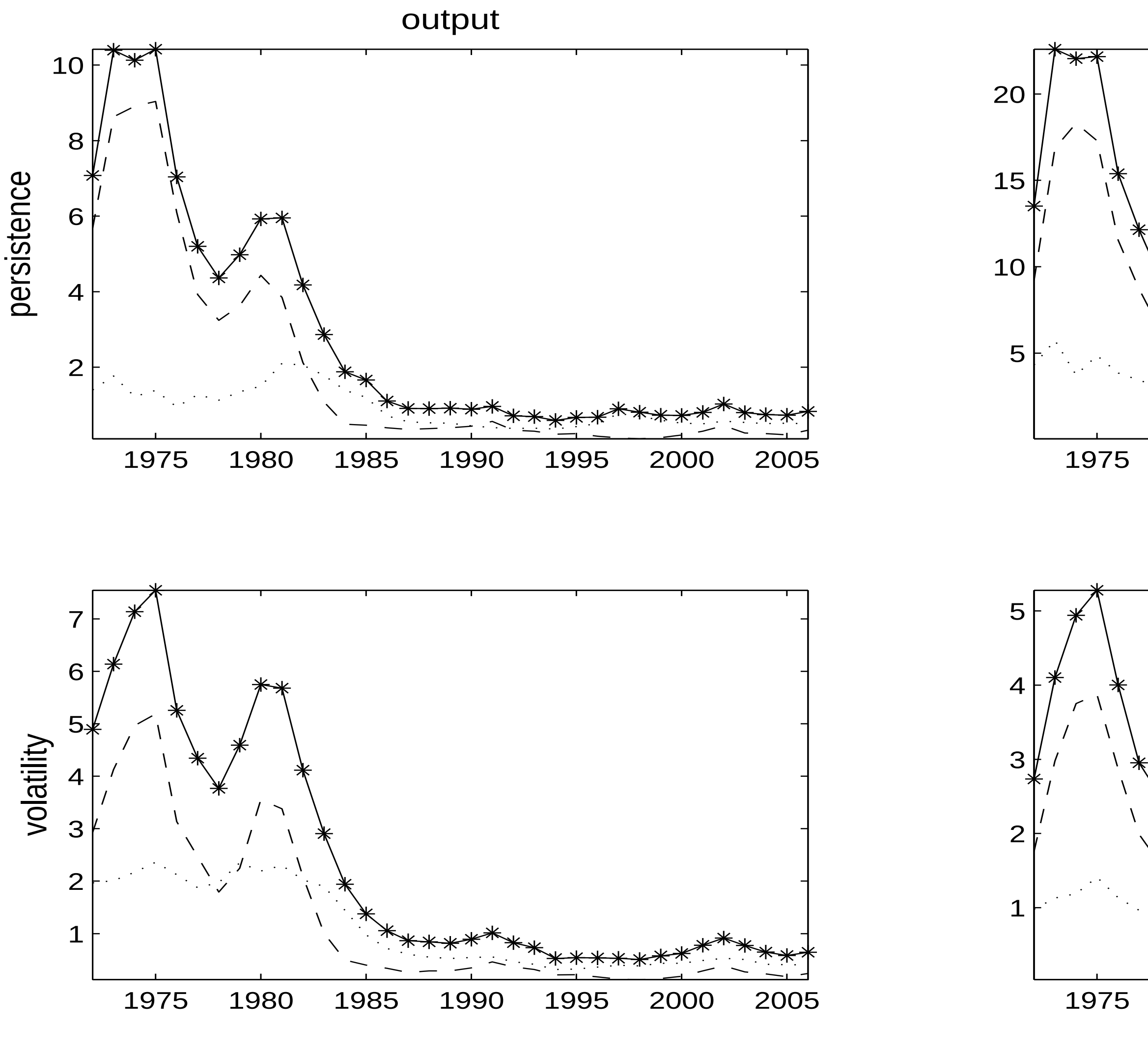

Figure 9: Contribution of sunspot (dotted) and supply (dashed) shocks to output and inflation volatility and persistence.

Before concluding, a few remarks are in order. We want to reiterate that the evidence on sunspot shocks we present is at best suggestive: in a three equation model it is difficult to find sharp implications that extract sunspot shocks and the restrictions on the real rate we have used are not entirely robust: there are parameter combinations which imply that sunspot shocks look like demand shocks. These parametrizations however have the disadvantage that sunspot shocks can not be interpreted as stagflation shocks.

While many have argued that sunspot disturbances could account for the US experience over the last 35 years, there are only three papers we are aware of which have explicitly dealt with the effects of sunspot shocks on interesting macroeconomic variables. Leduc et. al. (2005) identify shocks to expectations using delay restrictions and found that the response of the nominal interest rate is quite different in the 1970 and post 1980 subsamples. However, the shocks they have identified fail to look like the sunspot shocks we presented in figure 1 and this makes the comparison difficult. Lubik and Schorfheide (2004) and Boivin and Giannoni (2006) have estimated a model like the one presented in section 2 allowing for sunspot shocks. While their results support the idea that an indeterminate regime was in place until the end of the 1970s, they do not address the question of how much expectations matter to explain the Great Moderation episode, nor they discuss the role of sunspots in the experience. Boivin and Giannoni conduct some counterfactuals but, as mentioned, these are not informative about regime switches. In all papers, the conclusions are based on subsample analysis and, as we have argued, such an analysis is not necessarily informative about the importance of expectations over time.

8 Conclusions

This paper examines whether the restrictions imposed by the indeterminacy-determinacy story of the Great Moderation on inflation expectations are satisfied. Using a simple New-Keynesian model, parameterized so as to replicate the most salient aspects of Lubik and Schorfheide estimates, we show that expected inflation is a state variable in the indeterminate regime but not in the determinate one; that regimes can not be separated by examining the relative magnitude of changes in the lagged dynamics and in the variance of the reduced form shocks; and that several explanations are "locally" indistinguishable from the indeterminacy-determinacy story. Given these facts, we focus our analysis on the role of inflation expectations in the two regimes. In particular, using several VAR models which include output growth, inflation, the nominal interest rate, and a proxy measure of inflation expectations, we study whether lagged inflation coefficients are significant, whether there is a change in their significance over time and whether omitting inflation expectations from the estimated system causes time varying biases in the variance of reduced form shocks. We also examine whether the presence of inflation expectations alters the interpretation of the Great Moderation.

While inflation expectations are important, we fail to recover a pattern which is consistent with the indeterminacy-determinacy story of the Great Moderation. In particular, (i) lags of expected inflation are either always significant or always insignificant and there is no clear switch over time in their importance in any equation of the system, (ii) reduced form variances estimated in systems with and without inflation expectations display similar paths and little evidence of time varying biases, (iii) the economic interpretation of the Great Moderation episode is roughly independent of the inclusion or the exclusion of inflation expectations from the system; (iv) sunspot shocks are not more frequent in the 1970s than afterwards and their contribution to output and inflation volatility and persistence do not line up well with the time variations in these statistics.

There are many ways to refine our investigation. First, a three equation system is probably not the nest vehicle to distinguish various hypotheses regarding the Great Moderation. A larger scale model, while more difficult to estimate and identify, could go in this direction and, as a by-product, could also more convincingly separate sunspot from other shocks. Second, one could directly try to estimate the effects on expected inflation shocks using more structural methods. Such methods have the advantage that all the cross equation restrictions imposed by the model are taken into account and this may clearly help to separate various explanations. However, unless the model is correctly specified, inference will be distorted. The mix of reduced form and semi-structural analysis we perform here is more robust to this latter problem. Third, one can also try to examine how inflation expectations respond to structural shocks and try to compare their responses across different time periods. We leave all these issues for future research.

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Table A.1: F-tests, p-values

1 lags

	With Michigan expectations							
sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
Δ GDP	0.44	0.30	0.57	0.81	0.77	0.64	0.71	0.68
π	0.00	0.07	0.04	0.00	0.02	0.01	0.41	0.50
R	0.38	0.09	0.02	0.08	0.01	0.00	0.02	0.01

	With Term structure expectations							
sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
Δ GDP	0.25	0.28	0.10	0.18	0.10	0.19	0.11	0.14
π	0.44	0.52	0.37	0.01	0.00	0.00	0.44	0.06
R	0.01	0.01	0.01	0.00	0.00	0.00	0.12	0.01

2 lags

	With Michigan expectations							
sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
Δ GDP	0.49	0.35	0.76	0.85	0.96	0.67	0.90	0.49
π	0.01	0.08	0.01	0.00	0.00	0.00	0.36	0.49
R	0.41	0.01	0.05	0.12	0.00	0.05	0.03	0.01

	With Term structure expectations							
sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
Δ GDP	0.31	0.26	0.09	0.22	0.15	0.24	0.08	0.12
π	0.50	0.51	0.45	0.02	0.00	0.00	0.37	0.04
R	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00

3 lags

	With Michigan expectations							
sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
Δ GDP	0.62	0.55	0.95	0.98	0.69	0.72	0.97	0.91
π	0.60	0.08	0.00	0.00	0.00	0.00	0.10	0.08
R	0.16	0.07	0.20	0.18	0.00	0.01	0.05	0.02

	With Term structure expectations							
sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
Δ GDP	0.48	0.49	0.14	0.21	0.01	0.02	0.12	0.39
π	0.52	0.50	0.16	0.00	0.00	0.00	0.72	0.27
R	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00

8 lags

	With Michigan expectations							
sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
Δ GDP	0.06	0.24	0.02	0.00	0.26	0.13	0.16	0.22
π	0.00	0.03	0.01	0.02	0.02	0.00	0.00	0.01
R	0.11	0.10	0.53	0.42	0.01	0.06	0.18	0.05

	With Term structure expectations							
sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
Δ GDP	0.84	0.71	0.14	0.31	0.00	0.01	0.18	0.14
π	0.10	0.04	0.13	0.25	0.00	0.01	0.67	0.34
R	0.44	0.00	0.00	0.00	0.00	0.00	0.01	0.03

The table reports the P-value for the F-test that expected inflation coefficients in the equation are all equal to zero in a VAR with 4 variables and varying lags.

Table A.2: Variances of reduced form shocks

1 lags

	With Michigan expectations							
sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
Δ GDP	1.12	1.11	1.21	1.39	0.79	0.69	0.67	0.52
π	0.09	0.12	0.12	0.13	0.07	0.05	0.05	0.05
R	0.67	0.89	2.44	2.61	1.42	1.28	0.62	0.23
	With Term structure expectations							
sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
Δ GDP	1.12	1.07	1.14	1.33	0.77	0.69	0.62	0.48
π	0.12	0.12	0.14	0.14	0.06	0.06	0.05	0.04
R	0.57	0.71	1.93	2.06	1.18	1.15	0.58	0.21
	Without inflation expectations							
sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
Δ GDP	1.15	1.14	1.28	1.21	0.81	0.71	0.67	0.53
π	0.15	0.15	0.15	0.14	0.08	0.07	0.06	0.05
R	0.69	0.99	2.45	2.61	1.44	1.30	0.62	0.24

2 lags

	With Michigan expectations							
sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
Δ GDP	1.03	1.01	1.17	1.31	0.71	0.65	0.62	0.45
π	0.08	0.10	0.11	0.11	0.05	0.04	0.04	0.04
R	0.62	0.86	2.03	2.33	1.24	1.22	0.51	0.18
	With Term structure expectations							
sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
Δ GDP	1.01	1.00	1.11	1.26	0.69	0.64	0.59	0.44
π	0.10	0.11	0.12	0.12	0.05	0.05	0.04	0.03
R	0.52	0.64	1.78	1.99	1.09	1.11	0.52	0.18
	Without inflation expectations							
sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
Δ GDP	1.05	1.04	1.18	1.31	0.71	0.66	0.62	0.46
π	0.10	0.11	0.11	0.11	0.06	0.06	0.04	0.04
R	0.63	0.97	2.15	2.46	1.38	1.30	0.55	0.20

3 lags

sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
	With Michigan expectations							
Δ GDP	0.92	0.92	1.04	1.20	0.63	0.01	0.58	0.36
π	0.08	0.10	0.10	0.10	0.05	0.04	0.03	0.03
R	0.54	0.81	1.62	1.99	0.96	0.95	0.48	0.16

sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
	With Term structure expectations							
Δ GDP	0.91	0.92	0.97	1.13	0.57	0.56	0.54	0.35
π	0.10	0.10	0.11	0.11	0.05	0.04	0.04	0.03
R	0.45	0.55	1.15	1.50	0.67	0.67	0.48	0.16

sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
	Without inflation expectations							
Δ GDP	0.95	0.95	1.05	1.20	0.64	0.61	0.98	0.95
π	0.10	0.11	0.12	0.13	0.06	0.05	0.04	0.10
R	0.58	0.90	1.73	2.13	1.16	1.07	0.18	0.58

8 lags

sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
	With Michigan expectations							
Δ GDP	0.43	0.52	0.51	0.53	0.31	0.27	0.23	0.21
π	0.04	0.05	0.05	0.06	0.03	0.03	0.02	0.02
R	0.26	0.50	1.12	1.21	0.44	0.44	0.20	0.11

sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
	With Term structure expectations							
Δ GDP	0.56	0.59	0.58	0.71	0.26	0.24	0.23	0.20
π	0.05	0.05	0.06	0.07	0.03	0.03	0.02	0.02
R	0.30	0.41	0.72	0.79	0.36	0.35	0.18	0.11

sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
	Without inflation expectations							
Δ GDP	0.63	0.67	0.75	0.85	0.36	0.32	0.27	0.25
π	0.07	0.08	0.08	0.08	0.04	0.04	0.03	0.03
R	0.36	0.68	1.30	1.41	0.58	0.54	0.24	0.16

Table A.3: F-tests, p-values, Livingstone expectations

	1 lag							
sample	55:1-79:1	55:1-80:1	55:1-81:1	55:1-82:1	79:2-06:1	80:2-06:1	81:2-06:1	81:2-06.1
Δ GDP	0.59	0.77	0.68	0.63	0.29	0.88	0.77	0.51
π	0.49	0.48	0.24	0.15	0.00	0.09	0.84	0.66
R	0.86	0.80	0.79	0.61	0.00	0.04	0.26	0.53
	2 lags							
sample	55:1-79:1	55:1-80:1	55:1-81:1	55:1-82:1	79:2-06:1	80:2-06:1	81:2-06:1	81:2-06.1
Δ GDP	0.63	0.83	0.78	0.82	0.37	0.21	0.18	0.18
π	0.67	0.51	0.42	0.43	0.01	0.20	0.09	0.31
R	0.60	0.83	0.90	0.91	0.20	0.06	0.08	0.30

The table reports the P-value for the F-test that expected inflation coefficients in the equation are all equal to zero in a VAR with 4 variables and varying lags.

Table A.4: Variances of reduced form shocks, Livingstone expectations

	2 lags							
sample	55:1-79:1	55:1-80:1	55:1-81:1	55:1-82:1	79:2-06:1	80:2-06:1	81:2-06:1	81:2-06.1
Δ GDP	1.21	1.42	1.47	1.47	0.83	0.81	0.81	0.72
π	0.27	0.27	0.31	0.33	0.11	0.10	0.09	0.09
R	1.43	2.04	2.21	2.28	1.03	0.62	0.62	0.50
	4 lags							
sample	55:1-79:1	55:1-80:1	55:1-81:1	55:1-82:1	79:2-06:1	80:2-06:1	81:2-06:1	81:2-06.1
Δ GDP	0.80	1.13	1.18	1.19	0.48	0.36	0.37	0.37
π	0.21	0.20	0.19	0.19	0.08	0.08	0.07	0.07
R	1.12	1.75	1.86	2.03	0.81	0.47	0.46	0.40
	Without inflation expectations, 2 lags							
sample	55:1-79:1	55:1-80:1	55:1-81:1	55:1-82:1	79:2-06:1	80:2-06:1	81:2-06:1	81:2-06.1
Δ GDP	1.26	1.44	1.51	1.50	0.88	0.81	0.82	0.72
π	0.28	0.28	0.33	0.33	0.16	0.11	0.09	0.09
R	1.44	2.07	2.24	2.34	1.15	0.72	0.66	0.52
	Without inflation expectations, 4 lags							
sample	55:1-79:1	55:1-80:1	55:1-81:1	55:1-82:1	79:2-06:1	80:2-06:1	81:2-06:1	81:2-06.1
Δ GDP	0.83	1.17	1.22	1.23	0.53	0.39	0.40	0.40
π	0.22	0.22	0.20	0.20	0.09	0.09	0.08	0.08
R	1.15	1.79	1.90	2.08	0.84	0.49	0.49	0.43

Table A.5: F-tests, p-values, Large system

	With Michigan expectations							
sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
Δ GDP	0.60	0.15	0.58	0.01	0.41	0.57	0.95	0.90
π	0.94	0.90	0.96	0.71	0.95	0.90	0.97	0.96
Δ C	0.43	0.31	0.50	0.93	0.42	0.30	0.16	0.24
Δ I	0.18	0.14	0.26	0.11	0.14	0.16	0.06	0.04
Hours	0.91	0.88	0.75	0.78	0.29	0.22	0.35	0.30
Δ M	0.24	0.33	0.06	0.10	0.59	0.65	0.72	0.89
R	0.21	0.39	0.05	0.08	0.44	0.31	0.48	0.01
	With Term structure expectations							
sample	60:1-79:2	60:1-80:2	60:1-81:2	60:1-82:2	79:3-05:4	80:3-05:4	81:3-05:4	82:3-05.4
Δ GDP	0.60	0.35	0.73	0.39	0.60	0.68	0.83	0.87
π	0.74	0.84	0.43	0.84	0.96	0.68	0.38	0.50
Δ C	0.20	0.58	0.61	0.37	0.07	0.69	0.59	0.53
Δ I	0.33	0.41	0.25	0.73	0.38	0.03	0.19	0.16
Hours	0.92	0.57	0.97	0.99	0.60	0.52	0.59	0.64
Δ M	0.11	0.47	0.85	0.55	0.84	0.51	0.70	0.73
R	0.50	0.33	0.38	0.06	0.19	0.10	0.22	0.19

The table reports the P-value for the F-test that expected inflation coefficients in the equation are all equal to zero in a VAR with 8 variables and two lags.

Table A.6: Variances of reduced form shocks, Large system

	With Michigan Expectations							
sample	55:1-79:1	55:1-80:1	55:1-81:1	55:1-82:1	79:2-06:1	80:2-06:1	81:2-06:1	81:2-06.1
Δ GDP	1.06	1.14	1.20	1.32	0.60	0.58	0.44	0.45
π	0.30	0.30	0.30	0.32	0.31	0.30	0.31	0.29
Δ C	0.48	0.59	0.61	0.62	0.32	0.21	0.21	0.21
Δ I	9.09	10.2	11.0	10.6	5.04	4.07	2.95	2.91
Hours	0.40	0.45	0.43	0.42	0.59	0.55	0.55	0.56
Δ M	362.3	371.8	371.7	370.8	142.6	135.1	118.9	112.2
R	0.16	0.18	0.19	0.22	0.24	0.20	0.18	0.18
	With Term expectations							
sample	55:1-79:1	55:1-80:1	55:1-81:1	55:1-82:1	79:2-06:1	80:2-06:1	81:2-06:1	81:2-06.1
Δ GDP	0.33	0.46	0.99	1.14	0.63	0.61	0.47	0.47
π	0.30	0.30	0.30	0.31	0.31	0.30	0.31	0.29
Δ C	0.59	0.38	0.44	0.60	0.39	0.21	0.21	0.21
Δ I	2.09	6.02	6.78	7.80	5.26	3.91	2.99	2.92
Hours	0.22	0.31	0.44	0.42	0.59	0.55	0.54	0.56
Δ M	128.9	210.9	315.4	306.2	158.9	146.2	127.9	117.6
R	0.10	0.18	0.25	0.25	0.23	0.18	0.17	0.16
	Without inflation expectations							
sample	55:1-79:1	55:1-80:1	55:1-81:1	55:1-82:1	79:2-06:1	80:2-06:1	81:2-06:1	81:2-06.1
Δ GDP	1.08	1.21	1.22	1.49	0.61	0.59	0.45	0.45
π	0.30	0.30	0.30	0.32	0.31	0.30	0.31	0.30
Δ C	0.50	0.62	0.62	0.62	0.40	0.22	0.22	0.21
Δ I	9.63	10.8	11.5	11.3	5.26	4.25	3.16	3.16
Hours	0.40	0.45	0.44	0.42	0.61	0.57	0.56	0.57
Δ M	380.3	385.3	403.7	395.8	144.3	136.5	119.8	112.5
R	0.17	0.19	0.21	0.23	0.24	0.20	0.19	0.18

Table A.7: F-tests, p-values, Simulated data

	Continuity Solution							
sample	60:1-78:4	60:1-79:4	60:1-80:4	60:1-81:4	79:1-99:4	80:1-99:4	81:1-99:4	82:1-99.4
Δ GDP	0.06	0.04	0.44	0.90	0.60	0.47	0.70	0.65
π	0.08	0.08	0.39	0.57	0.52	0.51	0.49	0.40
R	0.53	0.54	0.82	0.22	0.99	0.99	0.93	0.93

	Orthogonality Solution							
sample	60:1-78:4	60:1-79:4	60:1-80:4	60:1-81:4	79:1-99:4	80:1-99:4	81:1-99:4	82:1-99.4
Δ GDP	0.04	0.04	0.08	0.22	0.60	0.60	0.70	0.65
π	0.00	0.00	0.12	0.81	0.36	0.39	0.49	0.40
R	0.90	0.90	0.71	0.44	0.84	0.82	0.93	0.93

The table reports the P-value for the F-test that expected inflation coefficients in the equation are all equal to zero in a VAR with 4 variables and varying lags. Data from 1960:1 to 1979:4 are generated from the indeterminate solution, data from 1980:1 to 1999:4 are generated from the determiante solution.

Table A.8: Variances of reduced form shocks, Simulated data

	Continuity solution							
sample	60:1-78:4	60:1-79:4	60:1-80:4	60:1-81:4	79:1-99:4	80:1-99:4	81:1-99:4	82:1-99.4
Δ GDP	3.32	3.22	3.27	3.26	1.05	0.99	0.96	0.89
π	1.63	1.58	1.56	1.54	0.38	0.36	0.37	0.34
R	0.87	0.84	0.83	0.89	1.07	1.11	1.16	1.09

	Orthogonality Solution							
sample	60:1-78:4	60:1-79:4	60:1-80:4	60:1-81:4	79:1-99:4	80:1-99:4	81:1-99:4	82:1-99.4
Δ GDP	1.01	1.02	1.04	1.15	0.99	0.93	0.96	0.89
π	0.16	0.16	0.19	0.25	0.37	0.36	0.37	0.34
R	0.08	0.08	0.08	0.17	1.08	1.12	1.16	1.09

	Without inflation expectations, Continuity solution							
sample	55:1-79:1	55:1-80:1	55:1-81:1	55:1-82:1	79:2-06:1	80:2-06:1	81:2-06:1	81:2-06.1
Δ GDP	3.48	3.40	3.29	3.26	1.05	0.99	0.96	0.89
π	1.68	1.63	1.56	1.54	0.38	0.36	0.37	0.35
R	0.88	0.88	0.83	0.90	1.08	1.11	1.09	1.10

	Without inflation expectations, Orthogonality solution							
sample	55:1-79:1	55:1-80:1	55:1-81:1	55:1-82:1	79:2-06:1	80:2-06:1	81:2-06:1	81:2-06.1
Δ GDP	1.04	1.04	1.06	1.12	0.98	0.87	0.93	0.84
π	0.18	0.19	0.19	0.24	0.35	0.34	0.34	0.32
R	0.09	0.09	0.08	0.17	1.00	1.04	1.08	1.04

Table A.9: F-tests, p-values, Simulated data with measurement error

	Continuity Solution							
sample	60:1-78:4	60:1-79:4	60:1-80:4	60:1-81:4	79:1-99:4	80:1-99:4	81:1-99:4	82:1-99.4
Δ GDP	0.09	0.00	0.05	0.07	0.16	0.10	0.92	0.70
π	0.14	0.17	0.23	0.94	0.16	0.20	0.26	0.32
R	0.05	0.05	0.10	0.17	0.10	0.10	0.25	0.26

	Orthogonality Solution							
sample	60:1-78:4	60:1-79:4	60:1-80:4	60:1-81:4	79:1-99:4	80:1-99:4	81:1-99:4	82:1-99.4
Δ GDP	0.05	0.05	0.10	0.34	0.74	0.30	0.92	0.70
π	0.36	0.28	0.60	0.05	0.23	0.25	0.26	0.32
R	0.61	0.63	0.82	0.68	0.10	0.15	0.25	0.26

The table reports the P-value for the F-test that expected inflation coefficients in the equation are all equal to zero in a VAR with 4 variables and varying lags. Data from 1960:1 to 1979:4 are generated from the indeterminate solution, data from 1980:1 to 1999:4 are generated from the determinate solution.

Table A.10: Variances of reduced form shocks, Simulated data with measurement error

	Continuity solution							
sample	60:1-78:4	60:1-79:4	60:1-80:4	60:1-81:4	79:1-99:4	80:1-99:4	81:1-99:4	82:1-99.4
Δ GDP	3.47	3.42	3.41	3.31	0.18	0.07	0.05	0.05
π	1.67	1.66	1.72	1.70	1.65	1.64	1.62	1.70
R	1.41	1.41	1.40	1.36	0.18	0.12	0.11	0.12

	Orthogonality Solution							
sample	60:1-78:4	60:1-79:4	60:1-80:4	60:1-81:4	79:1-99:4	80:1-99:4	81:1-99:4	82:1-99.4
Δ GDP	1.38	1.40	1.72	1.69	0.50	0.13	0.05	0.05
π	0.19	0.19	0.29	0.30	1.57	1.64	1.62	1.70
R	0.52	0.52	0.56	0.53	0.15	0.12	0.11	0.12

	Without inflation expectations, Continuity solution							
sample	55:1-79:1	55:1-80:1	55:1-81:1	55:1-82:1	79:2-06:1	80:2-06:1	81:2-06:1	81:2-06.1
Δ GDP	3.82	3.74	3.58	3.44	0.19	0.08	0.05	0.04
π	1.72	1.71	1.76	1.70	1.69	1.65	1.61	1.67
R	1.49	1.48	1.45	1.39	0.18	0.13	0.11	0.11

	Without inflation expectations, Orthogonality solution							
sample	55:1-79:1	55:1-80:1	55:1-81:1	55:1-82:1	79:2-06:1	80:2-06:1	81:2-06:1	81:2-06.1
Δ GDP	1.35	1.37	1.66	1.61	0.47	0.12	0.05	0.05
π	0.18	0.18	0.29	0.30	1.57	1.64	1.61	1.69
R	0.53	0.52	0.56	0.54	0.15	0.11	0.11	0.11