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A Measure for Credibility:  
Tracking US Monetary Developments

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# A Measure for Credibility: Tracking US Monetary Developments\*

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## Abstract

Our objective is to identify a way of checking empirically the extent to which expectations are de-coupled from inflation, how well they might be anchored in the long run, and at what level. This methodology allows us then to identify a measure for the degree of anchorness, and as anchored expectations are associated with credibility, this will serve as a proxy for credibility. We apply this methodology to the US history of inflation since 1963 and examine how well our measure tracks the periods for which credibility is known to be either low or high. Of particular interest to the validity of the measure is the start of the Great Moderation. Following the narrative of a number of well documented incidents in this period, we check how well our measure captures both the evolution of credibility in US monetary policy, as well as reactions to inflation scares.

*Keywords:* Great Inflation, Great Moderation, Anchors for Expectations

*J.E.L codes:* E52, E58

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# 1 Introduction

There is little disagreement that credibility is crucial to successful monetary policy. Numerous attempts in the literature have tried to define it, explain why it is necessary to have it and how it can be earned and maintained. Institutional commitment to a nominal anchor (Mishkin, 2007), or any explicit form of commitment more generally, (Albanesi et al, 2003 and Christiano and Gust, 2000), are often thought to promote price stability and are considered crucial to the successful management of inflation expectations. Commitment, in general, is the key ingredient to establishing credibility, and more so in the most recent theory on optimal monetary policy, referred to as the new-neoclassical (or new-Keynesian) synthesis (Clarida, Gali, and Gertler, 1999; Woodford, 2003). Empirically, a number of studies have shown the beneficial effects of a successful commitment to a nominal anchor, in terms of more stable and less persistent inflation (Levin et al 2004, Gürkaynak et al 2006) but also in terms of lower volatility of output fluctuations (Fatás et al 2007; Mishkin and Schmidt-Hebbel, 2002, 2007). Commitment to a well defined and credible nominal anchor has thus an effect on the dynamic relationship between inflation expectations and realized inflation. As such, a fully credible and transparent monetary policy provides an anchor for inflation expectations, and therefore de-couples them from short run inflation dynamics (Demertzis and Viegi, 2007).

Using this intuition, the purpose of this paper is two-fold: first, we propose a method for assessing the extent to which expectations are de-coupled from inflation. Hence, we identify a means for checking empirically whether expectations are anchored in the long run, and at what level. In this respect, the extent of anchoring will serve as a proxy for credibility. Second, to be able to assess how capable this measure is of identifying credibility correctly, we need to cross-check it against periods for which the level of credibility is known and generally agreed upon. To this end, we apply the measure to the US inflation history since 1963, which includes both the period of the *Great Inflation*, in which credibility was known to have been poor and deteriorating, as well as the period of the *Great Moderation* during which credibility in the monetary authority was gradually re-established. Of particular interest is the evolution of credibility during the early eighties, associated with *Volcker's Disinflation*, in which monetary policy makers worried explicitly about the way that 'inflationary psychology' was affecting their ability to be effective (Goodfriend and King 2005). Aiming to align these expectations with their own inflation objectives as well as effectively bringing inflation down, the Fed engaged in persistently aggressive policies. This was done at great costs to output in that period, but helped reverse the inflationary trend thereafter, and hence improve credibility, (Goodfriend 1993, 2007).

The paper is organized as follows. Section 2 summarizes how anchorness and credibility can be first identified and then measured. We propose a number of tests for identifying whether expectations are anchored. Section 3 presents

a number of stylized facts about US inflation and inflation expectations that allow us to divide periods according to their level of credibility. Section 4 then presents the results on the extent of anchorness for the different periods. Section 5 presents the evolution of credibility in the US since 1963 based on our measure, and attempts to track well-documented incidents of monetary policy behavior. Section 6 summarizes and concludes.

## 2 A Theory of Anchorness

In our attempt to examine anchorness we will consider a reduced form model for inflation and inflation expectations. Looking at inflation first, it is straightforward to show that inflation is affected by the level of expectations. Assume a model in which the Central Bank has a standard loss function in which it chooses the rate of inflation  $\pi$  to minimize the distance from the inflation objective set  $\pi^T$  and close the output gap  $y$ ,

$$L_{CB}|\xi = \frac{1}{2}\mathbb{E}\left[(\pi_t - \pi^T)^2 + y_t^2\right], \quad (1)$$

subject to a standard Lucas supply function,  $y_t = \pi_t - \pi_t^e + \xi_t$  where  $\xi$  is a supply shock with zero mean and constant variance,  $\sigma_\xi^2$ . Optimization of (1) implies that

$$\pi_t|\xi = \frac{\pi^T}{2} + \frac{\pi_t^e}{2} - \frac{\xi_t}{2}, \quad (2)$$

where  $\pi_t$  is now the *ex post* inflation outcome conditional on the shock  $\xi_t$ , before solving for private sector expectations,  $\pi_t^e$ . In a typical commitment setup, where the Central Bank commits to the target  $\pi^T$ , expectations formed are equal to the CB's objectives,  $\pi_t^e = \pi^T$ , and the ex post outcome is:

$$\pi_t|\xi = \pi^T - \frac{\xi_t}{2} \quad (3)$$

$$\mathbb{E}(\pi) = \pi^T. \quad (4)$$

However, it is questionable as to whether empirically it is justified to reduce (2) into (3). We would like to explore how inflation expectations actually evolve. To this end, we base our formulation on Bomfin and Rudebusch (2000), who assume that long-run inflation expectations at time  $t$ , denoted  $\pi_t^e$ , are a weighted average of a constant  $\pi^*$  (which in their case is the current target) and last period's inflation rate:

$$\pi_t^e = \lambda_t \pi^* + (1 - \lambda_t) \pi_{t-1}. \quad (5)$$

Parameter  $\lambda_t$  ( $\in [0, 1]$ ) then indexes the degree of anchorness of inflation expectations. If  $\lambda_t = 1$ , then inflation expectations are perfectly anchored to the constant  $\pi^*$ , which for inflation targeting regimes can be cross-checked against

the inflation objective  $\pi^T$  communicated. Credible regimes will then be those for which both  $\lambda_t = 1$  as well  $\pi^* = \pi^T$  hold. It follows that if  $\lambda_t = 0$ , there is no credibility, the inflation target is ignored in the formation of expectations and expectations simply follow past inflation. For countries that do not have an explicit inflation objective, such as the US, the value of parameter  $\lambda$  alone is then a proxy for credibility. The formation of expectations based on (5) is also consistent with expectations formed either heuristically (Brazier *et al* 2008), or based on an information game (Demertzis and Viegi, 2008). However, while expectations are a continuum between a constant and last period's inflation in (5), the latter two approaches assume a discrete switch between the two values. In both approaches however, credibility is the 'lever' that moves expectations from one state to the other.

## 2.1 Testing for Anchorness

The main observation of the previous analysis is that a credible regime will be characterized by a disconnect between inflation and inflation expectations dynamics. In what follows we identify how this disconnect would manifest itself in the data, and then how inflation expectations are anchored once they are disconnected from historical inflation experience.

Following (2) and (5), and allowing for the presence of dynamics, we model  $\pi_t$  and  $\pi_t^e$  in the following VAR specification:

$$\begin{pmatrix} \pi_t \\ \pi_t^e \end{pmatrix} = \begin{pmatrix} c_1 \\ c_2 \end{pmatrix} + \begin{pmatrix} a(L) & b(L) \\ c(L) & d(L) \end{pmatrix} \begin{pmatrix} \pi_{t-1} \\ \pi_{t-1}^e \end{pmatrix} + \begin{pmatrix} e_{1t} \\ e_{2t} \end{pmatrix}, \quad (6)$$

$$\begin{pmatrix} e_{1t} \\ e_{2t} \end{pmatrix} \sim i.i.d. \left( \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_{11} & \sigma_{12} \\ \sigma_{12} & \sigma_{22} \end{pmatrix} \right).$$

**Conjecture 1** *A credible inflation expectations disconnect would imply that the following hypotheses are satisfied:*

- H1: *Expected inflation is not affected by lagged actual inflation, i.e.,  $c(L) = 0$ .*
- H2: *Expected inflation is anchored to a constant on average, i.e.,  $c(L) = 0$  and  $d(L) = 0$ .*
- H3: *Actual inflation is not affected by expected inflation, i.e.,  $b(L) = 0$ .*
- H4: *The persistence of actual inflation, the sum of the coefficients of  $a(L)$ , decreases with credibility.*
- H5: *There is no contemporaneous transmission of shocks from actual to expected inflation and vice versa, i.e.,  $\sigma_{12} = 0$ .*

We test hypotheses H1-H3 with standard Wald tests. In particular, H1 and H3 correspond to Granger non-causality of, respectively, actual inflation for expected inflation, and expected inflation for actual inflation. If there is evidence



of some heteroskedasticity in the errors, we apply a robust (HAC based) version of the Wald test. We examine hypothesis 4 by comparing estimated persistence in different periods for which credibility of monetary policy is known. Hypothesis 5 can be verified by checking the non-significance of the correlation between the VAR errors ( $corr(e_{1t}, e_{2t}) = 0$ ) by applying a Fisher transform test. Note that H1, H3 and H5 jointly imply that all elements of the impulse response function (IRF) of actual inflation to a shock in expectations are zero, and the same should hold for the IRF of expected inflation to a shock in actual inflation.

## 2.2 A Proxy for Credibility

We turn next to the way expectations are formed. Note that (5) assumes *a priori* that inflation expectations do not depend on their own past behavior, i.e.,  $d(L) = 0$  in (6). However, this hypothesis should be tested and, as we will see in the next section, it is empirically systematically rejected. Hence, we use a VAR approach to provide a more general measure of  $\lambda$ . Our prior is that credible monetary policy implies that expectations are de-coupled from inflation (low correlation) and are anchored to an ‘implicit’ target. Expectations are then partly following that implicit ‘anchor’  $\pi^*$ . We derive the values of  $\lambda$  and  $\pi^*$  next.

Consider for simplicity the VAR(1) version of (6):

$$\begin{aligned}\pi_t &= a_0 + a\pi_{t-1} + b\pi_{t-1}^e + e_{1t} \\ \pi_t^e &= c_0 + c\pi_{t-1} + d\pi_{t-1}^e + e_{2t},\end{aligned}\tag{7}$$

which implies that in equilibrium (i.e., in the long run) it is:

$$\pi = \frac{a_0}{1-a} + \frac{b}{1-a}\pi^e \quad \text{and}\tag{8}$$

$$\pi^e = \frac{c_0}{1-d} + \frac{c}{1-d}\pi.\tag{9}$$

Matching coefficients of (5) and (9), it follows that:

$$\begin{aligned}\lambda\pi^* &= \frac{c_0}{1-d} \\ 1-\lambda &= \frac{c}{1-d}\end{aligned}$$

and therefore,

$$\lambda = 1 - \frac{c}{1-d}\tag{10}$$

$$\pi^* = \frac{c_0}{(1-d)\lambda}.\tag{11}$$

Empirically,  $\lambda$  and  $\pi^*$  can be estimated by substituting parameters  $c_0$ ,  $c$  and  $d$  with their estimates from (7). Parameter  $\lambda$  will serve as a proxy for credibility

and the estimated value of  $\pi^*$  as the implicit long-term anchor for inflation expectations.

Last, we make the following remarks. First,  $\lambda$  in (10) is not constrained to belong to the  $[0,1]$  interval. Using the VAR coefficients it can be re-written as:

$$c = (1 - \lambda)(1 - d),$$

which yields

$$\pi_t^e = c_0 + (1 - \lambda)(1 - d)\pi_{t-1} + d\pi_{t-1}^e + e_{2t}. \quad (12)$$

Second, the formulae for  $\lambda$  and  $\pi^*$ , and the restrictions on the VAR parameters, can be easily extended to allow for higher order VARs (see Appendix A for the general result). Third, we consider a constant equilibrium (long-run) value for credibility (see Argov et al, 2007) and estimate the VARs over sub-periods where credibility is believed to be fairly constant. An alternative approach is to estimate the VAR over the whole sample and allow its parameters to be time-varying, as we will explain further down. Finally, it is worth mentioning that our measure of credibility is precisely the one employed by King (1995), who analyzes the difference between long-run inflation expectations (derived from nominal and real yield curves) and inflation targets. It is also close to the expectational definitions in Johnson (1998, 2002) and Croushore and Koot (1994), who use short-run inflation expectations from surveys.

### 3 Stylized facts

We describe briefly the US inflation history from 1963 to 2007. Our main analysis will be done using series for CPI inflation<sup>1</sup> and long term expectations produced by the FRB model of the Fed. We will also look at two other survey-based measures for long term inflation, namely, (SPF) Federal Reserve Bank of Philadelphia's survey of professional long-run (10-year) inflation forecasts (quarterly), and the 6-10 years Consensus Forecasts (semi-annual). Both series start in 1990<sup>2</sup>.

#### 3.1 Inflation and Inflation Expectations

Figure 1 plots CPI inflation and FRB long term expectations. The literature typically identifies three distinct periods in the conduct and effectiveness of

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<sup>1</sup>Quarterly, y-o-y changes of CPI, 1963q1-2007q1. Appendix C will discuss also our main results based on PCE series for inflation, as this is the one used to represent inflation most often. However, Clark (1999) argues that when comparing the pros and cons of the two series CPI is the better index.

<sup>2</sup>The Federal Reserve Board (FRB) expectations series follows the SPF closely for most of its history. However, based on a learning model developed by Kozicki and Tinsley (1996), the series estimates a longer historical perspective. This permits us to carry out the analysis starting in 1963.

monetary policy (Goodfriend, 2007). First is the period of the Great Inflation during the late '60s and '70s. This is a period where inflation was steadily increasing with three noticeable peaks at 1969q4, 1974q4 and 1980q1 (see figure 1). The on-going debate on the sources of this pattern for inflation, summarized in Cecchetti et al. (2007), attributes it mostly to the behavior of oil and raw material prices, combined with an insufficiently tight monetary policy. Over this period, inflation expectations were also steadily increasing, but less than actual inflation, and remained systematically below actual inflation. This is generally considered a period of deteriorating credibility.

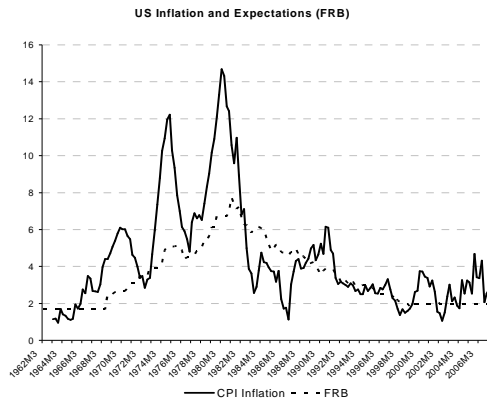


Figure 1: Inflation and Inflation Expectations

The second period identified, the '80s, is characterized by an overall downward trend in the level of inflation, associated with the Volcker Disinflation. Figure 1 shows that the decline in the long term FRB expectations was less pronounced, with a prolonged period of expectations above actual inflation. Goodfriend and King (2005) argue that this was also a period of poor credibility, which was the cause of the high costs of disinflation observed. In the third period, identified approximately between 1991 and 2007, we observe relatively stable inflation accompanied by a further decline in the long term inflation expectations, which stabilizes at a value around 2 per cent after 2000. This is generally believed to be a period of relatively high credibility, which as we shall see becomes full in the new century.

A similar picture emerges when looking at the descriptive statistics for the corresponding periods in Table 1. We report the standard statistics as well as the level of persistence and the correlation of actual and expected inflation<sup>3</sup>. Average and median values of actual and expected inflation steadily decrease across the three periods, and average expected inflation is higher than average

<sup>3</sup>Persistence is measured as the sum of the autoregressive coefficients in an AR(4) model with a constant. We examine the significance of the correlation coefficients between the

actual inflation, only in the second period, the '80s. The range and standard deviation shrink progressively over time. While this is a well known feature for inflation, a similar pattern emerges also for the expectations, the standard deviation of which reduces from 1.41 in 1968-80 to 0.54 in 1991-07. Furthermore, there is a noticeable decrease in the persistence of inflation. This is not the case for inflation expectations. In addition, and perhaps more interestingly, the correlation between actual and expected inflation drops from 0.81 in the '70s to 0.40 in 91-06 and is statistically insignificant after the year 2000. The latter period is also characterized by a major drop in the volatility and persistence of inflation expectations. Our results remain unchanged if we move the start and ending point of the three periods by a few quarters.

Table 1. Inflation and long run FRB inflation expectations, (and H4)

Sample	68q1-80q4		81q1-90q4		91q1-06q4		01q1-07q1	
	<i>Infl</i>	<i>Infl<sup>e</sup></i>	<i>Infl</i>	<i>Infl<sup>e</sup></i>	<i>Infl</i>	<i>Infl<sup>e</sup></i>	<i>Infl</i>	<i>Infl<sup>e</sup></i>
Mean	7.31	4.31	4.68	5.17	2.73	2.35	2.76	1.95
Median	6.28	4.45	4.22	4.86	2.75	1.95	2.78	1.95
Max	14.68	7.05	10.96	7.72	4.89	3.79	4.67	2.00
Min	2.84	1.68	1.13	3.50	1.06	1.75	1.06	1.90
St.Dev.	3.17	1.41	2.19	1.09	0.80	0.54	0.89	0.02
Persistence	0.91	0.99	0.83	0.96	0.60	0.93	0.37	-0.12
Corr with Infl	-	<b>0.81</b>	-	<b>0.54</b>	-	<b>0.40</b>	-	-0.15

Note: bold indicates significance at the 5% level.

Last, we examine how FRB long term inflation expectations compare to other measures of inflation expectations for overlapping periods. Figure 2 plots the three series as well as CPI inflation.

Table 2 summarizes the main descriptive statistics for long term expectations FRB, the Consensus Forecast and the Survey of Professional Forecasters.

variables in question, by applying Fisher's transformation:

$$z = 0.5 \ln \left( \frac{1 + \rho}{1 - \rho} \right)$$

This statistic is approximately normally distributed, with mean zero and standard deviation  $\sigma = (n - 3)^{-\frac{1}{2}}$ , where  $n$  is the sample size. Bold indicates significantly different from zero at the 5% level.

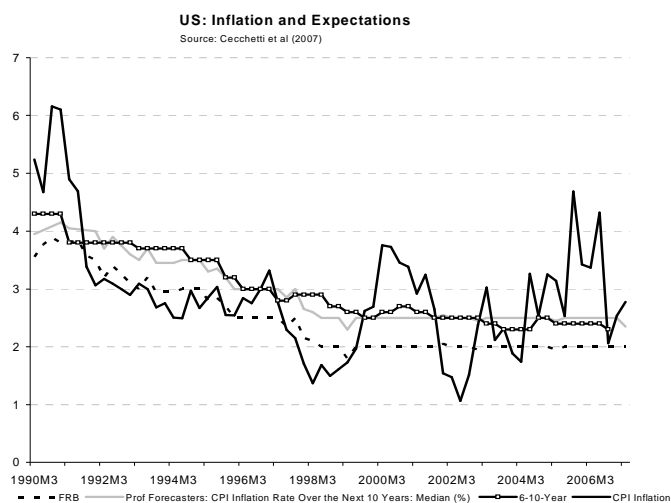


Figure 2: Alternative Measures for Inflation Expectations

Table 2. Alternative long run inflation expectations

	Consensus (6-10)		FRB	SPF
	<i>Infl</i>	<i>Infl<sup>e</sup></i>	<i>Infl<sup>e</sup></i>	<i>Infl<sup>e</sup></i>
Mean	2.87	2.97	2.43	2.90
Median	2.76	2.70	1.97	2.50
Max	6.10	4.30	3.79	4.15
Min	1.06	2.10	1.90	2.45
St.Dev.	1.02	0.63	0.63	0.54
Persistence	0.71	0.95	0.85	0.85
Corr with Infl	-	<b>0.48</b>	<b>0.57</b>	<b>0.42</b>
Sample	90:s1-07:s1	90:s1-07:s1	90:s1-06:s2	91:s2-06:s2

Note: bold indicates significance at the 5% level.

The differences between the three measures of expectations are minor: FRB has a slightly lower average and median value and shorter range of variability, while SPF has a slightly lower standard deviation and correlation with actual inflation. Overall the three series of inflation expectations move closely together, ( $\text{correl}(\text{Cons}, \text{FRB})=0.96$ ,  $\text{correl}(\text{Cons}, \text{SPF})=0.96$ ,  $\text{correl}(\text{FRB}, \text{SPF})=0.99$ ). The contemporaneous correlation of actual and expected inflation is 0.48, 0.57 and 0.42 for the three measures respectively. However, these values can be spuriously upward biased, due to their overall decreasing behavior in the period examined. Hence, the issue of correlation needs to be addressed within a formal dynamic model, as we will see in the next section.

## 4 Results for Anchorness

We present our results in the following order. We start with results for the period between 1968 and 1980 as a period of low credibility, using the series on FRB expectations only. We then test our model for the period between 1990 and 2007, as one where monetary policy is relatively credible. In the following section we will test whether this chronological classification is justified. For this latter period we carry out tests based on all three available expectations series. Last we repeat the analysis with a time-varying VAR as in Stock and Watson (1996) and thus examine the stability of the coefficients of the VAR across the whole sample 1968-2007, inclusive of the Volcker disinflation period, during the 80s. This technique will allow us to examine how parameter  $\lambda$  has evolved across the whole sample, in the next section. For each of the sub-sections that follow, there is a corresponding sub-section in Appendix B describing the econometric methodology and robustness checks in greater detail.

### 4.1 1968-1980: A Period of Low credibility

The period generally associated with the Great Inflation is dated to start in 1965 and is to last for about 20 years, after which Volcker's period of disinflation begins to bear results. This period is also associated with low and deteriorating credibility and generally an inability to control inflation (Cecchetti et al 2007). Meltzer (2005) attributes this to a number of reasons, including both lack of knowledge of how the underlying economy worked at the time, as well policy and institutional choices/arrangements made. Given this general description of the time-period, we evaluate the performance of the VAR model and the outcome of tests for hypotheses 1-5, for the period up to the end 1979<sup>4</sup>. Our choice of ending point is motivated by the appointment of Volcker as the chairman of the Federal Reserve, which is identified with the start of a new era in monetary policy effectiveness. Our main finding is that over this period hypotheses 1 and 3, no effects of actual inflation on long term expectations, and vice versa, are strongly rejected, (see Table 3 below). Hypothesis 5 is not rejected, indicating that there is still no evidence of contemporaneous shock transmission (insignificant correlation).

Table 3. Granger Causality (H1, H3 and H5)

<i>Dependent</i>	<i>Excluded</i>	<i>df</i>	$\chi^2$	(Pr)	$\text{cor}_{e_1, e_2}$
$\pi$	$\pi_{FRB}^e$	6	<b>27.19</b>	(0.00)	-0.17
$\pi_{FRB}^e$	$\pi$	6	<b>22.49</b>	(0.00)	

Notes: Bold indicates significance at 5% level.

In summary, there appears to be a lot of interaction between actual inflation and long term inflation expectations over a period of low credibility. Based on

<sup>4</sup>Note that if  $\lambda$  is equal, or close, to zero, the VAR framework is not suited due to perfect collinearity between the regressors. In this case a single equation approach along the lines of (5) would be appropriate. However, we have never found such a case to be true in practice (correlations in Table 1 are at most 0.81).

the VAR(2) choice, the IRFs in figure 3 show that there is great persistence in both inflation as well as expectations and both variables affect each other.

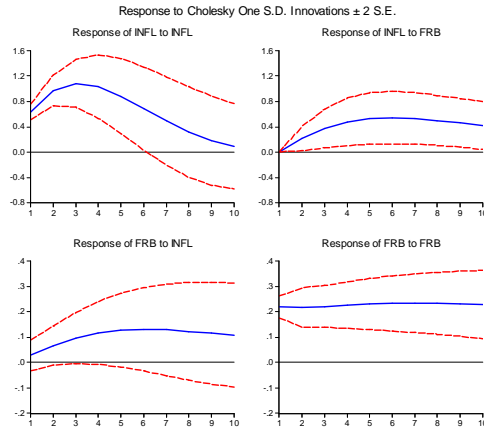


Figure 3: FRB Expectations, 1968-1980

Our analysis demonstrates that for a period of generally deteriorating performance in inflation and low credibility, there is a close relationship between inflation and the way expectations are formed, even in the long run.

## 4.2 1990-2007: A Period of High Credibility

Goodfriend (2007) describes US monetary policy of this period as follows: “Under Greenspan’s leadership, the Fed demonstrated additional practical principles of monetary policy that have become part of the new consensus. The most important is that monetary policy could sustain low inflation with low unemployment on average, and with infrequent, mild recessions.” This period is one in which inflation is on a long declining trend, eventually becoming stationary after the year 2000. We check for anchorness in this period based on three alternative measures for expectations.

The lag length selection criteria indicate 5 lags for the series FRB and SPF and 1 lag for the Consensus Forecasts. From the Wald tests for hypotheses 1 and 3, which are reported in table 4 below, expected inflation is not significant in the actual inflation equation, and vice versa.<sup>5</sup> Moreover, the correlation in the VAR residuals is not statistically different from zero (although the test fails when using FRB expectations).

<sup>5</sup>A robust version of the Wald test yields the same results, the p-values are, respectively, 0.56 and 0.56.

Table 4. Granger Causality (H1, H3 and H5)

<i>Depend.</i>	<i>Excluded</i>	<i>df</i>	$\chi^2$	(Pr)	$\text{cor}_{e_1, e_2}$
				(1989s2 2007s1)	
$\pi$	$\pi_{FRB}^e$	5	2.30	(0.81)	<b>0.38</b>
$\pi_{FRB}^e$	$\pi$	5	3.63	(0.60)	
				(1991s2 2006s2)	
$\pi$	$\pi_{SPF\_10Y}^e$	5	2.39	(0.79)	0.15
$\pi_{SPF\_10Y}^e$	$\pi$	5	1.71	(0.89)	
				(1990s2 2007s2)	
$\pi$	$\pi_{(6-10)}^e$	1	0.43	(0.51)	0.28
$\pi_{(6-10)}^e$	$\pi$	1	0.63	(0.43)	

Note: Bold indicates significance at 5% level.

As already mentioned, the joint validity of hypotheses 1, 3, 5 should imply that each value of the cross IRF is not statistically different from zero. This is indeed the case, with the only exception of the small and positive reaction of the FRB expectation measure (in line with the findings of Table 4). Figures 4-6 report the estimated impulse responses and their 95% confidence bands.

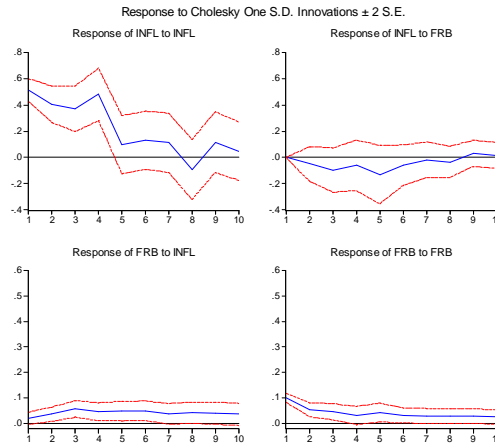


Figure 4: FRB Expectations, 1989-2007

Hypothesis 2 however, (no persistence in expected inflation), is strongly rejected. The estimated persistence (the coefficient of lagged expected inflation in this case), for example for Consensus forecasts is 0.95, similar to the result from the AR(4) reported in Table 1. The estimated persistence in inflation is instead 0.57, again in line with the previous finding based on the AR(4) model. Figures 4-6 confirm the higher persistence of inflation expectations, but they also highlight



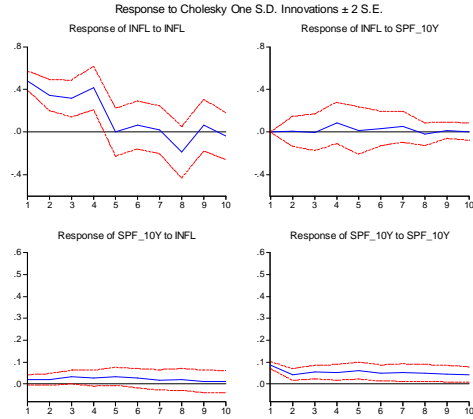


Figure 5: SPF Expectations, 1989-2007

the fact that shocks that hit expectations are much smaller in size by comparison to inflation.

Summarizing, our results for this period, using 3 alternative measures for inflation, show neither contemporaneous nor dynamic statistically significant correlation between actual values and long term expectations of inflation. This stands in contrast to the earlier period described above, where the relationship between the two variables was tighter. There appears therefore to be a disconnect between inflation and expectations for periods when monetary policy is generally considered to be credible. We examine next the stability of our parameters across the whole period, and thus describe also monetary policy during the 80s.

### 4.3 A Time-Varying VAR

So far we have assumed that there are discrete changes in the parameters of the VAR in (6), which define periods with different credibility of monetary policy. The results we have obtained are fairly robust to changes in the start/end date of the sub-periods. As an alternative, we consider VARs with time-varying parameters estimated over the whole sample, along the lines of, for example, Stock and Watson (1996), Cogley and Sargent (2005), or Clark and Nakata (2008). Based on Stock and Watson (1996) we specify a time-varying VAR(1) version of (6) as follows:

$$\begin{aligned}\pi_t &= a_{0t} + a_t \pi_{t-1} + b_t \pi_{t-1}^e + e_{1t}, \\ \pi_t^e &= c_{0t} + c_t \pi_{t-1} + d_t \pi_{t-1}^e + e_{2t},\end{aligned}\tag{13}$$

where each parameter is assumed to evolve according to a random walk, the errors of the random walks are uncorrelated among themselves and with the VAR

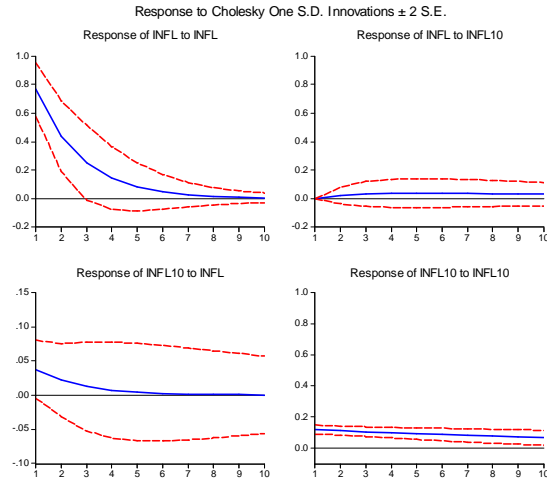


Figure 6: Consensus Forecasts (6-10), 1990-2007

errors, and the VAR errors are assumed to be uncorrelated and homoskedastic. We estimate model (13) by the Kalman filter and figure 7 below reports the (smoothed) estimates of the time-varying parameters.

Starting with the inflation equation, parameter  $a_t$  decreases, on the whole, over time. It becomes relatively constant for the period between 1981-2000 and then decreases. The opposite occurs for parameter  $a_{0t}$ , which increases in the latter period. Parameter  $b_t$  is fairly constant at about 0.4, with peaks in the mid 70's and early '80s (with values that become statistically significant for a few quarters after 1978), associated with peaks in  $a_t$ . Overall, these results are in line with our earlier observations, namely that the '70s were a problematic period, in the sense of being fairly unstable, that inflation persistence decreases across the decades (as measured by the  $a_t$  parameter), and that inflation expectations can have a significant effect on actual inflation when credibility is thought to be low (the  $b_t$  parameter).

In the inflation expectations equations, the  $c_t$  parameter is higher in the '70s and early '80s, declines after that, and reaches values close to zero in the most recent period. The  $d_t$  parameter increases steadily up to the early '80s, then declines until the end of the '90s, and stabilizes afterward. Again these results are coherent with the picture emerging from the split sample VARs. In the absence of credibility, inflation expectations are more persistent, and can be directly affected by the evolution of actual inflation, while the two variables are de-coupled when credibility is restored.<sup>6</sup>

<sup>6</sup>We should point out that we find much more evidence of instability in the relation between actual and long term expected inflation than Clark and Nakata (2008). This is due to different

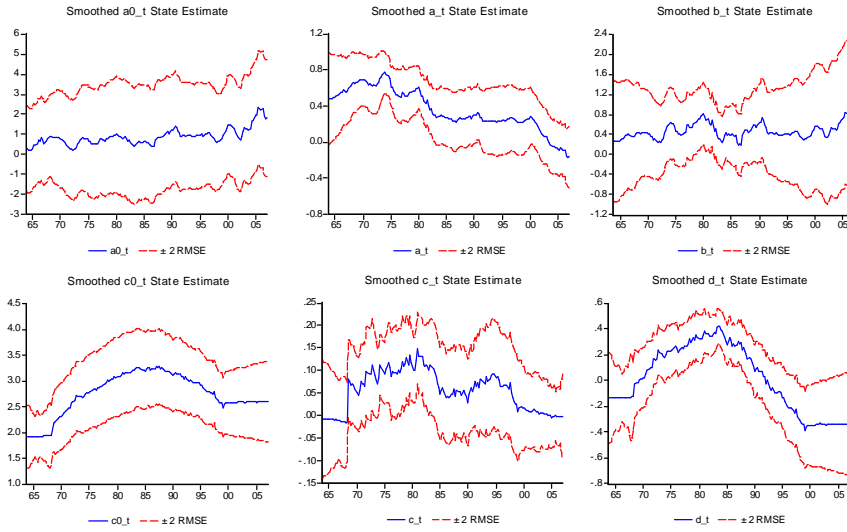


Figure 7: Time-Varying VAR

## 5 A Measure for Credibility

Based on the estimated parameters from the time-varying VAR (figure 7), we calculate the time varying  $\lambda$  (from 10) and its standard errors, for the period from 1963 till 2007. Figure 8 shows that the value of  $\lambda$ , and by proxy also credibility, has varied significantly across the whole period. It is important therefore to discuss this measure separately for different periods.

Using next our estimates for  $\lambda$ , we can in turn estimate  $\pi^*$  (from 11). While the estimate of  $\lambda$  indicates the extent to which expectations are anchored to a constant, (and therefore, past inflation does not affect expectations),  $\pi^*$  provides an estimate for what that anchor might be. Figure 9 plots CPI inflation and FRB expectations, as well the estimated values for  $\lambda$  and  $\pi^*$ .

The period of the Great Inflation, from 1965 to the early 1980s, was characterized by both high as well as very volatile inflation, and reached its peak in 1980q1. Meltzer (2005) writes “...The Great Inflation of 1965 to the mid-1980s was the central monetary event of the latter half of the 20th century. Its economic cost was large. It destroyed the Bretton Woods system of fixed exchange rates, bankrupted much of the thrift industry, heavily taxed the U.S. capital stock, and arbitrarily redistributed income and wealth.” Our measure of credibility,  $\lambda$ , exhibits a considerable decline in this period, starting from a value of 1 and reducing to a value 0.75. At the same time, the implicit long run anti-specification choices (see Appendix C for a detailed discussion).

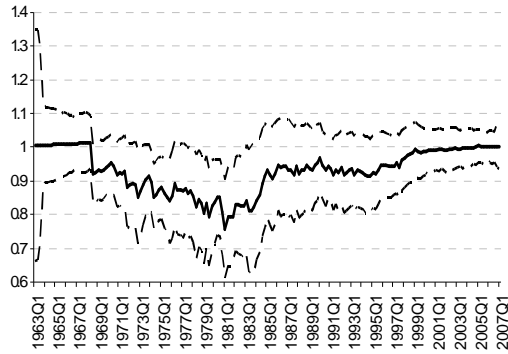


Figure 8: Estimated  $\lambda$  and its significance ( $\pm 2SE$ )

pated inflation increased steadily, following the trend, and more often than not also the level, of FRB expectations closely. This is in our view consistent with the perception that for this period monetary policy was losing credibility. The period of the end of the 1970s and early 1980s was to see two important events for the course of inflation thereafter: first was the appointment of Volcker at the summer of 1979 and second, inflation reached its peak in the first quarter of 1980. This marked the start of what has come to be known as the ‘Volcker Disinflation’ period associated with the start of a long and declining path for inflation for the following 10-15 years. And while there is no doubt about the importance of this period in terms of altering the long term inflation trend, there is some discussion as to what the associated cost has been. Goodfriend and King (2005) argue that “...the reduction in inflation engineered by the Fed under Volcker was accompanied by substantial output losses ... because it was viewed as not credible, in the sense that firms and households believed for several years that the reduction in inflation was temporary with a return to high inflation likely.”, (p983). Indeed figure 9 concurs this view, in the sense that credibility of that period is the lowest in the whole sample. It also shows that even though inflation reached its peak in 1980q1, credibility continued to fall for another four quarters before changing direction. It required therefore a year of rapidly declining inflation before the public began to change its opinion. This delay in public perceptions is also alluded to by Goodfriend and King (2005) who argue “...that the Volcker disinflation did not really start in earnest until late 1980 or early 1981.”<sup>7</sup>

Figure 10 concentrates on the Volcker disinflation period, which saw four ‘inflation scares’ identified by Goodfriend (1993)<sup>8</sup>. Our objective is to map the

<sup>7</sup>Goodfriend (2005) has the timing of the reversal slightly later, in the summer of 1982, based on evidence on long bond rates.

<sup>8</sup>Inflation scares are instances of sharply rising long-term bond rates reflecting rising long-term inflation expectations.

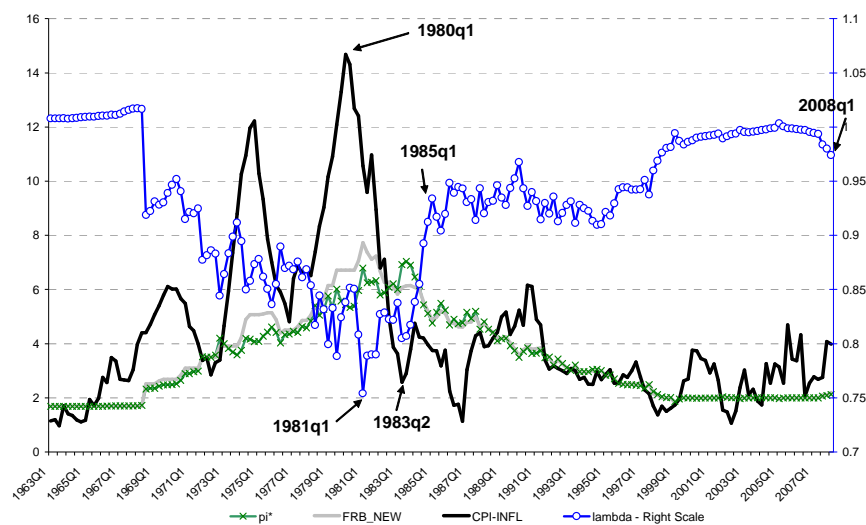


Figure 9: The Evolution of Credibility

evolution of credibility during this period to the events themselves. The first of these inflation scares was observed at the start of 1980. “In retrospect, 1980 was a disaster from a monetary policy point of view. The U.S. economy suffered a recession along with a destabilizing inflation scare and policy reaction, and yet at the end of the year, inflation remained above 10 percent. The events of 1980 heightened public unhappiness with inflation”, Goodfriend (2007). Indeed we see that after the first inflation scare there is substantial loss in credibility (of about 10 basis points), even though inflation is already declining. The second inflation scare in 1981 was accompanied with an extraordinarily tight monetary policy, which was a very hard choice to make as the recession deepened, but proved beneficial in term of reversing, and sustaining, the downward path in credibility.

The third inflation scare, in the summer of 1984, was met with an equally determined Fed- “For the first time in its history, the Fed successfully employed interest rate policy to hold the line on inflation (at 4 percent) without creating a recession.”, Goodfriend (2007). The graph demonstrates how credibility is increasing throughout the length of the third inflation scare, at levels which allow a costless tightening “...indicating that the Volcker Fed had acquired credibility for 4 percent trend inflation.”, Goodfriend (2007). Parameter  $\lambda$  is now above 0.9 and increasing, and both expectations as well as the implicit  $\pi^*$  have stabilized at just above 4 percent.

The fourth inflation scare in October 1987 was qualitatively different. It is true that it took a number of years to revert (bond yields returned to their 1987 levels in 1992) but by that time, both inflation as well inflation expectations

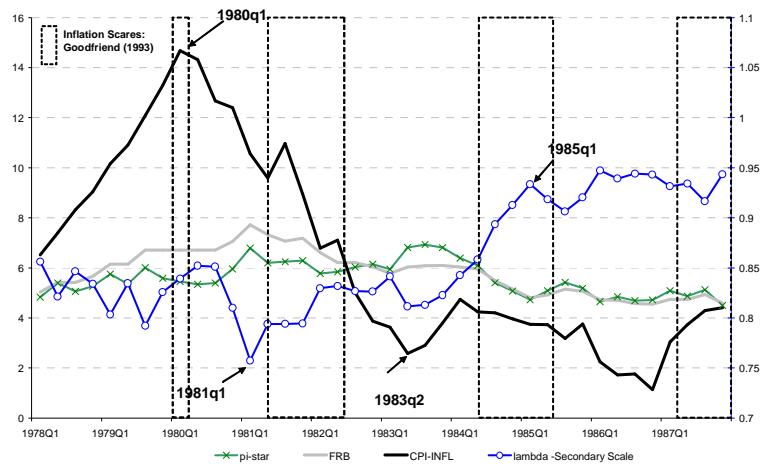


Figure 10: The Volcker Disinflation

had improved considerably and the level of anchorness  $\lambda$  was hovering between 0.9 and 0.95. Alan Greenspan had replaced Volcker as chairman of the Fed in 1987, but the credibility acquired under the Volcker Fed was sustained, allowing for inflation expectations to continue to fall. It would take 15 years (till the end of 1990s) for the inflation rate to stabilize around the 2 percent level, (figure 9), at which point the Fed became fully credible, showing that “(T)he Federal Reserve under Greenspan was patient in moving toward its implicit inflation target”, Goodfriend (2007).

Finally it is worth making a comment about the last four quarters on the graph (figure 9), leading up to, and including, 2008q1. Inflation expectations for the first time in 10 years are above the 2 per cent mark, at a level of 2.1 per cent. At the same time inflation is consistently above 2 per cent, since the middle of 2004. This causes  $\lambda$  to enter a declining path, which reaches the value of 0.97 at the last date of our sample. Two questions arise: first, when will that trend revert and second, which is the critical threshold for  $\lambda$ , below which monetary policy is no longer credible. The first question is naturally very difficult to answer, especially in view of the events in the financial markets since then. On the second question however, history shows us that periods during which monetary policy was considered to be credible corresponded to values of  $\lambda$  generally greater than 0.9. Although not a formal test, this would imply that there is still some way (buffer) for expectations to move away from the implicit anchor, before credibility is compromised.

## 6 Conclusions

Credibility is crucially important to the effectiveness of monetary policy because it allows the flexibility to deal with shocks without changing the trend of inflation, or it allows monetary authorities to disinflate without much cost on real interest rates and output. Our conjecture has been that for credible regimes there is a disconnect between inflation and inflation expectations. We have expressed this in terms of five hypotheses, which we have then proceeded to test. Our empirical set-up has allowed us to develop a measure for the extent to which expectations might be anchored, as well as at what level. The contribution of this paper is therefore to provide a method for quantifying anchorness and therefore also a proxy for credibility, in applied monetary policy.

We apply this measure to US data since 1963. As the history of monetary policy in the US has periods for which credibility is known to be low, as well as periods for which it is known to be high, we check how well this measure compares to the way the literature describes them. We find that it typically matches the general description of the different levels of credibility across different periods. We also test the measure against four incidents of inflation scares, as documented by Goodfriend (1993), and show that the measure typically tracks the timing as well as direction of changes in credibility. Equally important in implementing this approach is the realization that credibility and the underlying anchor are not constant but are subject to changes as new data becomes available, an important reminder that credibility can be gained but it can also be lost. Having seen how this technique applies in the US, we intend to apply it to a number of different countries in our future work.

## APPENDICES

### A A measure of credibility from a VAR(p)

The VAR(p) equations are:

$$\begin{aligned}\pi_t &= a_0 + a_1\pi_{t-1} + \dots + a_p\pi_{t-p} + b_1\pi_{t-1}^e + \dots + b_p\pi_{t-p}^e + e_{1t} \\ \pi_t^e &= c_0 + c_1\pi_{t-1} + \dots + c_p\pi_{t-p} + d_1\pi_{t-1}^e + \dots + d_p\pi_{t-p}^e + e_{2t}\end{aligned}$$

In the long run it is:

$$\begin{aligned}\pi &= a_0 + a_1\pi + \dots + a_p\pi + b_1\pi^e + \dots + b_p\pi^e \\ \pi^e &= c_0 + c_1\pi + \dots + c_p\pi + d_1\pi^e + \dots + d_p\pi^e\end{aligned}$$

and

$$\begin{aligned}(1 - a_1 - \dots - a_p)\pi &= a_0 + (b_1 + \dots + b_p)\pi^e \\ \pi &= \frac{a_0}{1 - a_1 - \dots - a_p} + \frac{b_1 + \dots + b_p}{1 - a_1 - \dots - a_p}\pi^e \quad \text{and} \\ (1 - d_1 - \dots - d_p)\pi^e &= c_0 + (c_1 + \dots + c_p)\pi \\ \pi^e &= \frac{c_0}{1 - d_1 - \dots - d_p} + \frac{c_1 + \dots + c_p}{1 - d_1 - \dots - d_p}\pi.\end{aligned}$$

It follows that,

$$\begin{aligned}\lambda\pi^* &= \frac{c_0}{1 - d_1 - \dots - d_p} \\ 1 - \lambda &= \frac{c_1 + \dots + c_p}{1 - d_1 - \dots - d_p}.\end{aligned}$$

The non-linear restrictions to be imposed on the VAR coefficients to ensure that  $\lambda \in [0, 1]$  can be derived as for the VAR(1) case. For example, for the VAR(2) case, it is

$$\pi_t^e = c_0 + c_1\pi_{t-1} + c_2\pi_{t-2} + d_1\pi_{t-1}^e + d_2\pi_{t-2}^e + e_{2t}$$

and

$$\begin{aligned}\lambda &= 1 - \frac{c_1 + c_2}{1 - d_1 - d_2} \\ \pi^* &= \frac{c_0}{(1 - d_1 - d_2)\lambda}.\end{aligned}$$

Therefore,

$$\pi_t^e = c_0 + [(1 - \lambda)(1 - d_1 - d_2) - c_2]\pi_{t-1} + c_2\pi_{t-2} + d_1\pi_{t-1}^e + d_2\pi_{t-2}^e + e_{2t}.$$



## B Robustness Checks

In the empirical implementation, the lag length of the VAR is chosen based on recursive likelihood ratio tests for the non-significance of the longest lag and on the Schwarz (BIC) information criterion, starting with a VAR(4). In both cases, the statistical congruence of the model is controlled by means of standard diagnostic tests on the residuals for no correlation, homoskedasticity and normality. These hypotheses are typically not rejected, in particular when the lag selection is based on testing. When the testing and information criteria give conflicting results on the lag length of the VAR, two VARs of different order are estimated in order to control the robustness of the results.

### B.1 A note on Section 4.1

The recursive tests for lag length suggest a VAR(6), when starting with 8 lags, while the Schwarz criterion indicates a VAR(2). Since the hypothesis of no serial correlation of the errors is rejected for the latter, we continue the analysis with the VAR(6), but there are minor differences in the results with the VAR(2).

We find that we cannot reject the null hypothesis of a unit root for either actual or expected inflation over this sample, using an Augmented Dickey Fuller test. While this outcome could be the result of a small sample power of the test, as a final check on the robustness of the results we have repeated the analysis with an error correction model. We cannot reject the hypothesis of one cointegrating vector by the Johansen trace test, but the restriction that the coefficients of the variables are 1 and  $-1$  (i.e., that actual minus expected inflation is stationary) is strongly rejected. Hypotheses 1 and 3 would require first no cointegration (otherwise the error correction term should be significant in at least one of the equations, creating a dynamic link between actual and expected inflation), and, second, no significance of the lagged differences of expected inflation in the equation for the difference of actual inflation, and vice versa. Instead, we find cointegration, the error correction term is strongly significant in both equations, and the cross lags are also significant.

### B.2 A note on Section 4.2

As Cecchetti et al (2007) indicates, the FRB and SPF series follow each other very closely, ( $\text{corr}=0.99$ ) and that is why the VAR results are very similar. In particular, in both cases the lag selection is either 5, when based on testing, or 1, when based on the Schwarz criterion. Since for the VAR(1) the hypothesis of uncorrelated residuals is rejected, we present results based on the VAR(5). However, those for the VAR(1) are qualitatively similar. Modelling actual inflation and the Consensus expectation (inflation expectations 6-10 year ahead) with a VAR over the period 1990-2007, the lag length selection criteria indicate just one lag. From the Wald tests for hypotheses 1 and 3, which are reported in table 4 expected inflation is not significant in the actual inflation equation,

and vice versa. A robust version of the Wald test yields the same results, as the p-values are, respectively, 0.56 and 0.56.

Given the relatively high level of persistence estimated (0.95 for the Consensus Forecasts, the highest of the three), it is worth examining whether we can assume expectations to be stationary, or in other words whether the estimated persistence of 0.95 is significantly different from 1. The Augmented Dickey Fuller test rejects the null hypothesis of a unit root for inflation but not for inflation expectations. However as the sample considered is relatively small, unit root tests are not reliable. To examine the variables stationarity, we simulate stochastically the VAR(1) model over the period 2007:1-2050:2, and evaluate, first, whether and how quickly the values of actual and expected inflation stabilize and, second, whether the long-run equilibrium values are compatible with the credibility assumption, in the sense that actual inflation is not statistically different from expected inflation. The simulation results show that both properties are satisfied, and the convergence to the equilibrium, in the absence of shocks, is fairly quickly<sup>9</sup>.

Finally, Consensus reports data also on inflation expectations at shorter horizons, specifically, 1, 3, and 5 years (labelled Infl1, Infl3, and Infl5, respectively). We have therefore repeated the analysis using these alternative series. In all cases, a VAR(1) is selected by the Schwarz criterion and it is sufficient to obtain uncorrelated, homoskedastic and normal residuals. The only exception is the VAR for Infl1 and Infl, for which three lags are needed to avoid correlation in the residuals, but qualitatively the results are equal to the VAR(1) case. For all the three measures of expectations, the results of the hypothesis testing are similar as for the Infl10 case, in the sense that there is no dynamic or contemporaneous interaction between expectations and actual inflation emerging from the VAR. This is not surprising for the 3- and 5-year horizon expectations, while one might expect a stronger dependence of the short 1-year horizon expectation on actual inflation. Our finding for Infl1 could be due to a timing issue, a mismatch in timing between the expectation and realization data, which led Johnson (2002) to suggest the use of a slightly modified definition of inflation. Actually, when we adopt his definition of inflation we find that Infl is strongly statistically significant in the Infl1 equation.

### **B.3 A note on Section 4.3**

We discuss in more details here why our results differ from those in Clark and Nakata (2008). To start with, Clark and Nakata (2008) analyze actual minus expected inflation and the change in expected inflation, rather than the levels of the two variables as in our case. Moreover, they de-mean the variables using a constant (full-sample) estimate for the mean, while we allow for changes in the mean by including a time-varying ‘constant’ in the model. Hence, following the specification choices of Clark and Nakata (2008), the model in (13) would

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<sup>9</sup>Results available from the authors.

become:

$$(\pi_t - \pi_t^e - \mu_{\pi-\pi^e}) = a_t(\pi_{t-1} - \pi_{t-1}^e - \mu_{\pi-\pi^e}) + b_t(\pi_{t-1}^e - \pi_{t-2}^e - \mu_{\Delta\pi}) + e_{1t}, \quad (14)$$

$$(\pi_t^e - \pi_{t-1}^e - \mu_{\Delta\pi}) = c_t(\pi_{t-1} - \pi_{t-1}^e - \mu_{\pi-\pi^e}) + d_t(\pi_{t-1}^e - \pi_{t-2}^e - \mu_{\Delta\pi}) + e_{2t}.$$

Our theoretical model requires that we estimate the VAR in levels. But if we estimate the model in (14), starting not in 1963 but in 1970 as in Clark and Nakata (2008), we also find much less evidence of parameter instability, (see figure 11 below). Actually, coefficients  $b_t$  and  $c_t$  are in practice stable, and the variability of  $d_t$  is very limited.<sup>10</sup> Other differences with respect to Clark and Nakata (2008) are in the precise definition of the variables, and in the fact that they allow for stochastic volatility in the VAR errors, which does not appear to be necessary in our case since the time-varying ‘constant’ already captures the volatility in inflation and inflation expectations.

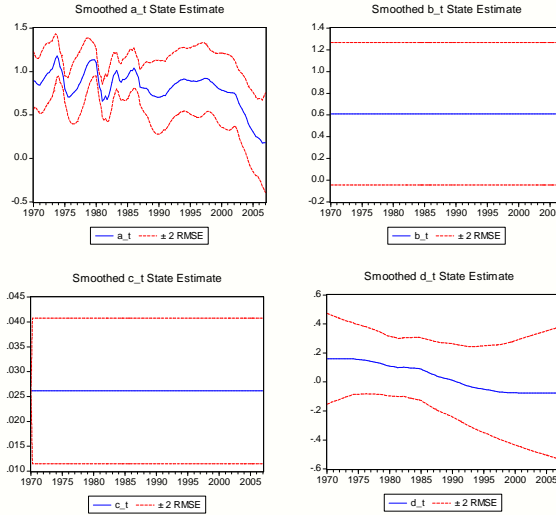


Figure 11: Based on the model by Clark and Nakata

Last, since the analysis of the time-varying VAR has highlighted the sample 2000-2007 as a period of substantial stability, in line also with the descriptive statistics of Table 2 and the graphical evidence of figure 1, it is worth repeating the analysis with a constant parameter VAR focusing on this most recent period. In addition to the results reported in Table 6 below, expected inflation does not significantly depend on its lag, and the persistence of inflation (as measured

<sup>10</sup>We should point out that we have experienced numerical convergence problems in the estimation of the model in (14), which are not present for (13). However, Figure 11 is based on a model for which convergence of the numerical estimation procedure is achieved.

by the coefficient of its own lag) drops to 0.47. Hence, all the hypotheses 1-5 appear to be satisfied for the US over the most recent period.

Table 6. Granger Causality (2000q1 2007q1)

<i>Dependent</i>	<i>Excluded</i>	<i>df</i>	$\chi^2$	(Pr)	$\text{cor}_{e_1, e_2}$
$\pi$	$\pi_{FRB}^e$	1	0.28	(0.59)	-0.21
$\pi_{FRB}^e$	$\pi$	1	0.11	(0.73)	

Notes: Bold indicates significance at 5% level.

## C An alternative measure for inflation: CPE

We plot three alternative definitions for inflation based on CPE, CPE and core CPE. Figure 12 shows that CPI is the most volatile of the three.

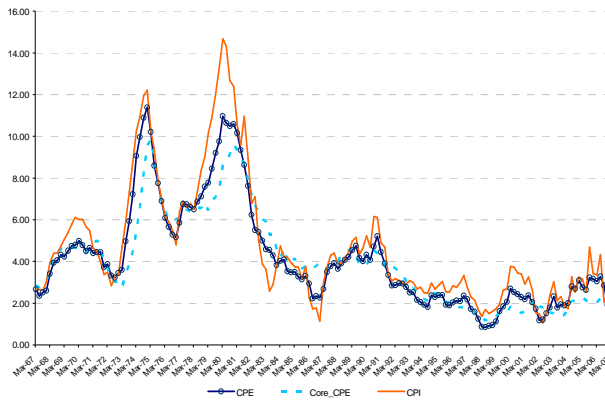


Figure 12: Alternative Inflation Definitions

We then recalculate the credibility measure,  $\lambda$ , (grey line) based on CPE inflation (figure 13). It is worth remembering however, that the expectation measure refers to CPI not CPE so that this derivation of  $\lambda$  is not entirely consistent. Since the CPE series is both lower on average and less volatile, the corresponding  $\lambda$  is also lower and smoother. This is particularly so for the start of the period of the Great Moderation. The evolution of credibility however, matches our previous analysis throughout the whole period.

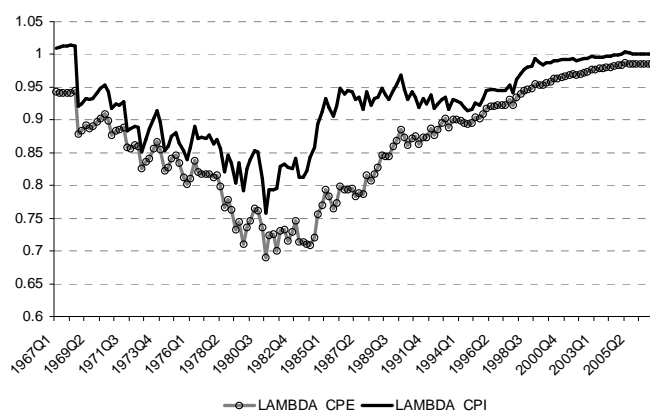


Figure 13: Credibility: CPI vs. CPE

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