

The Great Inflation and the Greenbook*

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Abstract

We ask whether the story of evolving Federal Reserve beliefs in *The Conquest of American Inflation* can simultaneously explain the Great Inflation and the forecasts published in the Greenbook during that time. If Sargent is correct and the Great Inflation was caused by the Federal Reserve learning the Phillips curve, then evolving beliefs should be reflected not only in policy outcomes but also in Greenbook forecasts. In our estimations they are. By conditioning on the Greenbook, we show that both inflation outcomes and Greenbook forecasts can be rationalised by the evolution of beliefs. Our results improve on recent empirical evidence that has been criticised for relying on unrealistic beliefs that produces forecasts inconsistent with the Greenbook.

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1 Introduction

The publication of *The Conquest of American Inflation* by Sargent (1999) provided one of the first fully-articulated explanations for the rise and fall in American inflation in the latter half of the twentieth century. The story is one in which the Great Inflation resulted from changes in the conduct of monetary policy as the Federal Reserve learned and revised its view of the monetary transmission mechanism. In the best tradition of economic research, it has proved both influential and controversial, with Primiceri (2006), Sims and Zha (2006) and Cogley and Sargent (2005a, 2005b) leading a pack of alternative explanations. Which of these will emerge victorious depends on how well they cohere with macroeconomic data and narrative evidence, so the legacy of Sargent’s treatise will ultimately be decided by thorough empirical analysis.

The most impressive empirical contribution to date is Sargent, Williams and Zha (2006), who operationalise Sargent (1999) and estimate its parameters using a Bayesian MCMC algorithm.¹ Their results strongly support Sargent’s view; a model where the Federal Reserve learns about the monetary transmission mechanism easily outperforms even a Bayesian vector autoregression in terms of its ability to match and forecast inflation. Proponents of other explanations naturally have a less sanguine interpretation. Primiceri (2006) expresses concern that central to the results is a Federal Reserve that is excessively open to new data, and so changes its view of the monetary transmission mechanism with a frequency and magnitude that is implausible:

“Sargent, Williams, and Zha [2004] use a model that is very similar to Sargent [1999] and seem to be able to reconcile the prediction of the model with the observed data in the 1970s thanks to a very volatile evolution of policy-makers’ beliefs.”

Sims (2007) is similarly unconvinced, arguing that excessive openness to new data also leads to the Federal Reserve often holding - and acting upon - a view of the monetary transmission mechanism that is unrealistic. For example, the estimation results imply that the Federal Reserve regularly expects unemployment to fluctuate wildly on a month-to-month basis, even

¹Sims (2007) describes Sargent, Williams and Zha (2006) as “The most ambitious, original, and careful behavioral empirical modeling exercise in the entire macro literature”.

though policy is attempting to stabilise the economy. Sims also suspects that a fair proportion of the good statistical fit of the model is driven by treating initial conditions as free parameters to be estimated:

“The estimated results are very far out in the tails of reasonable prior beliefs. The source of the problem is a special case of the ‘likelihood conditional on initial conditions tends to lead to estimates that explain too much as return to steady state’ problem.”

It is true that the Federal Reserve beliefs underpinning the results of Sargent, Williams and Zha (2006) are volatile and unrealistic. The problem is potentially serious because Sargent’s explanation of the Great Inflation relies on the Federal Reserve setting policy according to these ‘crazy’ views of the monetary transmission mechanism. If the rationale behind policy is unrealistic then it is difficult to argue that the results *strongly* support Sargent’s view of the Great Inflation, even if the model outperforms an atheoretical alternative. The problem has been acknowledged by Sargent (2008) in his presidential address to the American Economic Association, where he admits that any empirical support is undermined if the Federal Reserve holds unrealistic views of the monetary transmission mechanism:

“But relative to available alternatives, the imputed beliefs do a poor job of forecasting unemployment, a deficiency of the model that hints that the reverse-engineering exercise may be imputing unrealistic views about joint inflation-unemployment dynamics to the Phelps problem in order to rationalize observed inflation outcomes.”

The purpose of this paper is to show there is strong empirical support for *The Conquest of American Inflation* even when restrictions are imposed to remove volatile and unrealistic beliefs. The restricted model we estimate is able to explain the low frequency rise and fall in inflation without recourse to the Federal Reserve having volatile/unrealistic beliefs or being excessively open to new data. We therefore demonstrate that unrealistic beliefs are not needed to explain the Great Inflation, so the concerns of Primiceri (2006), Sims (2007) and Sargent (2008) are unfounded. Our restricted model performs less well in terms of explaining high frequency movements in inflation, but we interpret this positively because Sargent (1999) never intended to explain inflation movements on a month-by-month basis.

To impose restrictions on the beliefs of the Federal Reserve we re-estimate the model of Sargent, Williams and Zha (2006) using a new richer dataset incorporating information published in the Greenbook for each FOMC meeting. Specifically, we extract unemployment forecasts from historical Greenbooks as a proxy for real-time estimates of how the Federal Reserve believed its policy would impact on the economy. By conditioning estimates on these Greenbook forecasts, we effectively restrict the forecasts from our estimated model of the Federal Reserve to be consistent with those published in the Greenbooks. In essence, our contribution is to impose a cross-equation restriction that forces estimated beliefs of the Federal Reserve to explain both policy actions and the Greenbook. Our use of Greenbook data allows us to explicitly impose the cross-equation restriction, and perform an ‘Irrational Expectations Econometrics’ exercise of the type advocated by Ireland (2003).² Furthermore, evidence in support of the Sargent (1999) view of the Great Inflation is found to be robust to relaxation of some of the simplifying assumptions.

The paper is organised as follows. In Section 2 we estimate a simplified version of Sargent, Williams and Zha (2006) to confirm concerns that their results are predicated on volatile and unrealistic beliefs. Section 3 explicitly incorporates Greenbook data into estimation and finds that imposing consistency with published forecasts repairs volatile and unrealistic beliefs while leaving the basic Sargent (1999) story intact. The robustness of the result is examined in Section 4, which shows that evidence remains strong even if simplifying assumptions are relaxed so the Federal Reserve is allowed to react to parameter uncertainty or to have an explicit policy smoothing objective. Section 5 embeds the learning model in a structural model of the economy to enable direct comparison of our results with those of Sargent, Williams and Zha (2006). A final Section 6 concludes.

²Ireland (2003) suggests deriving cross-equation restrictions from learning models in the same way as cross-equation restrictions are derived in the ‘Rational Expectations Econometrics’ of Hansen and Sargent (1980). To the best of our knowledge, our paper is one of the first to seriously take up the suggestion.

2 Estimation without Greenbook data

2.1 A simple model of optimal policy

To highlight the role of unrealistic beliefs in the results of Sargent, Williams and Zha (2006) we estimate a simplified version of their model using the same inflation and unemployment dataset as they do. Our estimations are simplified by focusing entirely on the behaviour of the Federal Reserve. The analysis of Sargent, Williams and Zha (2006) is more sophisticated because their estimations embed a model of Federal Reserve behaviour in a ‘true’ model of the economy. However, the informational gain in doing so is low and for our purposes it is sufficient to restrict attention to the behaviour of the Federal Reserve. In Section 6 we show anyhow that our results are robust to embedding Federal Reserve behaviour in a ‘true’ model of the economy.

At the heart of our model is a step back from full rationality, in that the Federal Reserve is assumed to be unaware of the underlying structure determining unemployment in the economy. Instead, it has an approximating model of unemployment-inflation dynamics:

$$u_t = \alpha_t' \Phi_t + \sigma_w w_t, \quad (1)$$

in which Φ_t is a vector of current inflation, lags of inflation, lags of unemployment and a constant. Furthermore, the Federal Reserve believes that the coefficients in its model follow a simple drifting process $\alpha_t = \alpha_{t-1} + \Lambda_t$, where the innovation term Λ_t is i.i.d. Gaussian with mean zero and variance-covariance matrix V . Λ_t is perceived as independent of w_t . Given the simplicity of the perceived drifting process, the monetary authority obtains current estimates of the coefficients in its model from a standard Kalman filter recursion. Defining $\hat{\alpha}_{t|t-1} \equiv E(\alpha_t | \mathcal{J}_{t-1})$, $P_{t|t-1} \equiv Var(\alpha_t | \mathcal{J}_{t-1})$ and the time t dataset as $\mathcal{J}_t = \{u_1, \pi_1, \dots, u_t, \pi_t\}$, we have:

$$\hat{\alpha}_{t+1|t} = \hat{\alpha}_{t|t-1} + \frac{P_{t|t-1} \Phi_t (u_t - \Phi_t' \hat{\alpha}_{t|t-1})}{\sigma_w^2 + \Phi_t' P_{t|t-1} \Phi_t}, \quad (2)$$

$$P_{t+1|t} = P_{t|t-1} - \frac{P_{t|t-1} \Phi_t \Phi_t' P_{t|t-1}}{\sigma_w^2 + \Phi_t' P_{t|t-1} \Phi_t} + V. \quad (3)$$

The objective for the Federal Reserve is set inflation π_t to minimise deviations in inflation and unemployment from their target levels π^* and u^* . δ is the discount factor and λ is the

relative weight given to unemployment deviations from target:

$$\min_{\{\pi_t\}_{t=0}^{\infty}} \hat{E} \sum_{j=0}^{\infty} \delta^j \{(\pi_{t+j} - \pi^*)^2 + \lambda (\tilde{u}_{t+j} - u^*)^2\}. \quad (4)$$

To improve tractability, we follow Kreps (1998) and Sargent (1999) and assume the Federal Reserve forms forward-looking expectations using its model of unemployment-inflation dynamics, but with coefficients fixed at their current estimates. Mathematically, such ‘anticipated utility’ behaviour implies that expected future values of unemployment are defined by the linear recursion $\tilde{u}_{t+j} = \hat{\alpha}'_{t|t-1} \tilde{\Phi}_{t+j}$, where the notation \tilde{u}_{t+j} indicates the expected value of u_{t+j} . The assumption that forward-looking expectations are formed in this way means the objective function is quadratic in the vector of expected values $\tilde{\Phi}_{t+j}$. This is convenient as it simplifies the derivation of optimal policy considerably. With an objective that is quadratic in expected values and expected values themselves defined by a simple linear recursion, the Federal Reserve faces a standard linear-quadratic control problem. The solution is a best response function $\pi_t = h(\hat{\alpha}_{t|t-1})' \phi_t$, where ϕ_t is a subset of Φ_t containing a constant and lagged values of inflation and unemployment. Optimal policy has inflation reacting linearly to the current state of the economy, with the strength of the reaction depending on the estimates of the coefficients in the Federal Reserve’s model.

2.2 Estimation, priors and data

We derive estimates of the free parameters in the model by acknowledging that the best response function provides only an approximate representation of Federal Reserve policy. The empirical specification therefore allows an i.i.d. Gaussian residual w_{2t} to explain discrepancies between the model and the data:

$$\pi_t = h(\hat{\alpha}_{t|t-1})' \phi_t + \sigma_2 w_{2t}. \quad (5)$$

The model is estimated by applying the Bayesian MCMC algorithm developed in Sargent, Williams and Zha (2006). Our estimation involves only minor changes to their methodology, so we restrict ourselves to a brief overview of the steps involved. At the centre of the algorithm is a Gibbs sampler that successively draws from two conditional distributions to generate a sample from the joint distribution of the free parameter estimates. The first conditional

distribution is for the variance σ_2^2 of the residual w_{2t} , and has an inverse gamma conjugate prior. The second conditional distribution is for $\{P_{1|0}, V\}$, the Federal Reserve's perception of initial estimation precision and the variance-covariance matrix of the drifting coefficients. There is no suitable conjugate prior for this so a Metropolis algorithm is used to generate draws for the conditional posterior distribution. The remaining free parameters $\{\delta, \lambda, \pi^*, u^*, \hat{\alpha}_{1|0}\}$ and all priors are set to the values in Sargent, Williams and Zha (2006), reproduced for completeness in Appendix A.³

Our data series and sample period are chosen to match Sargent, Williams and Zha (2006). As the empirical counterpart of unemployment we use the civilian unemployment rate, 16 years and older, seasonally adjusted from the BLS. Inflation is measured by the annual (12 month end) change in the seasonally-adjusted PCE chain price index published by the BEA. The sample period for both series is January 1960 to December 2003.

2.3 Results

The first set of results we present are posterior estimates of the structural parameters in the model. The estimates in Table 1 are based on 40000 draws of the Gibbs sampler, taken after a sufficiently long burn-in period to ensure that the Markov chain has converged to its ergodic distribution.⁴

³There is a small error in the C++ codes used in Sargent, Williams and Zha (2006), meaning their results are derived under a more diffuse prior on V than that stated in their paper. We adopt a similar diffuse prior on V to maintain comparability with the earlier results.

⁴The point estimates reported are the mode of the posterior distribution. 68% probability intervals are given in parentheses.

<i>Parameter</i>	<i>Posterior estimate</i>
$P_{1 0}$	$\begin{pmatrix} 0.0029 & 0.0020 & 0.0005 & -0.0048 & -0.0002 & -0.0027 \\ 0.0020 & 0.6455 & 0.0518 & -0.5742 & -0.0293 & -0.2871 \\ 0.0005 & 0.0518 & 0.0042 & -0.0465 & -0.0024 & -0.0233 \\ -0.0048 & -0.5742 & -0.0465 & 0.6547 & -0.0071 & 0.2385 \\ -0.0002 & -0.0293 & -0.0024 & -0.0071 & 0.0092 & 0.0175 \\ -0.0027 & -0.2871 & -0.0233 & 0.2385 & 0.0175 & 0.1314 \end{pmatrix}$
V	$\begin{pmatrix} 0.1707 & -0.1342 & 0.0172 & 0.0324 & -0.0185 & -0.6956 \\ -0.1342 & 0.1268 & 0.0135 & -0.0125 & 0.0542 & 1.0649 \\ 0.0172 & 0.0135 & 0.0592 & 0.0315 & 0.0900 & 1.1349 \\ 0.0324 & -0.0125 & 0.0315 & 0.0201 & 0.0418 & 0.4632 \\ -0.0185 & 0.0542 & 0.0900 & 0.0418 & 0.1521 & 2.0853 \\ -0.6956 & 1.0649 & 1.1349 & 0.4632 & 2.0853 & 30.5664 \end{pmatrix}$
$1/\sigma_2^2$	$\begin{matrix} 19.5972 \\ (18.1590, 20.5353) \end{matrix}$

Table 1: Structural parameters estimated without Greenbook data

The structural parameter estimates are close to those of Sargent, Williams and Zha (2006). We therefore replicate their finding that the Sargent (1999) view of the Great Inflation receives strong support from real-world data. This is apparent in Figure 1 in the small variance of the residual w_{2t} and the closeness of actual and fitted values of inflation.

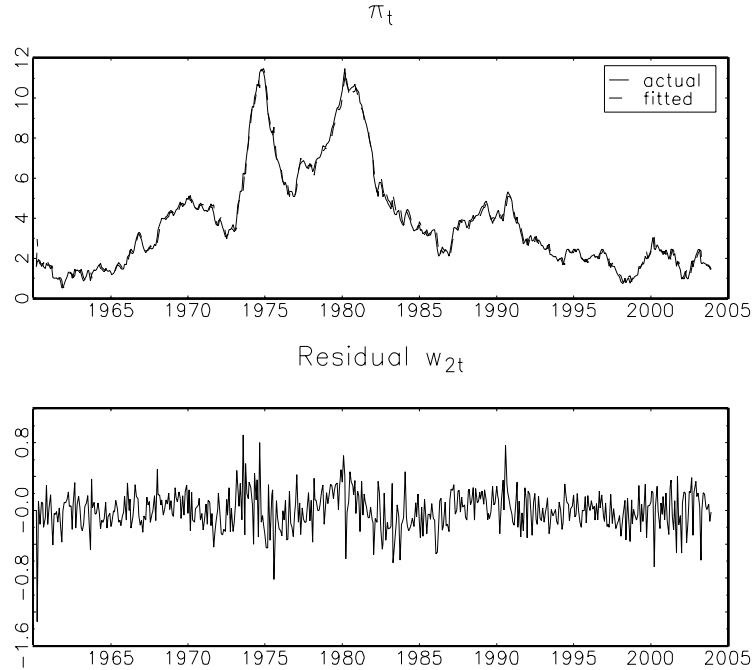


Figure 1: Actual inflation and inflation fitted without Greenbook data

The ability of a simple model to closely match forty years of inflation dynamics is impressive but raises the possibility that there is some ‘overfitting’ of the data. One cause for concern is the magnitude of the estimated elements of $P_{1|0}$, which imply that the Federal Reserve was very open to changing its views already in January 1960, despite the stability of the monetary transmission mechanism in the preceding decade. Indeed, the Federal Reserve is imputed to have a very imprecisely estimated model of unemployment-inflation dynamics at that time:

$$u_t = \underbrace{-0.13}_{(0.05)}\pi_t + \underbrace{0.14}_{(0.80)}\pi_{t-1} + \underbrace{1.09}_{(0.06)}u_{t-1} - \underbrace{0.02}_{(0.81)}\pi_{t-2} - \underbrace{0.13}_{(0.10)}u_{t-2} + \underbrace{0.22}_{(0.36)}.$$

In comparison, a simple regression of the model with presample data from January 1948 to December 1959 has standard errors in the range of 0.05 to 0.12. The imprecision in model estimation makes the Federal Reserve very open to new data, meaning its view of the monetary transmission mechanism changes easily at the beginning of the sample period. This is not necessarily unrealistic, but does pave the way for criticism from Sims (2007) that too much may be explained by return to steady state from initial conditions in the tails of reasonable prior beliefs.

Another concern is the estimated elements in V , where large magnitudes imply that the Federal Reserve is much more likely to attribute forecast errors to changes in drifting coefficients than to random fluctuations from the model residual. For example, the innovation variance of the drifting constant term is an order of magnitude greater than the variance of the residual. This results in the Federal Reserve always changing its view of the monetary transmission mechanism in response to forecast errors, a perpetual openness to new data that lies behind the Primiceri (2006) observation that policy-maker's beliefs are very volatile. Just how volatile is shown by the evolution of beliefs in Figure 2.

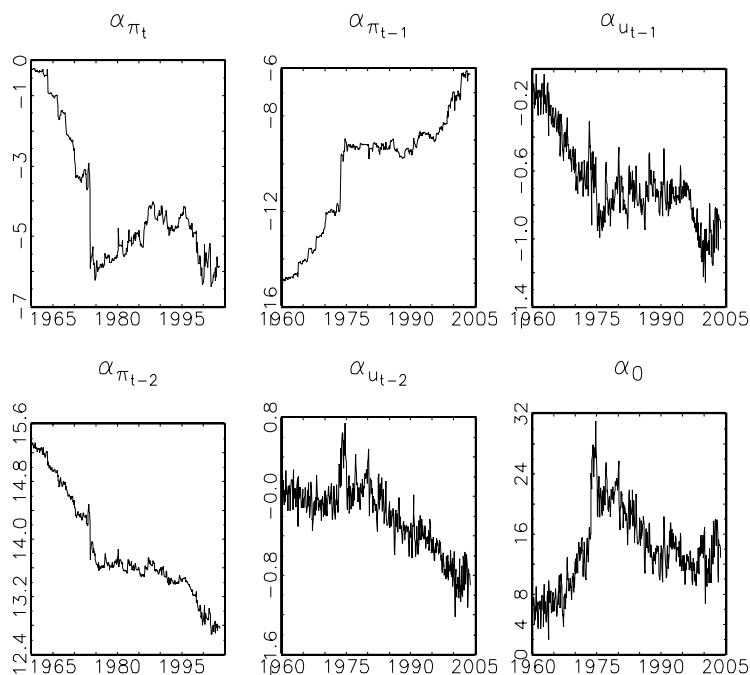


Figure 2: Coefficients of Federal Reserve model estimated without Greenbook data

It is not immediately obvious how to interpret evolving beliefs when individual coefficients take on the very large positive and negative values in Figure 2. One possibility is to focus on the key trade-offs perceived by the Federal Reserve, as summarised in Figure 3. We measure the short-run trade-off by the sum of coefficients on current and lagged inflation, and the long-run trade-off by how much unemployment would exceed its target level u^* if inflation

were to be held constant at its target level π^* .⁵

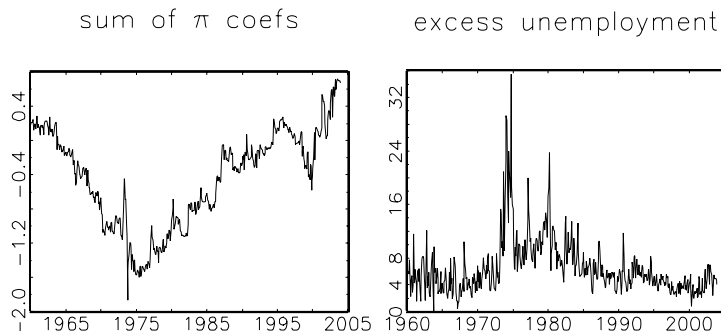


Figure 3: Perceived trade-offs estimated without Greenbook data

The perceived short-run trade-off supports the Sargent (1999) view of the Great Inflation. Starting with almost no trade-off in the 1960s, there is clear evidence of the Federal Reserve discovering and then discounting the short-run Phillips curve. The trade-off was perceived at its strongest in the mid 1970s but had almost completely disappeared by the mid 1990s. In contrast, the perceived long-run trade-off does not rise until around 1974. Its role in shaping policy appears to mirror that in Cogley and Sargent (2005a, 2005b), where fear of possible high unemployment prevents the Federal Reserve from disinflating even when the short-run Phillips curve starts to disappear. Any interpretation should probably be treated with caution though; the relative stability of trade-offs in Figure 3 at least partially masks the volatile evolution of individual coefficients in Figure 2.

2.4 Implications for constant policy projections

A final concern raised by Sims (2007) and Sargent (2008) is the possibility that ‘overfitting’ occurs not because beliefs are volatile but because beliefs are unrealistic. The worry is that inflation outcomes are rationalised by having the Federal Reserve set policy according to a ‘crazy’ model of inflation and unemployment dynamics. To see the grounds for this we

⁵Mathematically, the sum of inflation coefficients is $\alpha_{\pi_t} + \alpha_{\pi_{t-1}} + \alpha_{\pi_{t-2}}$ and excess unemployment is $((\alpha_{\pi_t} + \alpha_{\pi_{t-1}} + \alpha_{\pi_{t-2}})\pi^* + \alpha_0)/(1 - \alpha_{u_{t-1}} - \alpha_{u_{t-2}}) - u^*$. The sum of inflation coefficients implies a high cost of disinflation in the 1970s at a time when oil shocks created stagflation and positive co-movements between unemployment and inflation in the data. It remains an open question whether this is a plausible representation of Federal Reserve beliefs, or an artefact of the reverse engineering exercise performed.

calculate what beliefs imply if the Federal Reserve uses its model to make projections of future unemployment. We assume that policy (inflation) and beliefs are held at their current levels, and then iterate forward using the Federal Reserve’s model of unemployment-inflation dynamics (1). The constant policy projections in Figure 4 are therefore akin to the constant interest rate projections sometimes produced in central banks.

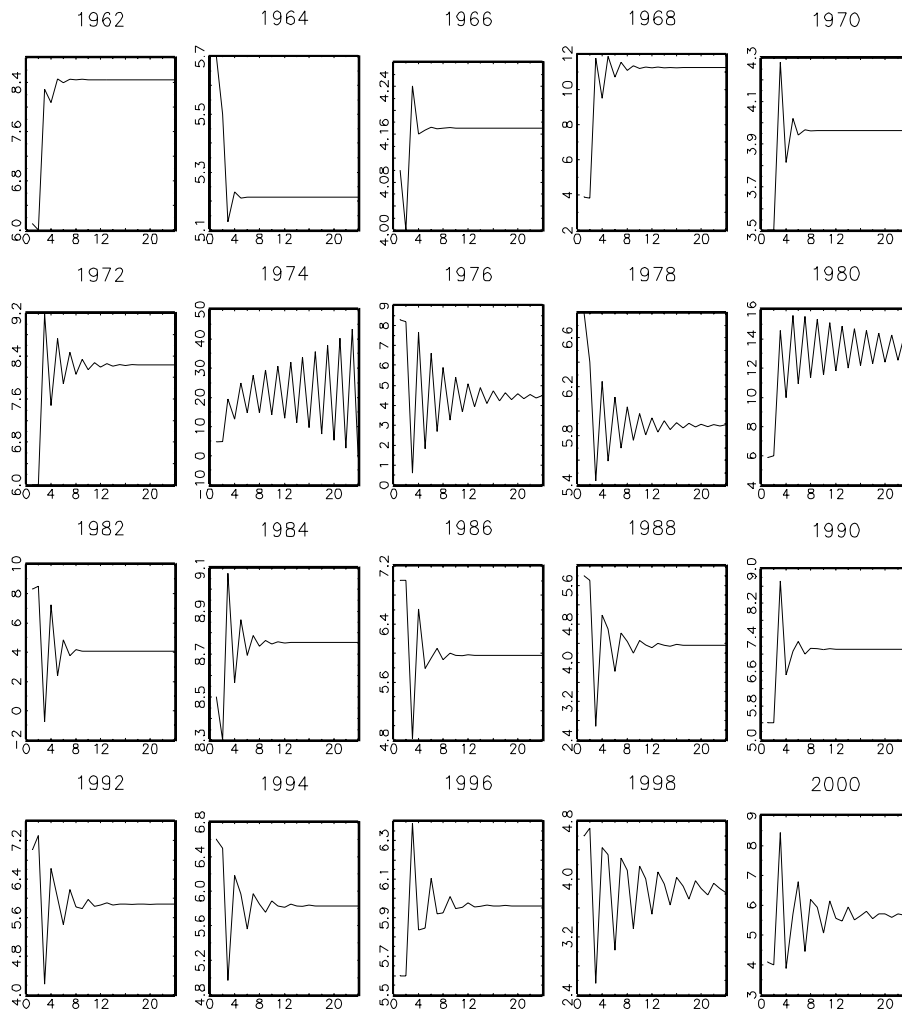


Figure 4: Constant policy unemployment projections estimated without Greenbook data

Many of the projections have monthly swings in unemployment that exceed ± 500 basis points, which are clearly without precedent in the history of the US economy. The projections are oscillatory because the Federal Reserve tends to believe that lagged values of unemployment have an unrealistically large and negative effect on current unemployment.⁶

⁶See Figure 2. Further evidence that beliefs are unrealistic is provided by the explosive projection for 1974

2.5 Implications for conditional Greenbook forecasts

A more objective metric for whether beliefs are realistic is the extent to which unemployment projections implied by our Federal Reserve model match the unemployment forecasts actually published by the Federal Reserve in its Greenbook. Our understanding is that Greenbook forecasts are ‘judgemental’, which we interpret as meaning conditional on expected current policy.⁷ The Greenbook unemployment forecasts therefore correspond to conditional model forecasts defined by $\hat{E}(u_t) = \hat{\alpha}'_{t|t-1} \Phi_t$ from equation (1) and $\pi_t = h(\hat{\alpha}_{t|t-1})' \phi_t$ from the best response function. The forecast for current unemployment is a linear function $\hat{E}(u_t) = g(\hat{\alpha}_{t|t-1})' \phi_t$ of a constant and lagged values of inflation and unemployment, with coefficients determined by the current estimates of parameters in the Federal Reserve model.

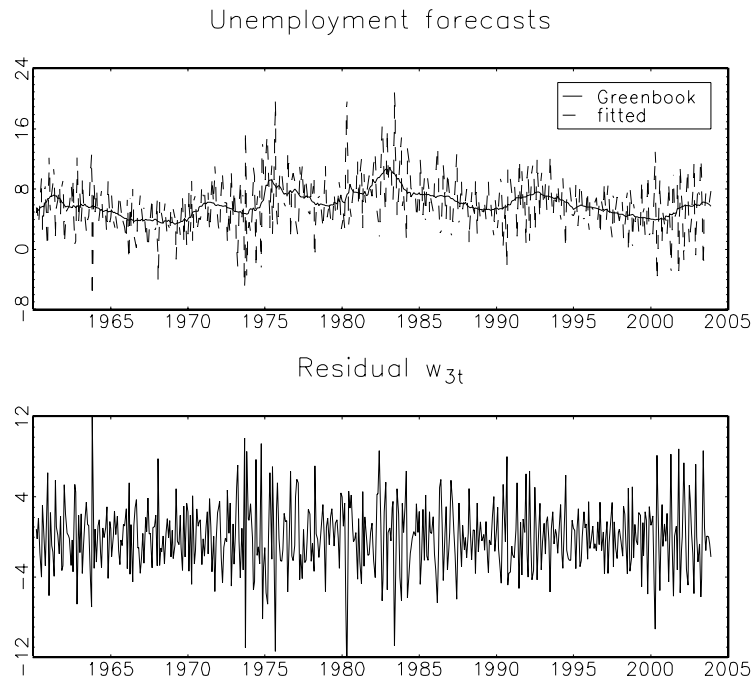


Figure 5: Conditional unemployment forecasts estimated without Greenbook data

and the negative projection for 1982.

⁷As summarised by Kozicki and Tinsley (2006), ‘The multiperiod forecasts in a Greenbook provide repeated observations of predictions by the implicit forecast model of that Greenbook. Importantly, Greenbook forecasts provide measures of real-time central bank *perceptions* that are not evident in real-time data.’ (original italics of authors). The Federal Reserve also adjusts its model-based forecasts using information from outside the model, a process that stylised models (quite rightly) make no attempt to account for. The details of how we constructed unemployment forecasts from the Greenbooks is described in Appendix B.

The forecasts of unemployment implied by the Federal Reserve model are shown in Figure 5, together with actual forecasts extracted from historical Greenbooks. The upper panel shows $\hat{E}(u_t)$, the forecast of current unemployment. It is immediately apparent that a large discrepancy exists between forecasts from the estimated model and those from the Greenbooks. The problem is the huge volatility in forecasts from the estimated model, with a standard deviation of 3.7 percentage points that completely swamps the volatility in Greenbook forecasts. The correlation between the two forecasts is significant at 0.40, but high frequency volatility in forecasts from the estimated model makes it difficult to argue that the forecasts are consistent. The forecasting performance of the estimated model is even worse when we examine its ability to forecast the change in unemployment $\hat{E}(u_t - u_{t-1})$. In this case we find absolutely no correlation between the change in unemployment forecast by the estimated model and that forecast in the Greenbooks. The correlation coefficient is only 0.015, with problems of excess volatility in forecasts from the estimated model. Such evidence is problematic for the Sargent (1999) view of the Great Inflation. Whilst our estimated model can explain inflation dynamics well, the rationale behind policy appears to be inconsistent with that implicitly identified in the Greenbooks.⁸

3 Estimation with Greenbook data

3.1 Incorporating Greenbook forecasts

A natural response to concerns about empirical results in the previous section is to impose restrictions that remove volatile and unrealistic beliefs. We do this primarily by explicitly incorporating Greenbook forecasts when estimating the model. This is achieved by continuing to acknowledge that the model is only an approximate representation of Federal Reserve behaviour, in which case the empirical specification permits an i.i.d. Gaussian residual w_{3t} to

⁸We also note that the correlation coefficient between the residuals w_{2t} and w_{3t} is 0.22, so the model is misspecified to some extent. An alternative metric for whether beliefs are realistic is the extent to which *inflation* projections implied by the model match those in the Greenbook. We investigated this possibility and found a good match, even before estimating with Greenbook data. Full details are available from the authors on request.

explain any discrepancies between Greenbook forecasts $E^{GB}(u_t)$ and the forecasts $g(\hat{\alpha}_{t|t-1})'\phi_t$ derived from the Federal Reserve's model:

$$E^{GB}(u_t) = g(\hat{\alpha}_{t|t-1})'\phi_t + \sigma_3 w_{3t}. \quad (6)$$

The new residual w_{3t} represents both unavoidable forecast error and any adjustments made to forecasts due to the Federal Reserve having information from outside the model. The policy and forecasts functions (5)-(6) form a system of equations to be jointly estimated using our dataset derived from historical Greenbooks. The fact that both functions are nonlinear transforms of the same parameters, $\hat{\alpha}_{t|t-1}$, means we effectively impose a cross-equation restriction that Federal Reserve beliefs have to explain not only policy actions but also Greenbook forecasts. Restricting estimation in this way is consistent with the call of Ireland (2003) to impose cross-equation restrictions when estimating learning models.

Conditioning estimation on Greenbook forecasts removes nearly all the unrealistic evolution of beliefs, although a few periods in the 1970s are still characterised by the Federal Reserve's model producing explosive constant policy projections of unemployment. To clear this up we impose a second restriction that the Federal Reserve only updates the coefficient estimates of its model if the updated model implies stable unemployment projections. Invoking this projection facility conveniently rules out explosive roots in the Federal Reserve's model, but in practice does not greatly affect our estimation results.

The imposition of restrictions has only minor consequences for the Bayesian MCMC algorithm used to estimate the model. The addition of a second measurement equation means there are now two variance parameters $\{\sigma_2^2, \sigma_3^2\}$ in the first conditional distribution of the Gibbs sampler, but the second conditional distribution is unchanged. The variance of the new residual w_{3t} has the same inverse gamma conjugate loose prior as the variance of the w_{2t} residual. All remaining free parameters and priors are kept at values used in the previous section when estimating without Greenbook data.

3.2 Results

Table 2 and Figure 6 show that our simple model does a good job of explaining the Great Inflation even when restrictions are imposed to remove unrealistic beliefs. The fit to inflation

remains impressive, with the model able to track low frequency movements with high precision. The fit at high frequencies is not as good as in Figure 1 when Greenbook data was ignored, but we see this as a positive result because Sargent (1999) never intended to explain every twist and turn in monthly inflation. We consequently interpret the rise in σ_2^2 from Table 1 to Table 2 as a signal of reduced ‘overfitting’, rather than as a fall in the model’s ability to fundamentally explain the Great Inflation. In terms of the marginal data density, the improved fit to unemployment forecasts easily dominates the slight rise in σ_2^2 so our overall fit to the data is better.

<i>Parameter</i>	<i>Posterior estimate</i>
$P_{1 0}$	$\begin{pmatrix} 0.0417 & 0.0013 & -0.0283 & -0.0060 & 0.0140 & 0.0052 \\ 0.0013 & 0.0142 & 0.0008 & 0.0011 & -0.0041 & -0.0115 \\ -0.0283 & 0.0008 & 0.0195 & 0.0043 & -0.0101 & -0.0048 \\ -0.0060 & 0.0011 & 0.0043 & 0.0889 & -0.0207 & -0.0240 \\ 0.0140 & -0.0041 & -0.0101 & -0.0207 & 0.0101 & 0.0099 \\ 0.0052 & -0.0115 & -0.0048 & -0.0240 & 0.0099 & 0.0164 \end{pmatrix}$
V	$\begin{pmatrix} 0.0155 & -0.0140 & 0.0276 & -0.0018 & -0.0267 & -0.0600 \\ -0.0140 & 0.0193 & -0.0369 & -0.0041 & 0.0324 & 0.1045 \\ 0.0276 & -0.0369 & 0.0723 & 0.0069 & -0.0638 & -0.1994 \\ -0.0018 & -0.0041 & 0.0069 & 0.0051 & -0.0039 & -0.0361 \\ -0.0267 & 0.0324 & -0.0638 & -0.0039 & 0.0576 & 0.1662 \\ -0.0600 & 0.1045 & -0.1994 & -0.0361 & 0.1662 & 0.6300 \end{pmatrix}$
$1/\sigma_2^2$	1.3659 (1.0317,1.1680)
$1/\sigma_3^2$	10.3459 (8.9070,10.0516)

Table 2: Structural parameters estimated with Greenbook data

The elements of $P_{1|0}$ and V in Table 2 have much smaller magnitude than the estimates without Greenbook data reported in Table 1. Small values in the initial precision matrix $P_{1|0}$ mean that the Federal Reserve is no longer excessively open to changing its view of the monetary transmission mechanism at the beginning of the sample period. Instead, it has a reasonably precise model of unemployment-inflation dynamics in January 1960:

$$u_t = \underset{(0.20)}{-0.13}\pi_t + \underset{(0.12)}{0.14}\pi_{t-1} + \underset{(0.14)}{1.09}u_{t-1} - \underset{(0.30)}{0.02}\pi_{t-2} - \underset{(0.10)}{0.13}u_{t-2} + \underset{(0.13)}{0.22}.$$

The degree of imprecision still exceeds that given by a simple regression of the model with presample data, but in relative terms our estimates are much more realistic. With our Federal Reserve less open to new data, there is reduced scope for Sims (2007) to argue that initial conditions are in the tails of reasonable prior beliefs.

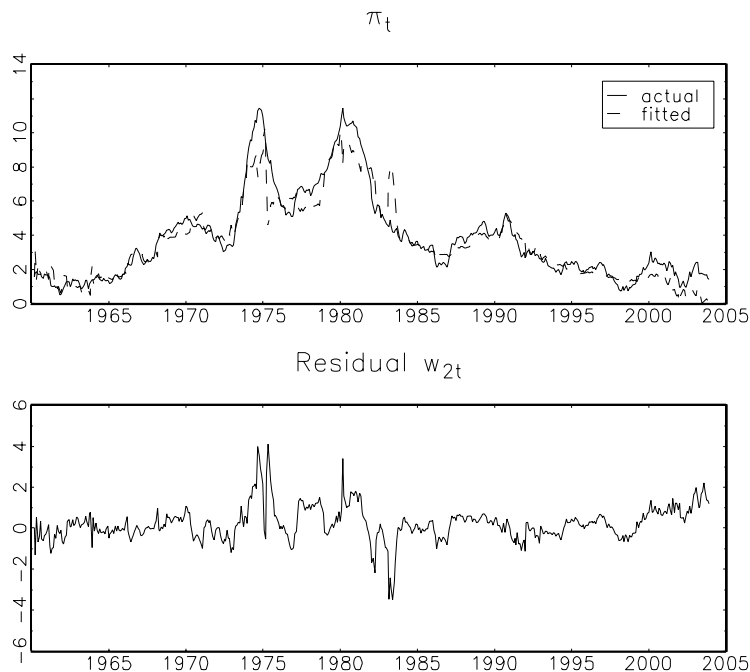


Figure 6: Actual inflation and inflation fitted with Greenbook data

The smaller elements in the variance-covariance matrix V of the perceived drift process imply that the Federal Reserve places a more realistic weight on coefficient drift as a source of forecast errors. For example, the perceived innovation variance of the drifting constant falls by a factor of forty when estimating with Greenbook data. The result is a Federal Reserve that is much less willing to change its view of the monetary transmission mechanism. In Figure 7,

the reluctance to entertain coefficient drift translates into a more stable and realistic evolution of policy-maker's beliefs.

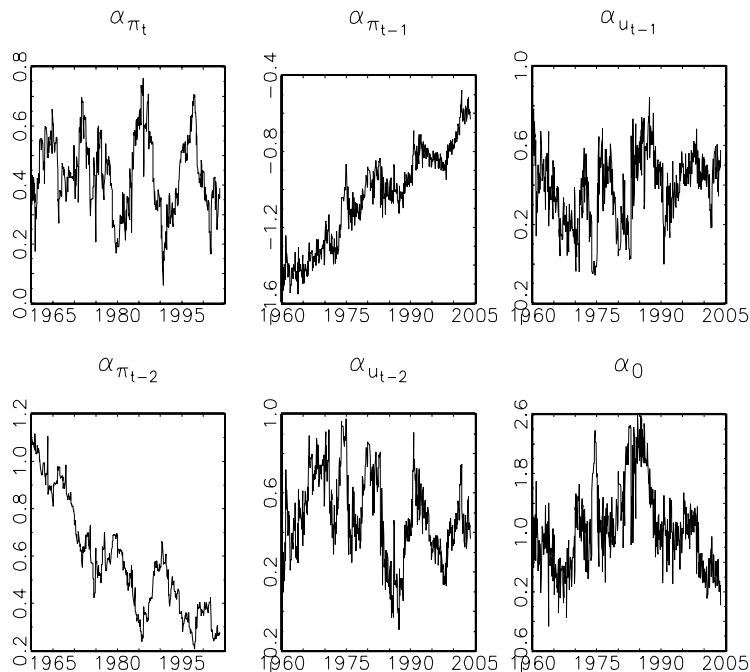


Figure 7: Coefficients of Federal Reserve model estimated with Greenbook data

The greater stability of beliefs at least partly assuages the concern of Primiceri (2006) that volatile beliefs are needed to explain the Great Inflation with the Sargent (1999) model. Our results show that it is possible to explain the rise and fall in inflation as a product of a reasonably stable evolution of Federal Reserve beliefs. The highly volatile beliefs in the previous section - and in the results of Sargent, Williams and Zha (2006) - appear to matter only for ‘overfitting’ high frequency inflation movements. Our relatively stable beliefs also leave intact the basic conquest story that changes in Federal Reserve beliefs caused the Great Inflation. In Figure 8, the perceived short-run trade-off continues to support the Sargent (1999) view, albeit with the magnitude of the trade-off peaking at a level about one tenth of that estimated without Greenbook data. The long-run trade-off in Figure 8 again has a similar role to that in Cogley and Sargent (2005a, 2005b), with large perceived costs of disinflating preventing the Federal Reserve bringing inflation down even after the Phillips curve begins to disappear.

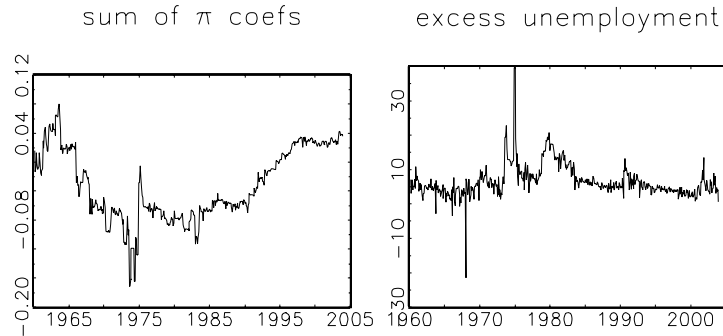


Figure 8: Perceived trade-offs estimated with Greenbook data

3.3 Constant policy projections

The constant policy projections in Figure 9 demonstrate that Federal Reserve beliefs are not only more stable but also more realistic with Greenbook data. There are none of the wild oscillations seen in Figure 4 for projections without Greenbook data. Instead, projections predict that unemployment would rise or fall steadily if policy (inflation) and beliefs were to be held at current levels. The smoothness of projections derives from the realistic coefficients in the Federal Reserve’s model of unemployment-inflation dynamics.⁹ Such realism directly answers the worries of Sims (2007) and Sargent (2008) that ‘crazy’ beliefs are needed to rationalise observed inflation outcomes. Our results show that this is not the case.

⁹The sum of coefficients on lagged unemployment varies between 0.68 and 0.99 with Greenbook data. In contrast, without Greenbook data the sum of coefficients on lagged unemployment never exceeds 0.25 and is strongly negative for most of the sample period. At worst it is -2.48.

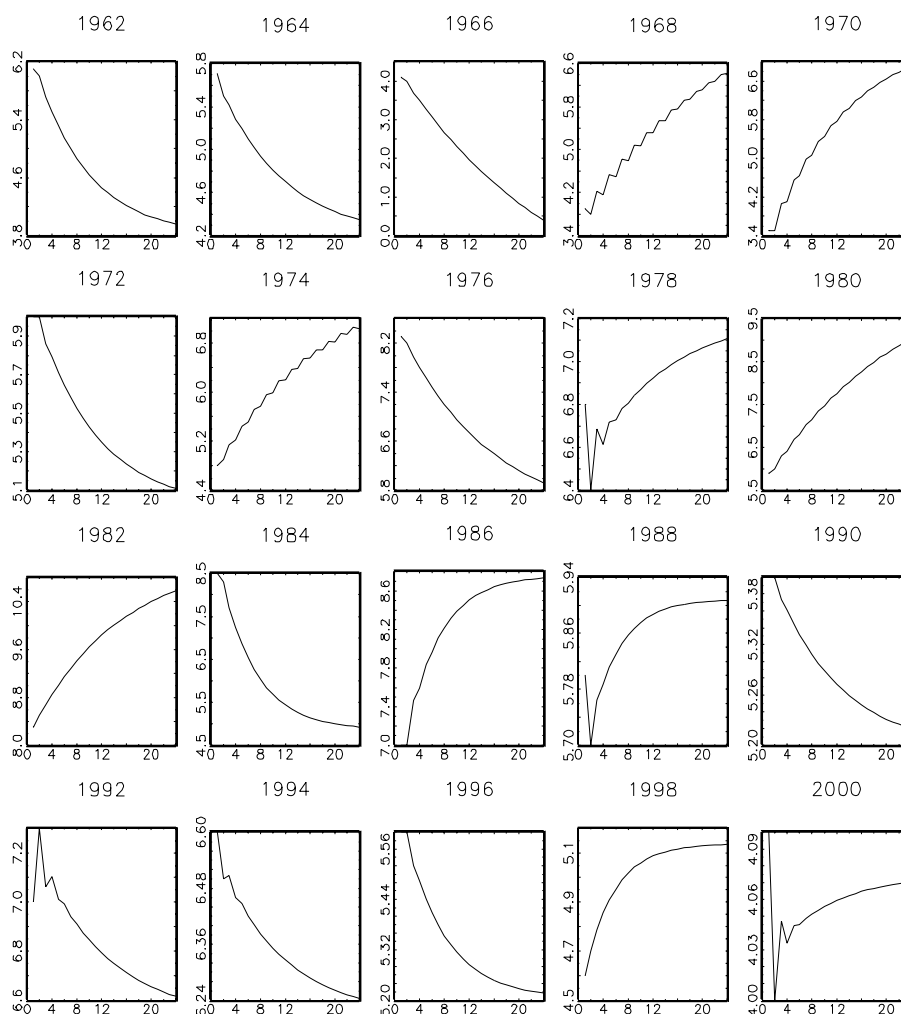


Figure 9: Constant policy projections of unemployment estimated with Greenbook data

3.4 Conditional Greenbook forecasts

Unemployment projections from the Federal Reserve’s model by definition match those in the Greenbook better once estimation is conditioned on Greenbook forecasts. Even so, it is impressive how much high frequency volatility has been removed from model forecasts in Figure 10. The correlation between ‘judgemental’ Greenbook forecasts and model forecasts conditional on expected policy is 0.98, with the change forecasts having a highly-significant correlation of 0.18.¹⁰

¹⁰The correlation between w_{2t} and w_{3t} falls to 0.11, suggesting that incorporating Greenbook data also improves the specification of the model.

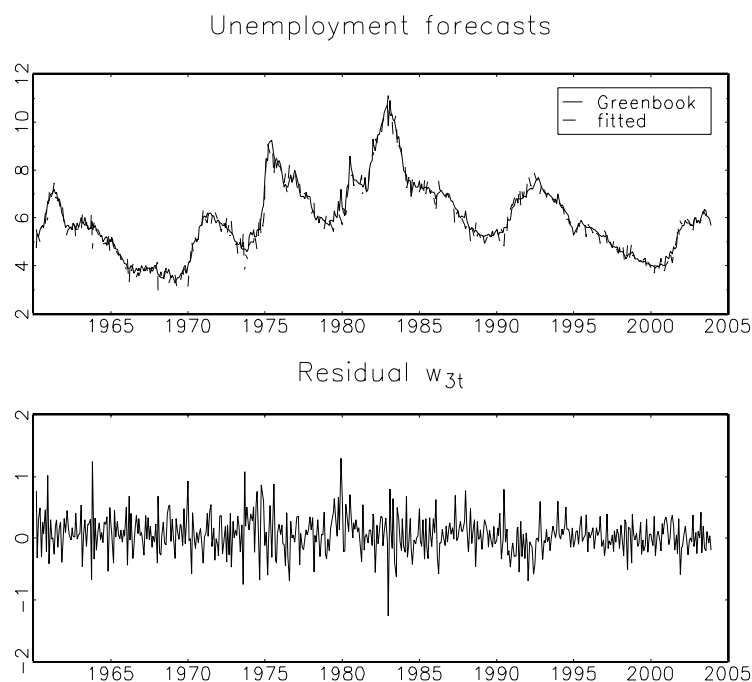


Figure 10: Unemployment forecasts with Greenbook data

4 Two robustness exercises

The results in the previous section of the paper have been obtained under quite strict simplifying assumptions. A good robustness check is therefore whether the results continue to hold when some of the simplifying assumptions are relaxed. The first simplification we relax is the assumption that the Federal Reserve completely ignores uncertainty when setting policy. Whilst this may be acceptable as a first approximation, it does beg the question of why the Federal Reserve would completely disregard the numerous policy implications in the vast academic literature on optimal and robust control under uncertainty. Brainard's paper on uncertainty and the effectiveness of policy was published as early as 1967, so should have been in the consciousness of the Federal Reserve throughout the Great Inflation period. The second simplification to relax is the assumption that the Federal Reserve has no explicit incentive to smooth its policy. Whilst it is difficult to find solid microfoundations for a smoothing term in the objective function, many empirical studies suggest that policy inertia is pervasive in

the economy. For example, Sack and Wieland (2000) discuss strong empirical evidence that interest rates are smoothed by the Federal Reserve.

4.1 Parameter uncertainty

The contention in this section is that policy should be based on the Federal Reserve's current view of the monetary transmission mechanism, but needs to explicitly take estimated parameter uncertainty into account. In other words, policy should respond to the current estimated coefficients $\hat{\alpha}_{t|t-1}$ of the Federal Reserve's approximating model and the precision $P_{t|t-1}$ with which those coefficients are estimated. This is potentially important because our results so far suggest that the Federal Reserve perceives a large degree of uncertainty at all times. We start the mathematical derivation of optimal policy under uncertainty by generalising the Federal Reserve's objective function (4) to:

$$\min_{\{\pi_t\}_{t=0}^{\infty}} \hat{E} \sum_{j=0}^{\infty} \delta^j \{ (\pi_{t+j} - \pi^*)^2 + \lambda((\tilde{u}_{t+j} - u^*)^2 + \sigma Var(u_{t+j})) \}. \quad (7)$$

The notation \tilde{u}_{t+j} again indicates the expected value of u_{t+j} , so our generalisation is akin to the bias-variance decomposition familiar in econometric forecasting. Indeed, increasing σ makes the monetary authority place less weight on expected unemployment being close to target (the bias term), and more weight on unemployment being certain (the variance term).¹¹ The next step is to explain how the Federal Reserve forms projections of the future bias and variance terms in its objective function. For the bias term, we follow Kreps (1998) and assume that the Federal Reserve projects forward using its model of unemployment-inflation dynamics, but with coefficients fixed at their current estimates. This 'anticipated utility' behaviour implies that expected future values of unemployment are given by $\tilde{u}_{t+j} = \hat{\alpha}'_{t|t-1} \tilde{\Phi}_{t+j}$. For the variance term, we follow Sack (2000) and assume that the Federal Reserve projects forward on the basis of the precision with which the parameters in its model are estimated. The Federal Reserve therefore approximates future uncertainty by $Var(u_{t+j}) \approx \tilde{\Phi}'_{t+j} P_{t|t-1} \tilde{\Phi}_{t+j}$, where the

¹¹Our choice of σ to characterise the monetary authority's attitude to uncertainty is not coincidental. There is a direct analogy to Whittle's (1990) specification of risk-sensitive preferences, since $-2\sigma^{-1} \log E \exp(-0.5\sigma(u_t - u^*)^2) \approx (\hat{u}_t - u^*)^2 + \sigma Var(u_t)$. Our measures of risk sensitivity are therefore equivalent up to an approximation error.

timing indicates that future projections are based on the current estimate of the precision matrix. The assumed form of future projections keeps the objective function linear-quadratic in the vector of expected values $\tilde{\Phi}_{t+j}$, and the Federal Reserve continues to face a standard linear-quadratic control problem. The solution is a best response function:

$$\pi_t = h(\hat{\alpha}_{t|t-1}; P_{t|t-1})' \phi_t. \quad (8)$$

Optimal policy under parameter uncertainty has inflation reacting linearly to the current state of the economy, with the strength of the reaction depending on both the estimates of the coefficients in the Federal Reserve’s model and the precision with which those coefficients are estimated. It is precisely here that policy differs from that in the previous section. There we adopted a stricter interpretation of Kreps (1998) ‘anticipated utility’ behaviour in which only the bias term was projected forwards, so the Federal Reserve ignored uncertainty and policy only depended on current coefficient estimates, not the precision with which they are estimated. The results in the previous section correspond to a special case of the generalised objective function where the risk sensitivity parameter σ is set to zero.

The only change in the Bayesian MCMC estimation algorithm we require is a redefinition of the conditional distribution for $\{P_{1|0}, V\}$ to allow for the reaction of policy to uncertainty. In the redefined distribution we set the risk parameter σ to unity to balance the incentives for policy to minimise the bias and variance terms. Table 3 presents our estimation results and compares them to the baseline where policy ignores parameter uncertainty. We also report the maximum log value of the likelihood (multiplied by the prior).

<i>Parameter</i>	<i>Baseline model</i>	<i>Parameter uncertainty</i>
$1/\sigma_2^2$	1.3659 (1.0317,1.1680)	1.7973 (1.4770,1.6709)
$1/\sigma_3^2$	10.3459 (8.9070,10.0516)	10.3145 (8.8626,10.0132)
log-likelihood	-534.0	-470.5

Table 3: Posterior estimates for parameter uncertainty with Greenbook data

The results when policy ignores uncertainty replicate those of Section 3. Against this benchmark, allowing policy to react to uncertainty has only mild implications. First and foremost is the rise in the log-likelihood, with a logarithmic gain of 63.5 implying a substantial improvement in the statistical fit of the model.¹² Second is the improved matching to inflation dynamics, achieved at the cost of only a slightly worse match to Greenbook forecasts. However, the improvement in statistical fit does not translate into significant changes in the economic fit of the model. The estimates of $\{P_{1|0}, V\}$ are not sufficiently different to their baseline values to overturn our conclusions.¹³ This is clear in Figure 11, where the evolution of perceived trade-offs is robust to whether or not policy reacts to uncertainty. The changes in the variances of the residuals are not large enough to challenge our strong support for the Sargent (1999) view of the Great Inflation.

¹²Formally, given equal prior weights the posterior odds ratio almost completely favours the model where policy reacts to uncertainty. The likelihoods are directly comparable because both models have the same free parameters.

¹³Full estimation results are available from the authors on request.

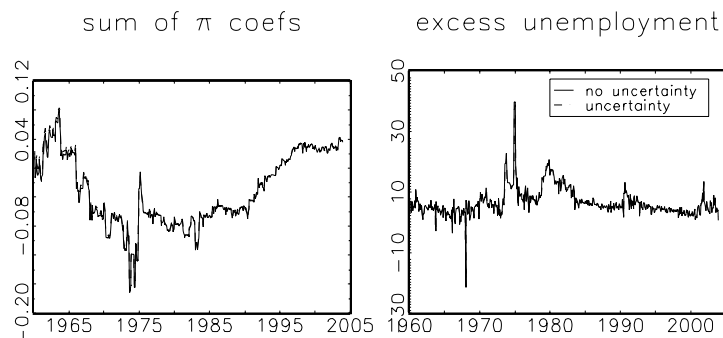


Figure 11: Perceived trade-offs under parameter uncertainty

The differences in estimation results are difficult to interpret because parameter uncertainty has a complex and potentially ambiguous effect on optimal policy. If uncertainty about the impact of policy dominates then the seminal result of Brainard (1967) applies and policy tends to be cautious, but this result can be overturned if there is sufficient uncertainty about transition dynamics.¹⁴ In addition, elements lying off the leading diagonal of the precision matrices have potentially ambiguous effects because they give incentives for optimal policy to exploit the dynamic structure of uncertainty, as discussed in Chow (1977). Our precision matrices are dominated by the off-diagonal elements, implying high covariance between parameter estimates and a complex role for uncertainty dynamics in policy

4.2 Policy smoothing

The argument in this section is that the Federal Reserve has an incentive to smooth policy for reasons that are not explicitly articulated in its model of unemployment-inflation dynamics. Perhaps the most compelling idea is the observation of Goodfriend (1987) that central banks smooth interest rates to maintain ‘orderly money markets’. The Federal Reserve’s model abstracts from the impact of policy on financial stability, in which case the costs of volatile policy may be understated. Our framework does not permit direct modelling of the risks of interest rate volatility, but we can investigate the effects of policy smoothing in general by

¹⁴Craine (1979) shows that very active policy is optimal when uncertainty about transition dynamics is dominant.

expanding the Federal Reserve’s objective function to include a term in the change in the policy instrument, inflation:

$$\min_{\{\pi_t\}_{t=0}^{\infty}} \hat{E} \sum_{j=0}^{\infty} \delta^j \{(\pi_{t+j} - \pi^*)^2 + \lambda(\tilde{u}_{t+j} - u^*)^2 + \omega(\Delta\pi_{t+j})^2\}. \quad (9)$$

The strength of the incentive to smooth policy is measured by the parameter ω . The additional term in the objective function has similar implications for Bayesian MCMC estimation as in the previous exercise where the objective was generalised to allow for parameter uncertainty. The conditional distribution for $\{P_{1|0}, V\}$ has to be redefined but otherwise the algorithm remains unchanged. We set $\omega = 0.5$ to allow for an incentive to smooth policy that does not jeopardise the fundamental focus of policy on stabilising inflation and unemployment around their target values π^* and u^* . The estimation results are given in Table 4.

<i>Parameter</i>	<i>Baseline model</i>	<i>Policy smoothing</i>
$1/\sigma_2^2$	1.3659 (1.0317,1.1680)	3.9670 (3.7368,4.2236)
$1/\sigma_3^2$	10.3459 (8.9070,10.0516)	14.5574 (13.7277,15.5352)
log-likelihood	-534.0	-159.3

Table 4: Posterior estimates for policy smoothing with Greenbook data

Introducing policy smoothing unambiguously improves the statistical fit of the model. The log-likelihood rises by 374.7 so a formal Bayesian odds ratio test overwhelmingly supports the policy smoothing model.¹⁵ The match to inflation dynamics and unemployment forecasts also improves. The improvement in statistical fit is not though reflected in substantially changed estimates of the structural parameters $P_{1|0}$ and V . The economic fit of the model is consequently unaffected by the introduction of policy smoothing, and the evidence in favour

¹⁵The log-likelihood also rises by 311.2 relative to the parameter uncertainty model, suggesting that the policy smoothing model also dominates the parameter uncertainty model.

of Sargent (1999) remains strong. Figure 12 shows only slight differences between estimates of the Federal Reserve’s view of the Phillips curve obtained with and without policy smoothing. Our fundamental message that evolving beliefs can explain the Great Inflation appears robust to the introduction of policy smoothing.

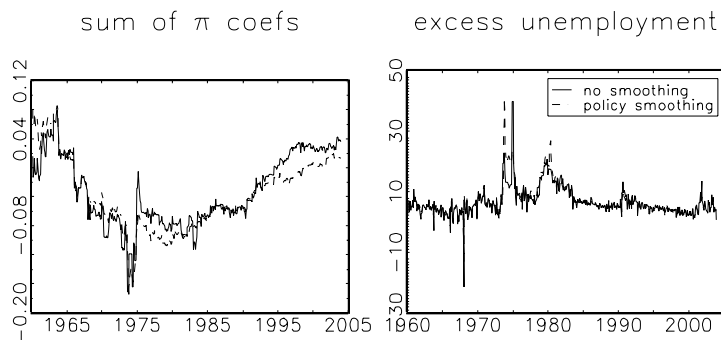


Figure 12: Perceived trade-offs under policy smoothing

The differences that do exist between estimation results can be explained by inertia induced by the smoothing term in the objective function. Policy inertia removes some of the need for persistent shocks to explain low frequency fluctuations in inflation, and helps dampen the volatile unemployment forecasts produced by the Federal Reserve’s model.

5 A structural model

In this section we follow Sargent, Williams and Zha (2006) and embed our simple model of Federal Reserve policy in a structural model of the economy. The advantages in doing so are threefold. Firstly, unemployment becomes endogenous so it is possible to test whether the Sargent (1999) view can also explain unemployment dynamics. Secondly, the ability to distinguish between anticipated and unanticipated changes in unemployment helps identify whether corresponding changes in inflation were themselves anticipated or unanticipated. Thirdly, it can be shown that the structural model converges to a well-defined self confirming equilibrium.¹⁶ The underlying structure of the economy adopted by Sargent, Williams and Zha

¹⁶Sargent and Williams (2005) use techniques from stochastic approximation theory to characterise the possible outcomes of the Federal Reserve’s learning process.

(2006) is described by a Lucas natural-rate Phillips curve and a true inflation process:

$$u_t - u^{**} = \theta_0(\pi_t - E_{t-1}\pi_t) + \theta_1(\pi_{t-1} - E_{t-2}\pi_{t-1}) + \tau_1(u_{t-1} - u^{**}) + \sigma_1 w_{1t}, \quad (10)$$

$$\pi_t = x_{t-1} + \sigma_2 w_{2t}, \quad (11)$$

where u^{**} is the natural rate of unemployment. Equation (10) is an expectations-augmented Phillips curve in which unemployment is driven by unexpected inflation movements and an unemployment shock. Equation (11) states that the Federal Reserve controls inflation up to a random control error. We refer to the policy instrument x_{t-1} as intended inflation. If we assume that private agents form expectations based on the empirical specification (6) then the random control error w_{2t} corresponds exactly to the residual w_{2t} in the previous sections. In this case expected inflation is given by $E_{t-1}\pi_t = h(\hat{\alpha}_{t|t-1})'\phi_t = x_{t-1}$ and unexpected inflation is simply w_{2t} .

The natural-rate Phillips curve has five structural parameters that need to be estimated alongside the parameters of the Federal Reserve's model. The first four $\{u^{**}, \theta_0, \theta_1, \tau_1\}$ are assigned a normal conjugate prior and are drawn in a third step of the Gibbs sampler. The fifth σ_1^2 has an inverse gamma conjugate prior and is drawn alongside σ_2^2 and σ_3^2 in the second step of the Gibbs sampler. The precise specification of these additional prior distributions follows the details of Sargent, Williams and Zha (2006) summarised in Appendix A.

The estimation results when embedding the behavioural model in a structural model are so close to the results in Sections 3 and 4 that we only report estimates of the new parameters in Table 5. The values of $P_{1|0}$ and V do not change much, so the evolving views of the Federal Reserve identified with and without Greenbook data are very similar to those in Figures 2 and 7. Sargent, Williams and Zha (2006) claim that estimation of the full structural model provides substantive evidence in support of Sargent (1999). We agree but note that the closeness of results means there is still a problem with excess volatility in the forecasts produced by the Federal Reserve's model when estimation is performed without Greenbook data. Beliefs only become realistic after imposing restrictions from the Greenbook.

<i>Parameter</i>	<i>Structural model estimated without Greenbook data</i>	<i>Structural model estimated with Greenbook data</i>
u^{**}	6.1097 (1.3590,7.5333)	5.4893 (0.7521,6.9528)
θ_0	-0.0025 (-0.0386,0.0312)	0.0146 (-0.0023,0.0311)
θ_1	-0.0136 (-0.0626,0.0002)	0.0159 (0.0016,0.0355)
τ_1	0.9890 (0.9862,0.9964)	0.9916 (0.9877,0.9978)
$1/\sigma_1^2$	34.8356 (29.5838,33.4617)	31.3181 (29.2634,33.1535)
$1/\sigma_2^2$	19.0723 (15.8680,18.7174)	1.3731 (1.2936,1.4623)
$1/\sigma_3^2$	—	10.3628 (9.8018,11.0763)

Table 5: Posterior estimates of structural parameters in a structural model

The estimate of σ_1^2 without Greenbook data suggests that the structural model is successful in explaining unemployment dynamics. However, the success is partially illusory because the estimated values of θ_0 and θ_1 have such small magnitude that unexpected inflation only plays a very minor role in the determination of unemployment.¹⁷ The small coefficients on unexpected inflation also mean that decomposing unemployment into anticipated and unanticipated changes is not very helpful when deciding whether changes in inflation are anticipated (from $h(\hat{\alpha}_{t|t-1})'\phi_t$) or unanticipated (from w_{2t}). With unemployment effectively rendered exogenous by the estimation process, it is no great surprise that results from previous sections are robust to embedding the Federal Reserve model in the structural model. The same broad intuition applies to estimation results with Greenbook data, with the small estimated values of θ_0 and θ_1 implying that unexpected inflation still only plays a very minor role in determining unemployment.¹⁸ We interpret the results in this section as suggesting that there is only

¹⁷Variance decomposition analysis of the results without Greenbook data attribute only 0.035% of the total variance in unemployment to unexpected inflation effects.

¹⁸The small estimates of θ_0 and θ_1 also support the Sargent, Williams and Zha (2006) view that the Great

limited value-added in embedding the simple model of Federal Reserve policy in a structural model based on the Lucas natural-rate Phillips curve.

6 Conclusions

The message of this paper is that empirical support for *The Conquest of American Inflation* remains strong even when restrictions are imposed to rule out volatile and unrealistic beliefs. We find a relatively stable evolution of Federal Reserve beliefs can simultaneously explain both the dynamics of the Great Inflation and the unemployment forecasts published in the Green-books. There is no need to resort to either volatile/unrealistic beliefs or excessive openness to new data to rationalise inflation outcomes. In our estimations, the Federal Reserve always sets policy using a model that produces reasonable constant policy projections and realistic conditional unemployment forecasts. We therefore argue that the concerns of Primiceri (2006), Sims (2007) and Sargent (2008) are unfounded.

Inflation cannot be explained by switches between Ramsey and Nash equilibria. At only 0.20%, the difference between Ramsey and Nash inflation is insufficient to explain the large rise and fall in U.S. inflation.

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A Calibration and priors

The calibrated values in Table A.1 are taken directly from Sargent, Williams and Zha (2006). As they explain, the parameter σ_w (the perceived standard deviation of shocks in the Federal Reserve’s approximating model) is unidentified when policy depends only on $\hat{\alpha}_{t|t-1}$ as in Sections 2, 3, 4.2 and 5. We follow their lead and normalise σ_w to their estimate of the standard deviation of unemployment shocks in a structural model. No such problems arise with parameter uncertainty in Section 4.1 because policy reacts to both $\hat{\alpha}_{t|t-1}$ and $P_{t|t-1}$. In this case we retain the same value of σ_w , but note that here it represents a calibration and not normalisation. The values for $\hat{\alpha}'_{1|0}$ are derived from estimating the Federal Reserve’s model on presample data from January 1948 to December 1959.

<i>Parameter</i>	<i>Value</i>
δ	0.9936
λ	1
π^*	2
u^*	1
σ_w	0.0169
$\hat{\alpha}'_{1 0}$	(-0.1324 0.1419 1.0928 -0.0216 -0.1338 0.2190)

Table A.1: Calibrated parameter values

The priors in Table A.2 are also based on Sargent, Williams and Zha (2006). The matrices \mathbf{C}_P and \mathbf{C}_V are upper triangular Choleski decompositions of $P_{1|0}$ and V such that $P_{1|0} = \mathbf{C}'_P \mathbf{C}_P$ and $V = \mathbf{C}'_V \mathbf{C}_V$. The scaling factor of 400 in the prior distribution of V corrects for the small C++ coding error highlighted in footnote 3. The stated prior in Sargent, Williams and Zha (2006) has a scaling factor of 0.5, but in their C++ codes the prior distribution is completely flat. To ensure comparability of our results we use a high scaling factor to create a very diffuse prior distribution for V .

<i>Parameter</i>	<i>Distribution</i>	<i>Mean</i>	<i>Standard error</i>
\mathbf{C}_P	Normal	0	0.5×5 on diagonals, 0.5×2.5 on off-diagonals
\mathbf{C}_V	Normal	0	400×5 on diagonals, 400×2.5 on off-diagonals
$u^{**}(1 - \tau_1)$	Normal	0.12	0.06
θ_0	Normal	-0.20	0.10
θ_1	Normal	-0.16	0.08
τ_1	Normal	0.98	0.01
$1/\sigma_1^2$	gamma	50	25
$1/\sigma_2^2$	gamma	50	25
$1/\sigma_3^2$	gamma	50	25

Table A.2: Prior distributions

B Construction of Greenbook forecasts

The Federal Reserve Bank of Philadelphia currently publishes historical projections from the Greenbooks of July 1966 to December 2001. Each Greenbook typically provides projections for the current quarter and a few quarters ahead, and we convert the Greenbook data into monthly unemployment forecasts by selecting the most appropriate quarterly projection for each month. January and February forecasts are Q1 projections from the same year; March, April and May forecasts are Q2 projections from the same year; June, July and August forecasts are Q3 projections from the same year; September, October and November forecasts are Q4 projections from the same year. The December forecast is the Q1 projection from the following year. There are no publicly-available Greenbook projections at the beginning and end of our sample period. For January 1960 to June 1966 we adopt a simple ‘no change’ forecast that unemployment will stay at its current level. For January 2002 to December 2003 we use the two year ahead projection published in the Greenbook of December 2001. Alternative methods for constructing the missing Greenbook forecasts were investigated, but found to have only minor implications for our results.