

Inflation Persistence, the NAIRU, and the Great Recession

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Table 1 contrasts the change in inflation and unemployment during the 2007-09 recession and its aftermath with the corresponding changes during and following the double-dip recessions of 1980-82.

TABLE 1: INFLATION AND UNEMPLOYMENT 1979-85 AND 2007-13	
A. 1979-1985	
Avg. inflation 1979:Q2-1979:Q4	8.1
Avg. inflation 1985:Q2-1985:Q4	3.5
Change in inflation	-4.6
Avg. unemployment rate 1979:Q2-1979:Q4	5.8
Peak unemployment rate (1982:M12)	10.8
Avg. unemployment rate 1985:Q2-1985:Q4	7.2
Increase 1979 to peak	5.0
Increase 1979 to 1985	1.4
B. 2007-13	
Avg. inflation 2007:Q1-2007:Q3	2.1
Avg. inflation 2013:Q1-2013:Q3	1.1
Change in inflation	-1.0
Avg. unemployment rate 2007:Q1-2007:Q3	4.7
Peak unemployment rate (2009:M10)	10.0
Avg. unemployment rate 2013:Q1-2013:Q3	7.5
Increase 2007 to peak	5.3
Increase 2007 to 2013	2.8

Notes: Inflation is reported percentage points at an annual rate and the unemployment rate is reported in percentage points.

In the six years following the start of the 1980-82 recessions inflation fell 4.6 percent (from 8.1% to 3.5%), while in the six years following the start of the 2007-09 inflation fell only 1.0 percent (from 2.1% to 1.1%). This difference occurred despite a similar increase in the unemployment rate during the two

episodes. This paper investigates the reasons for this difference.

The investigation is carried out in the context of a traditional Phillips curve equation:

$$(1) \phi(L)(1-L)\pi_t = \beta(L)(u_t - \bar{u}_t) + \gamma(L)Z_t + e_t$$

where π_t denotes inflation, $u_t - \bar{u}_t$ denotes the unemployment gap, with u_t the observed unemployment rate and \bar{u}_t the unobserved ‘natural rate’ or NAIRU, Z_t denotes additional controls (oil and import prices, for example), e_t is an error, and the dynamics of inflation are modeled through the lag-polynomials $\phi(L)$, $\beta(L)$, and $\gamma(L)$.¹

Equation (1) highlights three potential explanations for the tepid response of inflation to the increase in unemployment during 2007-13 relative to its response during 1980-85. First, inflation persistence (captured by $\phi(L)$) may have changed. Lower persistence means that variations in the right hand side of (1)

¹ This formulation is best known from a large body of work by Robert J. Gordon; see Gordon (2013) for discussion and references. The equation is often specified using π_{t+1} instead of π_t (e.g., Staiger, Stock and Watson (1997)), but the choice of specification makes little difference for the calculation carried out here.

have smaller effects on the trend inflation rate. Second, increases in the unemployment rate may have had a smaller impact on inflation either because the coefficients in $\beta(L)$ changed or because increases in the observed unemployment rate, u , was partially offset by increases in the NAIRU, \bar{u} . Finally, other factors (Z or e) may be the source of the difference.

The remainder of this paper investigates each of these explanations.

I. Inflation Persistence

Several authors have shown that the persistence of inflation has changed markedly over the last 15-20 years.² Stock and Watson (2010) discuss the implications of these changes for the pass-through of unemployment changes to inflation, and this section reviews and updates their calculations.

To begin, suppose that the lag polynomial $\phi(L)$ is parameterized as $\phi(L) = (1-\theta L)^{-1} = 1+\theta L+\theta L^2+\dots$ which captures the potentially long-lags in the inflation process. Letting $\eta_t = \beta(L)(u_t - \bar{u}_t) + \gamma(L)Z_t + e_t$ denote the terms on the right hand side of equation (1), the Phillips curve equation becomes

$$(2) \quad (1-L)\pi_t = (1-\theta L)\eta_t.$$

Using (2) to solve for the change in inflation between time periods t and $t+k$ yields:

$$(3) \quad \pi_{t+k} - \pi_t = \eta_{t+k} - \theta\eta_t + (1-\theta)\sum_{i=1}^{k-1}\eta_{t+i},$$

so that θ determines the pass-through of η_{t+i} to π_{t+k} . The parameter θ measures how well the trend level of inflation is ‘anchored’. When $\theta = 1$, a one unit change in η_{t+i} has no effect on the long-run level of inflation, while when $\theta = 0$, the long run level in inflation moves one-for-one with η_{t+i} . In general, (3) says that a one-unit increase in η_{t+i} leads to a permanent $(1-\theta)$ -unit increase in the level of inflation.

Stock and Watson (2007) estimate a time-varying version of (3) with η modeled as white noise, so that π follows an IMA(1,1) process with time varying moving average parameter, θ , and innovation variance, σ_η^2 . Estimation is via non-linear filtering in the context of an unobserved components model with stochastic volatility (a ‘UCSV’ model).³ Figure 1 shows estimates of θ computed using

² For example, see Cogley and Sargent (2001), Stock and Watson (2007), and Kang, Kim, and Morely (2009) (and the papers referenced there).

³ See Cogley, Primiceri, and Sargent (2010), Cogley, Sargent, and Surico (2012), Mertens (2012), and Shephard (2013) for related methods for estimating versions of (3).

quarterly core PCE inflation over 1959:Q2-2013:Q3.⁴

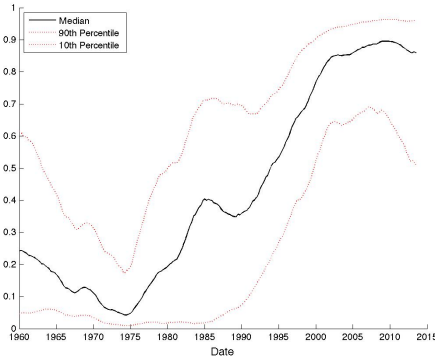


FIGURE 1: ESTIMATES OF θ FROM THE UCSV MODEL

While the figure indicates considerable uncertainty about the precise value of θ at any date, the results provide strong evidence for a change in inflation persistence. The estimated value of θ (the median value plotted in the figure) is around 0.3 during the early 1980's and has hovered around 0.9 since 2000. In this sense, inflation was much more anchored during 2007-13 than during 1980-85.

II. Estimating the parameters of the Phillips curve

Quantifying the influence of factors beyond inflation persistence requires estimates of the parameters in (1) and the NAIRU. This section briefly discusses the parameter

estimates used here, and the next section discusses estimation of the NAIRU.

Estimation of (1) is complicated by time variation in its components. The last section suggested substantial time variation in the persistence parameters in $\phi(L)$; there is a large literature documenting instability in the NAIRU, \bar{u}_t ⁵; several researchers have speculated on changes in the slope of the Phillips curve, $\beta(1)$, and on the pass-through of oil-price shocks (components of Z) to inflation⁶; and finally, changes in the volatility in inflation suggest possible changes in the variance of the error term e .

I have not attempted full-information estimation that simultaneously allows for all of these sources of time variation, but instead have estimated the model parameters using several shortcuts. To begin, time variation in $\phi(L)$ is estimated using the univariate UCSV model discussed in the last section. This yields an estimate of η_t , say $\hat{\eta}_t$, that is the one-period ahead forecast error in the UCSV model. Next, I constructed a preliminary estimate of \bar{u}_t using a (1-sided) band-pass 'trend' filter corresponding to periods greater than 15 years. Call the resulting estimate of

⁴ All of the data used in this paper are described in the online appendix.

⁵ See for example, Gordon (1997), Staiger, Stock, and Watson (1997), or more recently Basistha and Startz (2010), Fleischman and Roberts (2011), and Reifschneider, Wascher, and Wilcox (2013).

⁶ See the discussion and references in Stock and Watson (2010)

the gap, \hat{u}_t^{Gap} .⁷ I then estimated $\beta(L)$ and $\gamma(L)$ from a regression of $\hat{\eta}_t$ onto a distributed lag of \hat{u}_t^{Gap} and Z_t (which included changes in the relative price of food and energy, non-petroleum import prices, and Gordon's (1982) series for the Nixon wage and price controls). I allowed the pass through of food and energy prices to inflation to change discretely in 1984.⁸ Finally, I estimated the variance of the regression error using a rolling window that included 20 leading and lagging quarters of the estimated regression residual.

Details of the specification and results are provided in the online appendix. I highlight four results here. First, a key parameter is $\beta(1)$, the sum of coefficients on the unemployment gap. The estimated value of $\beta(1)$ is $\hat{\beta}(1) = -0.20$ with a standard error of 0.04. Second, the estimated value $\beta(1)$ is reasonably stable: splitting the sample in 1984 yields estimates of -0.21 in the early period and -0.19 in the latter period. Third, the results are generally robust to variation in the specification, including the number of lags, allowing for discrete breaks in the pass-through of energy and import prices, and so forth. Finally, the error variance changed

during the sample. It was higher in the early part of the sample ($\hat{\sigma}_{1960:Q2-1989:Q4} = 0.75$) than in the latter part ($\hat{\sigma}_{1990:Q1-2013:Q3} = 0.44$), and remained relatively low during the 2007-09 recession and its aftermath ($\hat{\sigma}_{2007:Q4-2013:Q3} = 0.45$).

III Estimating the NAIRU

The time varying NAIRU is estimated using standard methods (Gordon (1997), Staiger, Stock, and Watson (1997)). The details are as follows. First, isolate the unobservables \bar{u} and e by rewriting (1) as

$$\begin{aligned}
 (4) \quad \phi(L)(1-L)\pi_t - \beta(L)u_t - \gamma(L)Z_t &= -\beta(L)\bar{u}_t + e_t \\
 &\approx -\beta(1)\bar{u}_t + e_t \\
 &= \mu_t + e_t
 \end{aligned}$$

where the second line uses the approximation $\Delta\bar{u}_t \approx 0$ (under the assumption that quarter-to-quarter changes in the NAIRU are small) and the third line defines $\mu_t = -\beta(1)\bar{u}_t$. Suppose that \bar{u}_t evolves smoothly over time in a way that can be modeled as a random walk, and let $\sigma_{\Delta\bar{u}}$ denote the standard deviation of $\Delta\bar{u}_t$. From (4), μ_t will also follow a random walk with standard deviation $\sigma_{\Delta\mu} = |\beta(1)|\sigma_{\Delta\bar{u}}$. With

⁷ See Staiger, Stock, and Watson (2001) for a related application.

⁸ See Fleishman and Roberts (2011), Gordon (2013), and Reifschneider Wascher, and Wilcox (2013).

$\{e_t\}$ and $\{\Delta\mu_t\}$ uncorrelated, and assuming the parameters of the model ($\phi(L)$, $\beta(L)$, $\gamma(L)$, $\sigma_{\Delta\bar{u}}$ and σ_e) are known, μ_t can be estimated by signal extraction methods, and the estimate \bar{u}_t constructed as $\hat{\bar{u}}_t = -\hat{\mu}_t / \beta(1)$. The method is implemented using the estimated values of the model parameters ($\phi(L)$, $\beta(L)$, $\gamma(L)$, σ_e) discussed above (and where $\phi(L)$, $\gamma(L)$, and σ_e are time varying as already discussed).

The remaining parameter is $\sigma_{\Delta\bar{u}}$. This parameter is both important and difficult to estimate. It is important because it determines the signal-to-noise rate $\sigma_{\Delta\mu} / \sigma_e = |\beta(1)| \sigma_{\Delta\bar{u}} / \sigma_e$, for the estimation of μ_t and \bar{u}_t . It is difficult to estimate because it measures the low-frequency variability in Δu , and because there is limited sample information about low-frequency variability.

The literature has produced a range of estimates. For example, Gordon (1998) estimates $\sigma_{\Delta\bar{u}} = 0.09$ using a method developed in Stock and Watson (1998) and has used this value in his subsequent work. Basistha and Startz (2008), Fleischman and Roberts (2011) and Reifschneider, Wascher and Wilcox (2013) estimate $\sigma_{\Delta\bar{u}}$ using Gaussian maximum likelihood methods and find estimates ranging from 0.11 to 0.17. Larger values are also reasonable. For example, if \bar{u}_t is the long-run trend in u_t , then

$\sigma_{\Delta\bar{u}}$ is the long-run standard deviation of Δu_t . Using the nonparametric estimator of Müller (2007) based on frequencies corresponding to periods longer than 25 years, the estimate is $\hat{\sigma}_{\Delta\bar{u}} = 0.28$, although with substantial sampling uncertainty: a 90% confidence set includes values of $\sigma_{\Delta\bar{u}}$ between 0.12 and 0.43.

With this uncertainty in mind, I have estimated the NAIRU using a range of values of $\sigma_{\Delta\bar{u}}$. The results are shown in Table 2, where the numbers in parentheses are standard errors conditional on the estimated parameter used in the signal extraction.

TABLE 2: ESTIMATES OF NAIRU USING DIFFERENT VALUES OF $\sigma_{\Delta\bar{u}}$

$\sigma_{\Delta\bar{u}}$	2007:Q3	2010:Q3	2013:Q3	$\bar{u}_{2013Q3} - \bar{u}_{2007Q3}$
.10	5.55 (.36)	5.91 (.39)	5.99 (.48)	0.43 (.44)
.15	5.52 (.42)	6.12 (.46)	6.21 (.58)	0.70 (.61)
.20	5.43 (.48)	6.28 (.51)	6.35 (.67)	0.91 (.75)
.30	5.23 (.58)	6.50 (.61)	6.42 (.80)	1.19 (.96)

The results show that larger values of $\sigma_{\Delta\bar{u}}$ produce larger estimated changes in the NAIRU over 2007:Q3-2013:Q3 and larger estimated values of NAIRU in 2013:Q3. This is consistent with trend decreases in inflation that were smaller than would have been predicted using a constant NAIRU. The 2013:Q3 estimates of NAIRU range from 6.0 to 6.4 depending on the value of $\sigma_{\Delta\bar{u}}$. The corresponding changes increases in NAIRU over the 2007:Q3-2013:Q3 period range from

0.4 to 1.2. Figure 2 plots the estimated NAIRU using $\sigma_{\Delta \bar{u}} = 0.15$.

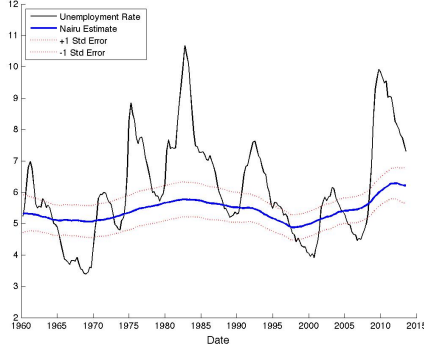


FIGURE 2: ESTIMATES OF NAIRU USING $\sigma_{\Delta \bar{u}} = 0.15$

Gordon (2013) finds similar increases in the estimated NAIRU, but also finds little change in NAIRU when it is estimated using the unemployment rate for workers unemployed less than 27 weeks ($u^{<27} = (\# \text{unemployed less than 27 weeks}) / (\text{labor force})$). Table 3 shows the estimated NAIRU I obtain using $u^{<27}$.

TABLE 3: ESTIMATES OF NAIRU USING THE SHORT-TERM UNEMPLOYMENT RATE

$\sigma_{\Delta \bar{u}}$	2007:Q3	2010:Q3	2013:Q3	$\bar{u}_{2013:Q3} - \bar{u}_{2007:Q3}$
.10	4.04 (.29)	4.06 (.31)	4.06 (.40)	0.02 (.41)
.15	3.98 (.35)	4.04 (.37)	4.05 (.48)	0.07 (.55)
.20	3.91 (.40)	4.04 (.41)	4.03 (.55)	0.12 (.66)
.30	3.81 (.49)	4.04 (.50)	3.98 (.67)	0.18 (.82)

Consistent with the results in Gordon (2013), Table 3 shows that the NAIRU associated with the short-term unemployed appears to be stable.

IV. Explaining the differences between 1979-85 and 2007-13

Varying the parameters of the estimated models produces counterfactual paths of inflation that can be used to explain why inflation fell less during 2007-13 than 1980-85. The simulations use historical values of inflation to initialize simulations in 1979:Q4 and 2007:Q3 and then simulate inflation for 24 subsequent quarters. The simulations are summarized in Table 4, which reports the resulting average value in the final three simulated quarters corresponding to 1985:Q2-Q4 and 2013:Q1-Q3.

TABLE 4: MODEL-IMPLIED AVERAGE VALUES OF INFLATION

Model	1985:Q1 – 1985:Q3	2013:Q1 – 2013:Q3
$\theta = 0.67$	3.5%	-0.7%
$\theta = 0.93$	5.9%	1.1%
NAIRU unchanged	3.3%	0.8%
$Z = 0$	5.6%	1.0%

The first two rows of Table 4 show simulations using the historical values of η_t (as estimated by the model), but different values of $\phi(L) = (1 - \theta L)^{-1}$. The first row uses $\theta = 0.67$ and the second uses $\theta = 0.93$. The actual average value of inflation in 1985 was 3.5%, and the value of $\theta = 0.67$ was chosen so that the simulations matched this value. Similarly, actual average value of inflation over 2013 was 1.1%, and the value of $\theta = 0.93$ was chosen so the simulations matched this

value.⁹ The table indicates that had inflation over 2007-13 been as ‘unanchored’ ($\theta = 0.67$) as it was over 1979-85, inflation would have fallen to -0.7% instead of 1.1% in 2013. Similarly, had inflation over 1980-85 been as ‘anchored’ ($\theta = 0.93$) as it was over 2007-13, inflation would have remained relatively high in 1985 (at 5.9% instead of 3.5%).

As Figure 2 indicates, the NAIRU increased over both 1979-85 and 2007-13, so that the unemployment rate gap increased less than the increase in the unemployment rate. The third row of Table 3 shows would have happened to inflation if the NAIRU had not increased, but rather had remained constant at its 1979 or 2007 values, respectively. While the increases in NAIRU mitigated the effect of u on π over these periods, the table indicates that the differences are not large (0.2% in 1985 and 0.3% in 2013).

The final row Table 3 shows result from setting the control variables, Z_t , equal to zero over the simulation periods. Recall that these variables measure shocks to food, energy, and import prices. These shocks had essentially no impact on inflation during 2007-13, but

explain a significant share of the reduction of inflation from 1979 to 1985.

V. Conclusions and Final Comments

This paper began by asking why inflation fell so little during 2007-13 relative to its decline during 1979-85. The results indicate that a change in inflation persistence (inflation is more anchored now than in the early 1980s) is an important reason.

This paper also reports estimates of the NAIRU over the recent period. While the estimates are inherently imprecise, the data suggest that the NAIRU increased nearly one percentage point from 2007 to 2013:Q3, where it stood at around 6.3% . However, as in Gordon (2013), the estimated NAIRU that excludes the long-term unemployed is essentially unchanged since 2007. This suggests that the increase in the NAIRU may be short-lived and return to its pre-Great Recession value of around 5.5% as the ratio of short-term to long-term unemployed returns to pre-recession level.

Finally, while the level of inflation has fallen only roughly 1% since 2007, it remains approximately 1% below the Federal Reserve’s target of 2% , and this raises the question of how it will return to the 2% value. In the context of (1), this will require sustained negative values of the

⁹ The value of $\theta = 0.67$ is larger than the estimates of θ shown in Figure 1 for the 1979-85 period. The larger value is required because the UCSV model that is used to estimate θ in Figure 1 implicitly estimates $(1-\theta L)^{-1} = 1+\theta L+\theta^2 L^2+\dots$, a nonlinear function of θ ; there is substantial sampling error, and Jensen’s inequality dictates a larger fixed value of θ .

unemployment gap or ‘favorable’ (Z, e) shocks. Note however that in (1) inflation is anchored to a distributed lag of past inflation. If instead, inflation is anchored at a higher level (say at the Fed’s target of 2%), then inflation will rise naturally toward this anchor, and prolonged negative unemployment gaps and/or (Z, e)-shocks are not necessary to return inflation to a 2% trend level. How, why, and to what inflation is anchored remain important questions.

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