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Inflation Targeting, the Natural Rate and Expectations

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Inflation Targeting, the Natural Rate and Expectations

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Abstract

In the new Keynesian model of endogenous stabilization governments have objectives with respect to macroeconomic performance, but are constrained by an augmented Phillips curve. Because they react quickly to inflation shocks, governments can lean against the macroeconomic wind. We develop an econometric test of this characterization of the political-economic equilibrium using the Kalman filter. Applying this methodology to a variety of quadratic social welfare functions, we find that an inflation target functional form is consistent with US history. We also find it more likely that expectations of inflation are adaptive, rather than rational.

Keywords: endogenous stabilization, policy objectives, adaptive expectations
JEL Classification: E61, E63

1. Introduction

A number of plausible assumptions are consistent with a endogenous stabilization model.[1] One of these relates to the functional form of the government's objective function. Using the state space methodology, we compare eight quadratic forms for the US series on inflation and growth. Although identification issues arise, our preferred form (circular indifference curves with an inflation policy target) has a significantly better statistical fit than the alternatives.

The state space specification is appropriate because the structural form of these models involves the unobserved natural rate of growth. This econometric method enables a coherent model of government stabilization decisions. By formalizing the relation between observables and unobservables, it provides Bayesian estimates of the natural rate conditioned on the observations that were available at each point in time. A comparison our estimates with the customary smoothed estimates of the natural rate show significant differences.

Because expected inflation enters the analysis as a shift variable in the augmented Phillips curve, another modeling assumption concerns the formation of inflation forecasts by economic agents. We develop theoretical solutions and econometric specifications for two possibilities: strongly rational and simple adaptive expectations. Rationality is the overwhelming assumption of the economics literature because it coheres with the notion on well-informed maximizing agents. We find, however, that its implications do not conform well to observed outcomes when applied to endogenous stabilization; an adaptive model fits the data better. The adaptive rule, often labeled naïve, could be the rational strategy in an uncertain world.

2. Economic structure and objectives

The literature on political macroeconomics invariably invokes an augmented Phillips curve as a structural constraint on policymakers.[2] Conventionally this is an inverse relation between the unexpected inflation and the gap between actual and natural unemployment. Since the labor and product markets are linked, the natural output Y_t^* is conceptually equivalent to the natural rate of unemployment. We substitute

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[1] Another name is political business cycle theory. The original insight for this literature dates to Kalecki (1943); also see Nordhaus (1975) or Hibbs (1977).
[2] See, for example, Nordhaus (1975), Barro and Gordon (1983) or Alesina (1987).

the output gap, defined as $y_t = \ln(Y_t) - \ln(Y_t^*)$, for the unemployment gap as the measure of macroeconomic disequilibrium in our Phillips curve,[3]

$$\pi_t = \pi_t^e + \psi y_t + \varepsilon_t \tag{1}$$

where π_t is the inflation rate and ε_t defines an inflation shock. Expected inflation is π_t^e, the forecast of a typical agent based on information available in the previous period. Assuming expectations are fulfilled in the long run, this relation rules out any long-run deviation from $y = 0$. However, as long as economic agents do not fully anticipate the effects of fiscal, monetary and other policies, governments are able to temporarily increase output at the cost of more rapid inflation.

Another essential element is an assumption about political objectives. One possibility is to suppose that the government's goals are given by a quadratic function of growth and inflation,

$$U_t = -\frac{1}{2}\left(\left(g_t - g_t^*\right)^2 + \left(\pi_t - \hat{\pi}\right)^2\right), \tag{2}$$

where the growth rate of real output is $g_t = \ln(Y_t) - \ln(Y_{t-1})$, and $g_t^* = \ln(Y_t^*) - \ln(Y_{t-1}^*)$ is the natural rate of growth.

The modeling of collective objectives is controversial. Textbooks often define social welfare as an aggregation of individual preferences. Governmental targets may reflect a weighted average of citizen preferences, with heavier weights assigned to the ruling party's core constituents. Differing targets for inflation could account for ideological differences. Functions such as (2) have been called "abbreviated social welfare functions" because they are written in terms economic indicators such as inflation rather than citizen preferences; see Lambert (1993). Quadratic forms are tractable because they always result in linear solutions. Within the quadratic family, a variety of alternatives are plausible. Equation (2) has circular indifference curves, but these can be made elliptical by adding a parameter to reflect the relative weight of inflation versus growth goals. Some models allow parabolic indifference curves. Sometimes the growth target differs from the natural rate. Another alternative asserts that goals are specified in terms of output levels, rather than growth rates. Objectives might also include the discounted value of expected future

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[3] The name of this equation derives from Phillips' (1958) study of the inverse relation between the unemployment rate and the wage inflation rate. Later Friedman (1968) reformulated the relation in terms on price inflation and added expected inflation.

outcomes. The government might plan for its current term of office only, or it might plan to be in office for several terms, discounting the future according to the probability of holding office. Alternatively, it might weigh pre-election years more heavily. Here we assume that only current conditions matter.[4] Beginning with (2), this paper examines the statistical performance of some of these possibilities.

3. Endogenous stabilization under circular objectives with an inflation target

The government has limited options in a new Keynesian model of activist stabilization. It is assumed that the government can exploit information and implementation advantages to lean against the macroeconomic wind, although its goals ($g_t = g_t^*$ and $\pi_t = \hat{\pi}$) may be unattainable.[5] The government uses up-to-date information to guide policy, observing shocks and setting inflation accordingly. It has an information advantage over agents, who forecast inflation in the previous period. Rational agents come to understand that a policy of $\hat{\pi} > 0$ implies inflation; this expectation is a self-fulfilling prophecy. The stylized fact of inflation is consistent with the hypothesis that governments target inflation.[6]

The long-run equilibrium is disturbed by exogenous shocks. To derive the government's policy, we rewrite the Phillips curve using the definition of the growth rate $g_t \equiv y_t - y_{t-1} + g_t^*$,

$$\pi_t = \pi_t^e + \psi\left(g_t + y_{t-1} - g_t^*\right) + \varepsilon_t$$

and use this to substitute for g_t in (2),

$$U_t = -\frac{1}{2}\left(\left(\frac{\pi_t - \pi_t^e - \varepsilon_t}{\psi} - y_{t-1}\right)^2 + \left(\pi_t - \hat{\pi}\right)^2\right)$$

Maximizing with respect to π_t, the government's preferred policy is

$$\pi_t = \frac{\pi_t^e + \varepsilon_t + \psi y_{t-1} + \psi^2 \hat{\pi}}{1+\psi^2} \tag{3}$$

$$g_t = g_t^* - y_{t-1} + \frac{y_{t-1} - \psi\left(\pi_t^e + \varepsilon_t - \hat{\pi}\right)}{1+\psi^2}$$

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[4] See Kiefer (2000) for empirical evidence that only current conditions matter in political business cycle econometrics.

[5] Fischer (1977) is an early example in this literature.

[6] Barro and Gordon (1983) originally identified this inflationary bias. Their paper invokes a slightly different objective function based on unemployment and inflation, with an unemployment target below the natural rate. An inflation bias can result from either the unemployment or the inflation target.

Among other things, this implies that inflation and growth depend on conditions inherited from the past, expectations and policy targets. We assume that the government can implement its preferred policy through various policy instruments, and that the various government agencies (central banks and treasuries) pursue this common policy.

In the absence of shocks or uncertainty, the time-consistent equilibrium inflation rate should occur where inflation is just high enough so that the government is not tempted to spring a policy surprise. This equilibrium is the natural output, natural growth and an ideologically determined rate of inflation, $y = 0, g = g^*, \pi = \hat{\pi}$.

Ideally a rational agent uses available information to forecast inflation. The typical agent knows what the inflation target is; she also knows the slope of the Phillips curve, the long-run growth trend and the pre-existing economic condition. However, we suppose that she cannot predict the next inflation shock ε_t. Her information set is $I = \{\hat{\pi}, g_t^*, \psi, y_{t-1}\}$. This assumption about forecaster sophistication is strong. To obtain the rational expectation of π given I, we take the conditional expectation of the inflation equation (3) and solve:

$$\pi_t^e = E(\pi_t) = \hat{\pi} + \frac{y_{t-1}}{\psi}, \tag{4}$$

so that expectations are given by the government's inflation target with a correction for pre-existing economic conditions.[7] Substituting (4) into (3) gives the rational solution

$$\pi_t = \hat{\pi} + \frac{\varepsilon_t}{1+\psi^2} + \frac{y_{t-1}}{\psi} \tag{5}$$

$$g_t = g_t^* - y_{t-1} - \frac{\psi \varepsilon_t}{1+\psi^2}$$

A weak alternative is that inflation expectations are simply observed inflation in the previous year $\pi_t^e = \pi_{t-1}$, which we substitute into (3) as a regression specification. Commonly referred to as the adaptive expectations model, it assumes that agents are quick learners, but forgetful. Although many economists

[7] Before elections the situation can be less certain. Then, a sophisticated agent takes into account her opinion about the outcome of the upcoming election. Invoking rational expectations under these conditions, expected inflation equals a weighted average of partisan targets, with the appropriate weights being the agent's prediction of which party will hold power during the next period, see Alesina (1987). Here we ignore these complications in order to concentrate on the functional form of the government's objective.

view the adaptive model with suspicion because such forecasts can be irrational, adaptive behavior may often be found. This simple forecasting rule has the desirable property that it too can converge to the time-consistent equilibrium. For this reason we characterize the adaptive model as weakly rational.

4. Elliptical objectives

In light of the formal adoption of inflation targeting at a number of central banks, including the new European Central Bank, we consider a modification to our restrictive assumption that equal deviations from natural growth and the target inflation imply equal loss. We can generalize (2) to give elliptical, rather than circular, indifference curves with

$$U_t = -\frac{1}{2}\left(\left(g_t - g_t^*\right)^2 + \lambda\left(\pi_t - \hat{\pi}\right)^2\right), \tag{6}$$

where the strength of inflation targeting is parameterized by the magnitude of λ.[8] Another reason for considering the elliptical form is the literature on the advantage of a conservative central banker, originating with Rogoff (1985). Often this type of conservatism is modeled in terms of the λ weight.[9]

Certainly the assumption that λ=1 is restrictive; perhaps we can settle this issue empirically. Deriving the government's preferred policy as before, the elliptical solution is

$$\pi_t = \frac{\pi_t^e + \varepsilon_t + \psi y_{t-1} + \lambda\psi^2\hat{\pi}}{1+\lambda\psi^2}, \tag{7}$$

$$g_t = g_t^* - y_{t-1} + \frac{y_{t-1} - \lambda\psi\left(\pi_t^e + \varepsilon_t - \hat{\pi}\right)}{1+\lambda\psi^2}.$$

In this model the rational inflation expectation is $\pi_t^e = \hat{\pi} + \frac{y_{t-1}}{\lambda\psi}$. Substituting this expression into (7) gives the rational expectations solution

$$\pi_t = \hat{\pi} + \frac{\varepsilon_t}{1+\lambda\psi^2} + \frac{y_{t-1}}{\lambda\psi} \tag{8}$$

$$g_t = g_t^* - y_{t-1} - \frac{\lambda\psi\varepsilon_t}{1+\lambda\psi^2}$$

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[8] Alesina's (1988) objective function generalizes (6) by allowing growth targets other than the natural rate and by including future inflation and growth.

[9] A similar advantage also results from a policymaker who is conservative in the sense that her target is closer to zero than that of the public; see Kiefer (2005).

5. Growth targets

There are other plausible objective functions; below we survey a variety of quadratic alternatives. Instead of an inflation target, the government might have a growth rate target,

$$U_t = -\frac{1}{2}\left(\left(g_t - \hat{g}\right)^2 + \pi_t^{\,2}\right), \tag{9}$$

where $\hat{g}$ is the government's preferred rate of growth. While (2) could be motivated by seigniorage, this form may be interpreted as compensation for labor market or tax imperfections, or it may be that governments prefer high growth for ideological reasons. Thus it is possible that governments and voters target growth rates in excess of the natural growth rate, even when this is logically unsustainable.

Governmental options are still limited by the Phillips curve (1), and the economic-political equilibrium is still disturbed by exogenous shocks. As before we derive the government's policy by using the Phillips curve to substitute for g_t in the objective function. In this case the government's preferred policy is

$$\pi_t = \frac{\pi_t^e + \varepsilon_t + \psi y_{t-1} + \psi\left(\hat{g} - g_t^*\right)}{1+\psi^2}. \tag{10}$$

$$g_t = g_t^* - y_{t-1} + \frac{y_{t-1} - \psi\left(\pi_t^e + \varepsilon_t\right) + \left(\hat{g} - g_t^*\right)}{1+\psi^2}.$$

In the absence of shocks and uncertain government changes, the time-consistent equilibrium is the natural output, natural growth and an ideologically determined rate of inflation,

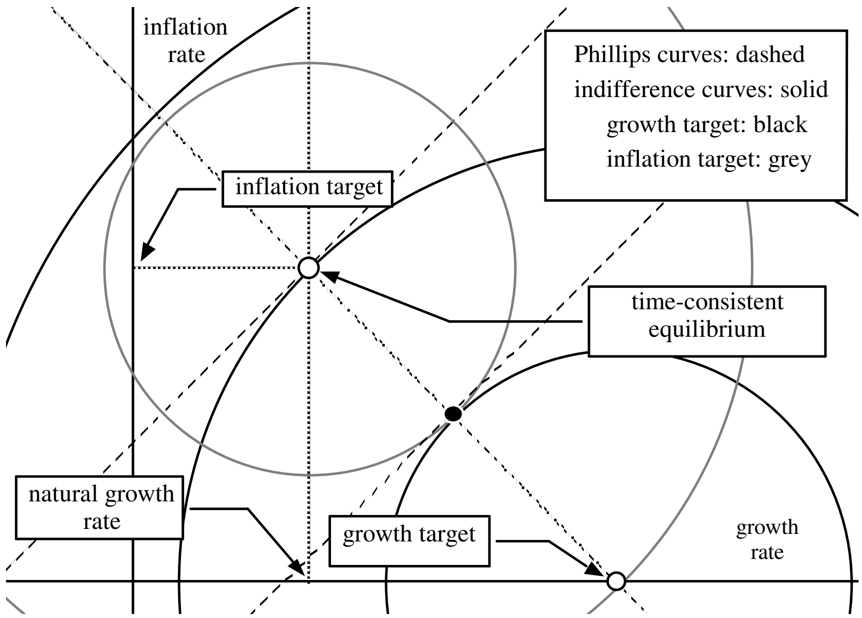
$$y = 0,\, g = g^*,\, \pi = \frac{\hat{g} - g^*}{\psi}.$$

An identification problem arises in the comparison of inflation and growth targets forms. Whenever $\left(\hat{g} - g_t^*\right) = \psi\hat{\pi}$, the solution (3) is indistinguishable from (10). This possibility is illustrated in Figure 1, where the two alternative forms give exactly the same set of tangency points.[10] However, notice that the growth target version implies a variable equilibrium (to the extent that g_t^* evolves over time), while the inflation target version assumes a fixed equilibrium. Thus, the two models do differ slightly, but, as

[10] In fact, the same conclusion holds for any target point along the dotted line joining these two targets.

empirical results below confirm, this difference may be insufficient to distinguish between them using only observations on inflation and growth.

Figure 1. Growth target versus inflation targets may be indistinguishable



In the case of a growth rate target, it can be seen that the rational expectation of π is $\pi_t^e = \frac{y_{t-1} + \hat{g} - g_t^*}{\psi}$. Substituting this expression into (10) gives the rational solution

$$\pi_t = \frac{\varepsilon_t}{1+\psi^2} + \frac{y_{t-1} + \hat{g} - g_t^*}{\psi} \tag{11}$$

$$g_t = g_t^* - y_{t-1} - \frac{\psi\varepsilon_t}{1+\psi^2}$$

We can also generalize the growth target form to elliptical indifference curves,

$$U_t = -\frac{1}{2}\left(\left(g_t - \hat{g}\right)^2 + \lambda\pi_t^{\,2}\right). \tag{12}$$

Now we find that the government's preferred policy is

$$\pi_t = \frac{\pi_t^e + \varepsilon_t + \psi y_{t-1} + \psi\left(\hat{g} - g_t^*\right)}{1+\lambda\psi^2}, \tag{13}$$

$$g_t = g_t^* - y_{t-1} + \frac{y_{t-1} - \lambda\psi\left(\pi_t^e + \varepsilon_t\right) + \left(\hat{g} - g_t^*\right)}{1+\lambda\psi^2}.$$

and the rational solution is

$$\pi_t = \frac{\varepsilon_t}{1+\lambda\psi^2} + \frac{y_{t-1} + \hat{g} - g_t^*}{\lambda\psi}, \tag{14}$$

$$g_t = g_t^* - y_{t-1} - \frac{\psi\varepsilon_t}{1+\psi^2}.$$

6. GDP gap objectives

Next we consider a related form parameterized on income levels rather than growth rates,

$$U_t = -\frac{1}{2}\left(y_t^{\,2} + (\pi_t - \hat{\pi})^2\right). \tag{15}$$

If voters are concerned about the income level rather than its growth rate, this is arguably the better form. Deriving the government's policy as before we find that the government's preferred policy is

$$\pi_t = \frac{\pi_t^e + \varepsilon_t + \psi^2\hat{\pi}}{1+\psi^2}, \tag{16}$$

$$g_t = g_t^* - y_{t-1} - \frac{\psi\left(\pi_t^e + \varepsilon_t - \hat{\pi}\right)}{1+\psi^2}.$$

In the absence of shocks, the time consistent equilibrium is unchanged, $y = 0, g = g^*, \pi = \hat{\pi}$.

Now the rational inflation expectation is $\pi_t^e = \hat{\pi}$. Substituting this expression into (16) gives the rational solution

$$\pi_t = \hat{\pi} + \frac{\varepsilon_t}{1+\psi^2} \tag{17}$$

$$g_t = g_t^* - y_{t-1} - \frac{\psi\varepsilon_t}{1+\psi^2}$$

Likewise, we can generalize the GDP gap form to elliptical indifference curves,[11]

$$U_t = -\frac{1}{2}\left(y_t^{\,2} + \lambda(\pi_t - \hat{\pi})^2\right). \tag{18}$$

Now we find that the government's preferred policy is

$$\pi_t = \frac{\pi_t^e + \varepsilon_t + \lambda\psi^2\hat{\pi}}{1+\lambda\psi^2}. \tag{19}$$

$$g_t = g_t^* - y_{t-1} - \frac{\lambda\psi\left(\pi_t^e + \varepsilon_t - \hat{\pi}\right)}{1+\lambda\psi^2}.$$

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[11] For example, see Clarida et al. (1999). Sargent et al. (2006) specify a generalized version of this objective based on unemployment rather than the GDP gap.

The time-consistent equilibrium is unchanged, as is the rational expectation. The rational solution is

$$\pi_t = \hat{\pi} + \frac{\varepsilon_t}{1+\lambda\psi^2} \tag{20}$$

$$g_t = g_t^* - y_{t-1} - \frac{\lambda\psi\varepsilon_t}{1+\lambda\psi^2}$$

7. Parabolic objectives

Another alternative quadratic form is a parabolic function,

$$U_t = g_i - (\pi_t - \hat{\pi})^2. \tag{21}$$

A shortcoming of the above forms is their implication of satiation with respect to growth. This parabolic form seems more plausible because it holds that governments are never sated.[12] We derive the policy as before,

$$\pi_t = \frac{1}{2\psi} + \hat{\pi}. \tag{22}$$

$$g_t = g_t^* - y_{t-1} + \frac{1}{2\psi^2} - \frac{\pi_t^e + \varepsilon_t - \hat{\pi}}{\psi}.$$

This solution implies that inflation depends only on the inflation target and the slope of the Phillips curve, while growth depends on expectations, lagged output and policy targets.

Now the rational expectation is $\pi_t^e = \frac{1}{2\psi} + \hat{\pi}$. Substituting into (22) gives the rational expectations solution

$$\pi_t = \frac{1}{2\psi} + \hat{\pi} \tag{23}$$

$$g_t = g_t^* - y_{t-1} - \frac{\varepsilon_t}{\psi}$$

The parabolic function can also be generalized with a policy weight on inflation analogous to our other elliptical forms.[13]

$$U_t = g_i - \lambda(\pi_t - \hat{\pi})^2. \tag{24}$$

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[12] For example, see Alesina (1987). Nordhaus (1975) considers a parabolic function with inflation as the linear term.

[13] See, for example, Alesina et al. (1997).

Now the solution is

$$\pi_t = \frac{1}{2\lambda\psi} + \hat{\pi}. \tag{25}$$

$$g_t = g_t^* - y_{t-1} + \frac{1}{2\lambda\psi^2} - \frac{\pi_t^e + \varepsilon_t - \hat{\pi}}{\psi}.$$

And substituting the rational expectation, $\pi_t^e = \frac{1}{2\lambda\psi} + \hat{\pi}$, into (25) gives the rational expectations solution

$$\pi_t = \frac{1}{2\lambda\psi} + \hat{\pi} \tag{26}$$

$$g_t = g_t^* - y_{t-1} - \frac{\varepsilon_t}{\psi}$$

Unfortunately the difference between the simple model and its policy-weighted generalization cannot be identified for either the adaptive and rational cases. Labeling the unweighted parameters with a tilde, it can be seen that the two parabolic models are indistinguishable whenever

$$\psi = \tilde{\psi} = \frac{1-\lambda}{2\lambda\left(\tilde{\hat{\pi}} - \hat{\pi}\right)}$$

8. Observed and unobserved data

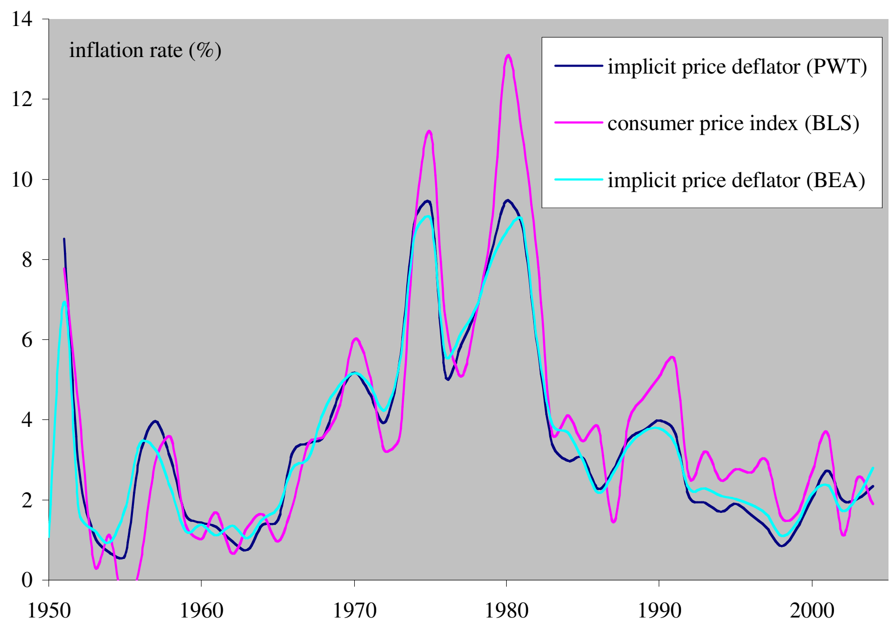
Although we may be unable to establish empirically a single most valid model, we nevertheless attempt to narrow the field by fitting the inflation and growth regressions implied by these eight objective functions and both expectations models. Our basic data are derived from the Penn World Table (PWT6.1), which includes internationally comparable time series on the national accounts for almost all the countries in the world for 1950-2004. Percentage growth is measured as the log difference in real GDP per capita; for details on variable construction see Table 1. Although it is customary to study stabilization outcomes with aggregate statistics, such analysis is equally appropriate with per capita data. The difference is that aggregate growth rates include population growth. Since population growth changes slowly, it has little effect on short-run stabilization.

Table 1. Variable definitions

	symbol	definitions using PWT 6.1 variable names
real GDP per capita	Y_t	$RGDPCH_t$
growth rate	g_t	$\ln(RGDPCH_t) - \ln(RGDPCH_{t-1})$
implicit deflator	p_t	$\dfrac{PPP_t(CGDP_t)}{PPP_{2000}(RGDPCH_t)}$
inflation rate	π_t	$\ln(p_t) - \ln(p_{t-1})$

The inflation rate is defined using the purchasing power parity and GDP estimates from the PWT. In Table 1 the numerator of the implicit deflator is GDP per capita measured in current local currency, and the denominator is the same quantity measured in real terms (2000 local currency units). Figure 2 compares this measure of inflation to official US statistics. It is clear that they are quite close and that the PWT measure can be interpreted as an implicit deflator rate, and is an appropriate indicator of macrostabilization.

Figure 2. Comparing inflation rates: US



Measuring the conceptual shock variable accurately is problematic. There are many potentially important types of shocks to consider. Here we use the world inflation rate of crude oil; see Campbell (2005).

Our models call for measures of macroeconomic disequilibrium and the underlying output trend. The published series include only real output per capita Y_t, and not its natural level Y_t^*, nor the rate of growth of natural output g_t^*. We apply the state space methodology to incorporate a recursive description of these unobserved state variables, specifying natural growth as a random walk, and defining the level of natural GDP recursively as

$$\begin{aligned} g_{t+1}^* &= g_t^* + \upsilon_t \\ \ln\left(Y_{t+1}^*\right) &= \ln\left(Y_t^*\right) + g_t^* \end{aligned} \tag{28}$$

where $\upsilon_t \sim N(0, \sigma_\upsilon^2)$. The observable variables of each model are written as a two-equation reduced form for inflation and growth of the form,

$$\begin{aligned} \pi_t &= \Pi\left(\pi_t^e, \varepsilon_t, \ln\left(Y_{t-1}\right)\ln\left(Y_{t-1}^*\right)g_t^*\right) + \mu_t \\ g_t &= G\left(\pi_t^e, \varepsilon_t, \ln\left(Y_{t-1}\right)\ln\left(Y_{t-1}^*\right)g_t^*\right) + \xi_t \end{aligned} \tag{29}$$

where the functions Π and G given by the various theoretical solutions: (3), (7), (10), (13), (16), (19), (22) and (25). Equations (28) are called the state equations, and (29) the observation equations.[14] Equations (29) are linear in variables but nonlinear in their coefficients. The two error terms have normal distributions: $\mu_t \sim N(0, \sigma_\mu^2)$ and $\xi_t \sim N(0, \sigma_\xi^2)$.

Conditional of the observations up to the t^{th} period, the Kalman filter defines a recursive forecast of the unobserved state variables for the next period, $\ln\left(\hat{Y}_{t+1|t}^*\right)$and $\hat{g}_{t+1|t}^*$. These Bayesian updates are a weighted average of the previous forecast and current observations, given the model specification. Although there is no guarantee that governments learn according to Bayes rule, we interpret these predictions as a rational basis for stabilization policy, our estimate of what the policymakers could have thought about the underlying potential of the economy at the time that policy decisions were taken. These Kalman filter forecasts are conditional on unknown model parameters, for example the invariant parameters in the inflation target model are $\psi, \hat{\pi}, \sigma_\upsilon^2, \sigma_\mu^2$ and σ_ξ^2. We estimate the invariant parameters, along with the evolving state variables, by maximizing the model's likelihood function. The state space methodology is initialed with prior opinions about the initial state variables, $\ln\left(\hat{Y}_{1|0}^*\right)$and $\hat{g}_{1|0}^*$, and their variances.

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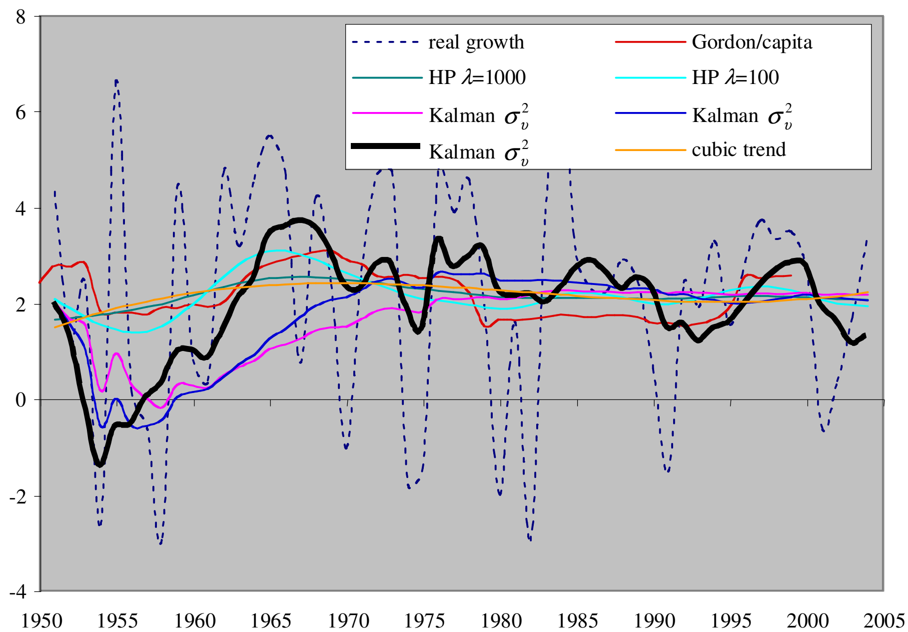
[14] See Hamilton (1994) for a textbook presentation of this methodology, and Harvey (1985) for an application to business cycles.

9. An empirical comparison of modeling assumptions

The natural rate literature reports other methods of estimating these unobserved variables. Gordon (1999) reports estimates calculated by picking a list of benchmark dates when he judges that the US economy approximated macroequilibrium, and then takes the natural growth rate between these benchmarks as constant.[15] Figure 3 compares our Kalman filter estimates natural growth with three alternatives: Gordon's benchmark-interpolation, the Hodrick-Prescott filter and a cubic trend.[16]

Figure 3. Alternatives estimates of the natural growth rate



Conventionally the natural level changes over time as technology advances and as capital is accumulated, assuming that these influences evolve slowly an independently of business cycles. Accordingly, researchers have imposed smoothness restrictions on natural growth. Gordon enforces constancy between benchmarks. The HP filter estimates of the natural rate series by minimizing the expression

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[15] Gordon (2003) compares his benchmark-interpolation method with alternatives based on the Kalman and Hodrick-Prescott filters. His benchmarks are: 1949Q1, 1954Q1, 1957Q3, 1963Q3, 1970Q2, 1974Q2, 1979Q3 1987Q3, 1990Q4, and 1995Q1. To make the series comparable, we convert Gordon's statistics from an aggregate basis to per capita by subtracting US population growth.

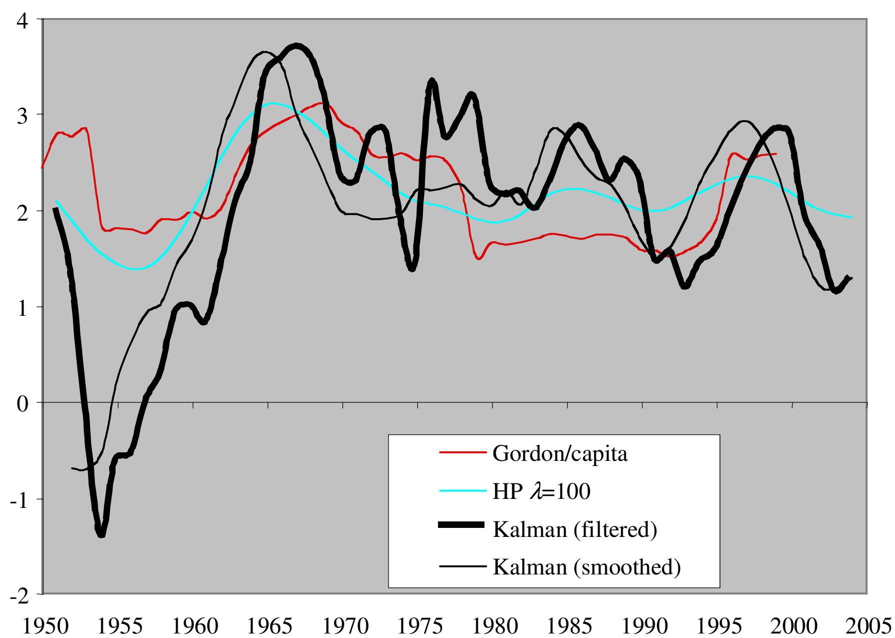
[16] These Kalman filter results all derive from a circular inflation target model under adaptive expectations, labeled model (a) in Table 3 below.

$$\sum_{t=0}^{T}\left\{\left(g_t-g_t^*\right)^2+\lambda\left[\left(g_{t+1}^*-g_t^*\right)+\left(g_t^*-g_{t-1}^*\right)\right]^2\right\},$$

where λ an arbitrary smoothness parameter that penalizes sharp curves in the g_t^* series. Kiefer (2000) predicts the natural growth rate as a cubic trend by fitting the regression, $g_t=\beta_0+\beta_1 t+\beta_2 t^2+\beta_3 t^3$; here smoothness is determined by the order of the polynomial.[17]

The Kalman filter can also smooth the natural growth by restricting σ_υ^2 to a small value. Of the three Kalman estimates plotted, the bold path maximizes likelihood of the data, while the other two impose smoother paths on g_t^*.[18] All methods illustrate the conclusion that the underlying growth rate of the US economy has changed over time. They show a slight slowing of growth for the US following a peak in the late 1960s, with an acceleration in the 1990s.

Figure 4. Comparing smoothed and filtered estimates of the natural growth rate



Clearly the bold Kalman path is more volatile than the usual estimates. The early years of our sample show a marked difference between all three Kalman estimates and the alternatives. These

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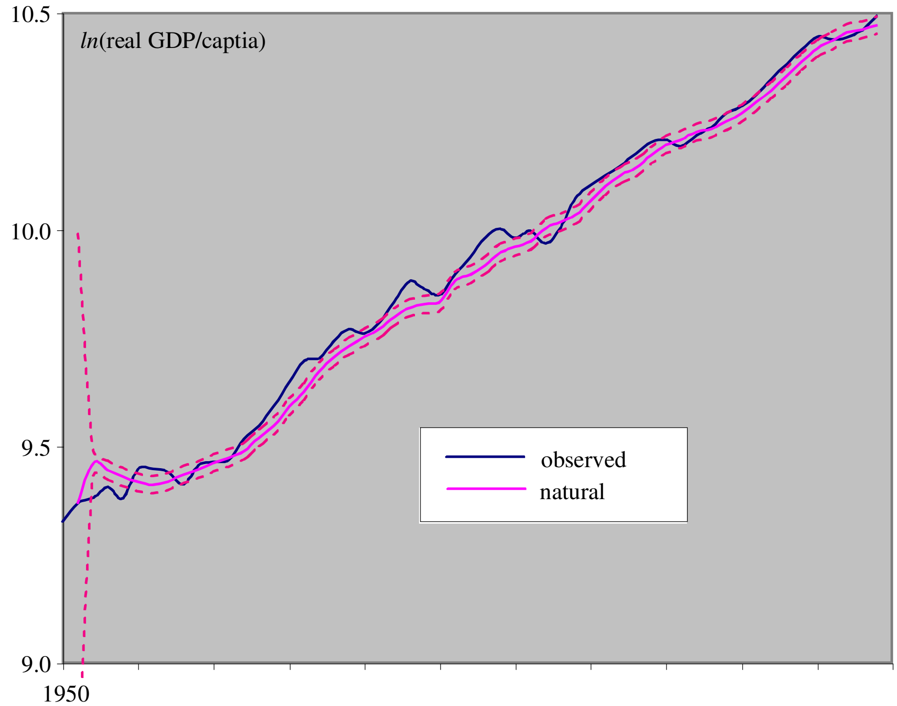
[17] In a related study, Staiger et al. (1997) model the trend in natural unemployment as a cubic spline with two knots.

[18] We specify $\hat{g}_{1|0}^*=2$ with a variance of 1 as a plausible prior for the natural growth, and $\ln\left(\hat{Y}_{1|0}^*\right)=9.37$ (the observed value in 1951) with a variance of 0.1.

differences reflect different assumptions about natural growth as well as different methods of estimation. The benchmark-interpolation, HP filter and cubic trend all impose a gradually evolving process, without large shifts. On the other hand, the Kalman filter assumes that the generating process is a random walk, typified by small random shifts, which can be occasionally large. An appealing methodological feature of the Kalman filter is that it is estimated recursively on past observations only, not future ones. This explains why it becomes smoother and converges with the others as more observations become available. The other methods are omniscient in the sense that they include both past and future observations. These are more comparable to "smoothed" Kalman predictions of the state variables conditioned on the entire data set, $\hat{g}^*_{t|T}$, see Figure 4. Although the smoothed estimate is less volatile, it is not always closer to the alternative estimates than the filtered estimate. Nor does smoothing remove the anomaly in the 1950s. Perhaps the underlying growth rate of the US economy then was slower than previously recognized.

Consequently we may want to impose a smaller variance on the natural growth process. It appears that our maximum likelihood estimate is inconsistent with the conventional notion of long-term growth to the extent that our σ_v^2=0.35 estimate is overly responsive to the business cycle. However, Figure 5 shows that the implied prediction of the logarithm of natural GDP/capita is still rather stable even though our predicted growth path is rather bumpy. It also shows how quickly observations come to dominate our prior.

Figure 5. Comparing observed GDP/capita with the maximum likelihood prediction its natural level



The likelihood statistics in Table 2 are the basis for our inferences about social welfare functions; these results cover 1952-2004. Each model, specification (28) and (29), is identified by its social welfare equation number. The table is divided into two different assumptions about the volatility of the natural growth rate. The results support the inference that government behavior is most like the circular inflation target model regardless of the assumption about the smoothness of the natural growth process. For a benchmark we estimate a simple VAR(1) model in growth and inflation rates; its log likelihood is –215. These estimations are repeated as a comparison of alternative models of expectation formation. First we assume adaptive, or weakly rational, expectations. For example, replacing π_t^e by π_{t-1} in (3) gives the specification for the circular inflation target model under adaptive expectations. And, second we invoke the strongly rational expectations. For example, using (5) gives the circular inflation target model under rational expectations. The results suggest the empirical superiority of the adaptive model of expectations; none of the rational expectations models exceed the VAR(1) benchmark. These results also validate our conjecture that it will be difficult to distinguish empirically between the models with inflation as a target and those with growth as target.

Table 2. Comparing models log likelihood statistics: US, 53 observations, 1952-2004

Natural growth variance	$\sigma_v^2 = 0.01$		$\sigma_v^2 = 0.35$	
Expectation assumption	Adaptive	rational	Adaptive	rational
circular inflation target (2)	-212	-255	-197	-240
elliptical inflation target (6)	-209	-255	-197	-240
circular growth target (9)	-214	-255	-201	-239
elliptical growth target (12)	-211	-255	-200	-239
circular output target (15)	-232	-263	-217	-254
elliptical output target (18)	-230	-260	-217	-251
parabolic (21)	-262	-263	-247	-254
weighted parabolic (24)	-262	-263	-247	-254

Table 3 reports detailed results for some of the more likely specifications, shaded in Table 2. In all cases the estimated target variable implies equilibrium inflation rates of around 3% or 4%. The estimated slopes of the Phillips curve are positive and statistically significant. However, none of the crude oil shock coefficients are significant. The circular specifications are restrictive because they impose the value judgment that inflation and growth are equally important in determining policy, but there may be merit in this restriction since neither of the weighting parameters is significantly different from unity.

As an extension of our basic results were re-specify the inflation target $\hat{\pi}$ in the models (a) and (b) as a time-varying coefficient in models (g) and (h). We suppose that the target as influenced by many factors, including the ideologies of the President, the Congress, the Governor of the Federal Reserve, the stage in the election cycle, and the fashions of conventional economic wisdom. Before of attempting to quantify these influences, we simply model them as a random walk, $\pi_{t+1} = \pi_t + \zeta_t$, where $\zeta_t \sim N\left(0, \sigma_\zeta^2\right)$. This evolving target model can be interpreted as the addition of a third state variable to (28).

Table 3. Detailed regression result from selected models (z statistics in parentheses)

Model	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Objective function	circular inflation target	circular inflation target	circular inflation target	elliptical inflation target	circular growth target	elliptical growth target	circular inflation target	circular inflation target
Expectation assumption	adaptive	rational	adaptive	adaptive	adaptive	adaptive	adaptive	rational
Natural growth variance	$\sigma_{\upsilon}^2 = 0.35$	$\sigma_{\upsilon}^2 = 0.35$	$\sigma_{\upsilon}^2 = 0.01$	$\sigma_{\upsilon}^2 = 0.35$	$\sigma_{\upsilon}^2 = 0.35$	$\sigma_{\upsilon}^2 = 0.35$	$\sigma_{\upsilon}^2 = 0.35$	$\sigma_{\upsilon}^2 = 0.35$
Phillips curve slope	0.65	1.39	0.34	0.65	0.65	0.62	1.06	2.54
	(8.74)	(6.12)	(7.14)	(6.19)	(7.26)	(5.16)	(5.76)	(7.25)
Target	3.63	3.44	3.43	3.63	4.32	5.27	3.52*	3.41*
	(8.08)	(10.16)	(3.14)	(8.10)	(8.94)	(6.37)	NA	NA
Goal weighting				1.02		1.46		
				(0.08)+		(1.07)+		
Crude oil shock	0.011	-0.020	0.010	0.011	0.011	0.013	0.008	-0.120
	(1.93)	(-1.70)	(0.85)	(1.77)	(1.41)	(1.64)	(1.14)	(-1.35)
Log likelihood	-197	-240	-212	-197	-201	-200	-197	-214

* The average of the random coefficient series.

+ $H_o : \lambda = 1$.

Our results show that this specification does not effect the fit of the adaptive model (a), but it does dramatically improve that of the rational model (b), although the adaptive version is still much more likely to have generated the observed outcomes.[19] Probably model (b) suffers from the restriction that the target (and by (4) the expected inflation rate) is fixed throughout the sample period, while model (a) accommodates changing economic conditions better with its simplistic expectation assumption. Here we have less interest in the one-year-ahead recursive forecast of the government's target, than in the "smoothed" estimate of the target $\hat{\pi}_{t|T}$ based on the entire data set. Figure 6 plots smoothed estimates of target trajectories. Our results show a continuous evolution, averaging about 3.5% for both the adaptive expectations and rational expectations assumptions. There were two low points at about a 2%-target, in the early 1960s and again late 1990s; and there is a high point at about a 7%-target in the 1970s. In recent years

[19] Model (g) defines the variance of the random target as a free parameter, maximizing the likelihood function at $\hat{\sigma}_{\zeta}^2 = 0.5$. However, there is no such maximum for model (h); its likelihood continues to fall as σ_{ζ}^2 increases until the model becomes divergent at $\sigma_{\zeta}^2 = 0.9$. For comparability with (g), we report model (h) results for identical variances, $\hat{\sigma}_{\zeta}^2 = 0.5$. This is a shortcoming of model (h). Other shortcomings are the rather steep Phillips curve estimate and the wrong sign for the crude oil shock effect.

the target appears to have risen slightly. The link between the target and observed inflation rates is also apparent; this is especially tight for the rational estimate of the target.[20]

Figure 6. The inflation targets as a random coefficient, or a reflection of political ideology

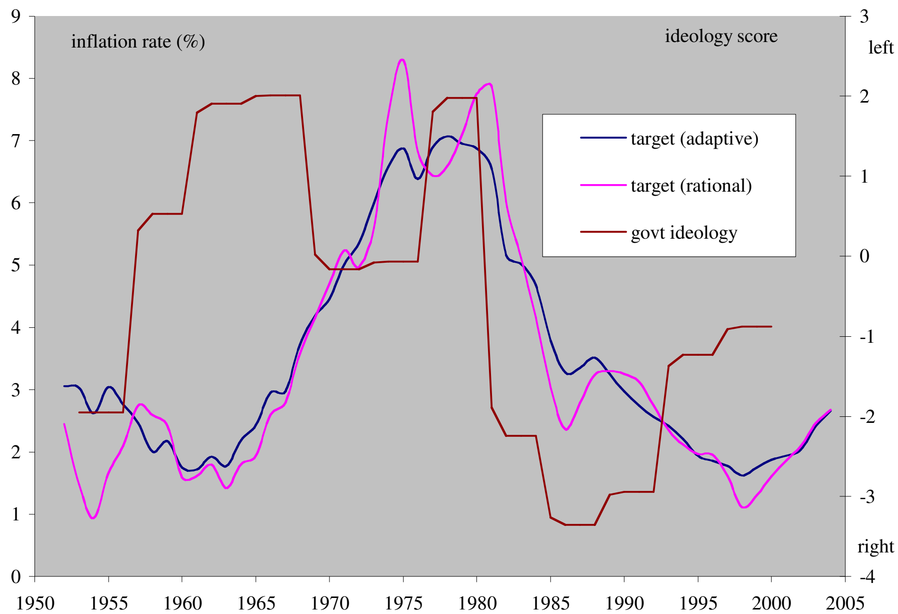


Figure 6 also compares these estimates to measures of ideology as a possible explanation of our results. Budge et al. (2001) publish Left-Right scores for political parties during 1953-1998 derived from a content analysis of pre-election platforms and manifestos; their scores range from 10 at the extreme Left to -10 at the extreme Right.[21] For the years in which the presidency changes we define annual government ideology score as averages, weighted according to the months in office. Thus, for example, since the president takes office in January, the out-going president's ideology is given a weight of 1/12th for that year. By this measure the second Reagan Administration was the farthest to the Right, while the Johnson and Carter Administrations were nearly tied for the farthest Left. Apparently, the connection between the inflation target and ideology is weak; the disparity between the ideology scores of Presidents Kennedy and Johnson and their revealed inflation target is obviously large.

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[20] Sargent et al. (2006) apply a similar model in a study of US experience with high inflation. While our model (g) specifies the target and the natural rate as state variables with the slope of the Phillips curve fixed, theirs takes the slope of the Phillips curve as a state variable with the target and the natural rate as fixed.

[21] We rescore Budge's –100 to +100 scale for convenience. These data are published online by Michael McDonald at www.binghamton.edu/polsci/research/mcdonalddata through 1995.

Nevertheless we explore a simple model of the government's target in which rightwing governments aim for lower inflation targets, we re-specify model (a) with $\pi = \pi^0 + \pi^\rho \rho_t$ where ρ_t is Budge's ideology measure. We obtain the result

$$\underset{(3.08)}{\pi = 4.00} + \underset{(1.44)}{0.88\rho_t} \qquad \text{log likelihood} = -181.8$$

Because the sample is diminished to 1953-2000 by availability of the ideology data, this likelihood statistic is not comparable to those above. A comparable re-estimation of model (h) for this sample achieves a log likelihood of –180.3. Thus, although the effect of ideology has the expected sign, it is statistically insignificant, and the model fit is inferior to that of random coefficient specification.

10. Conclusion

We develop a model of political and economic interaction, and test its relevance to the macroeconomic history. We conclude that the endogenous stabilization hypothesis contributes to our understanding of aggregate outcomes. Endogenous stabilization models are statistically superior to a more agnostic alternative, as long as we invoke an adaptive theory of expectations, rather than the more conventional rational theory. Even with a careful modeling the strongly rational model of expectations does not improve on a naive benchmark.

With regard to the functional form, an inflation target objective function is most likely to have generated the US observations, although a growth function fits nearly as well. It is more likely that the social welfare arguments are inflation and growth, rather than inflation and the GDP gap. And, it is even more likely that the function is quadratic, rather than parabolic.

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