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A 2-Equation Model of the North Atlantic Economies, a Dynamic Panel Study

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A 2-Equation Model of the North Atlantic Economies, a Dynamic Panel Study

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Abstract

Carlin and Soskice (2005) advocate a 3-equation model of stabilization policy to replace the conventional IS-LM-AS model. One of their new equations is a monetary reaction rule MR derived by assuming that governments have performance objectives, but are constrained by an augmented Phillips curve PC. They label their replacement model the IS-PC-MR. Central banks achieve the PC-MR solution by setting interest rates along an IS curve. Observing that governments have more tools than just the interest rate, we simplify their model to 2 equations. We develop a state space econometric specification as the solution of these equations, adding a random walk model of the unobserved potential growth. Applying this method to a panel of North Atlantic countries, we find it historically consistent with a few qualifications. For one, governments are more likely to target growth rates, than output gaps. And, inflation expectations are more likely backward looking, than rational, but a two-step estimation based on a forward-looking sticky-price model dramatically improves the empirical fit. Significant interdependence can be seen in the between-country covariance of inflation and growth shocks.

Keywords: new Keynesian, Kalman filtering, open economies
JEL Classification: E61, E63

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1. Introduction

Central to Carlin and Soskice's new approach to stabilization policy is a monetary reaction rule derived by assuming that governments have inflation and output targets, but are constrained by a Phillips curve.[1] A number of alternative assumptions are consistent with this approach. One of these relates to the functional form of the government's objective function. Keeping the inflation target, we highlight the differences between an output gap target and an output growth target. Using the state space methodology to specify a coherent model of policy formation, we estimate the dynamic behavior of inflation and growth for 14 democracies.[2] This methodology is appropriate because our model involves unobserved state variables: the output gap and potential growth rate. By formalizing the relation between observables and unobservables, it provides Bayesian forecasts of the unobservables at each point in time conditioned on available information. A comparison of our estimates of the potential growth shows significant differences from conventional smoothed estimates.

The state space methodology is also appropriate for globally linked economies. Although we do not formally model international trade, we introduce linkages in the form of the between-country covariance of shocks. We find substantial international covariance in inflation and growth shocks, but little covariance in the underlying productivity shocks. We also find that when contemporary covariances are well specified, there is little empirical justification for *ad hoc* autocorrelation.

Because expected inflation enters the analysis as a shift in the Phillips curve, another modeling assumption concerns the formation of inflation forecasts. We explore econometric specifications for several possibilities: strongly rational expectations, simple adaptive ones and the new Keynesian sticky-price model. Rationality is the overwhelming assumption of the economics literature because it coheres with the notion on well-informed forward-looking agents. We find, however, that its implications do not conform

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[1] This model also known as the monetary policy model, or political business cycle. The original insight for this literature dates to Kalecki (1943); also see Nordhaus (1975). Modern versions begin with Kydland and Prescott (1977) who introduced the logic of rational expectations; Barro and Gordon (1983) further develop this logic.

[2] These are Austria, Belgium, Canada, Denmark, Finland, France, Ireland, Italy, Netherlands, Norway, Sweden, Switzerland, United Kingdom and United States.

well to observed outcomes when applied in our model; a simple adaptive model fits the data better. Significantly, we develop a two-step method of estimating a forward-looking sticky-price model that dramatically improves the empirical fit.

2. Economic structure and objectives

The literature invariably invokes an augmented Phillips curve as a structural constraint on policymakers.[3] Conventionally this is an inverse relation between the unexpected inflation and the gap between actual and natural unemployment. Since the potential output Y_t^* is conceptually related to the equilibrium or natural rate of unemployment, the output gap is often substituted for the unemployment gap as the measure of macroeconomic disequilibrium,

$$\pi_t = E_{t-1}\pi_t + \psi x_t + \varepsilon_t, \tag{1}$$

where π_t is the inflation rate, $x_t \equiv \ln(Y_t) - \ln(Y_t^*)$ is the output gap, Y_t is real output and ε_t an inflation shock. Expected inflation is $E_{t-1}\pi_t$, interpreted as the forecast of a typical agent based on information available in the previous year; the expectations subscript gives the date of the forecast. Assuming expectations are fulfilled in the long run, this relation rules out any long-run deviation from $x = 0$. However, as long as economic agents do not fully anticipate inflation shocks or the counteracting effects of fiscal, monetary and other policies, governments are able to temporarily increase output at the cost of higher inflation.

Another essential element is an assumption about political objectives. A popular possibility supposes that the government's goals are given by a quadratic function of the output gap and inflation,[4]

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

where $\hat{\pi}$ is the inflation target. Textbooks often define social welfare as an aggregation of individual preferences. Woodford (2003) establishes microfoundations for several close relatives of this function form as an approximation to the utility of a representative consumer-worker. Differing targets for inflation could

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[3] See, for example, Nordhaus (1975) or Alesina (1987).

[4] For example, see Clarida et al. (1999).

account for ideological differences. Governmental targets may reflect a weighted average of citizen preferences.

Quadratic forms are tractable because they result in linear solutions.[5] 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 output goals. Some models allow parabolic indifference curves.[6] Often the output target exceeds its potential level.[7] Kiefer (2008) estimates eight different quadratic forms. He confirms the conventional wisdom that it is not possible to statistically separate the goal weight, inflation target and that for output.[8] Thus, our inflation target parameter can be interpreted as a composite measure of weights and targets. We report evidence below that a growth rate target model fits the data better than the output target.[9]

3. Optimal stabilization with an inflation target

The government has limited options in the new Keynesian model; it exploits information and implementation advantages to lean against the macroeconomic wind.[10] The government has an information advantage over agents, many of whom are locked into contracts made earlier; we explore an alternative perfect information assumption below. The short-run equilibrium is disturbed by exogenous shocks. To derive the government's reaction, we use the Phillips curve to substitute for x_t and in (2),

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

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

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[5] Ruge-Murcia (2003) presents evidence that questions the conventional linearity assumption. He develops an alternative where the government's inflation preferences are asymmetrical around its target.

[6] See, for example, Romer (1993) or Alesina et al. (1997).

[7] Barro and Gordon (1983) assume a zero inflation target and an unemployment target below that natural rate.

[8] Also see Ireland (1999).

[9] Objectives might also include the discounted value of expected future 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. See Kiefer (2000) for empirical evidence that only current conditions matter in political macroeconometrics.

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

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

This reaction rule is part of the solution to Carlin and Soskice's model.

Using the Phillips curve we find that the preferred output gap is

$$x_t = -\frac{\psi\left(E_{t-1}\pi_t - \hat{\pi}\right)}{1+\psi^2} - \frac{\psi\varepsilon_t}{1+\psi^2}.$$

Output gap and the growth rate are equivalent measures of stabilization policy because the real output growth rate can be defined in terms of the output gap as $g_t \equiv x_t - x_{t-1} + g_t^*$, where the growth rate is $g_t \equiv \ln(Y_t) - \ln(Y_{t-1})$, and $g_t^* \equiv \ln(Y_t^*) - \ln(Y_{t-1}^*)$ the potential rate of growth. Consequently, we can rewrite the output gap rule as preferred growth,

$$g_t = -\frac{\psi\left(E_{t-1}\pi_t - \hat{\pi}\right)}{1+\psi^2} - \frac{\psi\varepsilon_t}{1+\psi^2} - x_{t-1} + g_t^*. \tag{4}$$

This has the econometric advantage of putting an observable variable on the left-hand-side.

Among other things, (3) and (4) imply that observed inflation and growth depend on inflation shocks, conditions inherited from the past, expectations and policy targets. We assume that the government can implement its policy through various policy instruments, and that the various government agencies (central banks and treasuries) pursue this common policy. Some authors allow the perceptions of the policymakers about the structure of the economy to differ from reality; our model allows only for prediction errors with respect to the output gap and the potential growth rate, not the slope of the Phillips curve.[11] Equation (4) reflects the conventional conclusion that optimal policy perfectly accommodates any shifts in the potential output.[12]

In the long run rational agents come to understand that a policy of $\hat{\pi} > 0$ implies inflation; this expectation is a self-fulfilling prophecy. 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

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[11] See Sargent et al. (2006).
[12] See Clarida et al. (1999).

tempted to spring a policy surprise. This equilibrium occurs at the potential output, potential growth and the inflation target, $x = 0, g = g^*, \pi = \hat{\pi}$.

Logically a rational agent uses available information to forecast inflation. The typical agent knows the government's inflation target; she also knows the slope of the Phillips curve, the potential growth rate and the pre-existing economic condition. However, we maintain the Keynesian assumption that she cannot predict the contemporaneous shock, $E_{t-1}\varepsilon_t = 0$. This is a strong assumption about forecaster sophistication. To obtain the rational expectation of π given the information set $I = \{\hat{\pi}, g_t^*, \psi, x_{t-1}\}$, we take the conditional expectation of (3). We find that $E_{t-1}\pi_t = \hat{\pi}$.[13] Substituting into (3) and (4) gives the rational solution

$$\begin{aligned} \pi_t &= \hat{\pi} + \frac{\varepsilon_t}{1+\psi^2} \\ g_t &= -\frac{\psi\varepsilon_t}{1+\psi^2} - x_{t-1} + g_t^* \end{aligned} \tag{5}$$

We assume that the government exploits an information advantage to actively determine inflation and growth; this is controversial. The new classical literature assumes no such advantage, asserting instead that agents and the government both know the inflation shock before they act.[14] In the perfect information case agents predict inflation accurately, $E_t\pi_t = \pi_t$ and $x_t = -\frac{\varepsilon_t}{\psi}$. It then follows that the macroequilibrium is

$$\begin{aligned} \pi_t &= \hat{\pi} + \frac{\varepsilon_t}{\psi^2} \\ g_t &= -\frac{\varepsilon_t}{\psi} - x_{t-1} + g_t^* \end{aligned} \tag{6}$$

Note that the only difference between these rational and new classical solutions is their error specification.

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[13] 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 year, see Alesina (1987). We investigate election effects further below.

[14] See for example Barro and Gordon (1983) or Ireland (1999).

An alternative to rational expectations is the simple assumption that the forecast is the previous year's observation, $E_{t-1}\pi_t = \pi_{t-1}$. Often referred to as adaptive expectations, it assumes that agents are quick learners (one year), but forgetful (disregarding earlier observations).[15] Although many economists view such backward-looking models with suspicion because they lack microfoundations and because their forecasts can be irrational, they are well known to provide a good empirical fit. This simple forecasting rule has the desirable property that it too can converge to the time-consistent equilibrium. Below we explore an alternative specification that introduces a forward-looking new Keynesian Phillips curve.

4. Growth targets

Next we consider a related objective function parameterized on growth rates, rather than output levels,

$$U_t = -\frac{1}{2}\left(\left(g_t - g_t^*\right)^2 + \left(\pi_t - \hat{\pi}\right)^2\right). \tag{7}$$

Although this specification is uncommon, it is arguably the better form if voters are more concerned about the growth rate than the level of output. Woodford (2003) derives a similar form from microfoundations under the assumption that the representative citizen's utility exhibits habit persistence. Deriving the government's policy as before we find that the government's preferred outcome becomes

$$\begin{aligned} \pi_t &= \frac{E_{t-1}\pi_t + \psi x_{t-1} + \psi^2\hat{\pi}}{1+\psi^2} + \frac{\varepsilon_t}{1+\psi^2} \\ g_t &= -\frac{\psi^2 x_{t-1} + \psi\left(E_{t-1}\pi_t - \hat{\pi}\right)}{1+\psi^2} - \frac{\psi\varepsilon_t}{1+\psi^2} + g_t^* \end{aligned} \tag{8}$$

Comparing the two solutions, (3) and (4) versus (8), we see that only differences involve the lagged value of the output gap, which now enters the inflation reaction function. The lagged gap still influences preferred growth, but its impact is reduced in (8). In the absence of shocks, the time consistent equilibrium remains unchanged, $x = 0,\ g = g^*,\ \pi = \hat{\pi}$.

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[15] The "adaptive" label has also been applied to more complicated specifications of expectations, which include more than two or more lags of inflation, or even the rational expectations. Our specification is a special case of these alternatives.

Now the rational expectation is $E_{t-1}\pi_t = \hat{\pi} + \frac{x_{t-1}}{\psi}$, again determined by the target, but now with a correction for pre-existing economic conditions. Accordingly, the rational solution is

$$\begin{aligned} \pi_t &= \hat{\pi} + \frac{x_{t-1}}{\psi} + \frac{\varepsilon_t}{1+\psi^2} \\ g_t &= -\frac{\psi\varepsilon_t}{1+\psi^2} - x_{t-1} + g_t^* \end{aligned} \tag{9}$$

Under new classical assumption, the solution is

$$\begin{aligned} \pi_t &= \hat{\pi} + \frac{x_{t-1}}{\psi} + \frac{\varepsilon_t}{\psi^2} \\ g_t &= -\frac{\varepsilon_t}{\psi} - x_{t-1} + g_t^* \end{aligned} \tag{10}$$

Solutions (9) and (10) differ from the gap target solutions (5) and (6) by the addition of a term for previously exiting conditions in the inflation equation.

6. Observed and unobserved data

Using a theoretical argument, Clarida et al (2001) find that stabilization policy for open economies is qualitatively the same as that of the closed economy. We study the above models with a panel of countries. Our basic data are derived from the Penn World Table (PWT6.2), 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. We add a subscript to all variables to indicate the i^{th} country. Although it is customary to study stabilization outcomes with aggregate statistics, such analysis is equally appropriate with per capita data.[16]

Table 1. Variable definitions

	symbol	definitions using PWT 6.2 variable names
real GDP per capita	Y_{it}	$RGDPCH_{it}$

[16] The difference is that aggregate growth rates include population growth. Since population growth changes slowly, it has little effect on short-run stabilization.

growth rate	g_{it}	$100\left[\ln\left(RGDPCH_{it}\right)-\ln\left(RGDPCH_{it-1}\right)\right]$
implicit deflator	p_{it}	$\frac{PPP_{it}\left(CGDP_{it}\right)}{PPP_{i2000}\ \left(RGDPCH_{it}\right)}$
inflation rate	π_{it}	$100\left[\ln\left(p_{it}\right)-\ln\left(p_{it-1}\ \right)\right]$
openness	w_{it}	$OPENC_{it}$

An inflation rate is defined using 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 1 compares this measure of domestic inflation to official US statistics. It is clear that they are quite close and that the PWT measure can be interpreted as the domestic implicit deflator rate, an appropriate indicator of macrostabilization.

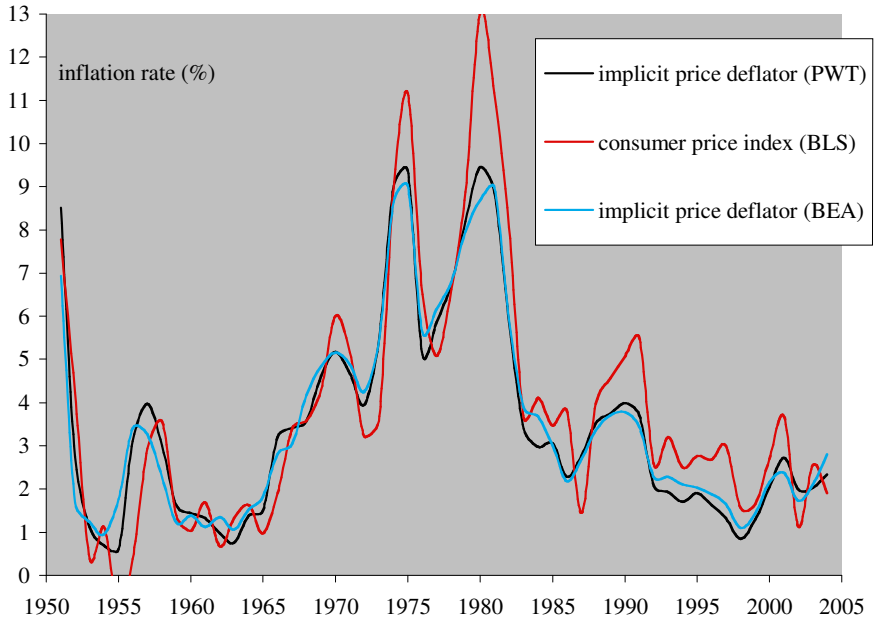
Our solutions call for a measure of output gap and the underlying potential trend. We apply the state space methodology to model the unobserved state variables: specifying potential growth as a random walk, and defining the level of potential GDP and the output gap recursively as

$$\begin{aligned} g^*_{it} &= g^*_{it-1} + \upsilon_{it} \\ \ln\left(Y^*_{it}\right) &= \ln\left(Y^*_{it-1}\right) + g^*_{it} \\ x_{it} &= \ln\left(Y_{it}\right) - \ln\left(Y^*_{it}\right) \end{aligned} \tag{11}$$

where $\upsilon_{it} \sim N(0,\sigma^2_{\upsilon})$. This is a simple, agnostic model of potential output and it's dynamics; others are certainly plausible.[17] Although these potential rates follow different paths in the different countries, we assume that their variances are the same. It seems plausible that these technological productivity shocks υ_{it} may be correlated across countries; thus we specify that $\mathrm{cov}\left(\upsilon_{it},\upsilon_{jt}\right)=\sigma^2_{\upsilon b}$ for $i \neq j$. We assume that these shocks are serially independent, $\mathrm{cov}\left(\upsilon_{it},\upsilon_{it-s}\right)=0$, and independent of inflation shocks $\mathrm{cov}\left(\upsilon_{it},\varepsilon_{it}\right)=0$.

[17] Natural growth and natural unemployment are analogous processes. Barro and Gordon (1983) assume that natural unemployment follows an AR(1) process, Gordon (1997) assumes a random walk, Ireland (1999) assumes an ARIMA(1,1,0) and Ruge-Murcia (2003) a higher order ARIMA. Of course, a random walk in natural growth is identical to an I(2) process in $\ln\left(Y^*_t\right)$.

Figure 1. Comparing US inflation rates



The two observable variables of each of our various model versions (gap-backward-looking, growth-rational etc.) have a common reduced form,

$$\begin{aligned} \pi_{it} &= \Pi\left(E_{t-1}\pi_{it}, x_{it-1}, g^{*}_{it}\right) + \mu_{it} \\ g_{it} &= G\left(E_{t-1}\pi_{it}, x_{it-1}, g^{*}_{it}\right) + \xi_{it} \end{aligned} \tag{12}$$

where the functions Π and G are given by our various solutions, and where the new error terms, μ_{it} for inflation and ξ_{it} for growth are functions of the inflation shocks ε_{it}. Equations (11) are the state equations, and (12) the observation equations.[18] Equations (12) are linear in the variables, but nonlinear in coefficients. We assume that inflation shocks are distributed normally with equal variances among all countries, $\varepsilon_{it} \sim N\left(0, \sigma^2_{\varepsilon}\right)$ with no autocorrelation $\text{cov}\left(\varepsilon_{it}, \varepsilon_{it-s}\right) = 0$. This is questionable since autocorrelation is widely observed in macroeconomic time series; we test its appropriateness below.

Conditional on the observations up through the t-1st year, the Kalman filter defines a recursive forecast of the unobserved state variables, $\hat{g}^{*}_{it|t-1}$, $\ln\left(\hat{Y}^{*}_{it|t-1}\right)$ and $x_{t|t-1}$. These Bayesian updates are a weighted

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

average of the previous forecast and current observations, given the model specification. Although we have no evidence that governments learn according to Bayes rule, we interpret these predictions as rational, an estimate of what the policymakers could have thought about the underlying potential of their economy at the time that stabilization decisions were taken. These Kalman filter forecasts are conditional on unknown model parameters. We estimate the invariant parameters, along with the evolving state variables, by maximizing each model's likelihood function.[19]

7. Error covariance

Our model solutions imply restrictions on the error structure of the reduced form (12). For both the gap and growth objectives, and for both adaptive and rational expectations, the Keynesian errors exhibit

$$\begin{aligned} \text{var}(\mu_{it}) &= \frac{\sigma_\varepsilon^2}{(1+\psi^2)^2}, \\ \text{var}(\xi_{it}) &= \frac{\psi^2\sigma_\varepsilon^2}{(1+\psi^2)^2}, \\ \text{cov}(\mu_{it},\xi_{it}) &= -\frac{\psi\sigma_\varepsilon^2}{(1+\psi^2)^2}. \end{aligned} \tag{13}$$

Within a group of linked economies it is plausible that inflation shocks are contemporaneously correlated. Thus we assume $\text{cov}(\varepsilon_{it},\varepsilon_{jt}) = \sigma_{\varepsilon b}$ for $i \neq j$, which further implies

$$\begin{aligned} \text{cov}(\mu_{it},\mu_{jt}) &= \frac{\sigma_{\varepsilon b}}{(1+\psi^2)^2}, \\ \text{cov}(\xi_{it},\xi_{jt}) &= \frac{\psi^2\sigma_{\varepsilon b}}{(1+\psi^2)^2}, \\ \text{cov}(\mu_{it},\xi_{jt}) &= -\frac{\psi\sigma_{\varepsilon b}}{(1+\psi^2)^2}. \end{aligned} \tag{14}$$

We require five parameters to specify the error structure, $\psi, \sigma_\upsilon^2, \sigma_\varepsilon^2, \sigma_{\upsilon b}$ and $\sigma_{\varepsilon b}$. A two-country example shows richness of the covariance structure of our specification:

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[19] This state space estimate is initiated with prior opinions about the state variables, $\ln(\hat{Y}^*_{i0|-1})$ and $\hat{g}^*_{i1|0}$, and their variances.

$$\operatorname{var}\left(\upsilon_{1t},\mu_{1t},\xi_{1t},\upsilon_{2t},\mu_{2t},\xi_{2t}\right)=\begin{bmatrix} \sigma_{\upsilon}^2 & 0 & 0 & \sigma_{\upsilon b} & 0 & 0 \\ 0 & \frac{\sigma_{\varepsilon}^2}{\left(1+\psi^2\right)^2} & -\frac{\psi\sigma_{\varepsilon}^2}{\left(1+\psi^2\right)^2} & 0 & \frac{\sigma_{\varepsilon b}}{\left(1+\psi^2\right)^2} & -\frac{\psi\sigma_{\varepsilon b}}{\left(1+\psi^2\right)^2} \\ 0 & -\frac{\psi\sigma_{\varepsilon}^2}{\left(1+\psi^2\right)^2} & \frac{\psi^2\sigma_{\varepsilon}^2}{\left(1+\psi^2\right)^2} & 0 & -\frac{\psi\sigma_{\varepsilon b}}{\left(1+\psi^2\right)^2} & \frac{\psi^2\sigma_{\varepsilon b}}{\left(1+\psi^2\right)^2} \\ \sigma_{\upsilon b} & 0 & 0 & \sigma_{\upsilon}^2 & 0 & 0 \\ 0 & \frac{\sigma_{\varepsilon b}}{\left(1+\psi^2\right)^2} & -\frac{\psi\sigma_{\varepsilon b}}{\left(1+\psi^2\right)^2} & 0 & \frac{\sigma_{\varepsilon}^2}{\left(1+\psi^2\right)^2} & -\frac{\psi\sigma_{\varepsilon}^2}{\left(1+\psi^2\right)^2} \\ 0 & -\frac{\psi\sigma_{\varepsilon b}}{\left(1+\psi^2\right)^2} & \frac{\psi^2\sigma_{\varepsilon b}}{\left(1+\psi^2\right)^2} & 0 & -\frac{\psi^2\sigma_{\varepsilon}^2}{\left(1+\psi^2\right)^2} & \frac{\psi^2\sigma_{\varepsilon}^2}{\left(1+\psi^2\right)^2} \end{bmatrix}$$

The new classical models (6) and (10) imply are different covariance restrictions,

$$\operatorname{var}\left(\mu_{it}\right)=\frac{\sigma_{\varepsilon}^2}{\psi^4},$$

$$\operatorname{var}\left(\xi_{it}\right)=\frac{\sigma_{\varepsilon}^2}{\psi^2},$$

$$\operatorname{cov}\left(\mu_{it},\xi_{it}\right)=-\frac{\sigma_{\varepsilon}^2}{\psi^3}.$$

and when as above we allow for cross-country covariance,

$$\operatorname{cov}\left(\mu_{it},\mu_{jt}\right)=\frac{\sigma_{\varepsilon b}}{\psi^4},$$

$$\operatorname{cov}\left(\xi_{it},\xi_{jt}\right)=\frac{\sigma_{\varepsilon b}}{\psi^2},$$

$$\operatorname{cov}\left(\mu_{it},\xi_{jt}\right)=-\frac{\sigma_{\varepsilon b}}{\psi^3}.$$

Unfortunately, estimations of these models do not converge. However, we can obtain convergence by a plausible generalization, by just adding an additional error term ζ_{it} to all growth equations where $\zeta_{it} \sim N(0,\sigma_{\zeta}^2)$. Perhaps this added error accounts for policy-implementation errors.[20] We maintain the between-country covariance of potential growth and inflation shocks, and the inflation-growth covariance implied specified in (13) and (14). We further assume that added growth errors are related across countries

[20] Some studies add an inflation policy error to their specifications; for example see Ireland (1999). This differs from the growth error that we add here.

according to $\text{cov}(\zeta_{it}, \zeta_{jt}) = \sigma_{\zeta b}$ for $i \neq j$. Because we have added two parameters, we now require seven parameters to specify the covariance matrix.

8. An empirical comparison of modeling assumptions

The goodness-of-fit statistics in Table 2 are the basis for our inferences about macroeconomic theory. We select our sample period, 1954-1998, to precede the European monetary union and to provide complete observations on all variables and all countries. The table reports log likelihoods under different assumptions about the government's objective function, the formation of expectations and errors. All of these specifications restrict the variance of the potential growth random walk to 0.16, a standard deviation of 2/5 percent per year; the validity of this assumption is examined in the next section. The first two rows assume backward-looking expectations. For example, replacing π^e_{it} by π_{it-1} in (3) and (4) gives the specification for the gap target model under backward-looking expectations. The next rows impose strongly rational expectations. For example, using (5) gives the gap target model under rational expectations.

Clearly backward-looking expectations fit the data well. Comparing the two objective function assumptions, we infer that governments are more likely to target the growth rate than the output gap. Table 2 also shows that the Keynesian assumption of a government information advantage fits better than new classical assumption of full information. Finally, the columns compare specifications with and without international covariances; the first column sets $\sigma_{vb} = 0, \sigma_{\varepsilon b} = 0$ and $\sigma_{\zeta b} = 0$. Comparing columns strongly supports the presence of between-country covariance.

Table 2. Comparative log likelihood statistics:
14 North Atlantic countries, 630 observations, 1954-1998

model	observables equations	independent between countries	between-country covariance
backward-looking expectations gap target	(3) and (4)	-3146	-3029
backward-looking expectations growth target	(9)	-2953	-2874
rational expectations gap target	(5)	-3443	-3166
rational expectations growth target	(10)	-3408	-3225
new classical gap target	(6)	-3448	-3265
new classical grow target	(11)	-3408	-3225

The inflation and growth shocks could be serially correlated; the macroeconomic literature customarily allows for serial correlation among errors. Generalizing our best-fitting model (the backward-looking growth target with between-country covariance) to include AR(1) errors, we obtain an autocorrelation parameter -0.03 (-1.21) when the same parameter applies to both growth and inflation errors, -0.22 (-7.47) for inflation errors only and 0.17 (4.48) for growth errors only, however when we specify different autocorrelation parameters for inflation and growth errors, the estimation fails to converge. We expected positive autocorrelation. These results support the conclusion that our general contemporary covariance specification fits the data well without accounting for the possibility of serial correlation, and is not improved by adding autocorrelation terms. Perhaps this surprising conclusion only holds for our widely spaced annual observations; the relevant literature customarily studies quarterly or monthly data.

9. The natural rate of growth

The natural rate literature reports other methods of estimating unobserved potential output. Conventionally, the potential level changes over time as technology advances and as physical and human capital is accumulated. Assuming that these influences evolve slowly and independently of business cycles, researchers have applied smoothing procedures to estimate the underlying economic potential. Figure 2 compares two of our Kalman filter estimates[21] of potential growth for the US with several popular alternatives: the estimate published by the Congressional Budget Office (2001) and the Hodrick-Prescott filter. The popularity of the HP filter may be due to its simple agnostic formula.[22] The CBO estimate is more complicated. It uses a growth accounting method inspired by the Solow growth model. This method combines estimates of the trends in the labor force, the capital stock and technological progress. Cyclical components of the labor supply and productivity are removed from observed statistics by constraining

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[21] These results all derive from the best-fitting inflation-growth target model under adaptive expectations, labeled model (c) in Table 3 below.

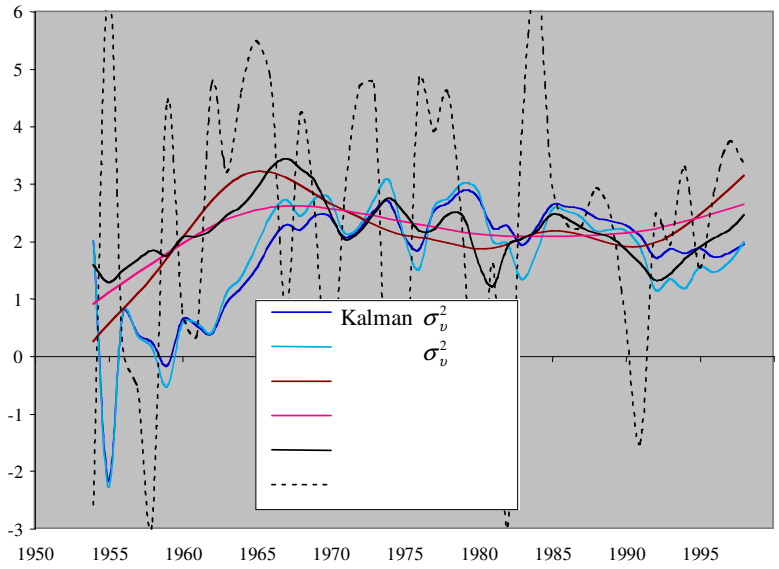
[22] It estimates of the natural rate series by minimizing the expression

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

where β an arbitrary smoothness parameter that penalizes sharp curves in the g_{it}^{*} series.

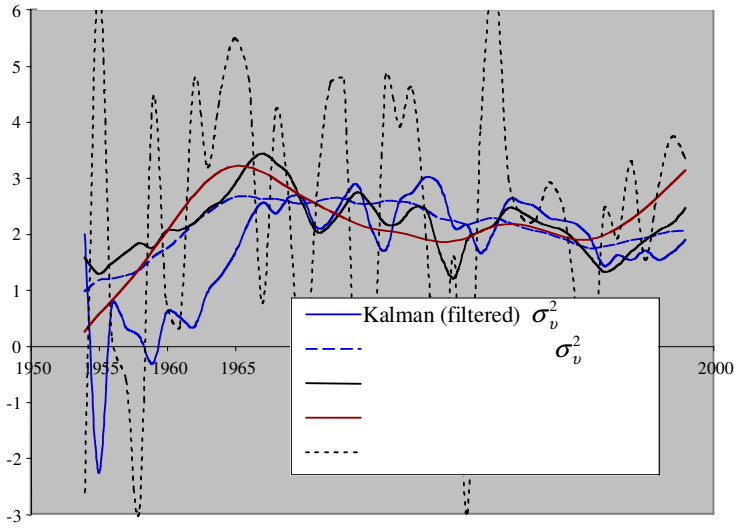
potential labor and productivity growth rates to be constant over the business cycle. The CBO's estimate also uses an estimate the non-accelerating inflation rate of unemployment. All methods illustrate the conclusion that the underlying growth rate of the US economy has changed over time. They show a slight slowing of growth following a peak in the mid-1960s.

Figure 2. Alternatives estimates of the US potential growth rate



Our 2-equation models can also smooth the potential growth by restricting the variance of the random step to a small value. Figure 2 displays Kalman estimates for a rather volatile assumption (turquoise) that $\sigma_v^2 = 0.25$ (a standard deviation of 1/2% per year), and repeats the analysis (blue) with stronger smoothing where $\sigma_v^2 = 0.04$ (a standard deviation of 1/5% per year). The maximum likelihood estimate of σ_v^2 is 0.175 for our best-fitting specification in Table 2; for comparability we restrict σ_v^2 to 0.16 for all models throughout this paper.

Figure 3. Comparing smoothed and filtered estimates of the US potential growth rate

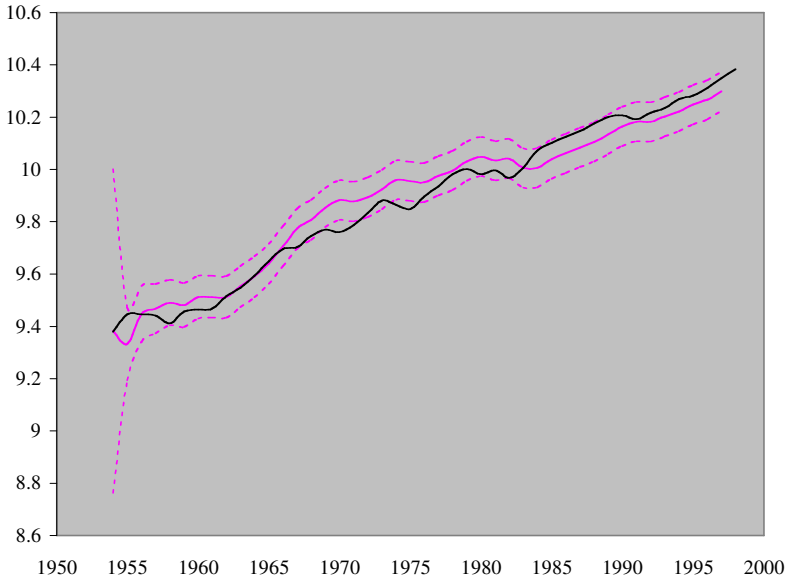


Clearly our Kalman estimates are more volatile than the usual estimates. For the early years of our sample, Figure 2 shows the US estimates are substantially below the alternatives. This difference reflects different assumptions about potential growth as well as different methods of estimation. The HP filter and CBO estimate both impose a gradually evolving process, without large shifts. On the other hand, our assumed generating process is a random walk, typified by small random shifts that can occasionally be large. An appealing methodological feature of the Kalman filter is that potential growth is estimated recursively on past observations only, not future ones. This explains why the Kalman series become smoother and converge with the alternatives as more observations become available.[23] Our estimates are also appealing because they are integrated into a macroeconomic model, and not a separate calculation. The other two methods are omniscient in the sense that they include both past and future observations; they are in this sense more comparable to "smoothed" Kalman predictions of the state variables conditioned on the entire data set, $\hat{g}^*_{it|T}$, plotted in Figure 3. Although the smoothed estimate is not always closer to the

[23] We specify $\hat{g}^*_{1|0} = 2$ with a variance of 9 as a plausible prior for the potential growth, and set $\ln\left(\hat{Y}^*_{0|-1}\right)$ equal to the values observed in 1952 with a variance of 0.1. We start with 1952 because all versions of the observable equations (11) include only the lagged output gap x_{it-1}, although they do include the current potential growth g^*_{it}.

alternatives than the filtered estimate, it is less volatile, and it does remove the 1950s anomaly. This plot shows the significant difference between forward-looking and omniscient forecasts.

Figure 4. Comparing observed *ln*(GDP/capita) with the Kalman prediction of the US potential level



The volatility of our $\sigma_v^2 = 0.16$ estimate may be inconsistent with the conventional notion of smooth potential growth. The filtered estimate in Figure 3 appears overly responsive to the business cycle. However, Figure 4 shows that the implied prediction of potential GDP/capita level is fairly smooth even though our potential growth path is not. The 95% confidence interval (dashed) shows that these estimates are imprecise; the observed *ln*(GDP/capita) is only rarely outside of this interval. This plot also shows how quickly the observations come to dominate our prior.

10. The new Keynesian Phillips curve

Table 3 reports detailed results for some of the more likely specifications, shaded in Table 2. We shorten the sample period by one year for comparability with a sticky-price version of the model, explained below.[24] We continue to impose the restriction that $\sigma_v^2 = 0.16$. In most cases the estimated target variable is plausible, implying equilibrium inflation rates of between 5% and 6%. We allow for between-country covariance in all models except (b). The results suggest that inflation-shock and growth-shock covariances

[24] For this specification the 1998 observation is incomplete because the variable $E_{t-1}\pi_{t+1}$ is not defined.

are much more important than potential-growth-shock covariance. In light of the technological interpretation of potential output, we expected greater potential-growth covariance among countries. In our best-fitting model (c) the inter-country growth-shock covariance is nearly twice as great as that for inflation. The growth shocks are unexpected; Clarida et al. (1999) argue that output shocks (and by extension growth shocks) should be perfectly offset under optimal monetary policy. Perhaps the growth shocks reflect the extent to which governments are unable to practice optimal stabilization policy. The growth-shock covariance appears to be an important mechanism of international connectedness.

Most of the estimated slopes of the Phillips curve are statistically significant and positive, but they vary considerably. Models (d) and (e) show that inferences about the slope of the Phillips curve are strongly affected by our modeling assumptions; we estimate it as essentially zero for model (d) in which the government has an informational advantage and an output gap target, and nearly unity for model (e) in which there is no such advantage and an growth gap target; both specifications assume rational expectations.

Even though backward-looking expectations fit the data better, many may be skeptical of this *ad hoc* assumption. Model (f) takes a step toward microfoundations. It introduces a version of Calvo's (1983) stochastic price adjustment model. This sticky price model specifies that $(1-\eta)$ is the probability that a firm can adjust its price in the current year. It is assumed that the optimal price p_t^* for the typical firm varies with the aggregate price and the marginal costs. Under imperfect competition the profit-maximizing price is a markup of marginal cost.[25] Furthermore, under certain conditions it can be argued that the deviation from steady-state marginal costs is proportional to the aggregate output gap; thus the optimal price depends on the output gap.[26] Again we use ψ to specify this price-gap relation.

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[25] Some authors (for example, Gali (2008)) develop further microfoundations at this point, assuming an economy of monopolistically competitive firms providing a continuum of differentiated consumer goods.

[26] There is doubt in the empirical literature about whether the conditions necessary for the cost-gap link hold. Gali and Gertler (1999) report consistent results for a measure of marginal cost, but not for the output gap, while neither variable can explain observed inflation in the Rudd and Whalen (2006) study.

Table 3. Selected regression results: 14 North Atlantic countries, 1954-1997, 616 annual observations
(z-ratios in parentheses)

	(a)	(b)	(c)	(d)	(e)	(f)
model	Keynesian, output gap	Keynesian, growth	Keynesian, growth	Keynesian, output gap	new classical, growth	new Keynesian, growth
expectations	backward looking	backward looking	backward looking	rational	rational	sticky price
Phillips curve slope	0.217	0.252	0.207	-0.053	0.973	0.227
	(5.946)	(21.17)	(13.35)	(-1.216)	(27.69)	(17.88)
stickiness parameter						0.515
						(211.4)
target	5.797	5.353	5.247	5.154	5.204	8.581
	(1.225)	(21.05)	(4.170)	(5.986)	(8.183)	(2.526)
var(υ_i) potential (imposed)	0.160	0.160	0.160	0.160	0.160	0.160
var(ε_i) inflation	6.421	5.942	5.883	14.739	4.401	0.646
var(ζ_i) growth	5.753	5.081	5.198	5.787	14.582	5.985
cov(υ_i, υ_j)	0.014		0.046	0.013	0.017	0.014
	(1.145)		(1.391)	(1.155)	(1.343)	(0.766)
cov($\varepsilon_i, \varepsilon_j$)	1.277		0.806	8.159	0.753	0.230
	(3.282)		(4.027)	(2.734)	(2.200)	(3.101)
cov(ζ_i, ζ_j)	2.423		1.409	2.270	7.056	1.830
	(2.845)		(2.568)	(3.040)	(2.666)	(3.057)
log likelihood	-2974	-2896	-2819	-3101	-3157	-2172

Since firms may not be able to change their prices for some time, those currently resetting forecast future market conditions. They average observable conditions with their forecasts, weighted according to the probability that their price will remain fixed in each year.[27] Customary derivations date expectations from the current period, but it is more appropriate to lag the expectation date,

$$p_t^* = (1-\eta)\sum_{\tau=0}^{\infty} \eta^\tau E_{t-1}(p_{t+\tau} + \psi x_{t+\tau}) + \varepsilon_t .$$

We now define ε_t as an exogenous price shock added to account for all other factors affecting the pricing decision. The t-1 date for the expectations is realistic because aggregate price indices are not published

[27] It is appropriate for firms to discount future profits. But since this complicates the result, we follow much of the literature by weighting all quarters equally, except for the probability of price resetting. Since we focus on short-run decisions here, this neglect of discounting is a reasonable simplification. Below we estimate that the average length of price fixity is about 2 years.

until after the current date, and then usually they are released as advance estimates that can be later revised several times.

The aggregate price level combines the firms who reset their price in the current year with those who set prices previously according to a geometric distribution. It can be shown that aggregate inflation is then determined as

$$\pi_t = \frac{(1-2\eta)}{(1-\eta)} E_{t-1}\pi_t + \frac{\eta}{(1-\eta)} E_{t-1}\pi_{t+1} - \eta E_{t-1}\varepsilon_{t+1} + (1-\eta)\psi E_{t-1}x_t + \varepsilon_t. \tag{15}$$

Equation (15) also involves a forecast of the output gap and of next year's shock. This is not the usual result.[28] Usually expectations are dated currently, so that $E_{t-1}\pi_t = \pi_t$, $E_{t-1}x_t = x_t$, $E_{t-1}\pi_{t+1} = E_t\pi_{t+1}$ and $E_{t-1}\varepsilon_{t+1} = 0$. Under these assumptions, (15) simplifies to the conventional

$$\pi_t = E_t\pi_{t+1} + \frac{(1-\eta)^2\psi}{\eta} x_t + \frac{1-\eta}{\eta}\varepsilon_t \tag{16}$$

We estimate a sticky price version of the growth target model (f) by a two-step procedure: first we use an backward-looking model (c) to estimate the unobserved expectations, and then we use these forecasts to evaluate the equilibrium policy solution using (15) instead of (1), setting $E_{t-1}\varepsilon_{t+1} = 0$ and $E_{t-1}x_t = x_t$. For growth targets the second step models the observable equations as

$$\pi_{it} = \frac{\left(\frac{(1-2\eta)}{(1-\eta)} E_{t-1}\pi_{it} + \frac{\eta}{(1-\eta)} E_{t-1}\pi_{it+1}\right) + (1-\eta)\psi x_{it-1} + \left((1-\eta)\psi\right)^2 \hat{\pi}}{1+\left((1-\eta)\psi\right)^2} + \frac{\varepsilon_{it}}{1+\left((1-\eta)\psi\right)^2} \tag{17}$$

$$g_{it} = -\frac{\left((1-\eta)\psi\right)^2 x_{it-1} + (1-\eta)\psi\left(\left(\frac{(1-2\eta)}{(1-\eta)} E_{t-1}\pi_{it} + \frac{\eta}{(1-\eta)} E_{t-1}\pi_{it+1}\right) - \hat{\pi}\right)}{1+\left((1-\eta)\psi\right)^2} - \frac{(1-\eta)\psi\varepsilon_{it}}{1+\left((1-\eta)\psi\right)^2} + g_{it}^* + \zeta_{it}$$

where we have changed the subscripts to reflect the pooled nature of our data and added the *ad hoc* growth shock that we needed above to obtain convergent estimates. Our use of lagging expectations is appropriate to this method; if we use (16) instead of (15) to derive the model, then we may introduce simultaneity bias because in the one-step Kalman forecast $E_t\pi_{t+1}$ assumes knowledge of the knowledge of the current

[28] See, for example, Froyen and Guender (2007).

dependent variables. This methodology differs markedly from the literature: most empirical sticky-price studies do not model expectations, customarily (16) is invoked, and customarily the output gap is measured in a deterministic fashion, not as part of a general macroeconomic equilibrium.

Table 3 shows that sticky price specification dramatically improves the empirical fit. At almost 9%, model (f) has a considerably higher inflation target, but not implausibly higher. The inclusion of forward-looking inflation forecasts markedly reduces the inflation-shock variance, even more than would be expected by the insertion η of into the error term of (17). Because our estimate of the stickiness parameter is $\hat{\eta}=0.52$, our modified curve (15) is quite close to the conventional form (16), as long as we change $E_{t-1}\pi_{t+1}$ to $E_t\pi_{t+1}$. When we attempt to apply this procedure using the output gap model (a) as the first step and then the output-gap analogue of (17) as the second step, the estimation fails to converge.

Figure 6. Comparing alternative forecasts of US inflation

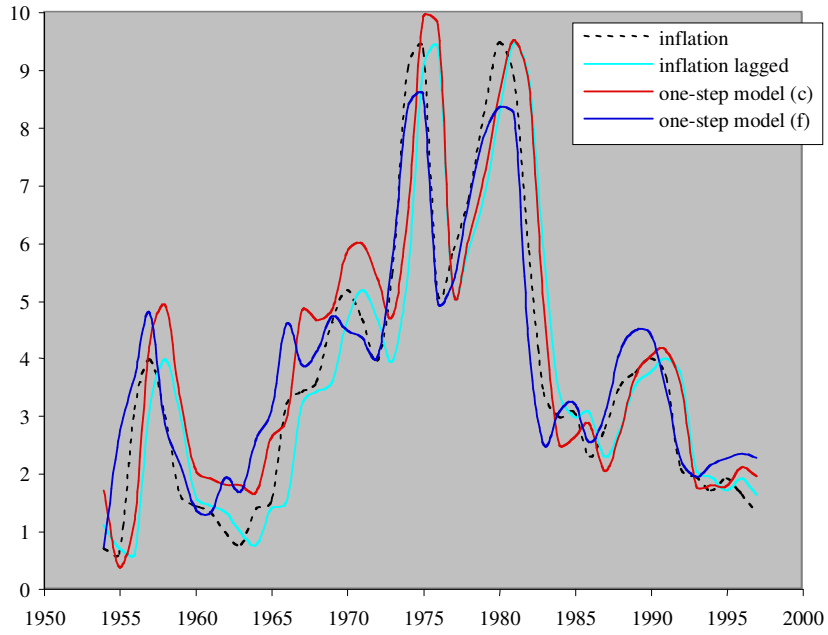

Figure 6 compares observations with one-step forecasts of inflation for three models: the backward-looking assumption, the forecast according to model (c) and the forecast according to model (f), which is the first two terms on the right-hand-side of (15). Although not always closer to observed inflation, the sticky-price forecast appears to accurately lead lagged inflation and the model (c) forecast and

to be a better predictor of inflation turning points. Our results support the inference that agents' expectations are forward looking, that prices are sticky and that governments actively stabilize their economies.

11. Refinements: accounting for ideology, regime change, openness and terms of trade

So far we have assumed that the inflation target does not vary across countries or time. Politics and institutions could influence outcomes through the inflation target parameter. A famous result by Rogoff (1985) concludes that appointing conservative central bank governors can mitigate the inherent inflation bias. This prescription can be modeled as $\hat{\pi}^b < \hat{\pi}^g$, where superscripts denote central bank and government targets. However, a conservative banker will be ineffective in this regard if she is not also given independence to pursue her goals. Following Eijffinger and Hoeberichts (1998), we model central bank independence with the composite objective function

$$U_{it} = \theta_{it}\left(-\frac{1}{2}\left(\left(g_{it} - g_{it}^{*}\right)^2 + \left(\pi_{it} - \hat{\pi}^b\right)^2\right)\right) + \left(1-\theta_{it}\right)\left(-\frac{1}{2}\left(\left(g_{it} - g_{it}^{*}\right)^2 + \left(\pi_{it} - \hat{\pi}^g\right)^2\right)\right),$$

where θ_t measures the degree of independence on the interval (0,1). With this extension we find that the reaction functions are unchanged, except that $\hat{\pi}$ in the various solutions is replaced by $\theta_{it}\hat{\pi}^b + (1-\theta_{it})\hat{\pi}^g$. This result shows that conservativeness without independence $(\theta_{it} = 0)$ has no impact, neither does independence without conservativeness $\left(\hat{\pi}^b = \hat{\pi}^g\right)$. Cukierman et al. (1992) develop a formal index of legal independence, defined on (0,1).[29] According to this measure the Italian central bank achieves the greatest independence in our sample (.92 in 1998), and the Norwegian and Belgian central banks were the most dependent (.15 before 1971). We interpret this index as a measure of independence θ, even though its coding definition includes elements of conservativeness (whether price stability is the only objective in the bank's charter).

Furthermore, political ideologies differ across countries and over time; all are democracies throughout the sample period. Rightwing governments may prefer for a lower inflation target. We

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[29] We use Cukierman et al (1992), augmented with the update by Polillo and Guillén (2005). Before 1980 Cukierman et al. report only decade averages for their index.

formalize this notion by rewriting the target as $\hat{\pi}_{it}^{g} = \hat{\pi}^{g0} + \hat{\pi}^{g\rho}\rho_{it}$ where ρ_{it} is a Left-Right index of the government ideology. To quantify this notion we use Budge's (2001) Left-Right scores for political parties derived from a content analysis of pre-election platforms and manifestos. The government ideology is measured as the score of the party in power; these range from -1 at the extreme Left to +1 at the extreme Right.[30] During years in which the government changes, our score is a weighted average according to the months in office. For example, since the US president takes office in January, the out-going government's ideology is given a weight of 1/12th. In countries ruled by a coalition the governing ideology is estimated by the average of the parties in the coalition, weighted by the respective percentages of seats in the lower house of Parliament. Furthermore, many studies have pursued the notion that governments change their policy in election years. We test for this possibility by allowing for a different inflation target $\hat{\pi}^{e}$ if an election occurs during the year, $\nu_{it} = 1$.

Combining these political and institutional hypotheses, we generalize the inflation target as

$$\hat{\pi}_{it} = \theta_{it}\hat{\pi}^{b} + (1-\theta_{it})\left[(1-\nu_{it})\left(\hat{\pi}^{g0} + \hat{\pi}^{g1}\rho_{it}^{g}\right) + \nu_{it}\hat{\pi}^{e}\right].$$

To evaluate the strength of these influences, we substitute this equation into the best-fitting model (f). The results are reported as model (g) in Table 4. The results suggest that central banks aim at an inflation target that is about 13% lower than governments, although the difference is not statistically significant. The ideological effect has the expected negative sign, but is not statistically significant, nor is the election-year target significantly different from the non-election-year target. Although these political extensions improve our fit (compared to model (f)) and have plausible values, these data are statistically inconclusive.

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[30] According to this measure the Danish government was the farther Right in our sample (.40 in 1983), and the Swedish was the farthest Left (-.61 before 1961).

Table 4. Extensions of model (f): 14 North Atlantic countries, 1954-1997, 616 annual observations
(z-ratios in parentheses)

	(g)	(h)	(i)	(j)	(k)
Phillips curve slope	0.221	0.115	0.214	0.227	0.134
	(17.22)	(3.296)	(16.82)	(16.91)	(4.037)
stickiness parameter	0.515	0.515	0.514	0.515	0.514
	(207.7)	(216.8)	(201.4)	(204.3)	(193.0)
government target	13.106	7.180	8.978	8.587	11.299
	(2.544)	(2.765)	(2.538)	(2.488)	(2.095)
central banker target	0.353				0.574
	(1.284)°				(1.053)°
election-year target	14.856				12.666
	(1.513)†				(1.232)†
ideology parameter	-11.003				-11.592
	(-0.834)				(-0.782)
openness-slope interaction		0.187			0.133
		(3.139)			(2.389)
openness-inflation variance			0.544		0.514
			(2.702)		(2.163)
openness-growth variance				-0.332	
				(-1.916)	
var(υ_i) potential (imposed)	0.160	0.160	0.160	0.160	0.160
var(ε_i) inflation	0.641	0.587	0.462	0.645	0.435
var(ζ_i) growth	5.918	6.154	6.001	7.336	6.062
cov(υ_i, υ_j)	0.016	0.022	0.017	0.014	0.026
	(0.781)	(1.120)	(0.839)	(0.790)	(1.105)
cov($\varepsilon_i, \varepsilon_j$)	0.222	0.177	0.218	0.228	0.173
	(2.960)	(3.249)	(2.946)	(2.929)	(2.848)
cov(ζ_i, ζ_j)	1.830	1.989	1.839	1.884	1.953
	(2.849)	(2.856)	(3.035)	(3.034)	(2.661)
log likelihood	-2168	-2168	-2169	-2171	-2162

° Tests the hypothesis that the central bank's target differs from the government's target.
† Tests the hypothesis that the election-year target differs from the government's target.

Differences in economic openness between countries and across time provide another possibility for refining our model. Romer (1993) argues that more open economies should have steeper Phillips curves. On the other hand, Clarida et al. (2001) predict the opposite; their Phillips curve becomes flatter with greater openness.[31] We extend our analysis by substituting into model (f) a slope-openness interaction

[31] More specifically, the slope of their Phillips curve depends on the elasticity of substitution between home and foreign goods and on relative risk aversion. Romer's steeper result follows only if the product of

term, $\psi_{it} = \psi_0 + \psi_w w_{it}$, using the ratio of exports plus imports to domestic output w_{it} to measure openness.[32] The results for model (h) support Romer's prediction. Clarida et al. also argue that due to terms of trade volatility, CPI inflation should be more volatile in more open economies. Although we model only domestic inflation here, we test the possibility that openness affects its volatility by re-specifying $\text{var}(\varepsilon_{it}) = \sigma_{0\varepsilon}^2 e^{\sigma_{w\varepsilon}^2 w_{it}}$ in model (i). The result suggests that domestic inflation error volatility does increase with openness. Although we have little understanding of the growth shock, we test an analogous volatility extension as $\text{var}(\zeta_{it}) = \sigma_{0\zeta}^2 e^{\sigma_{w\zeta}^2 w_{it}}$. On the basis of an aggregate demand spillover argument, we think that $\sigma_{w\zeta}^2 > 0$ is plausible. Model (j) rejects this hypothesis.[33]

Overall these extensions improve the fit of the baseline (f) significantly. Model (k) shows that including all effects (except the rejected openness-growth interaction) does not change any of our initial inferences.

12. Conclusion

We develop a standard model of macroeconomic stabilization, and test its relevance to recent macroeconomic history using a panel of interconnected countries. We compare a number of alternative econometric specifications. We conclude that the Keynesian model of asymmetric information and backward-looking expectations is more likely to have generated these data than the new classical model of full information. In between these methodological extremes, Calvo's model of price stickiness invokes forward-looking rationality as a microfoundation for the Phillips curve. A two-step implementation of the sticky-price approach dramatically improves the fit of our model.

With regard to the functional form, an objective function with inflation and growth targets is more likely to have generated these data than the more conventional inflation and output gap targets. We extend our specification to test for the influences of central bank independence, electoral politics and ideology on

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these two microparameters is less than unity. Clarida and his coauthors speculate that a flatter slope is empirically reasonable.

[32] Our openness indicator ranges from 0.085 in the US in 1954 to 1.632 in Ireland in 1998.

[33] See Carlin and Soskice (2006) for a discussion of "locomotive" and "beggar-thy-neighbor" spillovers among interdependent economies.

macroeconomic outcomes; the data are inconclusive. We also search for effects due to openness. We find that globalization affects stabilization policy because the Phillips curve slope is steeper in more open economies, and because of the between-country covariance of inflation and growth shocks (but not productivity shocks); we also find that greater openness is associated with greater inherent inflation volatility.

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