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New Keynesian Endogenous Stabilization in a Panel of Countries

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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. We develop an econometric characterization of the political-economic equilibrium using the Kalman filter to model the unobserved natural rate. Applying this methodology to a panel of North Atlantic countries, we find it consistent with history with a few qualifications. For one, governments are more likely to target growth rates, than output gaps. And, inflation expectations are more likely adaptive, than rational. Also, the error restrictions implied by the standard inflation-productivity shocks formulation needs to be relaxed.

Keywords: endogenous stabilization, objectives, expectations, Kalman filtering
JEL Classification: E61, E63

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1. Introduction

A number of plausible assumptions are consistent with an endogenous stabilization model, also known as time-consistent monetary policy model, or political business cycle.[1] One of these relates to the functional form of the government's objective function. We assume circular indifference curves with an inflation policy target, while highlighting the differences between an output gap target and an output growth target. Using the state space methodology, we estimate the dynamics of inflation and growth for 14 countries.[2]

Because the structural form of these models involves the unobserved natural rate, the state space statistical methodology is appropriate. This econometric method enables a coherent model of government policy formation. By formalizing the relation between observables and unobservables, it provides Bayesian estimates of the natural rate conditioned on the available information at each point in time. A comparison of our estimates shows significant differences from customary smoothed estimates of the natural rate.

The state space methodology is also appropriate for globally linked economies. It allows for between-country shock covariance. We find evidence of between-country covariance in inflation and growth shocks, but little covariance in productivity shocks. When contemporary covariance is fully specified, the empirical justification for *ad hoc* autocorrelation is reduced.

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 the representative agent. 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.

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[1] The original insight for this literature dates to Kalecki (1943); also see Nordhaus (1975) or Hibbs (1977). 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.

2. Economic structure and objectives

The literature on political macroeconomics 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 natural aggregate output Y_t^* is conceptually equivalent to the natural rate of unemployment, we substitute the output gap, defined as $x_t \equiv \ln(Y_t) - \ln(Y_t^*)$, for the unemployment gap as the measure of macroeconomic disequilibrium,

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

where π_t is the inflation rate and ε_t an inflation shock. Expected inflation is π_t^e, the forecast of a typical agent based on information available in the previous year. 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 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. 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. The modeling of collective objectives is controversial. 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 account for ideological differences. Governmental targets may also reflect a weighted average of citizen preferences, with heavier weights assigned to the ruling party's core constituents.

Quadratic forms are tractable because they always 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

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[3] See, for example, Nordhaus (1975), Barro and Gordon (1983) or Alesina (1987).
[4] For example, see Clarida et al. (1999).

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 natural level.[7] Kiefer (2008) estimates eight different quadratic forms. He confirms the conventional wisdom that it is not possible to statistically separate goal weights, inflation and output targets.[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 fits the data better than the output target.

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.[9]

3. Endogenous stabilization 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 ($x_t = 0$ and $\pi_t = \hat{\pi}$) may be unattainable.[10] The government has an information advantage over agents, who are locked into a forecast made in the previous year. Rational agents come to understand that a policy of $\hat{\pi} > 0$ implies inflation; this expectation is a self-fulfilling prophecy.

The long-run equilibrium is disturbed by exogenous shocks. To derive the government's policy, we use the Phillips curve to substitute for x_t and in (2),

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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 a unemployment target below that natural rate.

8 Also see Ireland (1999).

9 See Kiefer (2000) for empirical evidence that only current conditions matter in political macroeconometrics.

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

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

Maximizing with respect to π_t, the government's preferred policy (also known as its reaction function) is

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

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

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

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 $g_t^* \equiv \ln(Y_t^*) - \ln(Y_{t-1}^*)$ is the natural rate of growth. Consequently we can rewrite the government's output policy as

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

Among other things, (3) and (4) imply that observed inflation and growth depend on 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. Equation (4) reflects the conventional result that policy should perfectly accommodate any shifts in the natural output.[11]

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, $x = 0, g = g^*, \pi = \hat{\pi}$.

[11] See Clarida et al. (1999).

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 natural growth rate and the pre-existing economic condition. However, we suppose that she cannot predict the contemporaneous shock ε_t. 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 $E(\pi_t) = \pi_t^e = \hat{\pi}$.[12] Substituting into (3) and (4) gives the rational solution

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

The new Keynesian assumption that governments have a policy advantage remains controversial. The new classical literature assumes no advantage, either agents and the government both know the inflation shock before they act, or that neither do.[13] In the perfect information case they both predict inflation accurately, $\pi_t^e = \pi_t$ and $x_t = -\frac{\varepsilon_t}{\psi}$. It follows that the macroequilibrium is

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

A weak alternative to rational expectations is that forecasts are simply observed inflation in the previous year $\pi_t^e = \pi_{t-1}$, which we substitute into (3) and (4) in our preferred regression specification. Often referred to as the adaptive expectations model, it assumes that agents are quick learners (one year),

[12] 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.

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

but forgetful (disregarding earlier observations).[14] Although many economists 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. 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 policy is

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

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 preferred inflation equation. 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, $x = 0$, $g = g^*$, $\pi = \hat{\pi}$.

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

[14] 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.

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

Under new classical assumptions, the solution in (6) is unchanged.

6. Observed and unobserved data

We test this model on 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.[15]

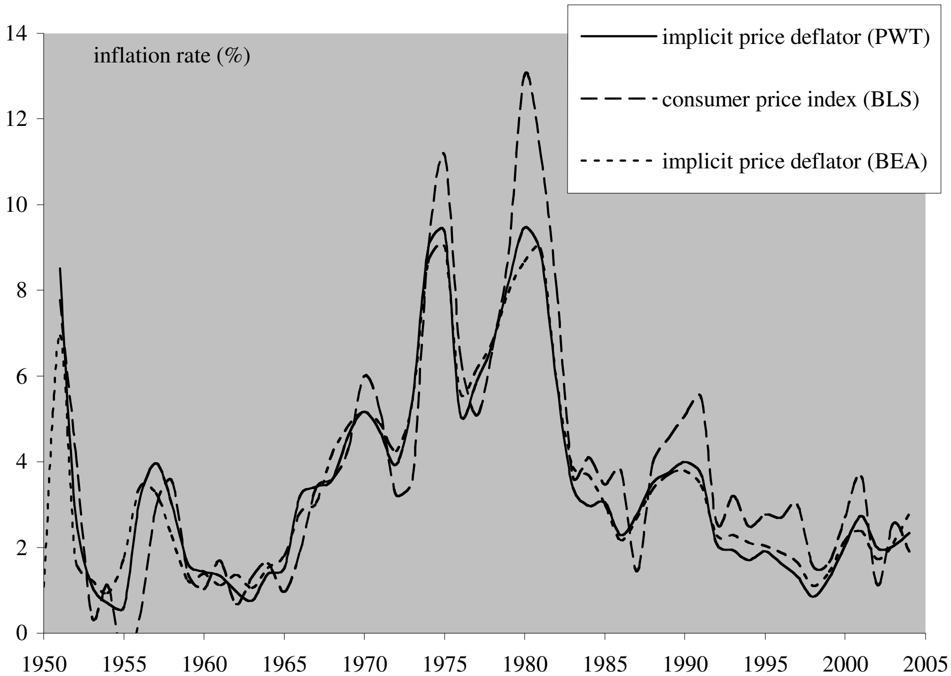
Table 1. Variable definitions

	symbol	definitions using PWT 6.2 variable names
real GDP per capita	Y_{it}	$RGDPCH_{it}$
growth rate	g_{it}	$100\left[\ln(RGDPCH_{it}) - \ln(RGDPCH_{it-1})\right]$
implicit deflator	p_{it}	$\dfrac{PPP_{it}(CGDP_{it})}{PPP_{i2000}\ (RGDPCH_{it})}$
inflation rate	π_{it}	$100\left[\ln(p_{it}) - \ln(p_{it-1})\right]$

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 1 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.

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

Figure 1. Comparing US inflation rates



Measuring the conceptual shock variable is problematic. There are many potentially important types of shocks to consider. Here we use the world inflation rate of the real price of crude oil π_t^{oil}, and we replace the shock variable by $\varepsilon_{it} = \varepsilon_{0it} + \alpha\pi_t^{oil}$.[16]

Our models call for measures of macroeconomic disequilibrium and the underlying output trend. The published series include only real output per capita Y_{it}, and not its natural level Y_{it}^*, nor the rate of growth of natural output g_{it}^*. 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

$$\begin{aligned} g_{it+1}^* &= g_{it}^* + \upsilon_{it+1} \\ \ln\left(Y_{it}^*\right) &= \ln\left(Y_{it-1}^*\right) + g_{it}^* \end{aligned} \tag{10}$$

where $\upsilon_{it} \sim N(0, \theta)$. This is a simple, agnostic model of natural output; others are certainly plausible.[17] Although these natural rates follow different paths in the different countries, we assume that their variances

[16] These data are from Campbell (2005).

are the same. It seems plausible that these productivity shocks υ_{it} may be correlated across countries; thus we specify that $\mathrm{cov}(\upsilon_{it},\upsilon_{jt})=\eta$ for $i \neq j$. We assume that these shocks are serially independent, $\mathrm{cov}(\upsilon_{it},\upsilon_{it-s})=0$, and independent of inflation shocks $\mathrm{cov}(\upsilon_{it},\varepsilon_{0it})=0$.

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

$$\begin{aligned} \pi_{it} &= \Pi\left(\pi_{it}^{e}, \ln\left(Y_{it-1}\right), \ln\left(Y_{it-1}^{*}\right), g_{it}^{*}, \pi_{t}^{oil}\right) + \mu_{it} \\ g_{it} &= G\left(\pi_{it}^{e}, \ln\left(Y_{it-1}\right), \ln\left(Y_{it-1}^{*}\right), g_{it}^{*}, \pi_{t}^{oil}\right) + \xi_{it} \end{aligned} \tag{11}$$

where the functions Π and G are given by our theoretical solutions, with the shock terms (involving ε_{0it}) replaced by new error terms, μ_{it} for inflation and ξ_{it} for growth. Equations (10) are the state equations, and (11) the observation equations.[18] Equations (11) are linear in the variables, but nonlinear in coefficients.

Conditional on the observations up through the t-1st year, the Kalman filter defines a recursive forecast of the unobserved state variables for the next year, $\ln\left(\hat{Y}_{it|t-1}^{*}\right)$ and $\hat{g}_{it+1|t}^{*}$. These Bayesian updates are a weighted 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 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 decisions were taken. These Kalman filter forecasts are conditional on unknown model parameters, here $\psi,\hat{\pi},\theta,\eta,\phi$ and γ. We estimate the invariant parameters, along with the evolving state variables, by maximizing the model's likelihood function. This state space estimate is initiated with prior opinions about the state variables, $\ln\left(\hat{Y}_{i0|-1}^{*}\right)$ and $\hat{g}_{i1|0}^{*}$, and their variances.

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[17] Natural growth and natural unemployment are analogous processes. Barro and Gordon (1983) assume that natural unemployment follows an AR(1) process, 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 $\ln\left(Y_t^{*}\right)$.

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

7. Error covariance

The new Keynesian models all imply the same restrictions on the error structure of the reduced form (11). These are

$$\mathrm{var}(\mu_{it}) = \frac{\phi}{\left(1+\psi^2\right)^2},$$

$$\mathrm{var}(\xi_{it}) = \frac{\psi^2\phi}{\left(1+\psi^2\right)^2}, \tag{12}$$

$$\mathrm{cov}(\mu_{it},\xi_{it}) = -\frac{\psi\phi}{\left(1+\psi^2\right)^2},$$

where $\phi = \mathrm{var}(\varepsilon_{0it})$. We further specify that $\varepsilon_{0it} \sim N(0,\phi)$, and $\mathrm{cov}(\varepsilon_{0it},\varepsilon_{0it-s}) = 0$.

Our initial specification envisions a closed economy except for the error terms. As with productivity shocks, it is plausible that inflation shocks are contemporaneously correlated across countries. Thus we assume $\mathrm{cov}(\varepsilon_{0it},\varepsilon_{0jt}) = \gamma$ for $i \neq j$ which further implies

$$\mathrm{cov}(\mu_{it},\mu_{jt}) = \frac{\gamma}{\left(1+\psi^2\right)^2},$$

$$\mathrm{cov}(\xi_{it},\xi_{jt}) = \frac{\psi^2\gamma}{\left(1+\psi^2\right)^2}, \tag{13}$$

$$\mathrm{cov}(\mu_{it},\xi_{jt}) = -\frac{\psi\gamma}{\left(1+\psi^2\right)^2}.$$

Altogether we require five parameters to specify the error structure of the random aspect of our new Keynesian models, θ, η, ϕ, ψ and γ. A two-country example of the contemporaneous covariance matrix is

$$Var(\upsilon_1,\mu_1,\xi_1,\upsilon_2,\mu_2,\xi_2)=\begin{bmatrix} \theta & 0 & 0 & \eta & 0 & 0 \\ 0 & \frac{\phi}{\left(1+\psi^2\right)^2} & -\frac{\psi\phi}{\left(1+\psi^2\right)^2} & 0 & \frac{\gamma}{\left(1+\psi^2\right)^2} & -\frac{\psi\gamma}{\left(1+\psi^2\right)^2} \\ 0 & -\frac{\psi\phi}{\left(1+\psi^2\right)^2} & \frac{\psi^2\phi}{\left(1+\psi^2\right)^2} & 0 & -\frac{\psi\gamma}{\left(1+\psi^2\right)^2} & \frac{\psi^2\gamma}{\left(1+\psi^2\right)^2} \\ \eta & 0 & 0 & \theta & 0 & 0 \\ 0 & \frac{\gamma}{\left(1+\psi^2\right)^2} & -\frac{\psi\gamma}{\left(1+\psi^2\right)^2} & 0 & \frac{\phi}{\left(1+\psi^2\right)^2} & -\frac{\psi\phi}{\left(1+\psi^2\right)^2} \\ 0 & -\frac{\psi\gamma}{\left(1+\psi^2\right)^2} & \frac{\psi^2\gamma}{\left(1+\psi^2\right)^2} & 0 & -\frac{\psi^2\gamma}{\left(1+\psi^2\right)^2} & \frac{\psi^2\phi}{\left(1+\psi^2\right)^2} \end{bmatrix}$$

Notice that we are attempting to model macroeconomic outcomes without allowing for serial correlation. Since autocorrelation is widely observed in these variables, this is questionable. In the next section we present a test of this simplification.

The new classical model (6) also implies covariance restrictions, but they are much simpler: $\text{var}(\mu_{it}) = \text{var}(\xi_{it}) = -\text{cov}(\mu_{it}, \xi_{it})$.

We compare such restrictions to a more agnostic error specification where $\text{var}(\mu_{it}) = \sigma_\mu^2$, $\text{var}(\xi_{it}) = \sigma_\xi^2$, $\text{cov}(\mu_{it},\xi_{it}) = \sigma_{\xi\mu}$, and for $i \neq j$ $\text{cov}(\mu_{it},\mu_{jt}) = \sigma_{\mu b}$, $\text{cov}(\xi_{it},\xi_{jt}) = \sigma_{\xi b}$ and $\text{cov}(\mu_{it},\xi_{jt}) = \sigma_{\mu\xi b}$. We again assume that these variances and covariances are constant among the all countries and that υ_i, μ_{it} and ξ_{it} are normally distributed. Altogether we now require eight parameters to specify the covariance matrix. For our two-country example, the contemporaneous covariance matrix becomes

$$Var(\upsilon_1,\mu_1,\xi_1,\upsilon_2,\mu_2,\xi_2)=\begin{bmatrix} \theta & 0 & 0 & \eta & 0 & 0 \\ 0 & \sigma_\mu^2 & \sigma_{\xi\mu} & 0 & \sigma_{\mu b} & \sigma_{\mu\xi b} \\ 0 & \sigma_{\xi\mu} & \sigma_\xi^2 & 0 & \sigma_{\mu\xi b} & \sigma_{\xi b} \\ \eta & 0 & 0 & \theta & 0 & 0 \\ 0 & \sigma_{\mu b} & \sigma_{\mu\xi b} & 0 & \sigma_\mu^2 & \sigma_{\xi\mu} \\ 0 & \sigma_{\mu\xi b} & \sigma_{\xi b} & 0 & \sigma_{\xi\mu} & \sigma_\xi^2 \end{bmatrix}$$

8. An empirical comparison of modeling assumptions

The natural rate literature reports other methods of estimating these unobserved variables. Conventionally the natural level changes over time as technology advances, as capital is accumulated and as the labor force grows. Assuming that these influences evolve slowly and independently of business cycles, researchers have imposed smoothness restrictions on natural growth. Figure 2 compares our Kalman filter estimates[19] of natural growth for the US with two alternatives: the estimate published by the Congressional Budget Office (2001) and the Hodrick-Prescott filter. We select our sample period, 1954-1998, to precede the European monetary union and to provide complete observations on all variables and all countries, including the political ideology and central bank independence variables introduced below.

The popularity of the HP filter may be due to its simple agnostic formula.[20] The CBO estimate is more complicated. They use 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 using the CBO's estimate of the non-accelerating inflation rate of unemployment, constraining potential labor and productivity growth rates to be constant over the business cycle.

The Kalman filter can also smooth the natural growth by restricting the variance of the random step to a small value. Of the two Kalman estimates plotted, the more volatile path (bold red) maximizes likelihood of the data, while the other imposes a smoother path on g_{it}^* by restricting the variance to a smaller value, $\theta = 0.05$.[21] 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 mid-1960s.

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

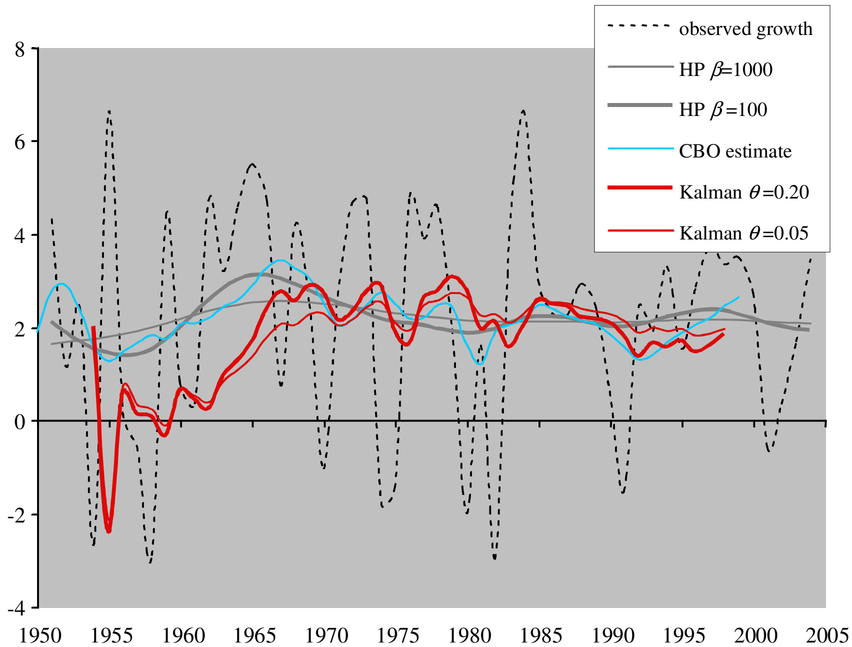
[20] It estimates of the natural rate series by minimizing the expression

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

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

[21] The maximum likelihood estimate of θ is 0.207 for the best-fitting specification (c) in Table 3 below; for comparability we restrict θ to 0.200 for all models in Tables 2, 3 and 4.

Figure 2. Alternatives estimates of the US natural growth rate



Clearly our Kalman estimates are more volatile than the usual estimates. The early years of our sample show the Kalman estimates substantially below the alternatives. This difference reflects different assumptions about natural 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 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.[22] The other two methods are omniscient in the sense that they include both past and future observations; they are more comparable to "smoothed" Kalman predictions of the state variables conditioned on the entire data set, $\hat{g}^*_{it|T}$. Although the smoothed estimate is not always closer to the alternative estimates than the filtered estimate, it is less volatile, and it does remove the 1950s anomaly, see Figure 3. This plot shows the significant difference between forward-looking and omniscient forecasts.

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[22] We specify $\hat{g}^*_{1|0} = 2$ with a variance of 9 as a plausible prior for the natural growth, and set $\ln\left(\hat{Y}^*_{1|0}\right)$ equal to the observed values in 1952 with a variance of 0.1.

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

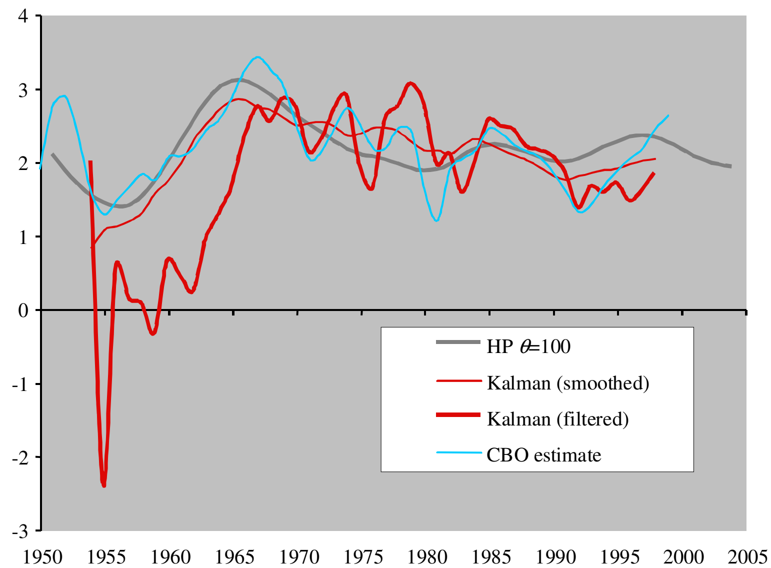
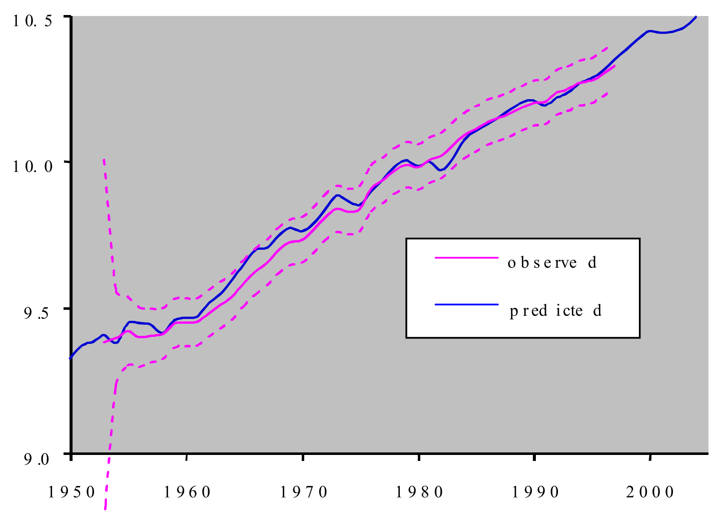


Figure 4. Comparing observed ln(GDP/capita) with the Kalman prediction of the US natural level



Because of the volatility of our θ=0.20 estimate appears inconsistent with the conventional notion of smooth long-term growth, some researchers may want to impose a smaller variance on the natural growth process. The bold red estimate in Figure 2 appears overly responsive to the business cycle. However, Figure 4 shows that the implied prediction of our natural GDP/capita level is fairly smooth even though our natural growth path is rather bumpy. The 95% confidence interval (dashed) also shows that these estimates are not very precise; the observed GDP is never outside of this interval. This plot also shows how quickly observations come to dominate our prior.

The goodness-of-fit statistics in Table 2 are the basis for our inferences about model specification. The table reports log likelihoods under different assumptions about the model, the error structure, the government's objective function and the formation of expectations. Comparing the top and bottom halves of the table, our results strongly reject the covariance restrictions implied by (12) and (13). This suggests sources of error other than inflation and productivity shocks.

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

expectation assumption	adaptive		rational	
between-country covariance	none	full	none	full
restricted covariance				
new Keynesian gap target	-14919	-13413	-15375	divergent
new Keynesian growth target	-14351	-13268	-15307	-14352
new classical	na	na	-27314	-26126
unrestricted covariance				
new Keynesian gap target	-3137	-3014	-3425	-3154
new Keynesian growth target	-2943	-2871	-3333	-3101
new classical	na	na	-3435	3156

The left half of the table assumes adaptive expectations. For example, replacing π_{it}^{e} by π_{it-1} in (3) and (4) gives the specification for the new Keynesian gap target model under adaptive expectations. The right half imposes strongly rational expectations. For example, using (5) gives the new Keynesian gap target model under rational expectations. Cell-wise comparisons between the left and right validate the conclusion that adaptive expectations are more likely.

Table 2 also compares the new Keynesian and new classical assumptions; the new Keynesian model fits better. Adaptive expectations are logically inconsistent with the new classical model. Within the new Keynesian framework we compare two objective function assumptions, concluding that governments are more likely to target the growth rate than the output gap. Finally, comparing columns strongly supports the existence of between-country covariance.

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 between 5% and 6%. All of the estimated slopes of the Phillips curve are statistically significant and positive, but vary considerably. The slope parameter is not identified under new classical assumptions. The crude oil shock coefficients are mostly positive as expected, but not statistically significant when we allow for between-country error covariance in models (c) through (f). Perhaps oil price shocks have not been as central to macroeconomic stabilization as is often thought.[23] We allow for between-country covariance in all models except (b). The results suggest that inflation-shock covariance is much more significant than natural-growth-shock covariance. We expected that greater between-country natural-growth covariance.[24]

[23] In an unreported estimate we modify model (c) to allow 14 different crude inflation effects to account for country-specific impacts. None of these 14 estimates are statistically significant.

[24] We follow Ireland (1999) in relaxing our assumption that the natural growth shock is independent of the inflation shock. In unreported estimates we re-estimate model (c) with an extra parameter for $\operatorname{cov}(\upsilon_{it}, \mu_{it})$ and likewise for model (d) with an extra parameter for $\operatorname{cov}(\upsilon_{it}, \varepsilon_{0it})$; both covariance estimates are small and insignificant.

Table 3. Selected regression results: 14 North Atlantic countries, 1954-1998, 630 annual observations (z-ratios in parentheses)

	(a)	(b)	(c)	(d)	(e)	(f)
model	new Keynesian, output gap	new Keynesian, growth	new Keynesian, growth	new Keynesian, growth	new Keynesian, growth	new classical
expectations	adaptive	adaptive	adaptive	adaptive	rational	rational
between-country covariance	full	none	full	full	full	full
Phillips curve slope	0.473	0.289	0.283	0.386	1.385	
	(14.46)	(20.12)	(13.77)	(451.64)	(11.46)	
crude oil inflation	0.008	0.011	0.010	0.009	-0.015	-0.005
	(2.041)	(4.175)	(1.062)	(0.571)	(-1.014)	(-0.994)
target	5.085	5.290	5.254	5.915	5.088	5.064
	(3.950)	(23.271)	(5.813)	(33.23)	(5.666)	(5.621)
var(υ_i)	0.200	0.200	0.200	0.200	0.200	0.200
cov(υ_i, υ_j)	0.010		0.043	0.017	0.006	0.008
var(ε_{0i})				18.561		
cov($\varepsilon_{0i}, \varepsilon_{0j}$)				2.930		
var(μ_i)	5.193	4.960	4.954	14.061*	5.977	14.953
var(ξ_i)	7.917	5.107	5.114	2.094*	11.235	6.150
cov(μ_i, ξ_i)	2.321	-0.976	-0.955	-5.426*	1.599	2.564
cov(μ_i, μ_j)	1.052		0.540	2.220*	1.625	8.510
cov(ξ_i, ξ_j)	3.808		1.356	0.331*	7.394	3.001
cov(μ_i, ξ_j)	1.162		-0.134	-0.857*	1.365	2.429
log likelihood	-3014	-2942	-2871	-13268	-3101	-3156

* Implied by (12) and (13).

The estimates of covariances in the best-fitting model (c) are entirely consistent with the signs predicted in (12) and (13), but not with the magnitudes. Enforcing the covariance restrictions in model (d) fits the observations poorly. Table 3 shows the theoretically implied variance and covariance estimates; these restrictions imply a higher inflation variance than the unrestricted estimate, a lower growth variance, a stronger negative covariance between inflation and growth, a higher inter-country inflation covariance and a lower inter-country growth covariance. The growth errors 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.[25]

A comparison of models (c) and (e) shows that inferences about the slope of the Phillips curve are strongly affected by our expectation theory, the curve is much flatter under the adaptive assumption. Even though adaptive expectations fit the data better, many may be skeptical of this naive model. Based on the best-fitting model (c), which assumes adaptive expectations, the best one-year-ahead forecast of inflation $\hat{\pi}_{it|t-1}$ is computed according to the Kalman filter; this forecast differs from the adaptive one. However, for the sample period the $\pi^e_{it} = \pi_{it-1}$ rule underestimates $\hat{\pi}_{it|t-1}$ by only about 0.03% on average, and the forecast error, $\hat{\pi}_{it|t-1} - \pi_{it-1}$, has a standard deviation of only 1.3%. We conclude that although the adaptive forecast may not be the best prediction of future inflation, its naivety does not result in large errors.

Estimating an AR(1) model on 616 residuals from the best-fitting model (c), we obtain an autocorrelation parameter –0.17 (-4.44) for inflation errors and 0.08 (1.96) for growth errors. Since we have the one-tailed alternative hypothesis that the autocorrelation parameters are positive, these statistics support the conclusion that our general contemporary covariance specification fits the data well, and that it would not be improved by adding autocorrelation terms. This is surprising because macroeconomic literature customarily allows for serial correlations among errors; perhaps this result only holds for our widely spaced annual observations.

9. Accounting for ideology, regime change and openness

Politics and institutions could influence outcomes through the inflation target parameter. A famous result by Rogoff (1985) concludes that appointing central bank governors can mitigate the inflation bias. This prescription can be modeled as $\hat{\pi}^b < \hat{\pi}^g$, where superscripts denote the central bank and the government. 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

[25] Although some studies add an inflation policy error to their specifications (see Ireland (1999) or Sargent et al. (2006) for example); this would not account for the growth shocks observed here.

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

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 above 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 $(\hat{\pi}^b = \hat{\pi}^g)$.[26] Cukierman et al. (1992) develop a formal index of legal independence, defined on (0,1).[27] According to this measure the Italian central bank achieves the greatest independence in our sample (.92 after 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 includes elements of conservativeness (whether price stability is the only objective).

Political ideologies differ across countries and over time; rightwing governments may prefer for a lower inflation target. We formalize this notion by rewriting the target as $\hat{\pi}^g_{it} = \hat{\pi}^{g0} + \hat{\pi}^{g\rho}\rho^g_{it}$ where ρ^g_{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 -10 at the extreme Left to +10 at the extreme Right. During years in which the government changes, the 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 percentage of seats in the lower house of Parliament.

Many studies have pursued the notion that government policy changes in election years. We test for this possibility by allowing for a different inflation target if an election occurs during the year, $\nu_{it} = 1$.

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[26] Equation (11) generalizes our output-inflation objective (2), and similar result follows as a generalization of the growth-inflation objective (6).

[27] 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. Inaccurate dating may not be a serious shortcoming because according to Cukierman (2005: 4), it is a "fact that during the forty years ending in 1989 there hardly had been [any] reforms in [central bank] legislation."

We also allow this election year target to vary with the ideology of the median voter, where ρ_{it}^{v} is a similar Left-Right index of the median voter ideology. Budge also publishes an estimate of the ideology of the median voter by using ballot percentages to interpolate between party scores.

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

$$\hat{\pi}_{it} = \theta_{it}\hat{\pi}^{b} + (1-\theta_{it})\left((1-\nu_{it})\left(\hat{\pi}^{g0} + \hat{\pi}^{g1}\rho_{it}^{g}\right) + \nu_{it}\left(\hat{\pi}^{e0} + \hat{\pi}^{e1}\rho_{it}^{v}\right)\right).$$

We evaluate the strength of these influences by substituting this equation into the best-fitting model (c). The results are reported as model (g) in Table 4. The results suggest that central banks aim at an inflation target that is about 3% lower than governments, although the difference is not statistically significant. The ideological effects have the expected negative sign, but are not statistically significant, nor is the estimated election-year target significantly different from the non-election-year target. These results suggest that with respect to macroeconomic outcomes central bank independence is more significant that politics.

Table 4. Extensions: 14 North Atlantic countries, 1954-1998, 630 annual observations
(*z*-ratios in parentheses)

	(g)	(h)	(i)	(j)	(k)	(l)
model	new Keynesian, growth, adaptive	new Keynesian, growth, adaptive	new Keynesian, growth, adaptive	new Keynesian, growth, adaptive	new Keynesian, growth, adaptive	new classical, rational
Phillips curve slope	0.305	0.327	0.282	0.449	0.494	
	(13.978)	(6.472)	(13.807)	(7.444)	(112.34)	
crude oil inflation	0.010	0.010	0.011	0.010	0.013	-0.003
	(0.921)	(0.987)	(1.119)	(0.859)	(0.573)	(-0.620)
government target	6.244	4.794	5.203	6.489	7.619	6.765
	(4.926)	(3.985)	(5.681)	(5.133)	(46.630)	(6.958)
central banker target	3.264			1.816	0.641	2.076
	(1.338)°			(2.009)°	(28.597)°	(3.100)°
election-year target	6.828			7.295	7.801	6.797
	(0.412)†			(0.352)†	(7.488)†	(0.054)†
government ideology	-2.606			-2.160	-1.036	-0.104
	(-0.739)			(-0.639)	(-7.669)	(-0.075)
median-voter ideology	-0.818			0.224	-1.450	1.802
	(-0.088)			(0.025)	(-6.909)	(0.494)
openness-slope interaction		-0.075		-0.224	-0.132	
		(-0.848)		(-2.172)	(-18.950)	
openness-target interaction		0.809		0.748	1.763	0.020
		(0.566)		(0.533)	(7.412)	(0.038)
openness-inflation variance			0.700	0.826	2.123	0.688
			(3.517)	(3.769)	(5.566)	(2.652)
var(υ_i)	0.200	0.200	0.200	0.200	0.200	0.200
cov(υ_i,υ_j)	0.042	0.048	0.045	0.044	0.017	0.008
var(ε_{0i})					17.808‡	
cov(ε_{0i},ε_{0j})					3.901	
var(μ_i)	4.900	4.958	4.808‡	4.714‡	11.498‡*	13.064‡
var(ξ_i)	5.111	5.092	5.106	5.080	2.811‡*	6.223
cov(μ_i,ξ_i)	-0.974	-0.937	-0.864	-0.838	-5.685‡*	2.491
cov(μ_i,μ_j)	0.524	0.537	0.513	0.469	2.519*	7.152
cov(ξ_i,ξ_j)	1.382	1.337	1.357	1.399	0.616*	3.064
cov(μ_i,ξ_j)	-0.127	-0.137	-0.130	-0.116	-1.246*	2.274
log likelihood	-2868	-2870	-2865	-2860	-13121	-3118

* Implied by (12) and (13).
° 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.
‡ Estimated at sample mean for the openness index, 0.6.

The implications of economic openness are another possibility for extending our model beyond simple between-country covariance. Romer (1993) argues that more open economies should have lower equilibrium inflation and steeper Phillips curves. We extend our analysis by substituting into model (c) a slope-openness interaction term, $\psi_{it} = \psi_0 + \psi_w w_{it}$, using the ratio of exports plus import to domestic output w_{it} to measure openness. We also generalize our inflation target as $\hat{\pi}_{it} = \hat{\pi}_0 + \hat{\pi}_w w_{it}$. On the other hand, Clarida et al. (2001) predict the opposite; starting with microfoundations their Phillips curve becomes flatter with greater openness.[28] The results for model (h) do not support either prediction. Both the estimated openness effects are essentially zero and statistically insignificant.[29] Clarida et al. also argue that due to terms of trade volatility, CPI inflation should be more volatile in more open economies. Note that our measure is domestic inflation, so it is unclear whether openness should increase its volatility. To test the possibility, we re-specify $\mathrm{var}(\mu_{it}) = \sigma_{0\mu}^2 e^{\sigma_{w\mu}^2 w_{it}}$ in model (i). The results suggest that domestic inflation error volatility does increases with openness.

Model (j) includes all extensions effects: target, slope and inflation variance. Including all effects does not change any inferences, except that a negative slope-openness interaction is now significant. In model (k) we impose the restrictions implied by (12) and (13) to the composite specification (j); all other results in Table 4 assume an unrestricted covariance structure. As before, the unrestricted assumption fits the data much better. It is interesting to note that most of political and central bank effects become statistically significant and all have the expected signs in model (k); furthermore the flatter slope estimate and increased inflation targets for more open economies are both significant, as is the greater inflation variance. Model (l) extends the new classical model (f) by adding target political, central bank and openness effects; the results validate the conclusion that the new Keynesian restrictions fit the data better.

10. Conclusion

We develop a standard model of political and economic interaction, and test its relevance to the macroeconomic history using a panel of countries. We compare a number of alternative econometric

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

[29] This is consistent with Temple's (2002) empirical study.

specifications. We infer that the new Keynesian model of asymmetric information and inflexibility is more likely to have generated these data than the new classical model of full information and flexibility. Our results are also more consistent with an adaptive theory of expectations, rather than the more conventional rational one.

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. There is also robust evidence of an influence of central bank independence on macroeconomic outcomes, although the effects of electoral politics and ideology seem slight. We search for effects due to openness. Globalization's main impact on stabilization policy comes from the between-country covariance of inflation and growth shocks (but not productivity shocks); openness is also associated with a greater inherent volatility of domestic inflation.

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