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Policy effectiveness is limited by a flat Phillips curve, stabilization as practiced in Europe and the US

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Abstract

A standard model of activist macroeconomic policy derives a monetary reaction rule by assuming that governments have performance objectives, but are constrained by an augmented Phillips curve. In addition to monetary policy, governments apply a variety of instruments to influence inflation and output, including fiscal policy, bailouts and foreign exchange policy, but effectiveness is limited by Phillips curve flatness. Solving the Phillips curve and reaction rule for a reduced form, we study this theory with a panel of countries. A textbook version of the activist model leads to disappointing results; the activist model fits the data only slightly better than a flat-Phillips-curve benchmark. The econometric results are enhanced by accounting for autocorrelated shocks. Although results are mixed, our interpretation favors inertial inflation expectations over rational ones. An extension of this approach suggests that US policy is more effective than that of European governments, finding that the US Phillips curve is more than twice as steep.

Keywords: stabilization policy, inflation targets, expectations

JEL Classification: E61, E63

1. Introduction

Central to an endogenous policy model is a monetary rule *MR* derived by assuming that governments have an inflation target and are constrained by a Phillips curve *PC*.[1] Carlin and Soskice (2005) label this the *IS-PC-MR* model, adding an *IS* curve to explain how policymakers set interest rates to pursue their goals.

This approach can be extended to include other policy instruments, but to keep the methodology simple, we do not formally model policy tools such as interest, tax or exchange rates, government spending or bailouts. This reduces our inferences to those that can be drawn indirectly from examining inflation and output outcomes.

But, is there evidence of effective activism beyond public pronouncements and decades of Keynesian doctrine? Perhaps these instruments are ineffective, or governments do not actually attempt to lean against the wind, or perhaps the Phillips curve is flat. If there is no short-run tradeoff, then there is no motivation to pursue activist intervention even with stabilization goals. We focus on the flatness question with an econometric analysis of a panel of European countries[2] and the US.

Because expected inflation enters the analysis as a shift in the Phillips curve, an important modeling issue is the nature of inflation forecasts. We assume that governments are rational throughout; but for agents we begin with simple backward-looking expectations, and develop extensions to forward-looking ones. Forward-looking expectations are appealing because they cohere with the notion of well-informed rational agents. We find, however, that rational expectations specifications do not clearly improve the statistical fit, as compared with the simple inertial model.

The estimation of a textbook version of these models fits the data poorly. The econometric results are improved by accounting for serial correlation. We do find evidence of activist

[1] This model is also known as the 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] Finland, France, Germany, Greece, Ireland, Italy, Spain, Sweden and the UK.

stabilization, but it is weak, and there are also some puzzles. We also find that the revealed inflation target has evolved over time, and that stabilization is less feasible in Europe than in the US due to the flatness of European Phillips curves.

2. Macroeconomic structure and government objectives

The policy literature often invokes an augmented Phillips curve as a structural constraint on policymakers; this is the *PC* part of the *IS-PC-MR* model. Conventionally it is an inverse relation between the unexpected inflation and the gap between actual and natural unemployment. Since the potential output Y_t^* is conceptually similar to the equilibrium, or natural rate, of unemployment, the output gap can be substituted for the unemployment gap as the measure of macroeconomic disequilibrium,

$$\pi_t = E^a\pi + \psi x_t + \varepsilon_t \qquad (1)$$

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 unexpected inflation shock. Expected inflation $E^a\pi$ is as the forecast of a typical agent based on available information. Given that expectations are fulfilled in the long run, (1) rules out any long-run deviation from $x = 0$. However, as long as economic agents do not fully anticipate policy, an activist government may be able to temporarily increase output at the cost of higher inflation.

Beginning with Fischer (1977) a number of explanations of the Phillips relationship have been offered, including overlapping nominal wage contracts, costly price adjustment and stochastic updating of information. Calvo's (1983) prominent sticky price model is also known as the new Keynesian Phillips curve. The essential result of this model is that agents' expectations are contemporaneous and forward-looking, or that $E^a\pi = E_t^a\pi_{t+1}$, with the operator subscript dating the forecast. In contrast, the conventional textbook assumption (often labeled inertial) is backward looking $E^a\pi = \pi_{t-1}$. An information lag implies backward dating $E_{t-1}^a\pi_t$, although rational forecasts are independent of past inflation. This paper explores these topics empirically.

Another modeling element is an assumption about political objectives; this is the basis of the *MR* curve. A simple possibility supposes that the government's goals are given by a quadratic function of the output gap and inflation,[3]

$$U_t = -\left(x_t^2 + \left(\pi_t - \pi^T\right)^2\right) \tag{2}$$

where π^T is the inflation target. The government objective function might be a weighted average of citizen preferences.[4] Social welfare is often defined as an aggregation of individual preferences.[5]

We assume that governments maximize (2) subject to (1). Quadratic goals are tractable because they result in linear solutions.[6] Within this family a variety of alternatives are plausible. Often the output target exceeds its potential level.[7] 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 assume parabolic indifference curves.[8] Kiefer (2008) estimates eight different quadratic forms. He concludes that it is not possible to statistically separate the goal weight, the inflation target and the output target parameters.[9] Thus, the target parameter π^T summarizes policy; it might be interpreted as a composite of weights and targets.

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

[4] This function 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.

[5] Woodford (2003) establishes microfoundations for several close relatives of this function form as an approximation to the utility of a representative consumer-worker.

[6] 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.

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

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

[9] Also see Ireland (1999).

3. Optimal policy with an inflation target

Following Carlin and Soskice, we assume that policymaking is only effective with a one-year delay. They explain this delay as a lag in the *IS* relation.[10] Accordingly, we re-date the government's objective to next year's outcome and add the expectations operator (the g superscript denotes that these are the expectations of the government),

$$E_t^g U = -E_t^g \left(x_{t+1}^2 + \left(\pi_{t+1} - \pi^T \right)^2 \right)$$

Subject to the Phillips curve constraint, the government's preferred inflation for next year is

$$\pi_{t+1}^* = \frac{E^a \pi + E_t^g \varepsilon_{t+1} + \psi^2 \pi^T}{1 + \psi^2}$$

To the extent that agents are rational and well informed they would expect this outcome, then expected output would be zero. However, if agent forecasts behave otherwise, the policymaker may be able to lean against the wind.

We add an inflation shock ε_{t+1} (unexpected by either agents or governments) to π_{t+1}^*. Using the Phillips curve, adding another output shock ξ_{t+1} and lagging both solutions by one year, gives

$$\begin{aligned} \pi_t &= \frac{E^a \pi + \psi^2 \pi^T}{1 + \psi^2} + \varepsilon_t \\ x_t &= -\psi \frac{E^a \pi - \pi^T}{1 + \psi^2} + \xi_t \end{aligned} \tag{3}$$

Equations (3) imply that macroeconomic outcomes depend on shocks, expectations, Phillips curve slopes and policy targets. This solution is the point where the *PC* and *MR* curve cross, except for shocks which we initially take as independent and identically distributed random variables. Governments might pursue influence macroeconomic outcomes by other mechanisms; our study is limited to policy that exploits the Phillips tradeoff.

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[10] Although plausible, this policy lag conflicts with conventional consumer choice derivations of the *IS* curve which do not show any lag; for example see Gali (2008).

We assume that governments implement policy through variety of instruments (monetary policy, unemployment insurance, tax rebates, infrastructure spending, bailouts, exchange rates, etc.) and that its various agencies pursue this common policy. Our model is two of the equations in Carlin and Soskice's three-equation model, dropping their *IS* equation.[11]

In the long run agents come to understand that a policy of $\pi^T > 0$ implies inflation. In the absence of shocks or uncertainty, the equilibrium inflation rate should occur where inflation is just high enough that the government is not tempted to spring a policy surprise. This time-consistent equilibrium occurs at the potential output and the inflation target, $x = 0$, $\pi = \pi^T$.

Because these equations are a reduced form, they are appropriate for econometric estimation. An alternative estimate of the Phillips curve slope could be based on the structural equation (1). The obvious objection to such a regression is that it may suffer from simultaneity bias because the output gap is endogenous, an issue that does not arise with (3).

Compared to the literature on monetary policy econometrics, this is a very small and stylized specification. Recent research reports much more complicated models; see the dynamic stochastic general equilibrium approach of Christiano et al. (2005) or Smets and Wouters (2003). The latter, for example, specifies 4 structural parameters without estimation and uses Bayesian methods to estimate 32 additional parameters in a 9-equation model. Their approach includes habit formation in consumption, technology and preference shocks, capital adjustment costs and less than full capacity utilization; it also accounts for sticky prices and wages, along with markups deriving from market power. By comparison our 2-equation model has only 2 parameters. Although the DSGE literature develops a detailed description of consumer and firm objectives and behavior, it often models government behavior as an agnostic stochastic process without an objective function.

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[11] To directly model the government's instruments we would need several more equations; we would also need to assume that these all can be separated from the underlying reaction functions, and that all display the same one-year lag.

4. Growth targets

We also consider a related objective function specified on the growth rate, rather than the output gap,

$$E_t^g U = -E_t^g \left(\left(g_{t+1} - g_{t+1}^* \right)^2 + \left(\pi_{t+1} - \pi^T \right)^2 \right)$$

Although this specification is less common, it could be appropriate if governments are more concerned about the growth rate than the level of output.[12] The output gap and the growth rate are related concepts; the growth rate is defined as $g_t \equiv \ln(Y_t) - \ln(Y_{t-1}) \equiv g_t^* + x_t - x_{t-1}$, where g_t^* is the growth of potential output. Substituting this identity into to the growth target objective function, we derive the short-run equilibrium as before

$$\begin{aligned} \pi_t &= \frac{E^a \pi + \psi^2 \pi^T + \psi x_{t-1}}{1+\psi^2} + \varepsilon_t \\ x_t &= \frac{x_{t-1} - \psi\left(E^a \pi - \pi^T\right)}{1+\psi^2} + \xi_t \end{aligned} \tag{4}$$

Comparing the solutions (3) versus (4), we see that the growth target solution adds an inherited condition, the lagged value of output.

5. Expected inflation

Expected inflation has been much studied. The inertial assumption, $E^a \pi = \pi_{t-1}$, is one possible model for this unobserved variable. This simple forecasting rule has the desirable property that the inertial versions of both (3) and (4) converge to the time-consistent equilibrium. Under this assumption, dramatic dynamic differences can arise between the output and growth-target models, as illustrated in Figure 1. These are simulated policy responses to a variety of inflation and output shocks. These two-dimensional impulse response functions are calculated according to a unit-slope Phillips curve, a zero inflation target and inertial expectations; each dot denotes one year. An

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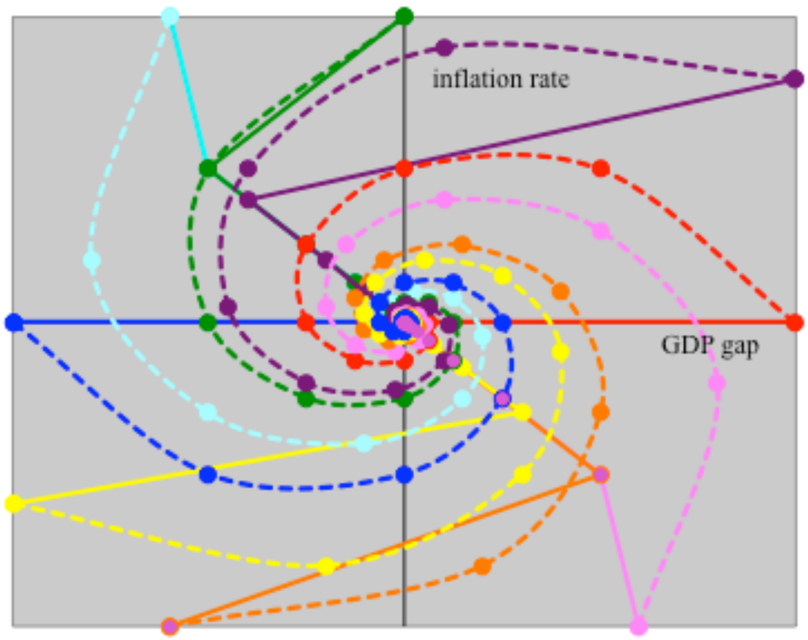
[12] Woodford (2003) derives a similar form from microfoundations under the assumption that the representative citizen's utility exhibits habit persistence.

inflation shock has consequences for subsequent Phillips curves because it affects expectations in the following years. The output target dynamics (solid paths) generate a negative-sloped *MR* curve.

Figure 1. Generic convergence trajectories: output target solid, growth target dashed

$$E^a\pi = \pi_{t-1}, \psi = 1, \pi^T = 0$$



Since positive output shocks are often accompanied by positive inflation shocks, the purple path is of interest. The output target model predicts that the response to any inflation shock is a recession (even one associated with an output boom as in the purple case), and that it responds to any deflation shock with a boom. Another implication of this model is the horizontal jump to the long-run equilibrium from any initial condition along the horizontal axis, for example the red or blue paths. This occurs because output shocks are assumed to have no effect on the location of the Phillips curve that is only shifted by an inflation shock or last-year's inflation. This implication is a surprising consequence of this standard model of activist policy under inertial expectations.

A noteworthy dynamic property illustrated in Figure 1 is that the growth target assumption (dashed paths) introduces stabilization policy that responds to output, as well as inflation shocks. The impulse response functions for (4) include the lagged output gap and thus lagged output shocks. Each combination of shocks produces a unique counterclockwise spiral that does not simplify to a *MR* schedule. For example, the dashed purple path begins with a pair of positive shocks, and responds with even greater inflation in the following year.

Many economists are skeptical of the backward-looking inertial assumption. The rational expectations approach acknowledges that the typical agent must to know the government's inflation target, and that she ought use this information to forecast inflation. Taking the expectation of (3) and recalling that future shocks are unpredictable, the model-consistent expectation dated in the previous year is $E^a_{t-1}\pi_t = \pi^T$. When these behavioral assumptions are valid (activist governments with rational agents and a one-year lag for both policy effectiveness and forecasting), the solution simplifies to

$$\begin{aligned} \pi_t &= \pi^T + \varepsilon_t \\ x_t &= \xi_t \end{aligned} \tag{5}$$

Now we cannot estimate the slope of the Phillips curve, although we can identify the inflation target.

A popular interpretation of rational expectations follows Calvo's (1983) sticky-price model of the Phillips curve, a stochastic derivation renown for its microfoundations. This new Keynesian model assumes that only a fraction of all firms receive a random "price-change signal" each year. Since resetting firms may be unable to reset again for some time, they rationally forecast future conditions weighing the future according to the resetting probability. The conclusion of this analysis is to rewrite (1) in terms of forward-looking expectations, $E^a\pi = E^a_t\pi_{t+1}$. Generally new Keynesian expectations are dated in the current year, without any information lag. Advancing the subscripts on the above rational result, it follows that $E^a_t\pi_{t+1} = \pi^T$ which implies that the new Keynesian solution is identical to (5).

Alternatively, for an agent who knows that government is pursuing a growth target, the expectation of (4) gives $E^a_{t-1}\pi_t = \pi^T + \dfrac{x_{t-1}}{\psi}$. When these behavioral assumptions are valid, the solution is

$$\pi_t = \pi^T + \frac{x_{t-1}}{\psi} + \varepsilon_t \qquad (6)$$
$$x_t = \xi_t$$

This specification enables an estimate of both the slope of the Phillips curve and the inflation target.

Invoking the new Keynesian approach, the model-consistent expectation advances the time subscript, $E_t^a \pi_{t+1} = \pi^T + \frac{x_t}{\psi}$. If a rational government knows that this model holds, then its preferred policy changes. Applying the same method, the solution is

$$\pi_t = \pi^T + \frac{\left(\psi + \psi^3\right) x_{t-1}}{1 + 3\psi^2 + \psi^4} + \varepsilon_t \qquad (7)$$
$$x_t = \frac{\psi^2 x_{t-1}}{1 + 3\psi^2 + \psi^4} + \xi_t$$

The difference between (6) and (7) can be interpreted as a steeper Phillips curve under new Keynesian expectations.

6. A panel of ten economies

We study a panel of countries from the European Commission's Annual Macro-economic Database (AMECO). Our dataset is a balanced panel of 10 countries covering 1967-2014. Our inflation rate is the percentage change in implicit GDP price deflator. GDP gap is the percentage deviation from potential GDP. Figure 2 plots annual observations of these series.[13] Notice the extreme path taken by Greece, and that the US path is in the middle of the cross section. The inflation plot shows high inflation rates initially, moderating during the 1990s and 2000s. The gap series reveals cyclical behavior and across-country correlation. The global crisis of 2008 is apparent as a negative spike to output, with a lesser impact on the inflation series.

[13] Using this approach Kiefer (2015) finds that the activist model is supported when the time period is a year, but not a quarter.

Figure 2. The AMECO macroeconomic data, 1967-2014

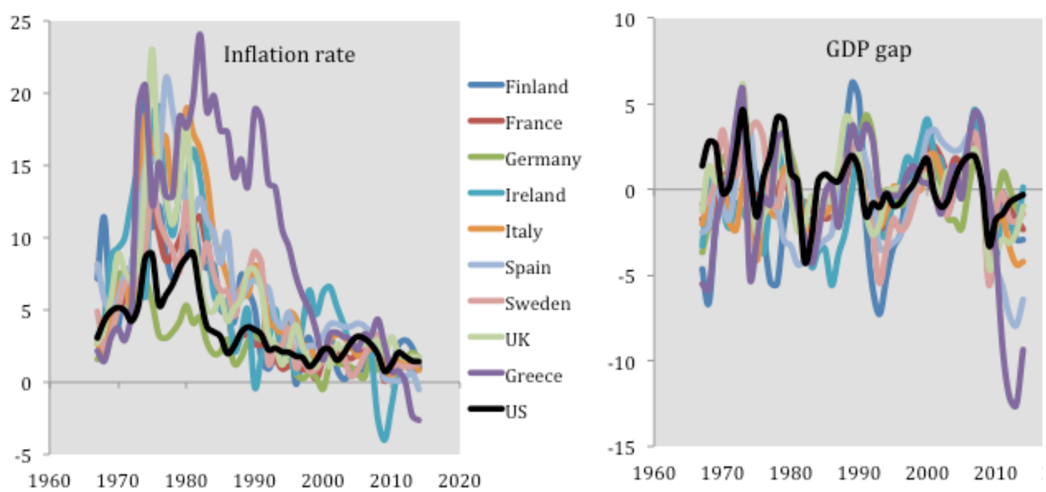


Table 1 reports descriptive statistics. The US has averaged the best GDP gap for our sample, while Spain has the worst. Given that by definition the GDP gap should be centered on zero, it is surprising to find negative averages for most countries, probably reflecting the severity of the 2008 crisis.

Table 1. Macroeconomic outcomes, 1969-2014 averages

	GDP deflator inflation (%)	GDP gap (%)
Finland	4.83	-0.65
France	4.34	-0.01
Germany	2.69	0.19
Greece	9.49	-0.59
Ireland	5.95	-0.55
Italy	6.80	-0.45
Spain	6.77	-0.88
Sweden	4.85	-0.16
UK	5.81	0.04
US	3.61	0.33
average	5.51	-0.27

Table 2 reports initial regression results. Although we do not make any modeling adjustments for openness or international trade, our specification does allow for across-country covariance.[14] We estimate a nonzero contemporaneous covariance for inflation shocks between countries (the same for all countries), and another between between-country covariance for output shocks. All specifications are systems of equations with cross-equation restrictions; all estimates are calculated by maximizing the corresponding likelihood function. Model (a) estimates (3), invoking the inertial assumption and requiring identical parameters in all countries. This standard model does not fit these data well, and neither parameter is statistically significant.[15] However imposing the rational expectations solution (5) fits the data even worse. The growth target model (c) imposes (4), and achieves the best fit in this table, although its target estimate is not statistically significant. These results suggest that none of these specifications are adequate.

Table 2. Initial econometric results,
10 countries, 46 annual observations, 1969-2014
(z-statistics in parentheses)

	(a)	(b)	(c)	(d)	(e)
	output target, inertial exp.	output target, rational exp.	growth target, inertial exp.	growth target, rational exp.	growth target, NK exp.
Phillips curve ψ	0.09		0.09	6.18	estimate
	(1.79)		(2.26)	(1.25)	does not
inflation target π^T	3.22	4.76	4.99	4.81	converge
	(0.76)	(1.56)	(1.44)	(1.69)	
inter-country inflation covariance	0.65	12.59	0.53	12.33	
inter-country output covariance	2.31	2.29	1.49	2.29	
Schwarz criterion	83.65	93.91	78.58	93.88	

As an appropriate benchmark we impose a flat Phillips curve on our solutions, $\psi = 0$. Imposing this restriction removes the tradeoff between inflation and the output; the target parameter drops out of (3). Under this restriction all motivation for activism is removed. Now the

[14] Justification lies in the theoretical result of Clarida et al (2001): that stabilization policy in an open economy is qualitatively the same as that of a closed economy.
[15] A VAR(1) model (6 parameters, identical for all countries) lowers the Schwarz statistic to 77.07.

government (even though it has activist goals) prefers the expected inflation rate, and a zero output gap.

$$\begin{aligned} \pi_t &= E^a \pi_t + \varepsilon_t \\ x_t &= \xi_t \end{aligned} \tag{8}$$

This benchmark is identical to the rational solution (5) in the presence of rational expectations, but differs under inertial expectations. Applying the same logic to the growth target model, we get a slightly modified flat solution

$$\begin{aligned} \pi_t &= E^a \pi_t + \varepsilon_t \\ x_t &= x_{t-1} + \xi_t \end{aligned} \tag{9}$$

Notice that an output target model, plus the inertial expectations, yields a random walk for inflation, while the gap is random. And, with a growth target, both inflation and output follow random walks.[16] Thus, unlike the other specifcations, these benchmark models do not converge to an equilibrium. Our flat model estimates fit nearly as well as their activist versions, not surprising in light of the small slope estimates, but disappointing for the stabilization activists.[17]

7. Serial correlation

In light of the frequent observation of serial correlation in macroeconomic time series, all the models in Table 2 above may suffer from misspecification because they assume uncorrelated errors.[18] This section modifies the error terms by introducing first-order autocorrelation, which implies that governments are now able to forecast the inflation shock. Solving by the same method for an output target gives

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[16] We estimate all alternatives as state space models; this enables maximum likelihood estimates of nonstationary specifications.

[17] The Schwartz criterion for the flat output target (8) is 83.66, and 78.88 for the flat growth target (9).

[18] Clovis and Zhang (2010) report the importance of accounting for autocorrelation in the error structure of the Phillips curve.

$$\pi_t = \frac{E^a\pi + E^g_{t-1}\varepsilon_t + \psi^2\pi^T}{1+\psi^2} + \mu_t \text{ where } \varepsilon_t = \rho_\varepsilon\varepsilon_{t-1} + \mu_t$$
$$x_t = \frac{-\psi\left(E^a\pi + E^g_{t-1}\varepsilon_t - \pi^T\right)}{1+\psi^2} + \xi_t \text{ where } \xi_t = \rho_\xi\xi_{t-1} + v_t$$

Only the unexpected part of the inflation shock is added to the inflation equation, as implied by the assumption that rational policy mitigates the expected shock. When the government's expectation is fulfilled, the inflation policy is achieved exactly; this is consistent with the theory that policy places the economy at the best point along the Phillips curve. The government's expectation is $E^g_{t-1}\varepsilon_t = \rho_\varepsilon\varepsilon_{t-1}$; it enters both equations, which we rewrite more conveniently as

$$\begin{aligned}\pi_t &= \frac{E^a\pi_t + \psi^2\pi^T}{1+\psi^2} + \rho'_\varepsilon\varepsilon_{t-1} + \mu_t, \text{ where } \rho'_\varepsilon = \frac{\rho_\varepsilon}{1+\psi^2}\\ x_t &= -\psi\frac{E^a\pi_t - \pi^T}{1+\psi^2} - \psi\rho'_\varepsilon\varepsilon_{t-1} + \rho_\xi\xi_{t-1} + v_t\end{aligned} \tag{10}$$

If, as a flat Phillips curve benchmark, we impose a $\psi = 0$. The target parameter drops out of flat solution; resulting in (8) with the AR(1) errors.

In the presence of rational agents who know the slope of the Phillips curve, the autocorrelation coefficient and the inflation target, our rational solution also needs revision. Taking an agent's expectation of (10) and solving for her inflation expectation, we get $E^a_{t-1}\pi_t = \pi^T + \frac{E^g_{t-1}\varepsilon_t}{\psi^2}$. The second term implies that agents expect the government to lean against expected shocks, and to lean harder when the Phillips curve is flatter. This amends the rational solution as

$$\pi_t = \pi^T + \frac{E^g_{t-1}\varepsilon_t}{\psi^2} + \mu_t$$
$$x_t = -\frac{E^g_{t-1}\varepsilon_t}{\psi} + \xi_t$$

which we rewrite as

$$\begin{aligned}\pi_t &= \pi^T + \rho'_\varepsilon\varepsilon_{t-1} + u_t, \text{ where } \rho'_\varepsilon = \frac{\rho_\varepsilon}{\psi^2}\\ x_t &= -\psi\rho'_\varepsilon\varepsilon_{t-1} + \rho_\xi\xi_{t-1} + v_t\end{aligned} \tag{11}$$

which reduces to (5) when $\rho_\varepsilon = 0$ and $\rho_\xi = 0$.

Extending this analysis to new Keynesian expectations implies that $E_t^a \pi_{t+1} = \pi^T + \frac{E_t^g \varepsilon_{t+1}}{\psi^2}$. Consistent with our timing assumptions, the solution now involves the government's expectation during year *t*-1 of the agent's expectation in year *t*, $E_{t-1}^g \left(E_t^a \pi_{t+1} \right) = \pi^T + \frac{\rho^2 \varepsilon_{t-1}}{\psi^2}$. Now we find

$$
\begin{aligned}
&\pi_t = \pi^T + \rho'_\varepsilon \varepsilon_{t-1} + u_t, \text{ where } \rho'_\varepsilon = \frac{\rho_\varepsilon \left(\rho_\varepsilon + \psi^2 \right)}{\psi^2 \left(1 + \psi^2 \right)} \\
&x_t = -\psi \rho'_\varepsilon \varepsilon_{t-1} + \rho_\xi \xi_{t-1} + v_t
\end{aligned}
\tag{12}
$$

which is observationally indistinguishable from (11). There are two interpretations of this model's estimate of the inflation autocorrelation parameter, one based on an information lag (11), and a second based on Calvo expectations (12).[19]

Applying the same logic, a growth target now gives

$$
\begin{aligned}
\pi_t &= \frac{E^a \pi_t + E_{t-1}^g \varepsilon_t + \psi^2 \pi^T + \psi x_{t-1}}{1 + \psi^2} + \mu_t \text{ where } \varepsilon_t = \rho_\varepsilon \varepsilon_{t-1} + \mu_t \\
x_t &= \frac{x_{t-1} - \psi \left(E^a \pi_t + E_{t-1}^g \varepsilon_t - \pi^T \right)}{1 + \psi^2} + \xi_t \text{ where } \xi_t = \rho_\xi \xi_{t-1} + v_t
\end{aligned}
$$

which we rewrite as

$$
\begin{aligned}
\pi_t &= \frac{E^a \pi_t + \psi^2 \pi^T + \psi x_{t-1}}{1 + \psi^2} + \rho'_\varepsilon \varepsilon_{t-1} + \mu_t, \text{ where } \rho'_\varepsilon = \frac{\rho_\varepsilon}{1 + \psi^2} \\
x_t &= \frac{x_{t-1} - \psi \left(E^a \pi_t - \pi^T \right)}{1 + \psi^2} - \psi \rho'_\varepsilon \varepsilon_{t-1} + \rho_\xi \xi_{t-1} + v_t
\end{aligned}
\tag{13}
$$

A flat benchmark reduces to (9) with the AR(1) errors.

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[19] Working backwards from (12), gives are two solutions for the autocorrelation coefficient $\rho_\varepsilon = -\frac{\psi \pm \sqrt{\psi^2 + 4\rho'_\varepsilon \left(\psi^2 + 1 \right)}}{2} \psi$.

In the presence of rational agents, our rational growth-target solution again needs revision. Now the rational expectation is $E_{t-1}^{a}\pi_t = \pi^T + \frac{x_{t-1}}{\psi} + \frac{E_{t-1}^{g}\varepsilon_t}{\psi^2}$ and this amends the rational solution to

$$\begin{aligned} \pi_t &= \pi^T + \frac{x_{t-1}}{\psi} + \rho_\varepsilon' \varepsilon_{t-1} + u_t, \text{ where } \rho_\varepsilon' = \frac{\rho_\varepsilon\left(\rho_\varepsilon + \psi^2\right)}{\psi^2\left(1+\psi^2\right)} \\ x_t &= -\psi\rho_\varepsilon'\varepsilon_{t-1} + \rho_\xi \xi_{t-1} + v_t \end{aligned} \tag{14}$$

which reduces to (6) when $\rho_\varepsilon = 0$ and $\rho_\xi = 0$.

Extending this analysis to new Keynesian expectations, the government's expectation during year t-1 of the agent's expectation in year t is $E_{t-1}^{g}\left(E_t^a \pi_{t+1}\right) = \pi^T + \frac{x_t}{\psi} + \frac{\rho^2 \varepsilon_{t-1}}{\psi^2}$. We find a new Keynesian extension to serial correlation

$$\begin{aligned} \pi_t &= \pi^T + \frac{\psi\left(1+\psi^2\right)x_{t-1}}{1+3\psi^2+\psi^4} + \rho_\varepsilon'\varepsilon_{t-1} + u_t, \text{ where } \rho_\varepsilon' = \frac{\rho_\varepsilon\left(\rho_\varepsilon+\psi^2\right)}{1+3\psi^2+\psi^4} \\ x_t &= \frac{\psi^2 x_{t-1}}{1+3\psi^2+\psi^4} - \frac{\left(1+\psi^2\right)}{\psi}\rho_\varepsilon'\varepsilon_{t-1} + \rho_\xi\xi_{t-1} + v_t \end{aligned} \tag{15}$$

If, as a flat Phillips curve benchmark, we impose a $\psi = 0$. The target parameter drops out of flat solution; this is (8) with the AR(1) errors. Applying the same logic to the growth target model, we get (9) with the AR(1) errors.

8. Estimation results

Table 3 repeats the specifications of Table 2 with this alternative error structure; the inferences change considerably. Comparing the Schwarz criteria here with those in Table 2 suggests that serial correlation is relevant. Now the rational output-target model (g) has the best fit, improving somewhat on the flat benchmark.[20] Model (g) permits two interpretations of $\hat{\rho}_\varepsilon$, one based on an information lag (reported in Table 3) and another based on new Keynesian expectations. Because many of our estimates of the inflation autocorrelation parameter are small, the last two lines

[20] The Schwartz criterion for the autocorrelated benchmark is 77.50.

compare the goodness-of-fit of models with and without the restriction that $\rho_\varepsilon = 0$.[21] We conclude that the inflation autocorrelation is mostly unimportant.

Table 3. Modifying the initial models for serial correlation,
10 countries, 46 annual observations, 1969-2014
(z-statistics in parentheses)

	(f)	(g)	(h)	(i)	(j)
	output target, inertial exp.	output target, rational exp.	growth target, inertial exp.	growth target, rational exp.	growth target. NK exp.
Phillips curve ψ	0.21	0.12	0.12	1.58	1.00
	(3.75)	(1.41)	(2.58)	(5.55)	(0.02)
inflation target π^T	3.33	4.46	4.98	5.05	3.15
	(0.89)	(3.27)	(1.49)	(6.07)	(9.76)
inter-country inflation covariance	0.73	0.75	0.56	7.85	1.35
inter-country output covariance	1.25	1.26	1.46	1.42	0.90
inflation auto ρ_ε	-0.11	0.01	-0.08	0.59	0.63
output auto ρ_ξ	0.73	0.72	0.12	0.71	0.64
Schwarz criterion	77.20	76.73	78.57	86.75	105.93
Schwarz criterion, $\rho_\varepsilon = 0$	77.22	87.62	78.55	87.59	87.70

An exception is the rational expectations model (g); its unrestricted model has the best fit, but nearly the worst when we restrict the inflation autocorrelation. Looking deeper, we find that (g) is unstable; its estimates of ψ and ρ_ε have high covariance. As Figure 3 illustrates, we can reject the joint hypothesis that both of these parameters are zero given model (g), but we cannot reject corresponding one-dimensional hypotheses.[22] This inference applies regardless of whether (g) is

[21] For several of these models there are two solutions for $\hat{\rho}_\varepsilon$. Table 3 reports only the positive estimate. For the new Keynesian version of the output model we estimate $\hat{\rho}_\varepsilon = -0.12, 0.11$, for the growth model with a information lag interpretation $\hat{\rho}_\varepsilon = -3.09, 0.59$, and $\hat{\rho}_\varepsilon = -1.64, 0.63$ for the new Keynesian interpretation. For all but one of specifications in Table 3, we cannot reject the hypothesis that the inflation autocorrelation parameter is zero. For model (f) $\Psi_1^2 = 0.5$, for (g) $\Psi_1^2 = 0.5$ with the information lag interpretation, $\Psi_1^2 = 2.1$ with the new Keynesian interpretation, for (h) $\Psi_1^2 = 0.4$, for (i) $\Psi_1^2 = 18.0$ and for (j) $\Psi_1^2 = 0.001$

[22] Given the information lag interpretation of model (g), $H_o : \psi = 0$ and $\rho_\varepsilon = 0, \Psi_2^2 = 291$, but $H_o : \psi = 0, \Psi_1^2 = 2.00$ and $H_o :\ \rho_\varepsilon = 0, \Psi_1^2 = 0.48$.

interpreted with the information lag or new Keynesian assumptions. When the $\rho_\varepsilon = 0$ restriction is applied to (11) or (12), the Phillips slope parameter is no longer identified. These specifications only identify the slope of the Phillips curve in the presence of autocorrelation. Since the $\rho_\varepsilon = 0$ version of (g) has a poor fit, we doubt whether these results support the rational assumption. We prefer (f), the inertial model.

Figure 3. Comparing 95% confidence ellipses for ψ and ρ_ε estimates

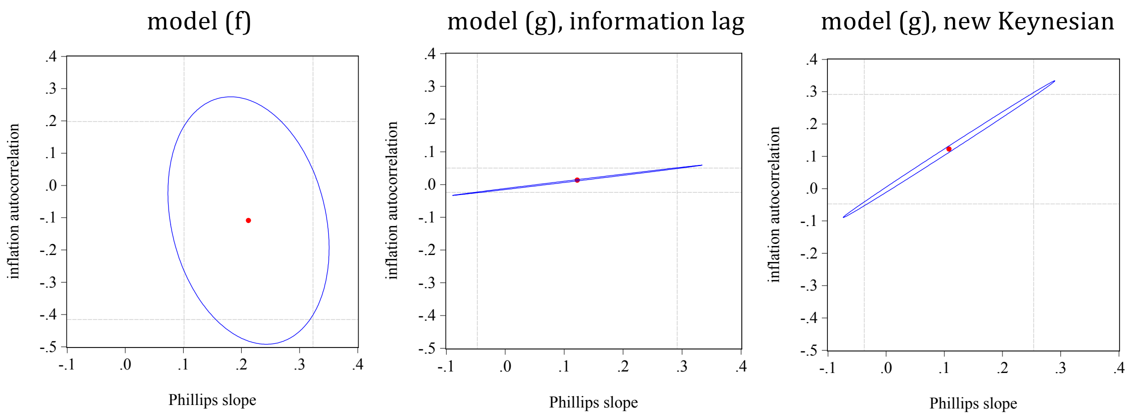
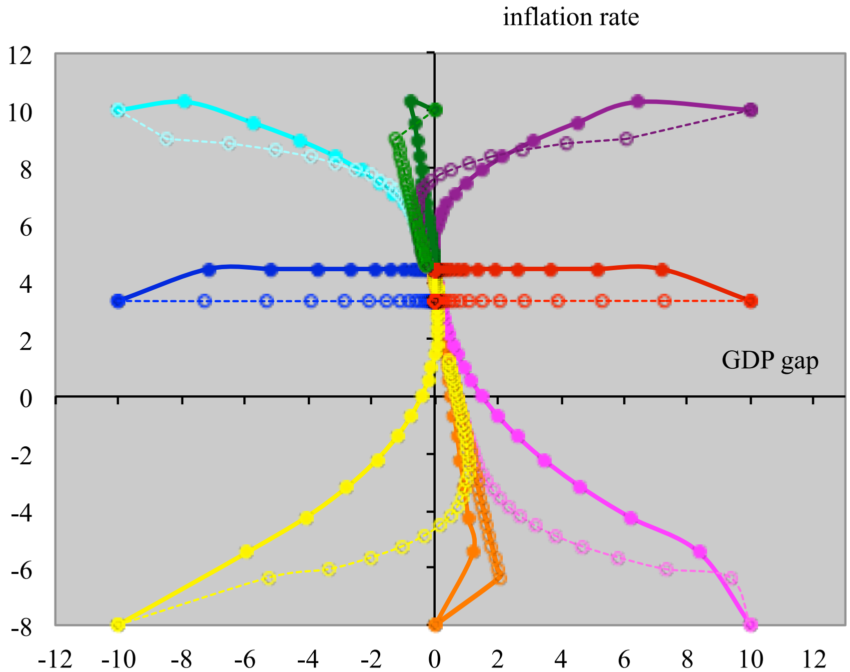


Figure 4 compares impact response functions for models (f) and (g), assuming a variety of output-inflation shocks. The estimated paths for (g) are consistent with the usual understanding that rational expectations limit the government's policy options, while (f)'s paths show limited effectiveness in leaning against inflation shocks (the green and orange paths). The two specifications trace similar trajectories, making it difficult to distinguish between the consequences of the alternative models despite the rather different solution equations.

Figure 4. Comparing the dynamic response of the inertial (f), dashed, and rational (g), solid



Both models converge in about ten years to a zero output gap; (g) converges to a target about 1% higher. These paths indicate recovery from a pure output shock follows a horizontal trajectory because (f) and (g) do not allow for leaning against such shocks. The growth target model predicts that governments react to output shocks, as well as inflation shocks.[23] Since the growth target specifications do not fit the data as well as the output versions, we conjecture that governments only lean against inflation shocks; Figure 2 shows that the 2008 crisis was close to a pure output shock.

9. The evolving inflation target

Throughout we have assumed that the inflation target is a constant parameter, ignoring the literature on structural shifts in stabilization doctrine.[24] Generalizing, we redefine the target as a state variable. We let (f)'s target be a random walk $\pi_t^T = \pi_t^T + \omega_t$, and assume that $\omega_t \sim N(0,0.25)$,

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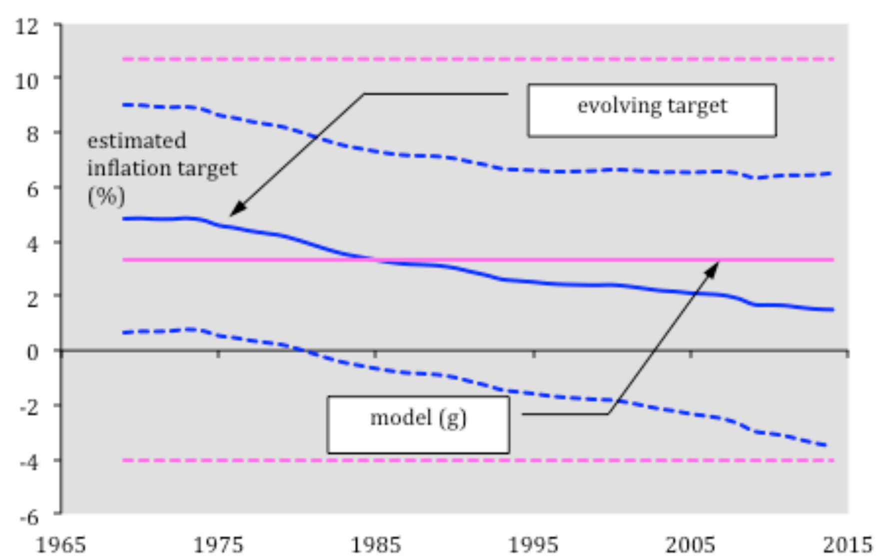
[23] Using different data for only the US, Kiefer (2015) finds that the growth-target, inertial-expectations model (i) is favored.

[24] See for example Clarida et al. (2000) or Estrella and Fuhrer (2003).

stipulating a small step variance to smooth the evolution of the inflation target.[25] This model is motivated by the conjecture that the target has evolved over time, while remaining agnostic about its path.[26] Figure 5 plots our smoothed estimate of the evolving target. It begins at about 5% in 1969 and declines to less than 2% near the end of the sample period. Its 95% confidence interval is tighter than that of (f), although considerable uncertainty about the inflation target remains. This estimate seems plausible in light of the evolution of stabilization doctrine.[27] It suggests that some of the inflation moderation that these countries experienced during this period can be attributed to a lowering of the target.

Figure 5. Estimating the government's inflation target as a random walk, dashed lines for the 95% confidence intervals



[25] This method requires an assumption of a prior for the target; we let $\pi^T_{110} = 4\%$ with a variance of 25.

[26] With this specification the maximum likelihood estimate for the slope is 0.22 (2.62), very close to that of (f).

[27] The evolving-target improves slightly on (f); its Schwartz criterion is 77.14; the benchmark Schwartz is 77.50.

10. Differences between Europe and the US

We extend model (f) by allowing different slopes for the US and for the rest of the European countries (all other parameters identical across countries, plus the $\rho_{\varepsilon} = 0$ restriction). Our result estimates a steeper Phillips curve for the US, $\hat{\psi} = 0.45\,(3.93)$; the European estimate is $\hat{\psi} = 0.18\,(3.06)$.[28] This extension improves on the fit of single slope model, lowering the Schwartz statistic to 77.12.[29] Figure 6 compares predicted trajectories for the US with those for the European countries, and suggests that the US diverges considerably from the rational paths plotted in Figure 4. These trajectories suggest that the US leans harder against inflation shocks. In the case of pure inflation shocks (the green and orange paths) the US achieves larger changes in output and returns the inflation rate to its equilibrium faster. Starting at equilibrium, if inflation jumps to 10%, the US leans against this shock with a 2% drop in output in the following year; European countries lean less than half as hard. These results are consistent with by our finding of a much steeper Phillips curve for the US economy, perhaps due to differences in supply-side institutions.

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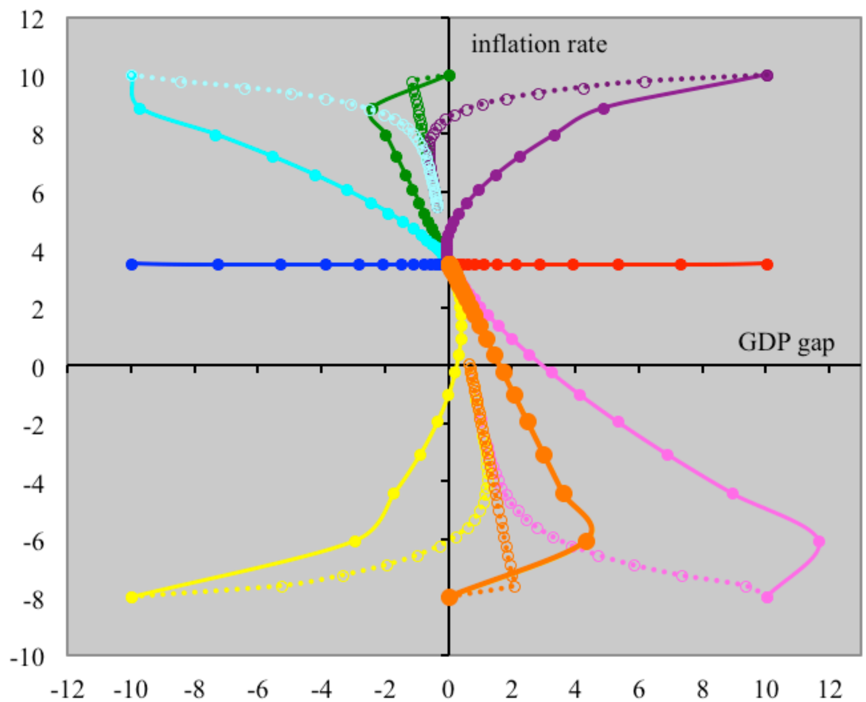
[28] Smets and Wouters (2003) find considerable price stickiness in a DSGE model of Euro area.

[29] A further extension introduces different, but fixed, inflation targets for all ten countries. This estimate results in a variety of different targets, but does not increase the goodness-of-fit.

Figure 6. Extending model (f) to allow different slopes for US, solid, and European countries, dashed



11. Conclusion

We develop a standard theory of activist policy, and test its relevance to recent macroeconomic history using a panel of European countries plus the US. Although the simplest models do not fit these data well, a correction for autocorrelation brings improvement. We find a plausible, but rather flat Phillips curve slope, and an inflation target around 4%. There is ambiguity about the issue of rational expectations; a specification derived for model-consistent rational expectations achieves a better fit, but yields unstable parameter estimates. We conclude that the Keynesian model of asymmetric information and backward-looking expectations is empirically and logically consistent.

An evolving-target extension confirms the conventional wisdom that inflation targets have been falling over time. Another extension suggests a significant difference between the effectiveness of stabilization policy in the European countries and the US. Our results suggest that European countries are constrained by a nearly flat Phillips curve. Since our stabilization models improve only slightly on the fit of a flat benchmark suggests that this model makes only a limited contribution to understanding macroeconomic outcomes.

References

Alesina, Alberto and Nouriel Roubini with Gerald Cohen (1997) *Political Cycles and the Macroeconomy*, Cambridge, MA, MIT Press.

Barro, Robert J and David B Gordon (1983) "A Positive Theory of Monetary Policy in a Natural-Rate Model," *Journal of Political Economy 91*: 598-610.

Carlin, Wendy and David Soskice (2005) "The 3-Equation New Keynesian Model–a Graphical Exposition," *Contributions to Macroeconomics 5*: Issue 1, Article 13.

Christiano Lawrence J, Martin Eichenbaum and Charles L Evans (2005) "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy," *Journal of Political Economy 113*: 1-45.

Clarida, Richard, Jordi Gali and Mark Gertler (1999) "The Science of Monetary Policy: a New Keynesian Perspective," *American Economic Review 37*: 1661-1707.

_____ (2000) "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory," *The Quarterly Journal of Economics 115*, 147-180.

_____ (2001) "Optimal Monetary Policy in Open versus Closed Economies: An Integrated Approach," *Journal of Economic Literature 91*: 248-252.

Clovis, J., Zhang, C., (2010) "The New Keynesian Phillips Curve of Rational Expectations: a Serial Correlation Extension," *Journal of Applied Economics 13*, 159-179.

Estrella, A., Fuhrer, J. C. (2003) "Monetary Policy Shifts and the Stability of Monetary Policy Models," *The Review of Economics and Statistics 85*, 94-104.

European Commission (various years), Annual macro-economic database, ec.europa.eu/economy_finance/db_indicators/ameco, accessed 8/31/2015.

Fischer, Stanley (1977) "Long-Term Contracts, Rational Expectations, and the Optimal Money Supply," *Journal of Political Economy 85*: 191-205.

Gali, Jordi (2008) *Monetary Policy, Inflation and the Business Cycle,* Princeton NJ, Princeton University Press.

Ireland, Peter N (1999) "Does the Time-Consistency Problem Explain the Behavior of Inflation in the United States?" *Journal of Monetary Economics 44*: 279-292.

Kalecki, Michael (1943) "Political Aspects of Full Employment," *Political Quarterly 4*: 322-331.

Kiefer, David (2008) "Revealed Preferences for Macroeconomic Stabilization," *Journal of Applied Economics 11*: 119-143.

_____ (2015) "Targets and lags in a two-equation model of US stabilization policy," *Economic Modeling 44*: 18-24.

Kydland, Finn E., and Edward C. Prescott (1977) "Rules Rather than Discretion: The Inconsistency of Optimal Plans," *Journal of Political Economy 85*: 473-92.

Nordhaus, William (1975) "Political Business Cycle," *Review of Economics Studies 42*: 169-190.

Romer, David (1993) "Openness and Inflation: Theory and Evidence", *Quarterly Journal of Economics 108*, 869-903.

Ruge-Murcia, Francisco (2003) "Inflation Targeting under Asymmetric Preferences," *Journal of Money, Credit and Banking*, 35: 763-785.

Smets, Frank and Raf Wouters (2003) "An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area," *Journal of the European Economic Association, 1*: 1123-1175.

Woodford, Michael (2003) *Interest and Prices*, Princeton NJ, Princeton University Press.