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Flattening of the Phillips Curve: Implications for Monetary Policy

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Abstract

Over the past decade, inflation has become less responsive to domestic demand pressures in many industrial countries. This development has been attributed, in part, to globalization forces. A small macroeconomic model, estimated on UK data using Bayesian estimation, is used to analyze the monetary policy implications of this structural change. The focus is on the implications of a globalization-related flattening of the Phillips curve for the trade-off between inflation and output gap variability and for the efficient monetary policy response rule.

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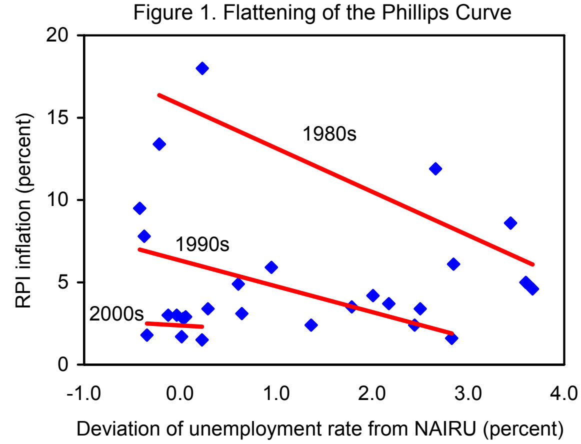
I. Introduction

Since the early 1990s, inflation in the U.K. has remained low and steady, and its correlation with measures of economic slack has weakened (Figure 1). The link between these variables is often referred to as "the short-run Phillips curve." Flattening of the Phillips curve has been observed in other industrial countries as well and has been attributed, in part, to globalization forces (Bean, 2006). IMF (2006), Borio and Filardo (2006), and Mody and Ohnsorge (2006) provide empirical cross-country evidence for globalization-related decline in the sensitivity of prices to domestic demand pressures.

Figure 1. Flattening of the Phillips Curve



The argument that globalization may lead to a flattening of the Phillips curve is based on three observations. First, due to increased competition from abroad, businesses have less scope to raise prices when demand rises. Second, increased trade and investment flows have made goods prices less sensitive to domestic demand pressures. Indeed, goods price inflation has borne very little relationship to estimates of demand pressures in the U.K. over the last decade, while service price inflation has been well predicted by domestic demand pressures. Third, labor mobility (both actual and virtual) has also increased in recent years. This could lead to further flattening of the Phillips curve if it results in declining sensitivity of service sector wages and prices to domestic demand shifts. Workers may not press for higher wages when the domestic labor market tightens for fear that their jobs may be taken by foreign labor.

A complementary explanation for the flattening is that good monetary policy has helped anchor inflation expectations (Laxton and N'Diaye, 2002). That has probably played a role in the initial years after the introduction of inflation targeting in the United Kingdom. IMF (2006) finds that globalization can account for more than half of the decline in the sensitivity of prices to domestic output, while improved monetary policy credibility and the low inflation environment account for the remainder. This paper will focus on the implications of the globalization-related explanation which is likely to be more relevant at the current juncture and going forward.

What are implications of a reduced sensitivity of inflation to demand shocks for monetary policy? On one hand, it makes the central bankers' job easier, since they need to worry less about temporary imbalances between demand and supply. On the other hand, responding to inflation shocks becomes more difficult - the central bank needs to move interest rates and aggregate demand more to offset the shock and bring inflation back to target. Therefore, it is an open question whether and how the central bank's response to shocks should change.[2]

This paper explores how a globalization-induced flattening of the Phillips curve would affect the monetary policy response to economic disturbances. Section II describes the general equilibrium model used in the analysis. In Section III, the best achievable combinations of inflation and output gap variability are derived and the efficient parameterization of the monetary policy response rule for different slopes of the Phillips curve is discussed. The conclusions are in Section IV.

II. Description of the Model

The analysis is conducted using a New Keynesian open economy macroeconomic model with rational expectations. The key behavioral equations for the U.K. are an output gap equation (IS curve), an inflation equation (expectations-augmented Phillips curve), an exchange rate relationship, and a monetary policy response function (the policymakers respond to the expected deviation of inflation from target and to the output gap):

$$ygap_t = \beta_1 \cdot ygap_{t-1} + \beta_2 \cdot ygap_{t+1} + \beta_3 \cdot rrgap_{t-1} + \beta_4 \cdot zgap_{t-1} + \beta_5 \cdot ygap_t^* + \varepsilon_t^{ygap} \quad (1)$$

$$\pi_t = \delta_1 \cdot \pi_{t+4}^4 + (1-\delta_1) \cdot \pi_{t-1}^4 + \delta_2 \cdot ygap_{t-1} + \delta_3 \cdot \Delta z_t + \varepsilon_t^{\pi}, \quad (2)$$

$$z_t = \phi \cdot z_{t+1} + (1-\phi) \cdot z_{t-1} + (rr_t - rr_t^*)/4 + \varepsilon_t^z / 4, \quad (3)$$

$$rs_t = \gamma_1 \cdot rs_{t-1} + (1-\gamma_1) \cdot [rr\_eq_t + \pi_t^4 + \alpha_1 \cdot (\pi_{t+4}^4 - \pi^T) + \alpha_2 \cdot ygap_t] + \varepsilon_t^{rs}, \quad (4)$$

where *ygap* denotes the output gap, *rs* is the nominal interest rate, *rr* is the real interest rate, *z* is the real exchange rate, *rrgap* is the gap between the real interest rate and its equilibrium value, *zgap* is the gap between the real exchange rate index and its equilibrium value, *ygap** is the foreign output gap, π is the quarterly annualized rate of CPI inflation, π^4 is a four-quarter moving average of π, and π^T is the target rate of inflation.

The U.K. is treated as a small open economy, with a foreign sector comprising of a weighted average of the euro area and the United States. The foreign sector is described by equations for the output gap, inflation, and the monetary policy reaction function similar to the equations above. See Appendix I for a full description of the model, including various identities. While the model is relatively simple, it has long been the workhorse of monetary policy analysis.[3] It effectively captures the key channels of monetary policy transmission and has the virtues of clarity and tractability.

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[2] This issue has come up recently in numerous speeches by monetary policymakers, including Charles Bean (2006), Donald Kohn (2006), and Lucas Papademos (2006).

The models' parameter values are estimated from UK quarterly data (over the period 1993 to 2005), using a Bayesian approach. The Bayesian approach starts with prior distributions for the model parameters, which are then combined with the data using a likelihood function to estimate the posterior distributions for the parameters.[4] Starting with prior distributions makes the highly nonlinear optimization algorithm considerably more stable, making it feasible to apply the technique when sample periods are short. In addition, the estimation procedure also allows for measurement errors in the data—these errors are omitted in the stochastic simulations. The values for the prior distributions were based on the prior distributions for Canada, as described in Berg, Karam, and Laxton (2006), augmented with specific UK evidence where available. Details on the prior distributions and the resulting posterior distributions are presented in Appendix I.

The simulations assume rational expectations—all agents know the true model, see correctly the current period shocks, and assume that all future shocks will be zero. When there is no uncertainty about the model parameters, the model-consistent forecasts of the endogenous variables will turn out to be correct in the absence of further shocks.

To consider the implications of a change in the sensitivity of inflation to domestic demand pressures, two versions of the model are employed. The first version uses the estimated equation parameters (the parameter on the output gap in the Phillips curve is 0.3). In the alternative version, the coefficient on the output gap in the Phillips curve is reduced to 0.1[5] (implying smaller responsiveness of inflation to the output gap).[6]

The dynamic adjustment of the key macro variables differ significantly under the two models. The monetary policy reaction function is assumed to be the same, based on the empirically estimated parameters. Demand shocks have much smaller effect on inflation under a flat Phillips curve (Fig. 2). Therefore, interest rates need to move very little. The weak policy response makes the demand shock more persistent (the output gap volatility increases). Shocks to inflation cause greater volatility in both inflation and output, since

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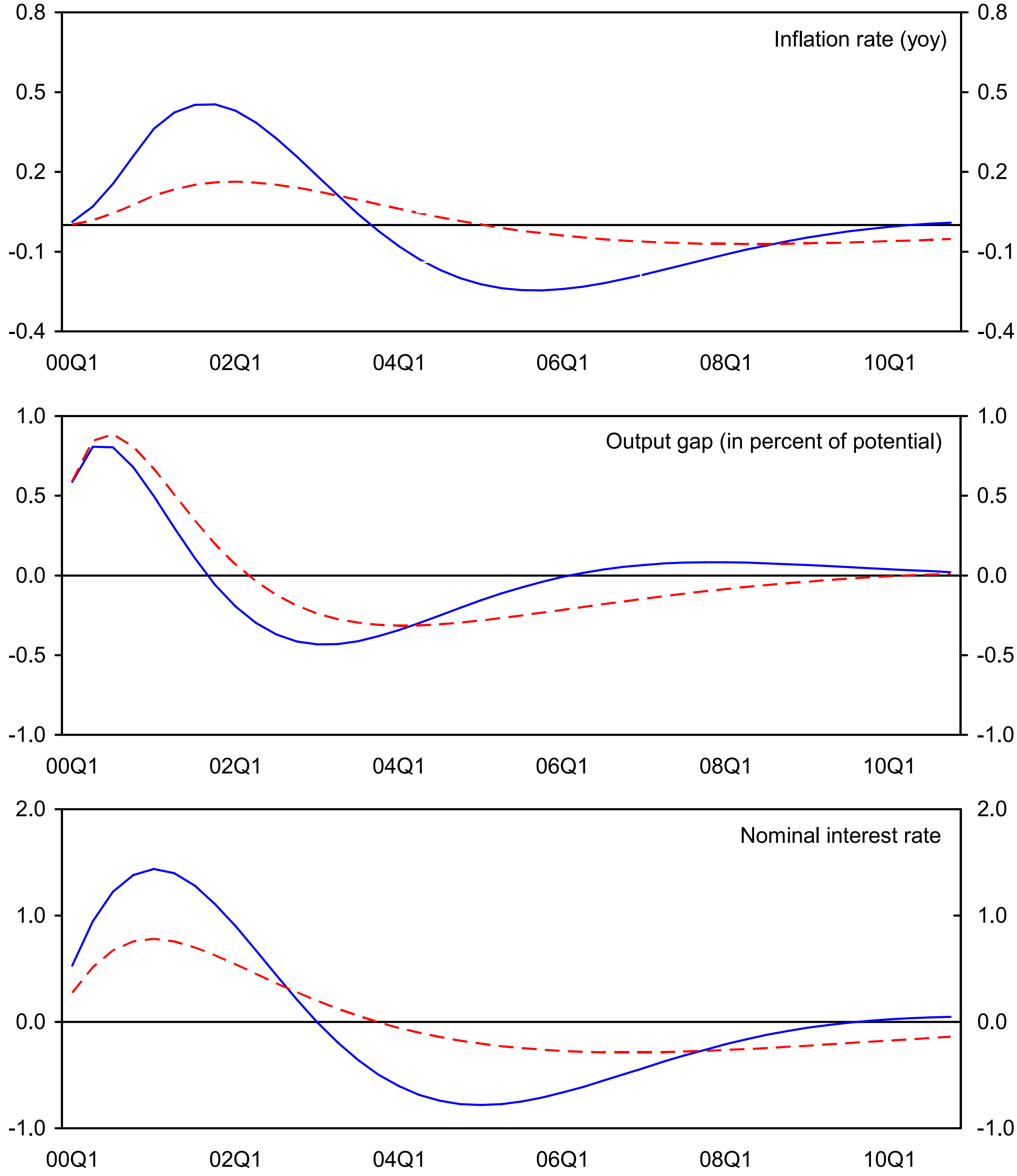
[3] There is a large literature in which models like the ones used here are derived from microeconomic optimizing foundations—see, for example, Roberts (1995), Gali and Monacelli (2005), and Monacelli (2004).

[4] For a description of the Bayesian estimation technique see Geweke (1999). Details on DYNARE, the software used for estimation, can be found in Juillard (2004). The author is grateful to Ben Hunt and Philippe Karam for providing the code used for the Bayesian estimation.

[5] Ball (2006) estimates that 10 percentage points increase in trade openness reduces the output gap coefficient by 0.08. In the U.K., the ratio of trade (imports plus exports excluding oil) to GDP has increased by 12 percentage points in the last 15 years (1991 to 2006), translating into a coefficient decline of 0.1. Since increased cross-border labor flows can also contribute to flattening of the Phillips curve, a greater decline of 0.2 is assumed. The direction of the results is robust to variations in this assumption.

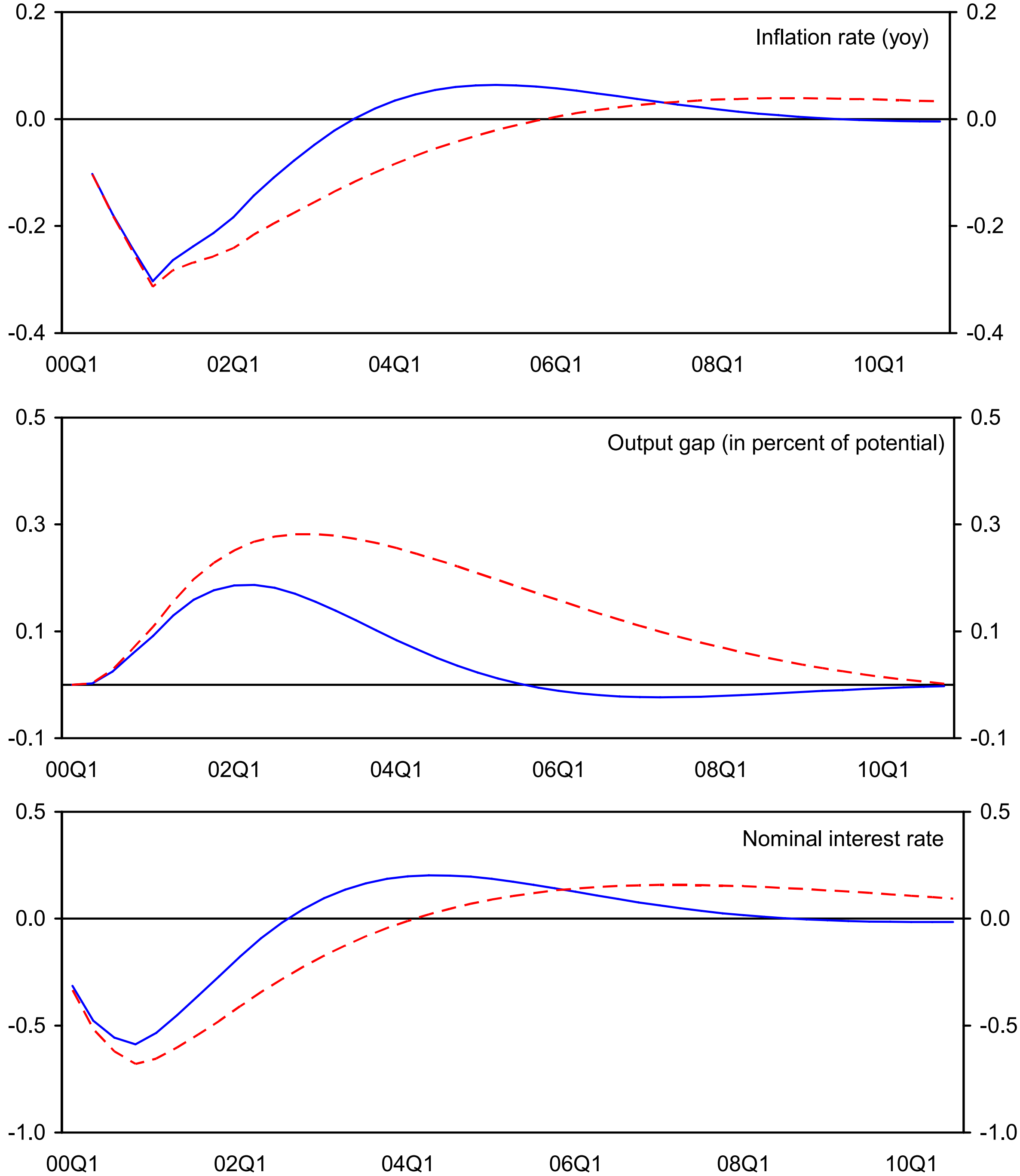
[6] Note that this specification of the structural change hinges on the globalization explanation for the flattening of the Phillips curve. If one wants to examine the implications of a more credible monetary policy, a natural way to model it would be as an increase of the coefficient on inflation expectations in the Phillips curve.

Figure 2. Impulse Responses to a Demand Shock
(percentage points deviation from baseline)



The solid line shows the impulse responses to a demand shock under a steeper Phillips curve, while the dashed line shows the adjustment under a flatter Phillips curve (for the same interest rate response function).

Figure 3. Impulse Responses to an Inflation Shock
(percentage points deviation from baseline)



The solid line shows the impulse responses to a demand shock for a steeper Phillips curve, while the dashed line shows the adjustment under a flatter Phillips curve (for the same interest rate response function).

unwinding the effect of such shocks requires more aggressive movement of interest rates and domestic demand (Fig. 3).[7]

III. Evaluating alternative monetary policy response rules

An "optimal" monetary policy response rule in this analysis is defined as the inflation-forecast-based interest rate rule defined by equation (4) which minimizes a standard quadratic loss function:

$$L = \sum_{t=0}^{\infty} [\lambda_{\pi} \cdot (\pi_t - \pi^T)^2 + \lambda_y \cdot (ygap_t)^2 + \lambda_r (rs_t - rs_{t-1})^2] \qquad (5)$$

Such rules deliver outcomes that closely approximate the fully optimal monetary policy response.[8] The preferences of the monetary policy authority over the variability of inflation and output can be represented by varying the preference parameters $\lambda_{\pi} / \lambda_y$.

The performance of alternative monetary policy rules is compared using stochastic simulations. Using the estimated model parameters and distributions of the stochastic shocks, solutions are derived for the variability of the main endogenous variables under alternative parameterizations of the monetary policy reaction function.[9] An efficient policy frontier is constructed based on these solutions. Since its introduction by Taylor (1979), the efficient policy frontier has become widely used to estimate what a monetary authority can achieve in terms of inflation and output stability. It traces the lowest achievable combinations of inflation and output gap variability under a range of alternative rules for operating monetary policy when the economy is subject repeatedly to economic disturbances. Each point on the frontier is based on 5,000 artificially-generated outcomes for inflation and the output gap, assuming that the policymaker is committed to following a specific policy instrument rule. Artificial data is produced by taking random draws from the estimated distribution of the

[7] Preliminary analysis of the effect of greater monetary policy credibility (higher coefficient on expected inflation in the Phillips curve) suggests quite different dynamics. In that case, responding to inflation shocks requires much smaller movement of the output gap since expectations are better anchored and that helps bring inflation back to target quickly. In general, the trade-off between inflation and output gap variability will improve in that case. Therefore, the monetary policy effects of a flattening Phillips curve are different, depending on the reason for the observed flattening.

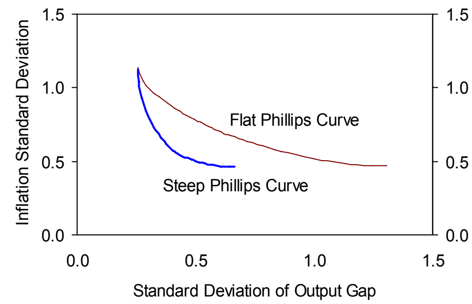
[8] Ball (1999) calls such rules "efficient" since they put the economy on the inflation variance/output variance frontier. Batini and Haldane (1999), and Tetlow and von zur Muehlen (1999), among others, show that such simple instrument rules closely approximate the stabilization properties of fully optimal rules. These rules are also more robust to model uncertainty than fully optimal rules (see, for example, Onatski and Williams (2004) and Levin et al. (1999)). Empirical studies find that simple instrumental rules represent well the way policymakers actually behave (Clarida, Gali, and Gertler (1998)). A similar rule is incorporated in the new Bank of England quarterly model (see Harrison and others (2005) for documentation).

[9] The monetary policy response coefficients on the output gap and deviations of inflation from target are varied in the interval 0.5 to 12 (with a step of 0.5). The interest rate smoothing coefficient is set at 0.5 in all simulations.

residuals and solving the respective model. The standard deviations of inflation and the output gap are then averaged over all draws.

The efficient policy frontiers for the two alternative models are presented in Figure 4. The achievable combinations of inflation and output variability are less favorable when the Phillips curve is flatter. The central bank needs to generate greater volatility in domestic demand to achieve any desired level of inflation variability (and vice versa).[10]

Figure 4. Efficient Policy Frontiers



The coefficients of the efficient rules for a range of policy preferences are shown in Table 1. The preferences considered are equal distaste for inflation and output variability, increasingly greater distaste for inflation variability, and increasingly greater distaste for output variability. In practice all central banks, including those with inflation targeting regimes, care to some extent about variability in the real economy, so only preferences with a positive coefficient on the output gap are presented.[11] A fixed weight is assigned to the variability of interest rate changes in the loss function in all scenarios.

Table 1. Optimized Response Rule Coefficients

Central Bank Preferences			Steep Phillips Curve		Flat Phillips Curve	
			Inflation	Output Gap	Inflation	Output Gap
λ_y	λ_π	λ_r	α_1	α_2	α_1	α_2
3	1	0.5	4	5.5	2	6
2	1	0.5	4	4.5	2.5	5
1	1	0.5	4.5	3	3	3.5
1	2	0.5	6.5	3	5	3.5
1	3	0.5	8	2.5	6.5	3

Note : The preferences specify the coefficients in the loss function corresponding to the variances of the output gap, inflation deviation from target, and interest rate changes.

[10] Note that this result is contingent on the assumption that the joint distribution of shocks going forward would be the same as the estimated historical distribution of shocks. It is possible that the structural changes which lead to a flattening of the Phillips curve may also change the distribution of shocks. For example, Bean (2006) argues that, with heightened competitive pressure, businesses might respond to cost shocks (such as an oil price increase) by lowering other costs instead of raising prices.

[11] See Bernanke (2003) and Svensson (2006). As Ball (1999) points out, varying the weight on the output gap in the loss function corresponds to different speeds of adjustment of inflation to target. An "inflation nutter" strategy of returning inflation to target as quickly as possible would create excessive output volatility (King, 1997). In practice, all inflation targeting central banks have a policy of gradual adjustment to the target.

The direction of change in the efficient coefficients is consistent across these preferences. When inflation responds less to the output gap, the optimal coefficient on the expected inflation deviation declines, while the optimal coefficient on the output gap increases.[12] What is the intuition? In a flat-Phillips-curve environment, policymakers would respond more actively to demand pressures to prevent them from affecting inflation (since these would be costly to reverse). Such policy would reduce both inflation and output gap volatility after a shock to aggregate demand. On the other hand, the response to inflation shocks is attenuated, since unwinding the shock quickly entails greater output gap variability. In that case, the optimized policy will reduce output gap volatility, but inflation will take longer to go back to target. On balance, adjusting the interest rate rule in a way that is optimal for the new structure of the economy would reduce volatility in the real economy and, in some cases, the volatility of inflation, compared to maintaining an unchanged rule.

What are the implications of the optimized rule for the actual nominal interest rate movement? Figure 5 illustrates the impulse responses after a negative shock to inflation under the two possible structures of the economy.[13] The solid line is the impulse response for a steep Phillips curve when the reaction function is set optimally for that case. The dotted line shows the adjustment under a flat Phillips curve, with the reaction function set optimally for that case. Even thought the policymaker reacts less aggressively to any given deviation of inflation from target, the nominal (and real) interest rate would fall by more in response to a negative inflation shock under a flat Phillips curve, since such shock leads to higher expected deviation of inflation from target.[14] After a demand shock, the reverse holds true: the cumulative interest rate gap would be smaller, since the expected deviation of inflation from target is smaller.

These results hold as long as inflation expectations remain anchored around the target in the long run. Under a flatter Phillips curve, inflation goes back to target more slowly after a shock to inflation (even for unchanged policy, see the dashed line on Figure 5). For expectations to remain anchored, people must understand that this is a natural consequence of the structural change in the economy, and not a reflection of the ability of the policymaker to

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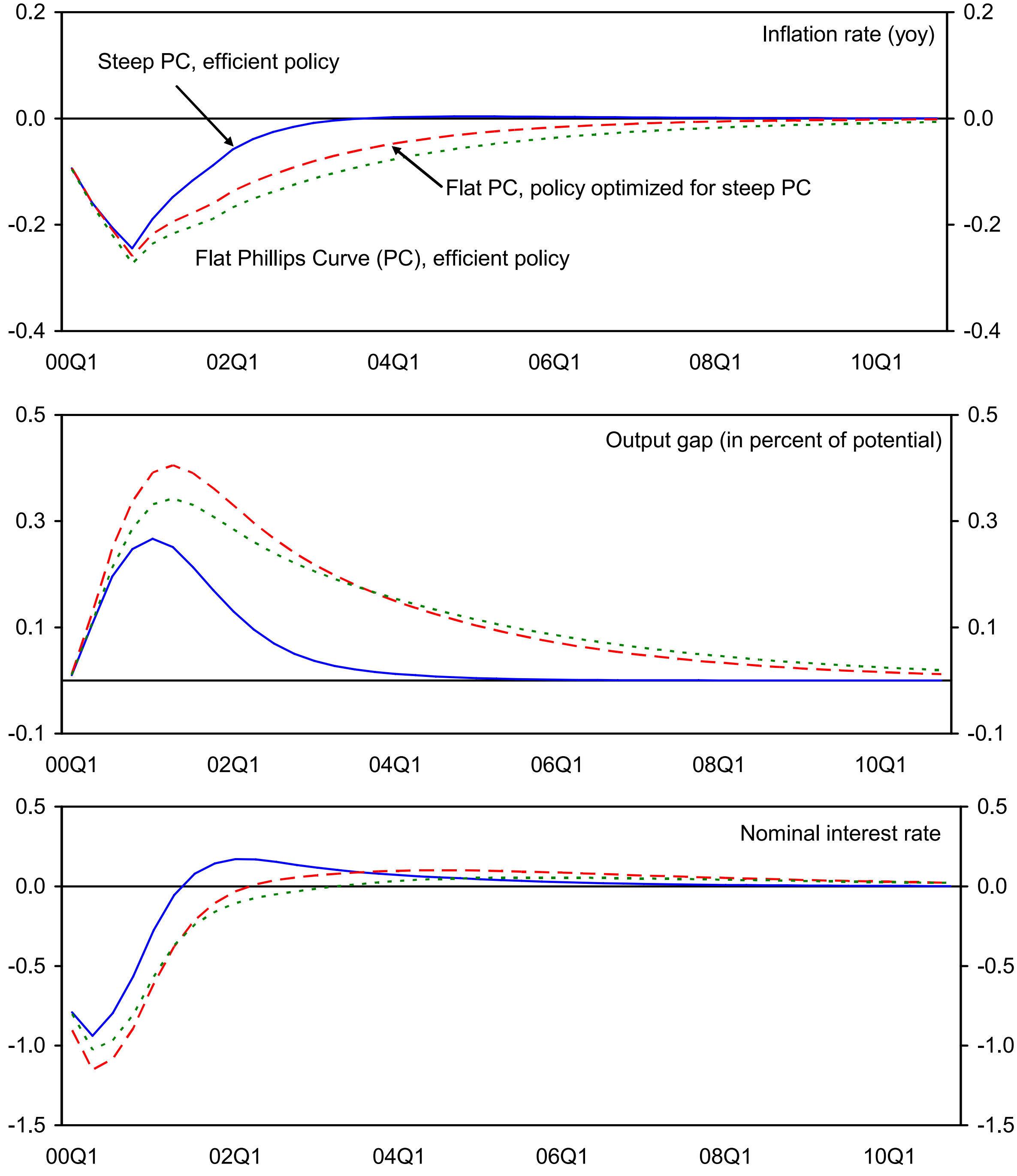
[12] The absolute magnitude of the coefficients depends on the weight attached to interest rate variability in the loss function. Higher weight attached to interest rate variability produces lower coefficients. Therefore the fact that the coefficients shown are greater in magnitude than the typical coefficients used in practice is of no particular significance. Under certain types of uncertainty, the efficient response coefficients may also be lower than those estimated under certainty (see Smets, 2002).

[13] The central bank is assumed to have greater dislike for inflation variability relative to output gap variability in the illustrated scenario (the ratio λ_π / λ_y is 3). The results have been verified for all preferences in Table 1.

[14] Note that if the monetary policy authority continued to use the same response function after the Phillips curve has flattened (illustrated by the dashed line in Figure 5), the interest rate move would be even more aggressive than the case when the policy is optimized for the new environment (the dotted line).

Figure 5. Impulse Responses to an Inflation Shock, Efficient Policy
(percentage points deviation from baseline)



The solid line shows the impulse responses to a demand shock for a steeper Phillips curve under the efficient reaction function for that case. The dashed line shows the adjustment under a flatter Phillips curve for the same response function. The dotted line is the adjustment under a flat Phillips curve when the reaction function parameters are optimally set for that case.

affect inflation. Enhancing the public understanding of the effect of structural changes (and possible policy changes) through communication is important to keep expectations anchored. If agents' expectations are more heavily influenced by the actual deviation of inflation from target than warranted by the model (the assumption of rational expectations is violated), the monetary policy response to inflation shocks would be more aggressive than the optimal response under stable expectations.

IV. Conclusions

The conduct of monetary policy is complicated by considerable uncertainty about the structure of the economy and the nature of economic shocks. Using a small estimated macroeconomic model, representing the main economic relationships in the UK economy, this paper sheds light on the monetary policy implications of one particular structural change—reduction in the responsiveness of inflation to domestic demand pressures due to globalization.

It was established that the policymakers could face a worse short run trade-off between inflation and output variability under a flatter Phillips curve. Achieving the same level of inflation variability would entail greater output variability (and vice versa). The implications of the structural change for the volatility and speed of adjustment of macroeconomic variables have to be communicated clearly to the public to ensure that inflation expectations remain anchored around the target.

A central bank that cares both about the inflation target and deviations of output from potential should respond relatively less to deviations of inflation from target and relatively more to deviations of output from potential in a world with a flatter Phillips curve. That would help reduce the volatility of output after an inflation shock, and the volatility of both output and inflation after a demand shock. Even when the response to a given deviation of inflation from target is attenuated, the interest rate would need to stay above the long-run equilibrium rate longer after a positive shock to inflation, since deviations of inflation from target are more persistent when the Phillips curve is flatter. Conversely, the cumulative interest rate gap would be smaller after a demand shock.

Finally, the monetary policy implications of a flattening Phillips curve will be different when the flattening is related to increased monetary policy credibility (which is likely to be a factor in the initial years after the introduction of an inflation targeting regime). It is important to differentiate empirically between the possible causes of a structural change at any point in time when setting policy.

APPENDIX I

A. The Model

The following provides a detailed description of the open-economy model estimated for the United Kingdom. The model is specified in gap and rate-of-change terms so that, under inflation targeting, all variables are stationary. For simulation purposes, the equilibrium values for the real interest rate and the real exchange rate are assumed to be time invariant.

Core behavioral equations for the domestic sector.

Aggregate Demand:

1) $$ygap_t = \beta_1 \cdot ygap_{t-1} + \beta_2 \cdot ygap_{t+1} + \beta_3 \cdot rrgap_{t-1} + \beta_4 \cdot zgap_{t-1} + \beta_5 \cdot ygap_t^* + \varepsilon_t^{ygap},$$

where *ygap* denotes the output gap, *rrgap* is the gap between the real interest rate and its equilibrium value, *zgap* is the gap between the real exchange rate index and its equilibrium value, *ygap** is the foreign output gap and ε^{ygap} is the stochastic error process. The inclusion of a lagged value of the output gap in the IS curve is typically justified by habit persistence.

Inflation:

2) $$\pi_t = \delta_1 \cdot \pi_{t+4}^4 + (1-\delta_1) \cdot \pi_{t-1}^4 + \delta_2 \cdot ygap_{t-1} + \delta_3 \cdot \Delta z_t + \varepsilon_t^{\pi},$$

where π is the quarterly annualized rate of CPI inflation, π^4 is a four-quarter moving average of quarterly annualized CPI inflation, Δz is the first difference in the real exchange rate index, and ε^{π} is the stochastic error process.

The real exchange rate:

3) $$z_t = \phi \cdot z_{t+1} + (1-\phi) \cdot z_{t-1} + (rr_t - rr_t^*)/4 + \varepsilon_t^z / 4,$$

where *z* is the log of the real exchange rate index, *rr* is the domestic real interest rate, *rr** is the foreign real interest rate, and ε^z is the stochastic error process.

The monetary policy reaction function:

4) $$rs_t = \gamma_1 \cdot rs_{t-1} + (1-\gamma_1) \cdot [rr\_eq_t + \pi_t^4 + \alpha_1 \cdot (\pi_{t+4}^4 - \pi^T) + \alpha_2 \cdot ygap_t] + \varepsilon_t^{rs},$$

where *rs* is the annualized short-term policy rate, *rr_eq* is it equilibrium real interest rate, π^T is the target rate of inflation, and ε^{rs} is the stochastic error process.

Core behavioral equations for the foreign sector.

Aggregate Demand:

5) $ygap_t^* = \beta_1^* \cdot ygap_{t-1}^* + \beta_2^* \cdot ygap_{t+1}^* + \beta_3^* \cdot rrgap_{t-1}^* + \varepsilon_t^{ygap*}$,

where $ygap^*$ denotes the output gap, $rrgap^*$ is the gap between the real interest rate and it equilibrium value, and ε^{ygap*} is the stochastic error process.

Inflation:

6) $\pi_t^* = \delta_1^* \cdot \pi_{t+4}^{4*} + (1-\delta_1^*) \cdot \pi_{t-1}^{4*} + \delta_2^* \cdot ygap_{t-1}^* + \varepsilon_t^{\pi*}$,

where π^* is the quarterly annualized rate of CPI inflation, π^{4*} is a four-quarter moving average of quarterly annualized CPI inflation, and $\varepsilon^{\pi*}$ is the stochastic error process.

The monetary policy reaction function:

7) $rs_t^* = \gamma_1^* \cdot rs_{t-1}^* + (1-\gamma_1^*) \cdot [rr\_eq_t^* + \pi_t^{4*} + \alpha_1^* \cdot (\pi_{t+4}^{4*} - \pi^{T*}) + \alpha_2^* \cdot ygap_t] + \varepsilon_t^{rs*}$,

Where rs^* is the annualized short-term policy rate, rr_eq^* is it equilibrium real interest rate, π^{T*} is the target rate of inflation, and ε^{rs*} is the stochastic error process.

Stochastic processes.

8) $\varepsilon_t^{ygap} = \rho^{ygap} \cdot \varepsilon_{t-1}^{ygap} + \xi_t^{ygap}$,

9) $\varepsilon_t^{ygap*} = \rho^{ygap*} \cdot \varepsilon_{t-1}^{ygap*} + \xi_t^{ygap*}$,

10) $\varepsilon_t^{\pi} = \rho^{\pi} \cdot \varepsilon_{t-1}^{\pi} + \xi_t^{\pi}$,

11) $\varepsilon_t^{\pi*} = \rho^{\pi*} \cdot \varepsilon_{t-1}^{\pi*} + \xi_t^{\pi*}$,

12) $\varepsilon_t^{rs} = \rho^{rs} \cdot \varepsilon_{t-1}^{rs} + \xi_t^{rs}$,

13) $\varepsilon_t^{rs*} = \rho^{rs*} \cdot \varepsilon_{t-1}^{rs*} + \xi_t^{rs*}$,

Identities.

14) $\pi_t^4 = (\pi_t + \pi_{t-1} + \pi_{t-2} + \pi_{t-3})/4.$

15) $\pi_t^{4*} = (\pi_t^* + \pi_{t-1}^* + \pi_{t-2}^* + \pi_{t-3}^*)/4.$

16) $rr_t = rs_t - \pi_{t+1}$,

17) $rr_t^* = rs_t^* - \pi_{t+1}^*$,

18) $rrgap_t = rr_t - rr\_eq_t$,

19) $rrgap_t^* = rr_t^* - rr\_eq_t^*$,

20) $zgap_t = z_t - z\_eq_t$.

B. Data

The NAIRU (in Figure 1) has been estimated using the methodology of Boone et al. (2002).

The model is estimated using quarterly data from 1993 to 2005. For the U.K., the price index is RPIX until the last quarter of 2003, and headline CPI thereafter. The inflation target is adjusted respectively. An index comprising the euro area and the United States is used to proxy foreign aggregate demand, interest rates and CPI inflation.[15] The trade weighted real exchange rate index published by the Bank of England is used for the real exchange rate. The nominal short-term interest rates are the 90-day Treasury bills rates. Equilibrium values for potential output, the real interest rate, and the real exchange rate have been constructed using a variant of the HP filter, with constraints added to the minimization problem to prevent the resulting equilibrium value from converging to the actual observed data at the ends of the sample period. These constraints can be used to force the equilibrium value to converge towards a user-specified value at the end of the sample period.

C. Estimation Results

The Bayesian, full system estimation is done in DYNARE. The observable variables are output gaps (real GDP), nominal short-term interest rates, inflation rates, and logs of the real exchange rates. The estimation has been done allowing for measurement error in the observable variables. The estimates for the U.K. and its foreign counterpart are presented in Tables 1A and 2A.

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[15] The euro area data is approximated by a weighted average of Germany, France, and Italy.

Table 1A: United Kingdom Model Parameter Estimation Results
Sample period 1993Q1 to 2005Q4

Parameter	Prior Mean	Distribution	Posterior Mean
Domestic			
β_1	0.85	gamma	0.677
β_2	0.10	beta	0.094
β_3	0.10	gamma	0.108
β_4	0.05	beta	0.034
β_5	0.15	beta	0.173
δ_1	0.20	gamma	0.201
δ_2	0.30	gamma	0.286
δ_3	0.10	gamma	0.084
Φ	0.30	beta	0.261
γ	0.55	beta	0.557
α_1	2.00	gamma	1.966
α_2	0.55	beta	0.557
Foreign			
β^*_1	0.85	gamma	0.748
β^*_2	0.10	beta	0.103
β^*_3	0.10	gamma	0.105
δ^*_1	0.20	beta	0.190
δ^*_2	0.30	gamma	0.237
γ^*	0.56	beta	0.588
α^*_1	2.00	gamma	2.001
α^*_2	0.50	beta	0.530

Table 2A: United Kingdom Estimation Results for the Error Processes and Measurement Errors

Sample period 1993Q1 to 2005Q4

Parameter	Prior Mean	Distribution	Posterior Mean
Domestic			
ρ^{ygap}	0.75	beta	0.772
std. dev. ξ^{ygap}	0.25	inverse gamma	0.157
std. dev. mes. er. ^{ygap}	0.20	inverse gamma	0.123
ρ^{π}	0.50	beta	0.499
std. dev. ξ^{π}	0.25	inverse gamma	0.286
std. dev. mes. er. $^{\pi}$	0.20	inverse gamma	2.206
ρ^{rs}	0.750	beta	0.767
std. dev. ξ^{rs}	0.25	inverse gamma	0.171
std. dev. mes. er. ^{rs}	0.20	inverse gamma	0.123
std. dev. ε^{z}	4.00	inverse gamma	5.992
Foreign			
ρ^{ygap*}	0.75	beta	0.765
std. dev. ξ^{ygap*}	0.25	inverse gamma	0.176
std. dev. mes. er. ^{ygap*}	0.20	inverse gamma	0.149
$\rho^{\pi*}$	0.50	beta	0.510
std. dev. $\xi^{\pi*}$	0.25	inverse gamma	0.165
std. dev. mes. er. $^{\pi*}$	0.20	inverse gamma	1.042
ρ^{rs*}	0.750	beta	0.837
std. dev. ξ^{rs*}	0.25	inverse gamma	0.163
std. dev. mes. er. ^{rs*}	0.20	inverse gamma	0.147

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