Traditional versus New Keynesian Phillips Curves: Evidence from Output Effects*

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We identify a crucial difference between the backward-looking and forward-looking Phillips curve concerning the real output effects of monetary policy shocks. The backward-looking Phillips curve predicts a strict intertemporal trade-off in the case of monetary shocks: a positive short-run response of output is followed by a period in which output is below baseline and the cumulative output effect is exactly zero. In contrast, the forward-looking model implies a positive cumulative output effect. The empirical evidence on the cumulated output effects of money is consistent with the forward-looking model. We also use this method to determine the degree of forward-looking price setting.

JEL Codes: E31, E32, E40.

1. Introduction

The dynamic effects of aggregate demand on output and inflation are still an open question. Even after decades of investigation, this issue is still highly controversial, with only a few definitive answers available. At stake in this discussion are the nature of the business cycle and the appropriate conduct of monetary policy, among others. The discussion has typically been framed within a Phillips-curve

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setup. The traditional Phillips curve relates inflation to some cyclical indicator and lagged values of inflation. It implies that inflation is a backward-looking phenomenon, produced by adaptive expectations or by price-setting behavior based on a backward-looking rule of thumb. While the traditional Phillips curve is subject to considerable theoretical criticism, the empirical evidence indicates that it describes the post-war inflation in the United States and Europe reasonably well; see, e.g., Rudebusch and Svensson (1999) and Galí, Gertler, and López-Salido (2001).

The so-called New Keynesian Phillips curve relates inflation to the output gap and a "cost-push" effect influenced by expected inflation. Obviously, inflation then is a forward-looking phenomenon caused by staggered nominal price setting as developed by Taylor (1979) and Calvo (1983) or quadratic price adjustment cost (Rotemberg 1982). This model is now widely used in the theoretical analysis of monetary policy (Clarida, Galí, and Gertler, 1999) and has been portrayed as "the closest thing there is to a standard specification" (McCallum 1997). While the new Phillips curve is attractive on theoretical terms, it has not proved to be a simple task to reconcile it with the data. In particular, the relevance of the forward-looking term has been subject to criticism by Fuhrer and Moore (1995), Fuhrer (1997), and Rudd and Whelan (2005).[1]

As an alternative, a number of researchers have investigated a hybrid form of the backward-looking and the forward-looking Phillips curve, e.g., Fuhrer and Moore (1995), Brayton et al. (1997), Roberts (1997), and Christiano, Eichenbaum, and Evans (2005). Empirically, the hybrid Phillips curve also has only limited success. For example, Chadha, Masson, and Meredith (1992), Fuhrer (1997), and Roberts (2001) argue that this specification is not able to replicate inflation dynamics at the quarterly frequency. Evidence from Galí and Gertler (1999), Galí, Gertler, and López-Salido (2001), McAdam and Willman (2004), and Christiano, Eichenbaum, and Evans (2005) is more favorable to the hybrid Phillips curve. However,

[1]McAdam and Willmann (2010) propose a new form of state-dependent Calvo price-setting signal dependent on inflation and aggregate competitiveness which allows to derive a New Keynesian Phillips curve expressed in terms of the actual levels of variables and thus is not regime dependent.

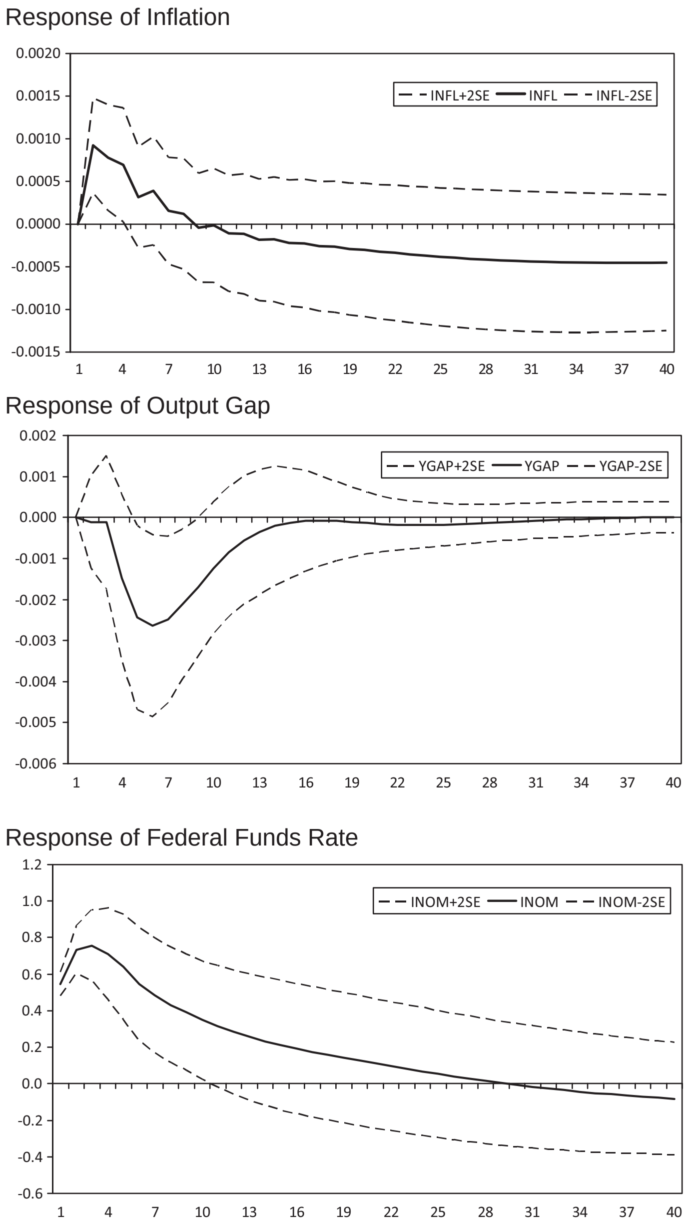
Rudd and Whelan (2006) have recently questioned the relevance of the forward term in the hybrid specification as well.

These empirical tests have so far exclusively focused on the price equation itself and have ignored other dimensions in which the two models—namely the Phillips curve with only backward-looking dynamics and the Phillips curve with (partly) forward-looking inflation expectations—make different predictions. One such dimension is the output response to a monetary policy shock. While both models imply that money is neutral in the long run, they make strikingly different predictions concerning the adjustment of output following a temporary monetary policy shock. Let us consider the effect of a one-period positive shock to the policy rate. In the backward-looking model this leads to a negative output effect due to the fall in demand, a decline in inflation in the current period, and a downward adjustment of inflation expectations in the next period, when the negative demand shock has already disappeared and actual inflation adjusts upwards. This positive inflation surprise leads to an increase of output above its potential during the adjustment process. Taken together, these positive output effects compensate for the initial output loss. In the forward-looking model, in contrast, firms correctly anticipate a rising inflation after the initial drop and respond by lowering prices insufficiently. Therefore, prices are too high over the entire adjustment period, which keeps output below potential and implies that the cumulated output effects are negative. This behavior of output as a response to temporary monetary policy shocks is in accordance with numerous VAR (vector autoregression) studies (e.g., Sims and Zha 2006, Castelnuovo 2009). Figure 1 illustrates the VAR evidence for the United States by showing the impulse-response functions of the output gap, inflation, and the federal funds rate to a monetary policy shock.

As will be shown in this paper, this feature of impulse responses for output is consistent with highly forward-looking price setting and cannot be generated with backward-looking Phillips curves. This dynamic adjustment pattern thus constitutes important empirical evidence in favor of the New Keynesian Phillips curve and against backward-looking specifications.

In this paper we propose to test the purely backward-looking Phillips curve and the purely forward-looking Phillips curve against a hybrid Phillips curve via their implications for cumulative output

Figure 1. Impulse Response to a Monetary Policy Shock



Notes: Sample is the United States, 1970:Q1–2009:Q4. Identification is via Cholesky decomposition using a lower triangular matrix with inflation, output gap, and the federal funds rate. VAR is estimated with four lags. The output gap has been calculated by detrending the logarithm of real U.S. GDP using an HP filter with lamda = 1600.

effects of monetary policy shocks. Compared with existing tests, our procedure is innovative in the sense that we have found a way of testing both versions of the Phillips curve against the hybrid model, while previous procedures test the forward-looking model against the backward-looking model without testing the traditional Phillips curve. Given the price puzzle with standard VARs which is also present in figure 1 and discussions about misspecification of VAR models (see Castelnuovo 2009 for a recent discussion), we do not test the zero cumulative effect within a VAR framework but resort to the approach suggested by Romer and Romer (2004), who carefully construct measures of monetary policy shocks. We estimate the output reaction to Romer and Romer monetary shocks under the hypothesis of long-run monetary neutrality. For our purpose of comparing the forward-looking and the backward-looking model with each other, this restriction suggests itself naturally, since it is implied by both hypotheses. As shown below, this hypothesis cannot be rejected by the data. Our tests focus on cumulative properties of the output response, the distinguishing feature between the traditional and the New Keynesian Phillips curve. We find that the empirical evidence is clearly more consistent with the forward-looking model.

The paper proceeds as follows. Section 2 derives the output implications of the backward-looking and the forward-looking Phillips curve—in particular, the adjustment process of output to a monetary shock. Section 3 presents empirical estimates and tests. Section 4 concludes.

2. The Model: Output Effects of Forward- and Backward-Looking Price Setting

2.1 The Traditional Phillips Curve

In a first step we derive that the backward-looking Phillips curve implies long-run monetary neutrality; i.e., a permanent increase in the money stock does not change the level of output in the long run. The traditional Phillips-curve approach is analyzed in the following standard macroeconomic model with aggregate supply,

$$\pi_t = \pi_{t-1} + \kappa x_t + u_t, \tag{1}$$

aggregate demand,

$$x_t = -\lambda(i_t - \pi_{t+1}) + e_t, \tag{2}$$

monetary policy (interest rate) rule,

$$i_t = \alpha_\pi \pi_t + \alpha_x x_t + v_t, \tag{3}$$

and money demand,

$$m_t - p_t = -\theta_i i_t + \theta_x x_t + z_t. \tag{4}$$

x denotes real output, m a nominal money aggregate, and p the price level. All of these variables are in logs. i is the nominal interest rate and π denotes the inflation rate. u, e, ν, and z denote i.i.d. shocks in aggregate supply, aggregate demand, the interest rate rule, and money demand, respectively. Setting the non-policy shocks equal to zero and solving equations equations (1), (2), and (3) for inflation yields

$$\left[1 - \frac{1 + \lambda\alpha_x + \kappa\lambda\alpha_\pi}{\kappa\lambda} L + \frac{1 + \lambda\alpha_x}{\kappa\lambda} L^2\right] \pi_{t+1} = v_t. \tag{5}$$

Using standard calculus, we can show for the roots of the characteristic equation that one root is smaller and one root is larger than one. Without loss of generality, we define τ_1 to be the larger root, i.e., $\tau_1 > 1$, and τ_2 to be the smaller root, $\tau_2 < 1$. Equation (5) can then be rewritten as

$$\pi_t = \tau_2 \pi_{t-1} - \left[\sum_{i=1}^{\infty} \left(\frac{1}{\tau_1}\right)^{\mathrm{i}} v_{t+i}\right]. \tag{6}$$

Taking into account $\pi_{t-1} = 0$, the effect of a temporary interest rate shock ν_t on period i inflation is

$$\pi_{t+i} = -\tau_2^i v_t. \tag{7}$$

Thus, the long-run effect of the interest rate shock on inflation is zero; i.e., a one-time change in the interest rate does not affect inflation in the long term:

$$\lim_{i\to\infty} \frac{d\pi_{t+i}}{dv_t} = 0. \tag{8}$$

How does this result relate to long-run monetary neutrality? From the traditional Phillips curve, equation (1), it follows that only changes in inflation affect output. Together with equation (7), this yields

$$x_{t+i} = \frac{1}{\kappa}(\pi_{t+i} - \pi_{t+i-1}) = \frac{1}{k}\tau_2^{i-1}(1-\tau_2)v_t. \quad (9)$$

Accordingly, the temporary interest rate shock does not affect output in the long run:

$$\lim_{i\to\infty} \frac{\partial x_{t+i}}{\partial v_t} = 0. \quad (10)$$

To derive the monetary effects of an interest rate shock, we combine equations (3) and (4) to get

$$m_t = p_t - \theta_i \alpha_\pi \pi_t + (\theta_x - \theta_i \alpha_\pi)x_t - \theta_i v_t. \quad (11)$$

Making use of

$$p_{t+n} = \sum_{i=0}^{n} \pi_{t+i} = \sum_{i=0}^{n} p_{t+i} - p_{t+i-1} = \sum_{i=0}^{n} -\left(\frac{1}{\tau_1}\right)^{i+1} v_t \quad (12)$$

and equation (11), the long-run effect of a temporary interest rate shock on the price level and the money stock is given by

$$\lim_{n\to\infty} p_{t+n} = -\frac{1}{1-\tau_1} v_t \quad (13)$$

and

$$\lim_{n\to\infty} m_{t+n} = -\frac{1}{1-\tau_1} v_t, \quad (14)$$

respectively.

A temporary negative interest rate shock causes a permanent increase in the money stock, equation (14), while it does not affect output in the long run, equation (10), so that monetary neutrality holds under the traditional Phillips curve:

$$\lim_{t\to\infty} \frac{dx_t}{dv_t} \Big/ \frac{dm_t}{dv_t} = 0. \quad (15)$$

What are the cumulative output effects of the temporary interest rate shock? We get this cumulative output effect by summing up the output effects (equation (9)) during the adjustment process following the temporary interest rate shock, which yields

$$\sum_{i=0}^{\infty} x_{t+i} = \sum_{i=0}^{\infty} \frac{1}{\kappa}(\pi_{t+i} - \pi_{t+i-1})$$
$$= (v_t - 0) + (v_{t+1} - v_t) + (v_{t+2} - v_{t+1}) + \cdots = 0. \quad (16)$$

This zero cumulative output effect of a temporary interest rate shock is related to the well-known superneutrality property of the traditional Phillips curve.

In summary, a standard macroeconomic model with a traditional Phillips curve implies that a permanent increase in the level of money

- does not affect output in the long run (long-run neutrality) and
- entails a cumulative output effect of zero during the adjustment process.

2.2 The New Keynesian Phillips Curve

What are the implications of the New Keynesian Phillips curve for monetary neutrality? We analyze the New Keynesian Phillips curve in the following standard macroeconomic model with aggregate supply,

$$\pi_t = \beta\pi_{t+1} + \kappa x_t + u_t, \quad (17)$$

and aggregate demand, monetary policy rule, and money demand as in the previous section, i.e., aggregate demand,

$$x_t = -\lambda(i_t - \pi_{t+1}) + e_t, \quad (2)$$

monetary policy (interest rate) rule,

$$i_t = \alpha_\pi \pi_t + \alpha_x x_t + v_t, \quad (3)$$

and money demand,

$$m_t - p_t = -\theta_i i_t + \theta_x x_t + z_t. \tag{4}$$

In addition to the previous notation, β is the discount rate with $0 < \beta \leq 1$.

Combining equations (2), (3), and (17) yields a first-order difference equation for inflation:

$$\pi_{t+1}\left(1 - \frac{1 + \lambda\alpha_x + \kappa\lambda\alpha_\pi}{\beta + \beta\lambda\alpha_x + \kappa\lambda}\mathbf{L}\right) = \frac{\kappa\lambda}{\beta + \beta\lambda\alpha_x + \kappa\lambda}v_t \tag{18}$$

with $\delta = \dfrac{1 + \lambda\alpha_x + \kappa\lambda\alpha_\pi}{\beta(1 + \lambda\alpha_x) + \kappa\lambda} > 1$.

Solving of equation (18) yields

$$\pi_{t+1} = -\sum_{i=1}^{\infty}\left(\frac{1}{\delta}\right)^i \frac{\kappa\lambda}{\beta(1 + \lambda\alpha_x) + \kappa\lambda}v_{t+i}. \tag{19}$$

A temporary interest rate shock ν_t produces an opposite contemporaneous movement of the inflation rate,

$$\pi_t = -\mu\nu_t \tag{20}$$

with $\mu = \dfrac{1}{\delta}\dfrac{\kappa\lambda}{\beta(1 + \lambda\alpha_x) + \kappa\lambda} > 0$.

As the interest rate shock dies out, inflation returns to its steady-state value. Solving equations (17) and (20) for output yields a similar effect on output:

$$x_t = -\frac{\lambda(1 - \alpha_\pi\mu)}{1 + \lambda a_x}v_t. \tag{21}$$

Finally, the effect of the interest rate shock on the money stock can be derived by combining equations (3), (4), (20), and (21) and taking first differences:

$$\mathbf{\Delta m_t} - \pi_t = \left[\theta_i(\alpha_\pi\mu - \mathbf{1}) + \frac{\lambda(\mathbf{1} - \mu)}{\mathbf{1} + \lambda\alpha_x}(a_x\theta_i - \theta_x)\right]\mathbf{\Delta v_t}. \tag{22}$$

A one-time reduction of the interest rate—i.e., a temporary negative unit shock in the Taylor-rule equation—is then equivalent to a permanent increase in the money stock,

$$\mathbf{m_t} = \mu v_t + m_{t-1}. \tag{23}$$

Taken together, a temporary negative interest rate shock implies a contemporaneous fall in output and inflation as well as a permanent drop in the price level and a permanent increase in the money stock. As a corollary monetary neutrality holds, because the change in monetary policy with the associated permanent increase in the money stock does not affect output in the long run,

$$\frac{\frac{dx_{t+i}}{dv_t}}{\frac{dm_{t+i}}{dv_t}} = 0 \quad i \geq 1. \tag{24}$$

What are the cumulative output effects of a temporary interest rate shock, i.e., a permanent change in the money stock? According to equation (24), a temporary interest rate shock has a contemporaneous output effect only, so that the cumulative output effect is given by

$$\sum_{i=0}^{\infty} \frac{dx_{t+i}}{dv_t} = \frac{dx_t}{dv_t} = -\frac{\lambda(1-\mu)}{1+\lambda\alpha_x} < 0. \tag{25}$$

Summarizing, a temporary negative interest rate shock has a positive output effect. As output remains positive during the adjustment process, the cumulative output effect is also positive.

While the backward- and the forward-looking models both imply long-run monetary neutrality—i.e., output is not affected by a permanent rise in the level of the money stock—they differ fundamentally with respect to the transition path following such a permanent increase in the money stock. This crucial difference between the two models in terms of output response is given by equations (16) and (25). While the traditional Phillips curve implies that these cumulated output effects are zero, the New Keynesian Phillips curve predicts a positive cumulated output effect.

In order to get a first idea on the quantitative importance of the cumulative output responses under the backward-looking and forward-looking specifications, we simulate the output effect of a monetary shock on the two Phillips-curve models estimated by Galí, Gertler, and López-Salido (2001, p. 1240). In addition, we also present results for a hybrid version of the Phillips curve with 50 percent share of forward-looking price setters, which is in the neighborhood of values often estimated in empirical studies. For this purpose we modify the New Keynesian Phillips curve by introducing an additional parameter s^F, which indicates the degree of forward-looking price setting:

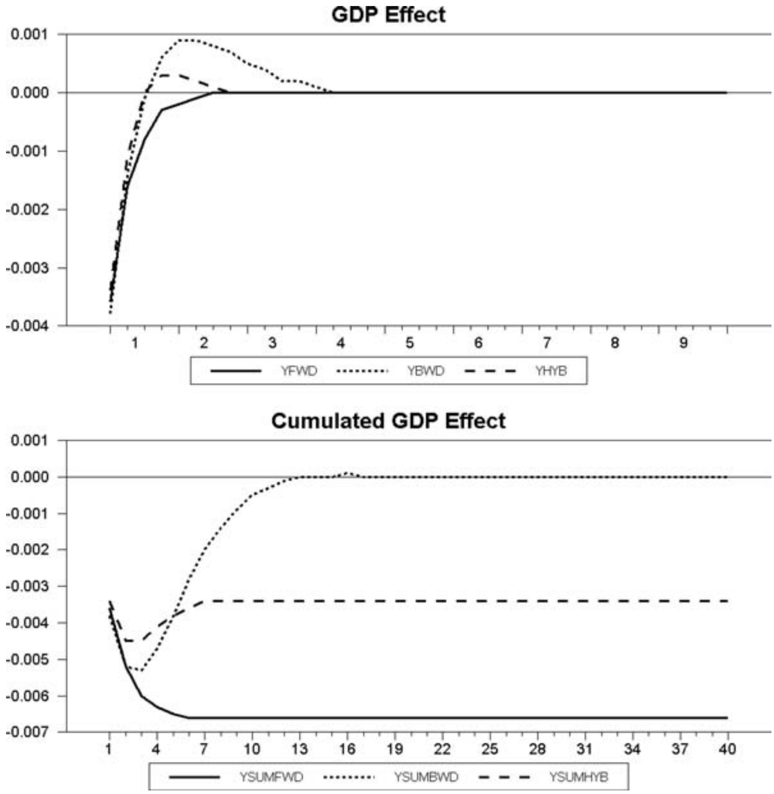
$$\pi_t = \beta(s^F \pi_{t+1} + (1 - s^F)\pi_{t-1}) + \kappa x_t + u_t \quad 0 \leq s^F \leq 1. \qquad (17b)$$

In all three models, the strongest output effect of a temporary increase in the nominal interest rate occurs in the first period (figure 2). The backward-looking model generates oscillatory movements of GDP (YBWD) around the baseline. Though the output effect of a positive interest rate shock is negative initially, it turns positive after about three quarters. The cumulated sum of the output effect (YSUMBWD) is zero. In the forward-looking model, the output effect (YFWD) stays negative during the adjustment process, implying a negative cumulative output effect (YSUMFWD).[2] The hybrid model lies somewhere between these borderline cases. The interesting question that emerges in this case is how the sum of positive and negative output effects (integrals above and below the zero line) is related to the degree of forward-looking price setting.

Tables 1 and 2 give the ratio of positive and negative output effects for alternative values of the parameter s^F which indicates

[2]Notice that firms adjust prices more rapidly in the case of a permanent change in the growth rate of money than in the case of a temporary monetary growth shock. Therefore, the strong cumulative output effect of the forward-looking model in the case of a temporary monetary growth (interest rate) shock is consistent with near superneutrality in the case of a permanent monetary growth (interest rate) shock. With the same parameter values, a permanent increase in the growth rate of money by 1 percent leads to a .025 percent gain in the level of output in the long run. Notice, however, that these estimates do not include possible resource or menu costs from inflation. We derived an alternative version of the New Keynesian price equation based on a model with convex costs of price adjustment (available from the authors by request) and find that using the Galí, Gertler, and López-Salido (2001) estimates, we can identify a price adjustment cost parameter which suggests that with rates of inflation exceeding 1.5 percent, the menu costs would already exceed the markup gains of inflation.

Figure 2. Simulated Output and Cumulated Output Effects



Notes: Shock: Temporary increase of nominal interest rates. Yxx: Deviation of GDP from baseline value. YCUMxx: Cumulated deviation of GDP from baseline value.

the degree of forward-looking price setting. There is a monotonic relationship between s^F and the ratio of the sum of positive and negative output effects. Unfortunately, the relationship is not linear but (sort of) concave. Therefore, the degree of forward-looking behavior cannot be determined with very high precision, while fairly robust statements can be made whether s^F is larger or smaller than .5.

Both Phillips-curve specifications have one problem in common when confronted with VAR evidence on the adjustment of output to a monetary shock. In contrast to the VAR evidence, the peak

Table 1. Fraction of Forward-Looking Firms and Output Effects (model without habit persistence)

s^F	1	.9	.8	.7	.6	.5	.4	.3	.2	.1	0
$\frac{Sumpositive}{Sumnegative}$	0	0	0	−.005	−.008	−.26	−.50	−.72	−.85	−.94	−1

Table 2. Fraction of Forward-Looking Firms and Output Effects (model with habit persistence)

S^F	1	.9	.8	.7	.6	.5	.4	.3	.2	.1	0
$\frac{Sumpositive}{Sumnegative}$	−.006	−.007	−.008	−.013	−.026	−.46	−.71	−.88	−.96	−.99	−1

of the output effect already occurs in the first period. As shown by Fuhrer (2000), habit persistence in demand allows for a delayed peak. Therefore, we also consider an alternative aggregate demand function,

$$x_t = (1 - h)E_t x_{t+1} + h x_{t-1} - \lambda(i_t - E_t \pi_{t+1}) + e_t, \qquad (2b)$$

where we set the parameter h equal to .9.

Since this introduces a backward-looking element into the model, it may affect the output dynamics and, in particular, the cumulative output effect. However, it turns out (see figure 3) that habit persistence does not affect the central propositions of the two hypotheses, concerning the size of the cumulative output effect and the symmetry of positive and negative output deviations.

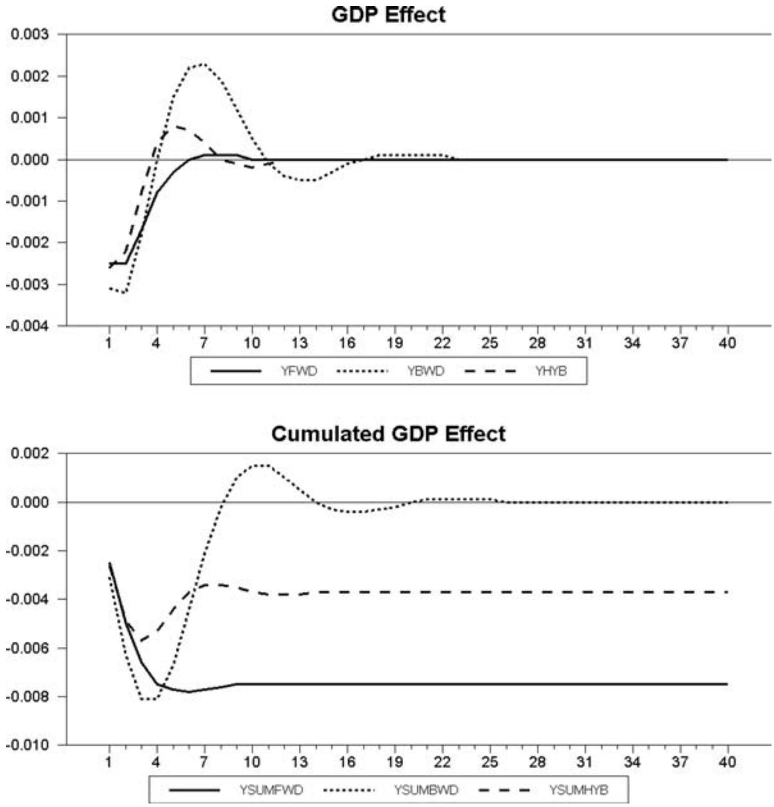
In particular, the empirical results from table 2 indicate that

- introducing habit persistence does not alter the basic prediction of the backward-looking model ($s^F = 0$) that the cumulative output effect of a monetary shock is zero, and
- the relationship between s^F and the ratio of positive and negative output effects remains concave (though slightly less).

3. Empirical Analysis

In this section we test the predictions of the forward- and backward-looking models concerning the cumulative output effects of monetary

Figure 3. Simulated Output and Cumulated Output Effects (with habit persistence)



Notes: Shock: Temporary increase of nominal interest rates. Yxx: Deviation of GDP from baseline value. YCUMxx: Cumulated deviation of GDP from baseline value.

policy shocks. The backward-looking model predicts that the sum of all output deviations is zero, while the forward-looking model predicts that a positive interest rate shock will only have negative output effects. The hybrid Phillips curve predicts a negative cumulative output effect but allows for periods with positive output effects. Using this information helps us to pin down the parameter s^F for the hybrid Phillips curve. As monetary policy shocks, we take the "new measure of monetary shocks" of Romer and Romer (2004).

They use quantitative and narrative records to infer the intended Federal Reserve interest rate policy. This series is then regressed on the Federal Reserve's internal forecasts to derive a measure that is relatively free of endogenous and anticipatory movements. Since the measure is available on a monthly frequency, we follow Romer and Romer and use the monthly measure of industrial production as our output variable. We replicate their specification by regressing the growth rate of industrial production Δx_t on its own lags, lags of the monetary policy shock measure v_{t-j}, and seasonal dummies D_{kt}:

$$\Delta x_t = a_o + \sum_{k=1}^{11} a_k D_{kt} + \sum_{i=1}^{24} b_i \Delta x_{t-i} + \sum_{j=1}^{36} c_j v_{t-j} + e_t. \qquad (26)$$

Our sample period is 1970:M1–1996:M12. Since we have shown above that both models imply monetary neutrality, we want to make sure that the data we use is consistent with this joint prediction; therefore, we also estimate the Romer and Romer specification by imposing a long-run monetary neutrality restriction $\sum_{j=1}^{36} c_j = 0$ on the parameter estimates for the monetary shocks. Tables 3 and 4 show the regression with and without neutrality restriction. The F-test yields a value of $F(1, 252) = 0.62$ with significance level 0.43; i.e., we cannot reject the neutrality hypothesis at conventional significance levels.

Table 3 reports our estimation results under the restriction of long-run monetary neutrality. Based on these results, the net cumulative output effects of a monetary policy shock can be calculated in a straightforward way. The adjustment path of output following a temporary 1-percentage-point increase of the monetary policy shock measure is generated by a dynamic forecast of output. The percentage deviations of output from its long-run level are aggregated to give the cumulated output effect of the monetary shock. As can be seen from figure 4, the output and the cumulated output response are similar to the prediction of the forward-looking price equation (figure 2). In particular, the negative response of output to a temporary increase in the interest rate is not compensated for by positive deviations from the baseline in later periods. Most importantly, the central prediction of the backward-looking model—namely, that the initially negative response would be fully compensated for by

Table 3. Impact of Monetary Policy Shock on Real GDP (with restriction)

Change in GDP			Monetary Policy Shock		
Lag	**Coefficient**	**Standard Error**	**Lag**	**Coefficient**	**Standard Error**
1	0.0627	0.0637	1	0.0038	0.0018
2	−0.0128	0.0633	2	0.0026	0.0018
3	0.1072	0.0628	3	−0.0038	0.0018
4	0.0484	0.0630	4	−0.0012	0.0018
5	0.0284	0.0629	5	−0.0039	0.0018
6	−0.0054	0.0628	6	−0.0001	0.0018
7	0.0179	0.0627	7	−0.0008	0.0019
8	0.0075	0.0626	8	−0.0029	0.0019
9	0.0396	0.0622	9	−0.0021	0.0019
10	−0.0426	0.0609	10	−0.0047	0.0018
11	0.0709	0.0593	11	−0.0025	0.0019
12	0.2867	0.0602	12	−0.0035	0.0019
13	0.0227	0.0608	13	−0.0021	0.0019
14	−0.1964	0.0604	14	−0.0007	0.0018
15	−0.1510	0.0610	15	−0.0003	0.0019
16	−0.1282	0.0623	16	0.0019	0.0018
17	0.0777	0.0635	17	−0.0009	0.0018
18	0.0853	0.0632	18	−0.0024	0.0018
19	0.0557	0.0632	19	−0.0023	0.0019
20	0.0805	0.0629	20	−0.0007	0.0019
21	−0.0604	0.0631	21	−0.0011	0.0019
22	−0.0171	0.0630	22	−0.0032	0.0018
23	−0.0675	0.0630	23	0.0015	0.0019
24	0.0863	0.0631	24	0.0000	0.0019
			25	−0.0001	0.0019
			26	−0.0000	0.0019
			27	−0.0007	0.0019
			28	0.0038	0.0019
			29	0.0013	0.0019
			30	0.0035	0.0019
			31	0.0018	0.0019
			32	0.0009	0.0018
			33	0.0014	0.0018
			34	0.0047	0.0018
			35	0.0011	0.0018
			36	0.0024	0.0018

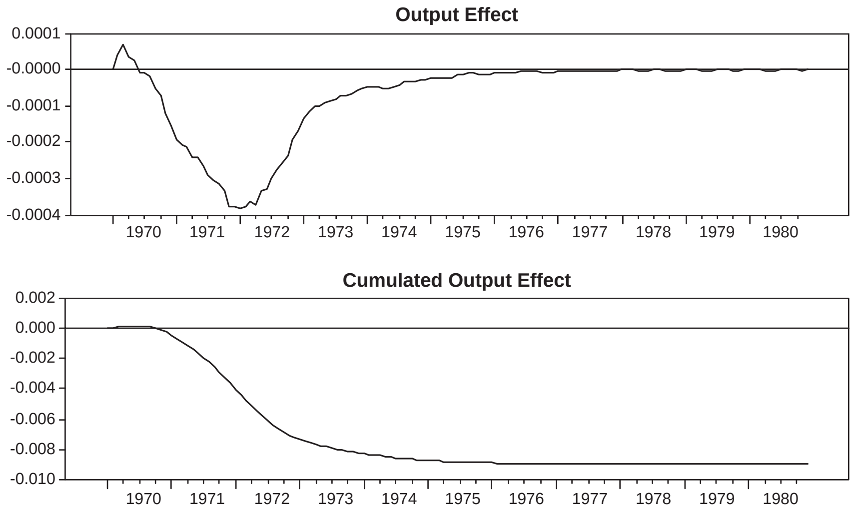
Notes: R2 = 0.81; D.W. = 2.01; s.e.e. = 0.009; N = 324. The sample period is 1970:M1–1996:M12. Coefficients and standard errors for the constant term and the monthly dummies are not reported.

Table 4. Impact of Monetary Policy Shock on Real GDP (without restriction)

Change in GDP			Monetary Policy Shock		
Lag	Coefficient	Standard Error	Lag	Coefficient	Standard Error
1	0.0650	0.0636	1	0.0040	0.0018
2	−0.0103	0.0632	2	0.0028	0.0018
3	0.1105	0.0626	3	−0.0037	0.0018
4	0.0519	0.0628	4	−0.0010	0.0018
5	0.0329	0.0626	5	−0.0038	0.0018
6	−0.0011	0.0626	6	0.0001	0.0018
7	0.0236	0.0622	7	−0.0007	0.0018
8	0.0138	0.0621	8	−0.0028	0.0019
9	0.0460	0.0616	9	−0.0020	0.0018
10	−0.0382	0.0606	10	−0.0045	0.0018
11	0.0754	0.0590	11	−0.0024	0.0018
12	0.2905	0.0600	12	−0.0034	0.0018
13	0.0264	0.0606	13	−0.0019	0.0019
14	−0.1927	0.0602	14	−0.0004	0.0018
15	−0.1484	0.0609	15	−0.0001	0.0018
16	−0.1268	0.0622	16	0.0021	0.0018
17	0.0807	0.0633	17	−0.0006	0.0018
18	0.0883	0.0630	18	−0.0022	0.0018
19	0.0578	0.0631	19	−0.0020	0.0018
20	0.0830	0.0628	20	−0.0004	0.0018
21	−0.0577	0.0630	21	−0.0008	0.0018
22	−0.0144	0.0628	22	−0.0029	0.0018
23	−0.0645	0.0628	23	0.0019	0.0018
24	0.0887	0.0629	24	0.0003	0.0018
			25	0.0003	0.0018
			26	0.0004	0.0018
			27	−0.0003	0.0018
			28	0.0042	0.0018
			29	0.0017	0.0018
			30	0.0039	0.0018
			31	0.0021	0.0018
			32	0.0013	0.0018
			33	0.0018	0.0018
			34	0.0050	0.0018
			35	0.0014	0.0018
			36	0.0027	0.0018

Notes: R2 = 0.81; D.W. = 2.02; s.e.e. = 0.009; N = 324. The sample period is 1970:M1–1996:M12. Coefficients and standard errors for the constant term and the monthly dummies are not reported.

Figure 4. Output and Cumulated Output Effects of Temporary Negative Interest Rate Shock (under long-run monetary neutrality)



a positive output response such that the cumulated output effect precisely sums to zero—does not seem to hold.

The estimated impulse response shows, however, one important difference from the standard New Keynesian Phillips curve, which concerns the peak of the output effect. In the Romer and Romer model, the output effect peaks in the second to third period, while the New Keynesian Phillips curve predicts the peak already in the first period. However, neither the hybrid nor the traditional Phillips curve is superior with respect to the timing of the output peak.[3] As discussed above, the peak response of output can be shifted by introducing a lagged response of demand, i.e., habit persistence in the IS curve. As was also shown above, adding demand persistence does not fundamentally alter the predictions of the two hypotheses concerning the magnitude of the cumulative output effect.

Since it is our interest to arrive at an estimate of the cumulative output effect and to test whether it is significantly different from

[3]The hybrid Phillips curve does better in terms of inflation persistence.

Table 5. Distribution of Cumulated Output Effects (YCUM)

1st Percentile	**5th Percentile**	**10th Percentile**	**Median**	**90th Percentile**	**95th Percentile**	**99th Percentile**
−.1726	−.0443	−.0270	−.0265	−.0265	−.0038	−.0030
Note: Sample mean = −.0252, standard error of mean = .0081, standard error = .2580, skewness = −29.6, kurtosis = 910.3, observations = 1,000.						

zero, it is important to get an idea of the precision in which the cumulated output effect can be estimated. This is not a straightforward exercise, since the cumulative output effect will generally be a complicated non-linear function of the estimated coefficients. Therefore, we base our calculation of confidence bounds on Monte Carlo simulations. For that purpose we generate 1,000 random samples of coefficients from the vector of estimated Π, using the estimated variance-covariance matrix Ω of Π. For each draw of parameters, we calculate the cumulated output effect over a period of 500 months by simulating the output effect of an 1-percentage-point increase in the "Romer interest rate shock variable" over this period and summing up the output response over time. This time horizon seems sufficient, since the long-run neutrality restriction implies that output will eventually return to its baseline level. As can be seen from figure 2, the effect of an increase in money on output is completed well within 100 months. Table 5 shows the characteristics of the distribution of YCUM (evaluated after 500 quarters) of the Monte Carlo exercise. The sample mean of the distribution is significantly negative (sample mean plus standard error of sample mean), thus suggesting that the cumulative output effect of a monetary policy shock is clearly negative. Because the empirical distribution shows some negative skewness with the mean being closer to zero than the median, we also show the percentiles of the distribution (area to the left of the distribution as percent of the total area). This shows that even at the 99th percentile, the values for YCUM are negative.

The results show that the probability that YCUM takes a positive value is less than 1 percent. Thus, we can reject the hypothesis of a zero cumulative output effect at the 1 percent level.

Table 6. Distribution of Backward-Looking Share Parameter in Hybrid Phillips-Curve Model

1^{st} Percentile	5^{th} Percentile	10^{th} Percentile	Median	90^{th} Percentile	95^{th} Percentile	99^{th} Percentile
.0004	.0026	.0048	.0543	.2460	.3338	.5257

Note: Sample mean = .0972, standard error of mean = .0038, standard error = .1211, skewness = 2.72, kurtosis = 11.14, observations = 1,000.

Similarly, we can test the forward-looking Phillips curve by testing whether the area of output effects $\sum_{s=0}^{500} Max(Y_s, 0)$ is significantly negative. For this we construct the following test statistic:

$$X = \frac{\sum_{s=0}^{500} \max(Y_s, 0)}{\sum_{s=0}^{500} \min(Y_s, 0)}.$$

Notice that X varies between 0 and -1. The backward Phillips curve is one extreme case, with exactly the same size for cumulated positive and negative output effects, implying a value of -1. The forward-looking model implies zero positive output deviations, thus implying a value of $x = 0$.

As shown above, different share parameters imply different relative sizes of these positive and negative deviations. Therefore, we can also use the Monte Carlo experiment to shed some light on the location of the share parameter (of a hybrid Phillips curve) by calculating the integrals of positive and negative effects.

Table 6 shows the distribution of X. Both the median and the mean of the empirical distribution of X are very small, suggesting a ratio between positive and negative deviations of below .1 in absolute value. Notice, however, that the mean of X is significantly different from zero; thus we also reject the forward-looking model at standard levels of significance. Comparing the estimated value of X with the values of X generated by alternative hybrid specifications (see tables 1 and 2) suggests that our estimate is consistent with a hybrid Phillips curve with a share of forward-looking price setters above 50 percent, an estimate often found in the empirical literature. It is interesting to note that the hybrid Phillips curve nevertheless makes predictions about the output effects of monetary policy which are close to the pure forward-looking model.

4. Conclusions

This paper looks into the monetary policy implications of backward-looking and forward-looking price equations. So far, no consensus has been reached among the macroeconomics profession regarding which of the two price adjustment schemes should be chosen on empirical grounds. We identify a crucial difference between the two hypotheses. The backward-looking Phillips curve predicts a strict intertemporal trade-off in the case of monetary shocks: a negative short-run response of output is followed by a period where output is above the baseline and the cumulative effect is exactly zero. In contrast, the forward-looking model allows the cumulative output effect of temporary monetary shocks to be non-zero. These contrasting predictions of the two hypotheses are tested in this paper. We find that the empirical evidence on the cumulated output effects of monetary shocks is in fact more consistent with the forward-looking model. Both qualitatively and quantitatively, the output response to a temporary interest rate innovation seems close to what is predicted by the New Keynesian Phillips curve.

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