ROBUSTNESS OF THE ESTIMATES OF THE
HYBRID NEW KEYNESIAN PHILLIPS CURVE

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ABSTRACT

Galí and Gertler (1999) developed a hybrid variant of the New Keynesian Phillips curve that relates inflation to real marginal cost, expected future inflation and lagged inflation. GMM estimates of the model suggest that forward looking behavior is dominant: The coefficient on expected future inflation substantially exceeds the coefficient on lagged inflation. While the latter differs significantly from zero, it is quantitatively modest. Several authors have suggested that our results are the product of specification bias or suspect estimation methods. Here we show that these claims are incorrect, and that our results are robust to a variety of estimation procedures, including GMM estimation of the closed form, and nonlinear instrumental variables. Also, as we discuss, many others have obtained very similar results to ours using a systems approach, including FIML techniques. Hence, the conclusions of GG and others regarding the importance of forward looking behavior remain robust.

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1 Introduction

In this paper we show that the estimates of the hybrid New Keynesian Phillips curve presented in Gali and Gertler (1999; henceforth GG) and refined in Gali, Gertler and Lopez-Salido (2001; 2003; henceforth, GGLS) are completely robust to recent criticisms by Rudd and Whelan (2005) and Linde (2005). It follows that the main conclusions in GG and GGLS remain intact. In this section, we first summarize the results in GG and GGLS and then provide a brief summary of the response to our critics. In the sections that follow we offer a more detailed response and also present some new results based on alternative estimation approaches.

1.1 Background

GG present evidence to suggest that postwar U.S. inflation dynamics are consistent with a simple hybrid variant of the New Keynesian Phillips curve (NKPC). The particular model GG propose is based on Calvo's (1983) staggered price setting framework. As in Calvo, each firm has a probability $1-\theta$ of being able to reset its price in any given period, independently of the time elapsed since its most recent price adjustment. Thus, a fraction θ of firms keep their prices unchanged in any given period. In contrast to Calvo, however, of those firms able to adjust prices in a given period, only a fraction $1-\omega$ set prices optimally, i.e. on the basis of expected future marginal costs. A fraction ω, on the other hand, instead use a simple rule of thumb: they set price equal to the average of newly adjusted prices last period plus an adjustment for expected inflation, based on lagged inflation π_{t-1}. The net result is a hybrid Phillips curve that nests the pure forward looking Calvo model as a special case.

In particular, let mc_t be (log) real marginal cost and β a subjective discount factor. Then the hybrid Phillips curve (with all variables expressed as deviations from steady state) is given by

$$\pi_t = \lambda \ mc_t + \gamma_f \ E_t\{\pi_{t+1}\} + \gamma_b \ \pi_{t-1} + \varepsilon_t \tag{1}$$

where

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\begin{aligned}
\lambda &= (1-\omega)(1-\theta)(1-\beta\theta)\phi^{-1} \\
\gamma_f &= \beta\theta\phi^{-1} \\
\gamma_b &= \omega\phi^{-1}
\end{aligned}
$$

with $\phi = \theta + \omega[1-\theta(1-\beta)]$ [1], and where the error term ε_t may arise from either measurement error or shocks to the desired markup. Note that in the limiting case where ω goes to zero, the equation becomes the pure forward-looking NKPC, with $\gamma_b = 0$ and $\gamma_f = \beta$.

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[1] The expression for λ arises in the case of constant returns to scale. Sbordone (2002) and Galí, Gertler, and López-Salido (2001) show that with decreasing returns to scale, a given value of λ is associated with a smaller value of θ, and hence a smaller degree of price rigidity.

Assuming rational expectations and that the error term $\{\varepsilon_t\}$ is i.i.d., GG estimate equation (1) using Generalized Method of Moments (GMM) with variables dated $t - 1$ and earlier as instruments. Three main findings emerge: (1) the coefficient λ on real marginal cost is positive and statistically significant; (2) the coefficient γ_b is statistically greater than zero, implying that the pure forward-looking model is rejected by the data; (3) however, forward looking behavior is dominant; across a range of estimates, the coefficients γ_f and γ_b generally sum to a close neighborhood of unity, with the coefficient on lagged inflation, γ_b, in the interval 0.2 to 0.4. In a subsequent paper, GGLS broadly confirm these estimates for U.S. data, though they tighten the range of point estimates of γ_b to the neighborhood of 0.35. As we elaborate below, these estimates suggest that the influence of backward-looking behavior on inflation, while statistically significant, is nonetheless quantitatively modest, certainly as compared to what the traditional Phillips curve literature suggests. Accordingly, a clear message from both GG and GGLS is that, while the pure forward looking version of the New Keynesian Phillips curve is rejected by the data, the hybrid variant with a dominant role for forward-looking behavior does reasonably well. It is in this respect that the New Keynesian Phillips curve provides useful insights into the nature of inflation dynamics.

A significant corollary result is that the use of real marginal cost as the relevant real sector forcing variable in the hybrid NKPC (as the theory suggests) is critical to the empirical success.[2] Specifications based instead on ad-hoc "output gap" measures (e.g., detrended log GDP) do not perform well: The coefficient on the output variable is either insignificant or significant but with the wrong sign. There has been of course considerable criticism of the output-gap based NKPC (e.g., Mankiw (2001)). Our results suggest that a key reason for the lack of success of this formulation is that detrended output is not a good proxy for real marginal cost, in addition to the need to allow for a modest amount of inertial behavior of inflation.

1.2   Criticism and Summary of Our Response

Several recent papers (Rudd and Whelan, 2005; hereafter RW, and Lindé, 2005) have suggested that some of the empirical findings described above may be the product of specification bias associated with our GMM procedure. Here we show that these claims are plainly incorrect. In addition to directly rebutting the arguments of these authors, we show that our estimates are robust to a variety of different econometric procedures, including GMM estimation of the closed form as suggested by RW and nonlinear instrumental variables, in the spirit of Lindé's analysis. Beyond the fresh results we present here, we also summarize work by authors who obtain very similar results to ours using alternative econometric approaches.

How could our conclusions be so different from those by RW and Lindé? Before going into detail in the sections that follow, we summarize our response to each.

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[2]Sbordone (2002) emphasizes a similar point, though she restricts attention to the pure forward looking model.

As we elaborate below, the essence of RW's argument is that our results are likely a product of mis-specification if estimates of the closed form (obtained from solving out for expected future inflation) are significantly different from those obtained from estimating the structural form directly. RW seem to suggest that this is in fact the case. However, as we discuss, RW fail to exploit the connection between the key parameters of the structural form of the hybrid model given by equation (1) and the reduced form parameters of the closed form they estimate. In particular, the reduced form parameters of the closed form are explicit functions of the parameters of structural form (1), including γ_f and γ_b, the parameters that identify the relative importance of forward versus backward looking behavior. As we show below *when one estimates the closed form equation in a way that incorporates the restrictions of the structural form, the parameter estimates are virtually identical to those obtained in GG and GGLS by estimating the structural form directly*. That is, estimating the closed form does not make any tangible bit of difference to our results, leading us to conclude that forward-looking behavior is as important as was suggested in our two earlier papers.

That one should take into account the mapping between the structural form and the closed form should be apparent from reading Sbordone (2002, 2005), who originally proposed estimating the closed form of the NKPC. While Sbordone (2002) focused on just the pure forward looking model, her paper in this volume, Sbordone (2005), estimates the closed form of a hybrid model similar to ours (using an alternative estimation technique). She obtains very similar conclusions to ours about the relative importance of forward versus backward-looking behavior. She also directly rebuts another claim by RW, who go on to suggest that because a discounted sum of expected future marginal cost adds little to the forecasting power of lagged inflation for inflation, forward looking behavior must be unimportant. She makes very clear why it is plainly incorrect to draw inferences about the relative importance of forward versus backward-looking behavior from this kind of evidence[3]. We refer the reader to this discussion in her paper.

As we also discuss, Lindé's conclusions hinge on using estimators that fail to properly account for the error term ε_t in equation (1), even though he emphasizes the importance of this error term is his subsequent Monte Carlo analysis. This consideration is the reason why the nonlinear least squares (NLS) procedure he proposes at the start of his paper appears to yield results contradictory to ours: NLS is clearly inappropriate in this case as the right hand side variables may be correlated with ε_t. Assuming that ε_t is i.i.d., it is instead appropriate to use a nonlinear instrumental variables estimator (NLIV) with lagged variables as instruments. Accordingly, we proceed to show that NLIV yields estimates that

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[3]See section 4 of Sbordone's paper in this volume. As she observes, the NKPC implies that inflation contains information about future movements in expected marginal cost. In a reduced form equation for inflation that omits the forward-looking terms (i.e. the terms for expected future marginal cost), the coefficient on lagged inflation may be enlarged due to omitted variable bias. Sbordone then presents evidence that this bias is likely important in practice, undermining any attempt to give a structural interpretation to coefficients of a reduced form equation for inflation. Hence one cannot draw inferences about the importance of backward-looking behavior simply from forecasting evidence.

are virtually identical to our GMM estimates (using a timing of instruments that is consistent with the model and our earlier analysis). Thus his claim that our results are not robust to using that alternative estimation approach is based on the fact that NLS is an inappropriate estimator in the presence of an error term in the inflation equation.

In the second part of his paper Lindé argues, on the basis of some Monte Carlo exercises, that full information maximum likelihood methods (FIML) may be a more robust procedure than single equation methods for the purpose of estimating the NKPC. While we do not take a stand on this claim, we find Lindé's argument unconvincing. In particular, as we discuss below, Lindé's Monte Carlo exercise is heavily tilted in favor of FIML. In a nutshell: he ends up comparing a single equation estimator (that in some cases is poorly designed) against a FIML estimator that presumes that the econometrician has a good deal of knowledge about the true model of the economy a priori, something which is quite unlikely to be true in practice. Also not convincing are Lindé's FIML estimates on actual data: his results are likely to be distorted because he uses detrended GDP rather than real marginal cost as a driving variable, as we discuss below. In addition, many others who have used a systems approach and have used real marginal cost in the NKPC have obtained very similar results to our single equation method.

2   New Estimates of the Hybrid NKPC

Here we first briefly review the GMM estimation in GG and then demonstrate the robustness of our results to two alternative estimation strategies: GMM estimation of the closed form and NLIV. We then discuss results in the literature that are similar to ours, but obtained using maximum likelihood estimation. Along the way we respond in detail to our critics.

Let $\mathbf{z}_{t-1}$ be a vector of variables dated $t-1$ and earlier. Then, given rational expectations and the assumption that the error term ε_t is i.i.d, it follows from equation (1) that

$$E_{t-1}\{(\pi_t - \lambda \; mc_t - \gamma_f \; \pi_{t+1} - \gamma_b \; \pi_{t-1}) \; \mathbf{z}_{t-1}\} = 0 \qquad (2)$$

The orthogonality condition given by (2) provides the basis for the GMM estimation in GG and GGLS.

A potential shortcoming of this approach is as follows: If the instrument set includes variables that directly cause inflation but are omitted from the hybrid model specification, the estimation of (1) may be biased in favor of finding a significant role for expected future inflation in determining current inflation, even if that role is truly absent or negligible. In GG (1999) and GGLS (2001, 2003) we addressed this issue by allowing for additional lags of inflation in the right hand side of (1) (in addition to using them as instruments), and then showing that these additional lags were not significant. This exercise provided evidence that additional inflation lags do not affect current inflation independently of the information they contain about future inflation.

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RW pick up on this potential bias problem and construct a very dramatic example of how it could lead of a significant upward bias in the estimate of γ_f. It is important to realize, however, that this example is based on the null hypothesis that inflation is purely backward looking, an extreme scenario where our model is clearly not identified. Our estimation strategy is instead based on the plausible null that there is at least *some* forward looking behavior. Conditional on this null, the steps we took to check for mispecification were entirely appropriate. In the end, however, we demonstrate the validity of our approach by showing that our estimates are robust across many different estimation strategies, including the closed form emphasized by RW.

2.1   GMM Estimates of the Closed Form Specification

In particular, RW propose addressing the potential bias problem by estimating the closed form of the hybrid model (1). As we noted earlier, however, in considering the closed form they do not exploit the connection with the structural hybrid model (1). In particular, as shown in GG (1999), the hybrid Phillips curve has the following closed form representation, conditional on the expected path of real marginal cost:

$$\pi_t = \delta_1 \; \pi_{t-1} + \frac{\lambda}{\delta_2 \; \gamma_f} \; \sum_{k=0}^{\infty} \left(\frac{1}{\delta_2}\right)^k \; E_t\{mc_{t+k}\} + \varepsilon_t \tag{3}$$

where δ_1 and δ_2 are, respectively, the stable and unstable roots of the second order difference equation given by (1). These roots are given by:

$$\delta_1 = \frac{1 - \sqrt{1 - 4\gamma_b\gamma_f}}{2 \; \gamma_f} \qquad ; \qquad \delta_2 = \frac{1 + \sqrt{1 - 4\gamma_b\gamma_f}}{2 \; \gamma_f} \tag{4}$$

Using the same logic as earlier, we can obtain from equation (3) the following orthogonality conditions

$$E_t\{(\pi_t - \delta_1\pi_{t-1} - \overline{\lambda}\sum_{k=0}^{\infty} \delta_2^{-k} \; mc_{t+k}) \; \mathbf{z}_{t-1}\} = 0 \tag{5}$$

with $\overline{\lambda} = \frac{\lambda}{\delta_2\gamma_f}$, and where (4) defines the mapping from the roots δ_1 and δ_2 to the parameters of hybrid model, γ_b and γ_f . One can then use GMM with lagged variables as instruments to estimate the closed form given by (5), just as it is possible with the structural form. As we will show shortly, estimating the hybrid NKPC in the form given by either equation (5) or equation (2) gives virtually identical estimates of the key parameters λ, γ_f and γ_b.

2.1.1   Pitfalls of the RW Approach

As we hinted earlier, RW appear to obtain different results because they fail to account for the connection between the structural hybrid model and the closed form specification. More

specifically, RW begin with the closed form of the pure forward-looking model, given by

$$\pi_t = \lambda \sum_{k=0}^{\infty} \beta^k \, E_t\{mc_{t+k}\} \tag{6}$$

Then they augment this equation with additional lags of inflation. In particular, for the case of one lag of inflation, the equation they consider is given by

$$\pi_t = \lambda \sum_{k=0}^{\infty} \beta^k \, E_t\{mc_{t+k}\} + \phi \, \pi_{t-1} \tag{7}$$

They recognize that this equation could be motivated as the reduced form of the hybrid model, but do not attempt to identify the structural parameters γ_f and γ_b. At minimum, however, the notation they use is confusing because β does *not* generally correspond to the consumer's discount factor β as in our analysis and elsewhere; instead it is a function of γ_f and γ_b, as equation (3) makes clear.

They then proceed to estimate equation (7) by GMM, using two different approaches. First, they calibrate β, and then estimate λ and ϕ. Second, they estimate all three parameters. While the first approach permits a test of the pure forward-looking model (i.e., of the null hypothesis $\phi = 0$), it cannot provide a legitimate assessment of the hybrid model. The reason is straightforward: Because they calibrate the discount factor β, they cannot identify the primitive key primitive parameters of the structural model, γ_f and γ_b, as comparison of equations (1), (3) and (7) makes clear. With their second approach, which involves estimating the discount factor, it is possible to identify these parameters, but they do not pursue this route. In our view, the only way to obtain a proper sense of the relative importance of forward versus backward-looking behavior is to indeed obtain direct estimates of γ_f and γ_b.

In this regard, it is critical to note that, in the closed form, the parameter ϕ on lagged inflation does not provide a simple measure of the degree of backward-looking behavior. That is, ϕ should not be confused with γ_b, the coefficient on lagged inflation in the baseline hybrid specification. More specifically, (3) implies that ϕ should correspond to the eigenvalue δ_1 which, as (4) makes clear, is a nonlinear function of γ_f and γ_b. To illustrate the danger of interpreting ϕ as a measure of the relative importance of the backward-looking component, consider the following numerical example. Suppose that (in the notation of equation (1)), $\beta = 1$, and $\gamma_f = \gamma_b = 0.5$, so that forward and backward-looking behavior are equally important. It is easy to check that in this case $\phi = \delta_1 = 1$. It would clearly be incorrect, however, to suggest that an estimate of $\phi = 1$ implies pure backward looking behavior. All this suggests that one cannot assess the relative importance of forward versus backward-looking behavior from the RW specification and that it is important to identify the parameters γ_f and γ_b directly.

2.1.2   Estimates of the Closed Form of the Hybrid Model

Given these considerations, we estimate the closed form for the hybrid model given by equation (1) that takes direct account of the coefficient restrictions. As we have discussed, our approach allows us to recover estimates of γ_f and γ_b, along with standard errors. As shown below, the resulting estimates are similar to the ones obtained in GG and GGLS.

All the estimates reported below are based on quarterly postwar U.S. data over the sample period 1960:I-1997:IV. The data set is the same used in GG and GGLS, which provide detailed descriptions. We report results for GDP deflator inflation, though similar results obtain when using a measure based on the nonfarm business deflator. We follow GGLS by using a smaller instrument set than in GG in order to minimize the potential estimation bias that is known to arise in small samples when there are too many over-identifying restrictions (see, e.g. Staiger and Stock (1997)).[4] Accordingly, we restrict the instrument set to four lags of inflation, and two lags of marginal cost, detrended real output and nominal wage inflation. Finally, we report estimates using two alternative driving variables in the structural Phillips curve: the log of real marginal cost (which we measure using the log of the nonfarm business labor income share, as explained in GG), and detrended (log) GDP.

To provide a benchmark we first report estimates of equation (1) based on the GMM approach employed in our earlier work. Table 1 reports the corresponding estimates of γ_b, γ_f and λ under the heading "baseline GMM.".[5] We report both unconstrained estimates and estimates that impose the constraint that $\gamma_b + \gamma_f = 1$. The results are very similar to those obtained in GG and GGLS. Marginal cost enters with the correct sign and is statistically significant. The coefficient on expected future inflation exceeds that of lagged inflation in each case: γ^f is roughly 2/3, while γ^b is roughly 1/3. Imposing the condition $\gamma_b = \gamma_f = 1$ (as implied by the assumption that $\beta = 1$) does not alter the estimates appreciably. Not surprisingly, given the results in GG, the estimate of λ switches sign when we use detrended GDP. As we stressed in GG (1999) this finding may simply reflect that detrended GDP is an inappropriate proxy for real marginal cost.

The middle panel of Table 1 reports the GMM estimates of the closed form specification (3). The estimates are based on the set of orthogonality conditions in (5). We follow RW by using a truncated sum to approximate the infinite discounted sum of real marginal costs.[6] However, as we stressed above, we differ by exploiting the link between the hybrid model and its closed form to identify the key parameters γ_b and γ_f of the hybrid model. The implied estimates for γ_b and γ_f are virtually identical to those obtained from estimating the hybrid model (1) directly. Finally, the slope coefficient on the discounted stream of expected future marginal cost is positive and highly significant, and does not differ much from the

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[4]See p.1250 in GGLS (2001) for a discussion of the weak instruments issue in this context.

[5]In GG and GGLS we also report estimates of the "deep parameters" θ, ω, and β that underly the reduced form coefficients.

[6]We use sixteen leads of real marginal cost to construct the discounted stream of real marginal cost. We also experimented with twelve or twenty-four, without the results being affected.

corresponding baseline GMM estimates. Once again, the results are not affected much when we constrain the sum of the two inflation coefficients to equal unity. When detrended GDP is used instead, the slope coefficient is no longer significant for the restricted case. We thus conclude that estimating the closed form in a way consistent with the hybrid Phillips curve specification yields results very close to those obtained in GG or GGLS, contrary to the claim in RW.

The mapping between the structural forms also permits us to be precise about why our results suggest that the influence of backward looking behavior, while statistically significant, is quantitatively modest. In particular, for the model with real marginal cost as the forcing variable, our closed form estimates of γ_b and γ_f imply an estimate of the stable root, δ_1, of 0.6 with a standard error 0.06. For quarterly data, this is indeed represents a very modest influence of lagged inflation on inflation persistence. Indeed, with δ_1 equal to 0.6, the "half-life" of a percentage rise in inflation at time t is only slightly above one quarter - about four months to be precise - everything else equal.[7] This implies that the influence of lagged inflation dies out a relatively rapid rate, certainly compared to the traditional Phillips curve literature, which often suggests a permanent (or near-permanent) effect of lagged inflation on current inflation. We add that even an estimate of δ_1 of 0.8, which lies more than two standard deviations above our point estimate, would still only suggest a modest degree of persistence: In this instance the half-life would rise to just above two quarters - about seven months to be precise.

2.2   NLIV Estimates of the Structural Hybrid NKPC

We next turn to the set of issues raised in the first part of Lindé (2005). Note that, as pointed out by Lindé, it is possible to rearrange equation (1) in the following form:

$$\pi_{t+1} = \frac{1}{\gamma_f}\ \pi_t - \frac{\gamma_b}{\gamma_f}\ \pi_{t-1} - \frac{\lambda}{\gamma_f}\ mc_t + \xi_{t+1} - \varepsilon_t \tag{8}$$

where $\xi_{t+1} \equiv \pi_{t+1} - E_t\{\pi_{t+1}\}$ is the inflation forecast error. Lindé proceeds to estimate equation (8) using nonlinear least squares (NLS). He also estimates a version that replaces real marginal cost with detrended output. In either case, he obtains estimates of λ that have the wrong sign and are generally insignificant (see Table 1 of his paper). He accordingly concludes that the hybrid NKPC does not perform well and that the use of real marginal cost versus detrended output makes no difference. Here we show that this conclusion is based on an inappropriate estimation procedure.

In particular, an NLS estimation procedure will generally yield biased estimates to the extent that a non-negligible error term ε_t is present, so long as this error term is correlated

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[7]The thought experiment is as follows: Hold constant the path of marginal cost. Then suppose it is exogenously given that inflation is one percentage point higher at time t. What then is the impact on inflation is subsequent periods? We define the half-life as the period length j of time after which the impact of the rise in inflation at t on inflation at $t + j$ is half the initial period t increase.

with some of the right hand side variables.[8] Here we repeat Lindé's exercise but using instead a non-linear instrumental variables (NLIV) estimator, with the same list of instruments that we used in our GMM analysis in the previous section. The bottom panel of Table 1 reports our NLIV estimates, both for the constrained and unconstrained cases. Clearly, the estimates are very similar to the ones obtained under our baseline GMM specification: the coefficient on expected inflation is much higher than that on lagged inflation, even though the latter is significant. Furthermore, the slope coefficient is significant and with the right sign when marginal cost is used as a driving variable, but of the wrong sign when detrended output is used, in direct contradiction to Lindé's claim.

We should also emphasize that our NLIV estimates are robust to using alternative instrument sets, though to economize on space we do not report the results here.[9] It is worth stressing, however, that the similarity between the NLIV and GMM estimates is further evidence that the latter are not plagued by a weak instruments problem.

In summary, we conclude that Lindé's assertion that real marginal cost does not enter significantly or with the right sign is simply a product of using least squares as opposed to instrumental variables. Accordingly, his justification for using detrended output as opposed to real marginal costs in his subsequent analysis (described below) vanishes.

2.3   Maximum Likelihood Estimates of the Hybrid NKPC

A possible alternative to the single equation/instrumental variables approach of the previous section is to use maximum likelihood. As Cochrane (2001) emphasizes, the issue of which approach is best is completely open: There are no general theorems or Monte Carlo exercises that suggest that one dominates the other. There are trade-offs: Single equation methods may be sensitive to the choice of instruments. On the other hand, maximum likelihood estimation may be sensitive to imposing false assumptions about either the error term (normality of the error term is required) or the overall model structure (in the case of FIML).

In Section 4 of his paper Lindé (2005) tries to make a case for the use of FIML methods in order to uncover "robust" estimates of the parameters of the NKPC. He starts by providing some Monte Carlo evidence that suggests that the magnitude of the biases using FIML estimates is smaller than the one that may arise from (poorly designed) NLS or GMM methods. However, the Monte Carlo exercise Lindé performs to demonstrate the superiority of FIML effectively assumes that the econometrician has a good deal of knowledge about the true model of the economy a priori, something which is quite unlikely to be true in practice. The whole point of the kind of single equation method we used is to avoid having

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[8]For this reason, we use only lagged instruments in GG and GGLS. See the discussion on p. 1250 of GGLS.

[9]In particular, we have compared our results with three alternative instrument sets: the first includes four lags of inflation, marginal cost, detrended output and wage inflation; the second consists of four lags of price inflation, marginal costs, changes in commodity prices and interest rate spread (see GG for details), and finally, we drop lag inflation from the last set of insruments. In all the cases the F-test of the first stage regression clearly supports the joint significance of the instruments.

to take a stand on the structure of the entire economy. In fact, when he allows for some mis-specification in the stochastic properties of the driving variables, FIML estimates display a bias of an order of magnitude not smaller than the one he uncovers for his single-equation GMM simulations.

Also not convincing are Lindé's FIML estimates on actual data. As we have suggested, his justification for using detrended output instead of real marginal cost in the hybrid phillips curve specification is based on a faulty estimation procedure. In turn, because detrended output is likely a poor proxy for real marginal cost the FIML estimates are likely biased in favor of a role for lagged inflation.[10]

It is also worth emphasizing that Lindé's FIML estimates are inconsistent with the results in a number of other recent papers that have similarly applied ML methods to estimate dynamic sticky price models that embed a hybrid NKPC similar to equation (1). In particular, a significant number of these papers have found a dominant role for forward-looking behavior in inflation dynamics. Using a FIML approach, Ireland (2001), for example, cannot reject the null hypothesis that inflation dynamics in the postwar U.S. are purely forward looking. Similarly, using Bayesian ML techniques, Smets and Wouters (2003 and 2004), Rabanal and Rubio (2005), and Levin, Onatski, Williams and Williams (2005) obtain results very to our single equation approach: In particular, the estimates of the relative importance of forward versus backing looking behavior are very close to the estimates we obtain. Importantly, and in contrast to Linde, these papers use marginal cost in the NKPC, as theory suggests, as opposed to detrended output.

Finally, Kurmann (2002) uses a limited-information ML procedure to estimate the hybrid version of the NKPC as in (1), using a real marginal cost measure as the driving variable. In a way consistent with our arguments above, he rejects an extreme version of (1) which ignores the presence of an error term. When he allows for such an error term (which he interprets as capturing deviations from rational expectations) he obtains coefficient estimates very similar to the ones found in GG. Indeed, he cannot reject the null hypothesis of a zero backward looking component.

We thus see that when different ML methods have been applied in the literature to estimate a properly specified hybrid NKPC, the resulting findings have been very much in line with those reported in GG and GGLS. In addition, as we noted earlier, in this volume Sbordone (2005) obtains very similar results to ours using a minimum distance estimator.

3   Conclusions

We have examined a number of criticisms of the GMM approach used in our earlier work to estimate the hybrid version of the NKPC originally proposed in Galí and Gertler (1999),

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[10]Another issue is that Lindé's FIML estimates do not take into account the restrictions that the model imposes on the variance covariance matrix of the residuals of the estimated equations. The papers we describe below, Ireland (2001) and Smets and Wouters (2002), properly take into account these restrictions.

which relates inflation to real marginal cost, expected future inflation and lagged inflation. In our earlier work we showed that GMM estimates of that model suggest that the forward looking component of inflation is very important and that real marginal costs are an important determinant of short run inflation dynamics, as predicted by the theory. Backward-looking behavior, while statistically significant, is quantitatively modest, particularly compared to what the traditional Phillips Curve literature has suggested.

Several authors have argued that our results may be the product of either some form of specification bias or poor estimation methods. Here we show that these claims are incorrect: Our results are robust to a variety of estimation procedures, including GMM estimation of the closed form, and nonlinear instrumental variables. We have also discussed recent work that obtains similar results using alternative econometric approaches, including maximum likelihood procedures. Hence the conclusions of GG and others regarding the importance of forward looking behavior appear to be robust.

There are two important unresolved issues. One involves providing a more coherent rationale for the role of lagged inflation in the hybrid NKPC. Christiano, Eichenbaum and Evans (2005; henceforth CEE) and Smets and Wouters (2003, 2004) show that our hybrid model can be motivated by a form of dynamic price indexing. Another possibility is that, despite having the virtue of parsimony, the simple Calvo price setting model is just too stylized. As Guerrieri (2001) has emphasized, with conventional time dependent staggering of price setting (as in Taylor), lagged inflation may enter the Phillips curve specification even if firms set price in a forward looking manner. Another possibilty is that lagged inflation might reflect some form of least squares learning on the part of private agents, as suggested by Erceg and Levin (2003), Dellas and Collard (2005) and others. More recently, Cogley and Sbordone (2004), have shown that accounting for shifting beliefs about trend inflation eliminates the role of lagged inflation in estimates of the NKPC. These explanations, as well as others, are worth pursuing.

Finally, it is important to stress the our results do not suggest that disinflations may be painless. In this regard it is important to gain a better understanding of the dynamics of marginal cost. As noted in GG (1999), it is hard to explain the inertial behavior in real marginal cost using a model with frictionless labor markets. CEE, Sbordone (2004) and others have made progress by allowing for nominal wage rigidity. More work along these lines would clearly be desirable.

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Table 1

GMM and NLIV Estimates

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Parameters	Marginal Cost			Detrended Output		
	γ_b	γ_f	λ	γ_b	γ_f	λ
Baseline GMM	0.349 (0.041)	0.635 (0.042)	0.013 (0.006)	0.325 (0.040)	0.684 (0.043)	-0.005 (0.003)
$\gamma_b + \gamma_f = 1$		0.653 (0.035)	0.009 (0.0051)		0.672 (0.040)	-0.004 (0.002)
Closed Form GMM	0.374 (0.028)	0.618 (0.033)	0.013 (0.004)	0.882 (0.017)	-0.000 (0.000)	0.016 (0.005)
$\gamma_b + \gamma_f = 1$		0.627 (0.022)	0.010 (0.001)		0.460 (0.034)	0.002 (0.001)
NLIV	0.260 (0.087)	0.738 (0.080)	0.013 (0.009)	0.216 (0.113)	0.811 (0.116)	-0.010 (0.005)
$\gamma_b + \gamma_f = 1$		0.740 (0.090)	0.013 (0.007)		0.776 (0.114)	-0.009 (0.005)

Note: in all cases the dependent variable is quarterly inflation measured using GDP Deflator. Sample Period: 1960:I-1997:IV. Standard errors are shown in brackets. Instrument set includes two lags of detrended output, real marginal costs and wage inflation and four lags of price inflation. The F test of the joint significance of the instruments in the first stage regression is 63.31 with p-value 0.000.