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**Robustness of the Estimates of the Hybrid
New Keynesian Phillips Curve**

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Robustness of the Estimates of the Hybrid New Keynesian Phillips Curve*

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Abstract

Galí and Gertler (1999) developed a hybrid variation 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 highly important; the coefficient on expected future inflation is large and highly significant. 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. We show that our results are robust to a variety of estimation procedures, including GMM estimation of the closed form, and nonlinear instrumental variables. Hence the conclusions of GG and others regarding the importance of forward looking behavior appear to be robust.

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1 Introduction

1.1 Background

Gali and Gertler (1999; henceforth, 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 θ of being able to reset its price in any given period, independently of the time elapsed since its most recent price adjustment. 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 a percent deviation from steady state) is given by

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

where

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

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 $\gamma_f = \beta$.

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 principle 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 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, Gali, Gertler and López-Salido (2001, 2001a;

¹The expression for λ arises in the case of constant returns to scale. Sbordone (2002) and Galí, Gertler, and López-Salido (2001a) 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.

henceforth, GGLS) broadly confirm these estimates for U.S. data, though they tighten the range of estimates of γ_b to the range of roughly 0.35 to 0.4. A clear message from both papers is that, while the pure forward looking version of the New Keynesian Phillips curve is clearly 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, 2002; hereafter RW, and Lindé, 2003) have suggested that our estimation results 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 maximum likelihood techniques.

How could our conclusions be so different from those by RW and Lindé? As we elaborate below, the essence of RW’s argument is that our results are likely a product of misspecification 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. As we show, however, the closed form model that RW estimate is inconsistent with the hybrid model given by equation (1).³ As a consequence, one cannot use the RW framework to obtain estimates of the key parameters of the hybrid model, γ_f and γ_b , that identify the relative importance of forward versus backward looking behavior. Thus, while the RW framework may be used to reject the pure forward looking model, it cannot be use it to assess how far off this model is from the data.

We show, in contrast, that when one estimates the closed form equation that evolves

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

³That is, RW solve for the closed form of the pure forward looking model and then append on lagged inflation, as opposed to directly solving for the closed form of the hybrid model. See section 3 for details.

explicitly from the hybrid model, the parameter estimates are virtually identical to those obtained in GG and GGLS by estimating the structural form directly. Thus, while we agree that it is interesting to consider estimating the closed form, the suggestion in RW that this approach yields significantly different estimates from ours is simply wrong. As we show, estimates based on a properly specified closed-form equation lead us to conclude that forward looking behavior is as important as was suggested in our two earlier papers.

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 in 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 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 an alternative single equation approach is based on using an inappropriate estimator.⁴

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 in favor totally 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 poorly designed single equation estimator 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 distorted because he uses detrended GDP rather than real marginal cost as a driving variable, as we discuss below.

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 that the error term ε_t is i.i.d, it follows from equation (1) that

⁴In addition, to not properly accounting for the error term in the estimation, Lindé also inappropriately uses annual rather than quarterly inflation. As we discuss, this also distorts the estimates, despite his claims otherwise.

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

The orthogonality condition given by equation (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) 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 lags affect inflation do not affect current inflation independently of the information they contain about future inflation.

2.1 GMM Estimates of the Closed Form Specification

RW propose instead estimating a closed form that solves out for expected future inflation as an alternative way to address the potential bias problem.⁵ The closed form they estimate, however, is generally inconsistent with the hybrid model (1), as we noted earlier. In particular, as shown in GG (1999), the simple hybrid Phillips curve has the following closed form representation, conditional on the expected path of real marginal cost:

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

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

$$\delta_1 = \frac{1 - \sqrt{1 - 4\gamma_b\gamma_f}}{2 \gamma_f} \quad ; \quad \delta_2 = \frac{1 + \sqrt{1 - 4\gamma_b\gamma_f}}{2 \gamma_f} \quad (4)$$

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

$$E\{(\pi_t - \delta_1\pi_{t-1} - \bar{\lambda} \sum_{k=0}^{\infty} \delta_2^{-k} mc_{t+k}) \mathbf{z}_{t-1}\} = 0 \quad (5)$$

⁵It is important to realize that RW's example of dramatic bias 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 misspecification are entirely appropriate. That our results are robust across many different estimation strategies (including estimation of the closed form) is evidence of the plausibility of this null.

with $\bar{\lambda} = \frac{\lambda}{\delta_2 \gamma_f}$, 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

$$\pi_t = \lambda \sum_{k=0}^{\infty} \beta^k E_t\{mc_{t+k}\} \quad (6)$$

They then 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

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

Conditional on a value for β , and the ex-post realizations of a measure of real marginal costs, they construct a time series for the truncated discounted sum variable $\pi_t^{RW} = \sum_{k=0}^{12} \beta^k mc_{t+k}$. Then they proceed to estimate,

$$\pi_t = \lambda \pi_t^{RW} + \phi \pi_{t-1} + \xi_t$$

where ξ_t is orthogonal to information available at time t . Accordingly, the parameters λ and ϕ can be estimated using an instrumental variables procedure.⁶

While RW's approach does permit 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. In particular, their empirical specification does not nest the hybrid model in an explicit way. The reason is straightforward: as equation (3) makes clear, the factor used to discount future expected marginal costs in the closed form does NOT generally correspond to the consumer's discount factor β ; instead it is a function of γ_f and γ_b , i.e., the coefficients on expected future inflation and lagged inflation in the hybrid model. It is only equal to β in the limiting case of no backward looking behavior. Hence, the variable π_t^{RW} does not generally constitute a good approximation to the term $\frac{1}{\delta_2 \gamma_f} \sum_{k=0}^{\infty} \left(\frac{1}{\delta_2}\right)^k mc_{t+k}$ in (3), even if we ignore the error associated with the need to truncate the sum at a finite lead.

⁶For simplicity we are ignoring the component error term that results from the truncation of the discounted sum.

In addition, 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 $\beta = 1$, 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 appropriate closed form for the hybrid model, i.e. the one given by equation (1). Among other things, this involves estimating the discount factor directly, as opposed to calibrating it. Overall, 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.

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)).⁷ Accordingly, we restrict the instrument set to four lags each of inflation, and two lags of marginal cost, detrended real output and nominal wage inflation. Finally, we report estimates using two alternative driving variables: the log of real marginal cost (which we measure using the log of the nonfarm business labor income share), 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.”⁸ 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^f is roughly 2/3, while γ_b^b is roughly 1/3. Imposing the condition $\gamma_b = \gamma_f = 1$

⁷See p.1250 in GGLS (2001a) for a discussion of the weak instruments issue in this context.

⁸In GG and GGLS we also report estimates of the “deep parameters”, θ, ω , and β that underly the reduced form coefficients.

(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 “correct” closed form specification (3), i.e., the closed form that evolves directly from the hybrid model. The estimates are based on the set of orthogonality conditions in (5). Further, we follow RW by using a truncated sum to approximate the infinite discounted sum of real marginal costs.⁹ However, as we stressed above, we differ by estimating the discount factor and 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 directly estimating the hybrid model (1). 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 corresponding baseline GMM estimates. Once again, the results are not affected much by 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. Furthermore, the point estimates of γ_b and γ_f take values that could not plausibly be associated with the coefficients on expected future and lagged inflation. 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.

2.2 NLIV Estimates of the Structural Hybrid NKPC

We next turn to the set of issues raised by Lindé (2003). Note that, as pointed out by Lindé, it is possible to rearrange equation (1) in the following form:

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

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 a flawed estimation procedure.

⁹We 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. In addition, as we discuss in GGLS (2001b), a limitation of this approach is that the discounted sum of real marginal cost is a generated regressor.

For two distinct reasons, Lindé’s NLS estimation of equation (8) likely produces biased coefficient estimates. First, Lindé inappropriately uses annual rather than quarterly inflation. To see why the use of annual inflation is problematic, notice that we can rewrite equation (8) in terms of annual inflation, $\pi_t^a \equiv p_t - p_{t-4}$, as follows:

$$\pi_{t+1}^a = \frac{1}{\gamma_f} \pi_t^a - \frac{\gamma_b}{\gamma_f} \pi_{t-1}^a - \frac{\lambda}{\gamma_f} \sum_{j=0}^3 mc_{t-j} + \sum_{j=0}^3 \xi_{t+1-j} - \sum_{j=0}^3 \varepsilon_{t-j}$$

Hence, even if an error term ε_t was not present in the “true” model (8), it is clear that estimation of (8) using NLS would be generally biased since all lags of marginal cost would be omitted, in addition to having an error term $\sum_{j=0}^3 \xi_{t+1-j}$ that would be correlated with the regressors (by construction).¹⁰

Second, even with quarterly inflation, 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 with some of the right hand side variables.¹¹ Interestingly, while Lindé allows for the error term ε_t in his Monte Carlo exercises in the second part of his paper, he inappropriately estimates equation (8) using NLS. 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.¹² 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

¹⁰In a footnote, Lindé claims to have performed the NLS estimation exercise also using quarterly inflation measure, with similar results (which are not reported). While we have been able to (nearly) replicate Lindé’s results using annual inflation, we find instead that with quarterly many of the estimates change considerably.

¹¹For this reason, we use only lagged instruments in GG and GGLS. See the discussion on p. 1250 of GGLS.

¹²In 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 on 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 instruments. In all the cases the F-test of the first stage regression clearly supports the joint significance of the instruments. These results are available from the authors upon request.

instrumental variables. Furthermore, his justification for using detrended output as opposed to real marginal costs in his subsequent analysis vanishes. In addition, the Monte Carlo study of single equation methods is contaminated by the failure to use an estimation procedure that takes into account the error term he introduces and inappropriately uses annual inflation. In particular, the bias he reports is amplified considerably by these failures.

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 the second part of his paper Lindé (2002) 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 much smaller than the one that may arise from (poorly designed) NLS or GMM methods. The bias he finds from single equation methods appears to arise largely from not using an appropriate instrumental variables estimator, as we discussed in the previous section, as opposed to any inherent problem with GMM or NLIV. In addition, 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 practice¹³. The whole point of the kind of single equation method we used is to avoid having to take a stand on the structure of the entire economy. Overall, because he does not make the playing field level in comparing the different estimators, and the Monte Carlo exercises are not convincing.

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.¹⁴

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 par-

¹³Lindé asserts that his results are robust to misspecification of the monetary policy rule but this seems hardly a general proposition that FIML estimates are robust to broad forms of model misspecification.

¹⁴Another 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.

ticular, a significant number of these papers have found a dominant role for the forward looking component. 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, in a recent paper, Smets and Wouters (2002) estimate a rich dynamic stochastic model for the Euro area economy using Bayesian ML techniques. In addition to a variety of other features (staggered wage setting, habit formation, etc.) their model embeds a version of the Calvo price setting framework that allows for partial price indexation, which in turn generates a hybrid-like NKPC, driven by variations in real marginal costs. Their estimates of the inflation equation yields a weight of 0.28 for lagged inflation in the Phillips curve (in spite of their significantly higher chosen prior), suggesting again that the forward looking component is the dominant one.

Finally, Kurmann (2002) uses a limited-information ML procedure to estimate the hybrid version of the NKPC as in (1), using 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.

3 Conclusions

We have examined a number of criticisms of the GMM approach used in our earlier work to estimate a hybrid version of the hybrid NKPC originally proposed in Galí and Gertler (1999), 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 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. 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 also discussed recent work that finds similar results using maximum likelihood procedures. Hence the conclusions of GG and others regarding the importance of forward looking behavior appear to be robust.

One important unresolved issue involves providing a more coherent rationale for the role of lagged inflation in the hybrid NKPC. One possibility is that, despite having the virtue of parsimony, the simple Calvo price setting model is simply too unrealistic. 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 possibility is that lagged inflation might reflect some form of least squares learning on the part of private agents. These, as well as other explanations, are worth pursuing.

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Table 1
GMM and NLIV Estimates

<i>Parameters</i>	Marginal Cost			Detrended Output		
	γ_b	γ_f	λ	γ_b	γ_f	λ
Baseline GMM	0.355 (0.039)	0.627 (0.023)	0.014 (0.006)	0.323 (0.047)	0.685 (0.051)	-0.006 (0.003)
$\gamma_b + \gamma_f = 1$		0.645 (0.023)	0.010 (0.0057)		0.672 (0.046)	-0.005 (0.003)
Closed Form GMM	0.378 (0.033)	0.612 (0.021)	0.033 (0.011)	3.227 (5.412)	-3.030 (7.816)	0.011 (0.034)
$\gamma_b + \gamma_f = 1$		0.624 (0.021)	0.010 (0.002)		0.530 (0.008)	0.0001 (0.0004)
NLIV	0.284 (0.089)	0.714 (0.087)	0.011 (0.006)	0.246 (0.116)	0.776 (0.119)	-0.008 (0.004)
$\gamma_b + \gamma_f = 1$		0.716 (0.089)	0.011 (0.005)		0.746 (0.118)	-0.007 (0.004)

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.