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Working Paper

No. 57 March 2007

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ABSTRACT

The New Keynesian Phillips Curve (NKPC) specifies a relationship between inflation and a forcing variable and the current period's expectation of future inflation. Most empirical estimates of the NKPC, typically based on Generalized Method of Moments (GMM) estimation, have found a significant role for lagged inflation, producing a "hybrid" NKPC. Using U.S. quarterly data, this paper examines whether the role of lagged inflation in the NKPC might be due to the spurious outcome of specification biases. Like previous investigators, we employ GMM estimation and, like those investigators, we find a significant effect for lagged inflation. We also use time varying coefficient (TVC) estimation, a procedure that allows us to directly confront specification biases and spurious relationships. Using three separate measures of expected inflation, we find strong support for the view that, under TVC estimation, the coefficient on expected inflation is near unity and that the role of lagged inflation in the NKPC is spurious.

Keywords: New Keynesian Phillips curve; time-varying coefficients; spurious relationships.
JEL classification: C51; E31

Acknowledgements: We thank Sophocles Brissimis, Stephen Hall, Nicholas Magginas, Peter von zur Muehlen and Arnold Zellner, for helpful comments. The views expressed are those of the authors and should not be interpreted as those of their respective institutions.

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1. Introduction

The New Keynesian Phillips Curve (NKPC) is a key component of much recent theoretical work on inflation. Unlike traditional formulations of the Phillips curve, the NKPC is derivable explicitly from a model of optimizing behavior on the part of price setters, conditional on the assumed economic environment (e.g., monopolistic competition, constant elasticity demand curves, and randomly-arriving opportunities to adjust prices) (see Walsh, 2003, pp. 263-268). In contrast to the traditional specification, in the NKPC framework current expectations of future inflation, rather than past inflation rates, shift the curve (Woodford, 2003, p. 188). Also, the NKPC implies that inflation depends on real marginal cost, and not directly on either the gap between actual output and potential output or the deviation of the current unemployment rate from the natural rate of unemployment, as is typical in traditional Phillips curves (Walsh, 2003, p. 238). A major advantage of the NKPC over the traditional Phillips curve is said to be that the latter is a reduced-form relationship whereas the NKPC has a clear structural interpretation so that it can be useful for interpreting the impact of structural changes on inflation (Gali and Gertler, 1999).

Although the NKPC is appealing from a theoretical standpoint, empirical estimates of the NKPC have, by-and-large, not been successful in explaining the stylized facts about the dynamic effects of monetary policy, whereby monetary policy shocks are thought to first affect output, followed by a delayed and gradual effect on inflation (Mankiw, 2001, p. C59; Walsh, 2003, p. 241). To deal with what some authors (e.g., McCallum, 1999; Mankiw, 2001; Dellas, 2006a, b) believe to be inflation persistence in the data,[1] a response typically found in the literature is to augment the NKPC with the addition of lagged inflation - - on the supposition that lagged inflation receives weight in these equations because it contains information on the driving variables (i.e., the variables driving inflation) - - yielding a "hybrid" variant of the NKPC. A general result emerging from the empirical literature is that the coefficient on lagged inflation is positive and significant, with some authors (e.g., Fuhrer, 1997; Rudebusch, 2002; Rudd and Whelan, 2005) finding that inflation is predominantly backward looking. The hybrid NKPC, however, is itself subject to

[1] Roberts (1997), however, provided evidence suggesting that inflation is not sticky.

several criticisms. First, derivations of the hybrid specifications typically rely on backward looking rules-of-thumb, so that a "more coherent rationale for the role of lagged inflation" is still wanting (Gali, Gertler and Lopez-Salido, 2005, p. 1117). Second, the idea that the important role assigned to lagged inflation derives from its use as a proxy for expected future inflation is contradicted by the large estimates of the effects of lagged inflation obtained even in specifications that include the discounted sums of future inflations (Rudd and Whelan, 2005, p.1179).[2]

The purpose of this paper is to examine whether the role played by lagged inflation in estimates of the NKPC might be due to specification biases contained in empirical work. The possibility that specification biases may explain the role found for lagged inflation in Phillips-curve formulations was raised by McCallum (1999, p. 193), who noted the possibility that "model [mis]specifications are likely to yield results spuriously suggesting the importance of lagged variables". In addressing this issue, we follow the approach of Swamy and Tavlas (2007, forthcoming), who provide a theoretical analysis showing that a pure NKPC - - i.e., one that does not include lagged inflation - - can be formulated in terms of a relationship that explicitly takes account of omitted variables, measurement errors, and unknown functional forms. To anticipate our findings, we provide empirical evidence supporting our theoretical result that the correlation between current and lagged inflation can be the spurious outcome of specification biases.

The remainder of this paper is divided into three sections. Section 2 briefly summarizes some of the theoretical analysis contained in Swamy and Tavlas (2007, forthcoming) and discusses the empirical approaches used. Specifically, each slope coefficient of both the pure and hybrid NKPCs is interpreted as the sum of three components: (i) a bias-free component, (ii) an omitted-variables-bias component, and (iii) a measurement-error bias component. By identifying separately the bias-free component, we are able to distinguish between spurious and non-spurious regressions. If the bias-free component of the coefficient of a regressor is zero, then the coefficient is considered spurious even if the components representing omitted-variables bias and measurement-error bias of the coefficient are nonzero. Section 3 presents empirical results. We apply NKPCs to U.S. quarterly data for the period 1970:1-2000:4 using

[2] Not all researchers have obtained large estimates of lagged inflation. Gali, Gertler and Lopez-Salido, (2005) found that the coefficient of lagged inflation, while significant, was quantitatively modest (i.e., generally on the order of .35 to .37).

two estimation methods: time-varying-coefficient (TVC) estimation developed in Chang, Hallahan and Swamy (1992) and Chang, Swamy, Hallahan and Tavlas (2000) and the generalized method of moments (GMM), the latter approach having been widely applied in previous empirical studies of NKPCs (e.g., Gali and Gertler, 1999; Gali, Gertler and Lopez-Salido, 2005; Linde, 2005). The TVC procedure has been designed to separate the bias-free component of each coefficient from the other components so that specification biases can be corrected.[3] Section 4 concludes.

2. Theoretical considerations and empirical methodology

The theoretical model underlying the NKPC can be derived from a model of price setting by monopolistically competitive firms (Gali and Gertler, 1999). Following Calvo (1983), firms are allowed to reset their price at each date with a given probability $(1-\theta)$, implying that firms adjust their price taking into account expectations about future demand conditions and costs, and that a fraction θ of firms keep their prices unchanged in any given period. Aggregation of all firms produces the following NKPC equation in log-linearized form

$$\dot{p}_t = \beta \mathrm{E}_t \dot{p}_{t+1} + \lambda_1 s_t + \eta_{0t} \qquad (1)$$

where $\dot{p}_t$ is the inflation rate, $\mathrm{E}_t \dot{p}_{t+1}$ is the expected inflation in period t+1 as it is formulated in period t, s_t is the (log of) average real marginal cost in per cent deviation from its steady state level, and η_{0t} is a random error term. The coefficient, β, is a discount factor for profits that is on average between 0 and 1, $\lambda_1 = \frac{(1-\theta)(1-\beta\theta)}{\theta}$ is a parameter that is positive; $\dot{p}_t$ increases when real marginal cost, which is a measure of excess demand, increases (as there is a tendency for inflation to increase). Since marginal cost is unobserved, in empirical applications real unit labor cost (ulc_t) is often used as its proxy.[4]

[3] For discussions, see Swamy and Tavlas (1995, 2001).

[4] The coefficients and the error term of equation (1) are not unique because β, λ_1, and η_{0t} can be changed without changing equation (1) (Pratt and Schlaifer, 1984, p. 13).

Many authors assume that firms can save costs if prices are changed between price adjustment periods according to a rule of thumb. For example, Gali and Gertler (1999) assume that only a portion $(1-\rho)$ of firms are forward-looking and the rest are backward-looking. This implies that only a fraction $(1-\rho)$ of firms set their prices optimally and the rest employ a rule of thumb based on past inflation. Recently, Christiano, Eichenbaum and Evans (2005) assumed that all firms adjust their price each period but some are not able to re-optimize so they index their price to lagged inflation. Under the above assumptions, the hybrid NKPC, which includes lagged inflation, can be derived as:

$$\dot{p}_t = \omega_f \mathrm{E}_t \dot{p}_{t+1} + \lambda_2 s_t + \omega_b \dot{p}_{t-1} + \eta_{1t} \qquad (2)$$

where $\dot{p}_{t-1}$ is the lagged inflation and η_{1t} is a random error term. The reduced form parameter λ_2 is defined as $\lambda_2 = (1-\rho)(1-\theta)(1-\beta\theta)\phi^{-1}$ with $\phi = \theta + \rho[1-\theta(1-\beta)]$. Finally, the two reduced form parameters, ω_f and ω_b, can be interpreted as the weights on "backward-" and "forward-looking" components of inflation and are defined as $\omega_f = \beta\theta\phi^{-1}$ and $\omega_b = \rho\phi^{-1}$, respectively. Unlike the "pure" NKPC, the hybrid NKPC is not derived from an explicit optimization problem.

Assuming rational expectations and that the error terms η_{1t}, t = 1, 2, …, are identically and independently distributed (i.i.d.), many researchers employ the GMM procedure to estimate the NKPC and/or its hybrid version. Under GMM estimation, $E_t \dot{p}_{t+1}$ is replaced by $\dot{p}_{t+1}$, which is actual inflation in t + 1, and the method of instrumental variables is used to obtain consistent estimates of the parameters of model (2), since $\dot{p}_{t+1}$ is correlated with η_{1t}. The instrumental variables are correlated with $\dot{p}_{t+1}$, ulc_t, and $\dot{p}_{t-1}$, but not with η_{1t}. The condition that $E(\eta_{1t}|z_t)$ = 0, where z_t is a vector of instruments dated t and earlier and is assumed to be orthogonal to η_{1t}, implies the following orthogonality condition:

$$\mathrm{E}_t \left\{ (\dot{p}_t - \lambda_2 ulc_t - \omega_f \dot{p}_{t+1} - \omega_b \dot{p}_{t-1}) z_t \right\} = 0 \qquad (3)$$

2.1 The NKPC: A TVC reinterpretation

In what follows, we establish the connection between the version of the NKPC that excludes a lagged dependent variable (i.e., the pure NKPC) and the underlying "true" model, presenting the conditions needed for the existence of the true model. To avoid confusion, let us state at the outset that we may not know much about this "true" model. Indeed, we do not even know whether it exists, just as any researcher who aims to investigate whether specification biases exist through various specification tests does not observe the actual data generating process.[5] In the case of TVC, we impose an existence condition, namely, that our definition of the true model coincides with the real-world relationship (*i.e.,* the actual data-generating process) (Swamy and Tavlas, 2007, forthcoming). The following discussion elaborates.

To assess whether the NKPC in equation (1) and/or the hybrid curve in equation (2) are spurious, we first address the issue of functional form. Although the functional form of the underlying "true" model is unknown, a straightforward way of capturing the unknown functional form is to allow all the coefficients of equation (1) to vary freely[6]:

$$\dot{p}_t = \gamma_{0t} + \gamma_{1t} x_{1t} + \gamma_{2t} x_{2t} \qquad (4)$$

where x_{1t} is a proxy for $\mathrm{E}_t \dot{p}_{t+1}$, x_{2t} is a proxy for s_t, and the definitions of γ *s* are provided below. Equation (4) is a TVC model. Clearly, it can be nonlinear since the time-varying coefficients allow it to pass through every data point.[7]

Next, we provide a definition of the true model, which, as noted above, need not exist. First, each observed variable in equation (4) is defined as the sum of two components - - the "true" value, which is unobserved, and an unknown measurement error. Thus, $\dot{p}_t = \dot{p}_t^* + v_{0t}$ and $x_{jt} = x_{jt}^* + v_{jt}$, j = 1, 2 where an asterisk denotes a "true" value and the v_{jt}, j = 0, 1, 2, denote measurement errors. Second, we use the (unobserved) true values to define the following model:

[5] Econometricians typically assume a particular form of a "true" model to conduct specification tests.
[6] See Swamy and Tavlas (2001).
[7] In the past, some commentators have misinterpreted the TVC model as linear. The set-up of the TVC model is such that it passes through each data point taking account of possible measurement errors in the data. Then, the coefficients are estimated, as discussed below. If the data points with or without measurement errors trace out a non-linear relationship, the TVC model is clearly non-linear.

$$\dot{p}_t^* = \alpha_{0t}^* + \alpha_{1t}^* x_{1t}^* + \alpha_{2t}^* x_{2t}^* + \sum_{g=3}^{m_t} \alpha_{gt}^* x_{gt}^* \tag{5}$$

Equation (5) is purely conceptual. Effectively, we have built on the TVC model in (4) by incorporating the true, but unobserved, values of the dependent and included explanatory variables of equation (4), and by adding the "true" (and also unobserved) values of other explanatory variables omitted from the equation, all with time-varying coefficients to capture the unknown functional form. If we assume that, for an unspecified m_t (i.e., the total number of the determinants of $\dot{p}_t^*$), all the determinants of $\dot{p}_t^*$ are included on the right-hand side of equation (5), whereby the number, m_t, may depend on time (so that the number of the determinants of $\dot{p}_t^*$ may change over time), then equation (5) is "true" by construction since: (i) none of the determinants of $\dot{p}_t^*$ is excluded from equation (5), (ii) none of the determinants of $\dot{p}_t^*$ in equation (5) contains measurement error, and (iii) the model in (5) has the correct functional form because its coefficients are assumed to have the correct (but unknown) time profiles.[8] While we do not observe equation (5), we will use it to derive expressions for omitted-variables bias and measurement-error bias components of each of the slope coefficients of equation (4) without making incorrect assumptions about the true functional form. In essence, the TVCs of equation (5) are used to express our ignorance of the true functional form.

It can be shown (Chang, Swamy, Hallahan and Tavlas, 2000; Swamy and Tavlas, 2007, forthcoming, Theorem 1) that the sufficient conditions for the TVC model in (4) to be an exact representation of the true model in (5) are that:

$$\gamma_{0t} = \alpha_{0t}^* + \sum_{g=3}^{m_t} \alpha_{gt}^* \lambda_{0gt}^* + v_{0t} \tag{6}$$

and

[8] Allen and Morzuch (2006, p. 489) argued that model (5) "still seems open to the charge of misspecified functional form unless it is viewed as a Taylor's series". However, they overlooked the fact that any nonlinear equation can be correctly specified in terms of an equation that is linear in variables and nonlinear in coefficients with the correct time profiles, without viewing the latter equation as a Taylor's series. For example, the nonlinear equation, $y_t = \beta_1 + \beta_2 x_t^{\beta_3} + \varepsilon_t$, can be written as $y_t = \gamma_{0t} + \gamma_{1t} x_t$, where $\gamma_{0t} = \beta_1 + \varepsilon_t$, $\gamma_{1t} = \beta_2 x_t^{\beta_3 - 1}$ with the correct but unknown time profile, since β_2 and β_3 are unknown, and with γ_{1t} and x_t being correlated with each other unless β_3 = 1. Model (5) is nonlinear in coefficients with the correct (but unknown) time profiles.

$$\gamma_{jt} = (\alpha^*_{jt} + \sum_{g=3}^{m_t} \alpha^*_{gt}\lambda^*_{jgt})(1 - \frac{v_{jt}}{x_{jt}}) \text{ (j = 1, 2)} \qquad (7)$$

for all t, where λ^*_{jgt}, j = 0,1,2, are the "true" coefficients of the "auxiliary" regressions of excluded variables (i.e., those explanatory variables of equation (5) that are excluded from equation (4)) on the "true" values of the included explanatory variables, x_{1t} and x_{2t} (i.e., the explanatory variables included in equation (4)):

$$x^*_{gt} = \lambda^*_{0gt} + \sum_{j=1}^{2} \lambda^*_{jgt} x^*_{jt} \text{ (g = 3,…, } m_t) \qquad (8)$$

The coefficients of the TVC model in (4) are unique when they satisfy equations (6) and (7) (Swamy and Tavlas, 2007, forthcoming, Proposition 3).

In what follows, we provide an intuitive explanation of the above conditions. First, it is evident from equation (6) that the intercept, γ_{0t} , of the TVC model in (4) is the sum of (i) the "true" intercept, α^*_{0t}, (ii) the net effect of the portions of excluded variables that remain after the effects of the "true" values of the included explanatory variables on those excluded variables have been removed, i.e., $\sum_{g=3}^{m_t} \alpha^*_{gt}\lambda^*_{0gt}$,[9] and (iii) the measurement error, v_{0t}, in the dependent variable.

Second, as shown by the mapping in equation (7), it is also evident that for $j > 0$, the jth coefficient of the TVC model is the sum of (i) the jth coefficient, α^*_{jt}, of the true model - - what we call the bias-free component, (ii) a term, $\sum_{g=3}^{m_t} \alpha^*_{gt}\lambda^*_{jgt}$, capturing the omitted-variables bias produced by excluded variables, and (iii) a

[9] The "true" model in (5) contains two sets of explanatory variables: (i) the "true" values of the explanatory variables included in the TVC model in (4), and (ii) the "true" values of the explanatory variables omitted from the TVC model in (4), but included in the "true" model in (5). The auxiliary regressions (8) regress each of the latter variables on the former variables (in our case, x^*_{1t} and x^*_{2t}). The former variables are called the "true" values of the included variables and the latter variables are called the excluded variables. The intercept, λ^*_{0gt}, of the *g*th regression in (8) is the remainder of the *g*th excluded variable after the effects of the "true" values of the included variables on that excluded variable is netted out. The net effect of all these remainders on the dependent variable of the TVC model in (4) is $\sum_{g=3}^{m_t} \alpha^*_{gt}\lambda^*_{0gt}$.

measurement-error bias component, $-(\alpha^*_{jt} + \sum_{g=3}^{m_t} \alpha^*_{gt} \lambda^*_{jgt})(v_{jt} / x_{jt})$, due to mismeasurement of the jth included explanatory variable.

Third, the "auxiliary" regressions (8) for g = 3, …, m_t have the following intuitive basis. We do not have the necessary data to estimate the true relationship represented by equation (5). We only have observations on the dependent and independent variables of equation (4); even these observations are subject to measurement errors. Undoubtedly, there are other variables that help explain $\dot{p}^*_t$ for which we do not have any data; we can refer to such variables as "excluded" variables, which are not unique in the absence of knowledge of the coefficients of equation (5) (Pratt and Schlaifer, 1984, p. 13). To model the data that we do have with corrections for specification biases (which are very hard to avoid because of omitted variables, measurement errors, and unknown functional forms), we need to specify a TVC model in terms of observed variables. Further, we need to make assumptions about the slope coefficients and the intercept of the TVC model so that the model can be estimated - - that is, we need to imbed the TVC model in a stochastic framework so that we can estimate the model. We follow the (reasonable) approach of Pratt and Schlaifer (1988, p. 34), who, in effect, argued that it is "meaningless" to assume that all the included explanatory variables in equation (4) are independent of the excluded variables themselves; as Pratt and Schlaifer demonstrated, such a condition can only be satisfied for certain "sufficient sets" of excluded variables under certain conditions.

To find such a sufficient set, we relate each of the excluded variables to the "true" values of all of the included explanatory variables, using TVC specification to capture the relevant nonlinearities, as in equation (8). This procedure is abstract as we are relating unobserved and/or unknown excluded variables to observed, but mismeasured, included variables. Yet, it accomplishes the following. It avoids the "meaningless" condition brought out by Pratt and Schlaifer since we are relating each of the excluded variables to all the included explanatory variables in the model. Thus, the included explanatory variables are not assumed to be independent of the excluded variables. While this procedure is still not operational, if we insert the expression (8) for the auxiliary equations into the "true" model in (5), we arrive at an expression specified only in terms of the dependent variable and the included explanatory variables. As our data on these variables contain measurement errors, we then replace each variable by the difference between the observed value and the measurement error. Rearrangement yields model (4) in which the dependent variable and all the independent variables are observed, with each of the coefficients being the sum of three terms, as in equations (6) and (7).

By examining the components of γ_{jt} in (6) and (7), if any are time-varying then the coefficients of the TVC model in equation (4) are also time-varying. From these components, we can discover the real-world sources of variation in the coefficients of the TVC model, that is, as shown in equations (6) and (7), we can relate the coefficients of the TVC model to the coefficients of the true model. It can be seen that the included explanatory variables in the TVC model are correlated with their own coefficients. For example, from equation (7) it is clear that the coefficient γ_{jt} is correlated with x_{jt}.

A TVC version of the hybrid NKPC (2) is

$$\dot{p}_t = \gamma_{0t} + \gamma_{1t}x_{1t} + \gamma_{2t}x_{2t} + \gamma_{3t}x_{3t} \qquad (9)$$

where x_{1t} and x_{2t} are as defined in (4) and $x_{3t} = \dot{p}_{t-1}$. Swamy and Tavlas (2007, forthcoming, Theorem 3) exploit the connection between the true model in (5) and equation (9) to show that the correlation between $\dot{p}_t$ and $\dot{p}_{t-1}$ can be spurious. Specifically, a significant coefficient on lagged inflation can reflect errors of functional form (by not taking account of the time-variation in the coefficients), omitted variables, and mismeasured variables.

In equations (4) and (9), let

$$\gamma_{jt} = \pi_{j0} + \sum_{d=1}^{p-1} \pi_{jd} z_{dt} + \varepsilon_{jt} \quad (j = 0, 1, 2, 3) \qquad (10)$$

where the πs are fixed parameters, $z_{dt} \neq 1$ for all d and t. In TVC parlance, the z's are called the coefficient drivers, which should be distinguished from the instrumental variables in equation (3), ε_{jt} and x_{jt} are conditionally independent given z_{dt}, the mean of ε_{jt} is zero, and the ε_{jt} may be serially and contemporaneously correlated. Models (4) and (9) are called the first-generation TVC models if the coefficients of the coefficient drivers in equation (10) are set equal to zero and are called the second-generation TVC models otherwise. Effectively, first-generation TVCs capture the effects of non-linearities (through the time variation of the coefficients) while second-generation TVCs also capture omitted-variable and measurement-error biases. The purpose of including the z's (the coefficient drivers) in equation (10) with nonzero coefficients is to decompose γ_{jt} into its components identified in equations (6) and (7) (Swamy and Tavlas, 2007, forthcoming, Assumption 1). In the next section, an Iteratively Rescaled Generalized Least Squares method (IRGLS) developed in Chang, Swamy, Hallahan and Tavlas (2000) is used to estimate the π s and γ s.

To derive the "correct" explanations of the dependent variable of the TVC models in (4) and (9) in terms of the included explanatory variables, each of the coefficients of these models is decomposed into its respective components. Specifically, we relate each of the coefficients to a set of coefficient drivers, assuming that each of the coefficients is linearly related to a set of coefficient drivers plus a random error, as in equation (10). Intuitively, the coefficient drivers may be thought of as variables, though not part of the explanatory variables of the NKPC, serve two purposes. First, they deal with the correlations between the included explanatory variables and their coefficients.[10] In other words, even though the included explanatory variables are not unconditionally independent of their coefficients in equations (4) and (9), they can be conditionally independent of their coefficients given the coefficient drivers.

Second, the coefficient drivers allow us to decompose the coefficients of the TVC models in equations (4) and (9) into their respective components. The coefficient drivers are selected such that the bias-free component and the sum of omitted-variables and measurement-error bias components of each of the coefficients of the TVC models are functions of distinct sets of drivers.[11] By inserting equation (10) into the TVC models, reduced form models with fixed coefficients are obtained. From these estimated regression models, the implied estimates of the bias-free components of the coefficients of the TVC models can be derived; these bias-free components appear in the true model in (5). Therefore, they help us learn about the true model. If, for example, the bias-free component of the coefficient of an included

[10] A formal definition of coefficient drivers (sometimes referred to as concomitants) is provided in Swamy and Tavlas (2001).
[11] See the discussion following Assumption 1 in Swamy and Tavlas (2007, forthcoming).

explanatory variable equals zero, the correlation between the dependent variable and that particular explanatory variable is considered to be spurious.

2.2 The relevance of time-varying coefficients

Why is TVC estimation apt to be an especially relevant procedure for capturing the dynamics underlying the NKPC? During the past two decades, several interrelated factors appear to have contributed to a nonlinear structure (or, equivalently, a linear structure with changing coefficients) of the U.S. economy, including the following. First, there has been a substantial fall in inflation, compared with the 1970s and early 1980s, reflecting the focus of monetary policy on achieving price stability,[12] increased globalization, which led to competitive pressures on prices, and an acceleration of productivity, beginning in the mid-1990s, that helped contain cost pressures. Second, the increased role of the services sector and an improved trend in productivity growth beginning in 1995 appear to have led to a changing non-accelerating inflation rate of unemployment (NAIRU), so that a given inflation rate has been associated with a lower unemployment rate in recent years compared with the 1970s (Sichel, 2005, pp. 131-132). Third, a structural decline in business-cycle volatility appears to have occurred beginning in the mid-1980s (Gordon, 2005). This decline has been attributed to such factors as the improved conduct of monetary policy and innovations in financial markets that allow for greater flexibility and dampen the real effects of shocks (Jermann and Quadrini, 2006). The implication of these changes for estimation of econometric models was noted by Greenspan (2004, p. 38), who argued: "The economic world in which we function is best described by a structure whose parameters are continuously changing … An ongoing challenge to the Federal Reserve … is to operate in a way that does not depend on a fixed economic structure based on historically … [fixed] coefficients."

Under fixed-coefficient estimation methods, dummy variables are typically used to capture changes in economic structure, such as a change in policy regime. This approach, however, involves several problems. First, it assumes that any changes in structure occurred at a given, known date, whereas changes in structure may have a gradual effect and/or take place with a lag. Second, structural changes may not only

[12] Greenspan (2004) argued that this focus reflected increased political support for stable prices, which was a consequence of, and reaction to, the unprecedented peacetime inflation of the 1970s.

change the coefficients, but can also change the error distribution. For example, adding a dummy variable to an equation is likely to change the variance of the error.

How does TVC estimation deal with structural changes? Consider the case in which a dummy variable is used to capture a change in structure. Unlike fixed-coefficient estimation, under which the dummy variable is added to the regression, in TVC estimation the dummy variable first appears as a coefficient driver, as in equation (10) above, and the resulting expression is substituted into equation (4), so that the coefficient driver can affect all the coefficients of (4), and it also affects the variances and covariances of the errors. We cannot, however, consider all structural changes that may have affected the U.S. economy during a particular sample period. The coefficient drivers (described below) that we have selected have been chosen to capture the main changes impacting the economy.[13]

3. Data and empirical results

All the estimates reported below are based on quarterly U.S. data over the period 1970:1 – 2000:4. As discussed below, one measure (x_{1t}) of expected inflation used is the forecast of inflation, as measured by the projected change in the implicit GDP deflator, contained in the Fed's Federal Open Market Committee (FOMC) *Greenbook.* The Greenbook forecasts have been used by Brissimis and Magginas (2006) in their empirical study of the NKPC.[14] As Brissimis and Magginas point out, the *Greenbook* forecasts appear to incorporate efficiently a large amount of information from all sectors of the economy as well as Fed officials' judgmental adjustments. *Greenbook* forecasts, however, are available only with a five-year lag, so that our estimation period ends in 2000:4. Another measure of expected inflation used is the consensus group median forecasts of inflation from the Survey of Professional Forecasters (consensus forecasts) conducted by the Federal Reserve Bank of Philadelphia.[15] (For both GMM and TVC estimation, we also used a third measure of

[13] For example, one coefficient driver that we used is the change in the t-bill rate. Clearly, the t-bill rate changes whenever policy is changed. These types of changes cannot be captured by including a dummy variable in a fixed-coefficient regression.

[14] Those authors find that the role of lagged inflation in the NKPC is not significant when using Greenbook forecasts.

[15] The advantage of consensus forecasts compared with *Greenbook* forecasts is that the former are available for periods after 2000:4. In order to keep the results comparable, we do not present findings using the post-2000:4 data. Their inclusion would not change the findings reported below.

expected inflation. As described below, the third measure differs between the two estimation methods.) The other data are as follows. Inflation ($\dot{p}_t$) is the annualized quarterly per cent change in the implicit GDP deflator. Real unit labor cost (ulc), is estimated using the deviation (x_{2t}) of the (log) of the labor income share from its average value; the labor income share is the ratio of total compensation of employees in the economy to nominal GDP. The CPI inflation rate (used as an instrument) is the annualized quarterly per cent change in consumer price index.[16] Wage inflation is the annualized quarterly per cent change in hourly earnings in manufacturing. The interest rate is the three month t-bill rate.[17] The measure of the output gap is computed as the deviation of actual output from the potential output. Potential output is computed with a Hodrick-Prescott filter.

Our estimation procedure was the following: In line with much of the literature, we estimated a hybrid model using GMM, the results of which are used as a benchmark with which to compare the results based on TVC estimation. Our aim is to assess whether the results reported in the literature - - namely, that the inclusion of lagged inflation is needed in the Phillips curve specification and that the coefficient on expected inflation, while significant, is well-below unity, results typically based on GMM - - reflect specification biases. In estimating with GMM, we followed the usual practice of using actual inflation in period $t+1$ to measure inflation expectations. Additionally, in two alternative estimation methods, we used the *Greenbook* and consensus forecasts of $\dot{p}_{t+1}$ formulated in period t as proxies for expectations formulated in period *t* about inflation in period $t+1$. In applying GMM, the vector z_t of instrumental variables in equation (3) includes two lags of inflation, the real unit labor cost variable, two lags of consumer price index (CPI) inflation, four lags of wage inflation and t-bill rate. The standard errors of the estimated parameters were modified using a Barlett or quadratic kernel with variable Newey-West bandwidth. In addition, prewhitening was used. In all cases the J-statistic was used to test overidentifying restrictions of the model (Greene, 2003, p. 155).

[16] Apart from the *Greenbook* forecasts, the source of the foregoing data is the Datastream OECD *Economic Outlook*.
[17] The data on wages and the t-bill rate are from the International Financial Statistics (*IFS*).

In TVC estimation, we also used three measures of $E_t \dot{p}_{t+1}$. As in the case of GMM estimation, two of these measures are the *Greenbook* and consensus forecasts of $\dot{p}_{t+1}$. The other measure (or proxy) we used in TVC is an estimate of $\dot{p}_{t+1}$. This proxy was generated as follows. To put TVC estimation on a comparable basis with GMM estimation, we employed in the former estimation a proxy for $E_t \dot{p}_{t+1}$ that was related to the instruments employed in the latter estimation. Specifically, the estimated values of inflation were generated using ordinary least squares (OLS) under which, initially, some of the explanatory variables for inflation were the same as the instruments used in the GMM estimation and consisted of the information set available at time *t*. Since our purpose is to estimate the expected inflation for period *t*+1 as it is formulated in period *t*, the information set should be the one available in period *t*. That is why, in the OLS regression, the information set at time *t*-1 was employed instead of the information set at time *t*. Thus, in the OLS regression, the dependent variable, the inflation rate, was dated *t* and all the explanatory variables were dated *t*-2 or earlier, except the output gap and the t-bill rate which were dated *t*-1 or earlier. Any variables with statistically insignificant estimated coefficients were dropped, and the regression was re-estimated. The estimate ($\hat{\dot{p}}_{t+1}$) of inflation in period *t*+1, given by the following regression, was used as a proxy for $E_t \dot{p}_{t+1}$:

$$\hat{\dot{p}}_t = \hat{\alpha}_0 + \hat{\alpha}_1 \dot{p}_{t-3} + \hat{\alpha}_2 \dot{p}_{t-4} + \hat{\alpha}_3 (\text{output gap})_{t-1} + \hat{\alpha}_4 (\text{wage inflation})_{t-2}$$

$$+ \hat{\alpha}_5 (\text{CPI inflation})_{t-2} + \hat{\alpha}_6 (\text{t-bill rate})_{t-1} \qquad (11)$$

where $\hat{\alpha}_j$, *j* = 0, 1, …, 6, are the OLS estimates computed from the U.S. quarterly data for 1970:2-2000:4.

Recall, TVC estimation deals with three types of specification errors - - those of functional form (through the time-variation of the coefficients), omitted variables, and mismeasured variables. In a first pass, in what may be considered first-generation TVC technology, the TVC method employing only the time-variation of the coefficients was used to estimate the hybrid NKPC. In contrast to GMM, which is based on a specific functional form (even if nonlinear) (Greene, 2003), first-generation TVC estimation considers a class of functional forms by allowing the coefficient vectors of models (4) and (9) to vary according to a distribution with fixed mean vector having π_{j0} as its jth element and constant variances and covariances; thus, the data choose a member of the class.[18] That is, we did not use coefficient drivers to decompose the coefficients into their respective components, a procedure that provides implied estimates of the bias-free components (i.e., the components free of omitted-variable and measurement-error biases) of TVCs. Next, this first-generation TVC procedure was applied to the pure NKPC. These regressions, are, however, misspecified because they do not take account of the correlations between the included explanatory variables and their coefficients. As well, in the TVC environment the distributional assumptions made about the coefficients in this first-generation TVC procedure can be inconsistent with the "correct" interpretation of the coefficients, whereby, under the correct interpretation, each of the slope coefficients is the sum of three terms: (1) a bias-free component, (2) an omitted-variables bias component, and (3) a measurement-error bias component. Because each slope coefficient is in fact the sum of these three components, the pattern of variation in each of these components may be inconsistent with the assumed pattern of variation of the sum. It is, therefore, important to isolate the bias-free component. To do so, we then estimated using coefficient drivers, which provide second-generation TVC results. As in the case with the first-generation technology, the second-generation approach was applied to both hybrid and pure versions of the NKPC. Three coefficient drivers were used: z_{1t} = the change in the t-bill rate in period $t-1$, z_{2t} = the change in CPI inflation in period $t-1$, and z_{3t} = the change in wage inflation in the manufacturing sector in period $t-1$. The use of these coefficient drivers means that the value of p in (10) is equal to 4. In sum, we estimated four sets of TVC regressions: the first- and second-generation TVC models in (4) and (9) with either $\hat{\dot{p}}_{t+1}$ from (11), the *Greenbook* or the consensus forecast of $\dot{p}_{t+1}$ formulated in period t appearing in place of $E_t\,\dot{p}_{t+1}$.

Table 1 presents the main empirical results. Panel A of the table reports regressions with actual (or estimated) inflation acting as a proxy for expected inflation, while Panel B and Panel C report results based on Greenbook and consensus forecasts, respectively, of inflation. The first column of each panel reports GMM

[18] See Swamy and Tavlas (2001). What first-generation TVC estimation does not do is to allow each coefficient to be subdivided into its components and to make assumptions about the sum of the components of each coefficient consistent with the time-varying properties of the components.

estimates of the coefficients in (3). These GMM estimates are very similar to the results reported by Gali, Gertler and Lopez-Salido (2005, p. 1114) in what they call their "Baseline GMM" estimates. For example, these authors obtained a coefficient on expected inflation of .635; our coefficients are .660 (Panel A), .616 (Panel B), and .793 (Panel C). Gali *et al.* obtained a coefficient for lagged inflation of .349; our coefficients are .345 (Panel A) and .307 (Panel B) and .257 (Panel C). Finally, Gali, Gertler and Lopez-Salido obtained a coefficient on marginal cost of .013; our coefficients are .037 (Panel A), .116 (Panel B), and .310 (Panel C). With one exception,[19] all the GMM coefficient estimates are highly significant.

Are the preceding findings the result of spurious correlation? To shed light on the issue, we now present the TVC results. Columns (2) in the three panels of Table 1 present estimates of the coefficients of the hybrid NKPC in (9) that are time-varying, as in first-generation TVC models, but are not corrected for the correlations between the included explanatory variables and their coefficients (i.e., they are not corrected for errors of omitted variables and mismeasured variables).[20] In general, the findings are similar to those obtained under GMM, though in Panels A and B, the coefficients on marginal costs are higher than those obtained under GMM. As well, in the regression incorporating estimated inflation to measure expected inflation (Panel A) the coefficient on lagged inflation is insignificant. Next, in columns 3 of the three panels, we report the results for the first-generation TVC regressions that exclude lagged inflation but that, nevertheless, fail to correct for the correlations between the included explanatory variables and their coefficients. Using the *Greenbook* and the consensus forecasts for inflation, the coefficient on expected inflation is close to unity (Panels B and C). Using estimated inflation in period $t+1$ as a proxy for expected inflation, the coefficient on expected inflation (at .71) is close to the results typically found in the literature (e.g., Gali, Gertler and Lopez-Salido, 2005; Rudd and Whelan, 2005).

Columns 4 of the three panels provide estimates of the hybrid NKPC in (9) using the second-generation TVC technology that corrects for all specification biases, yielding what we call "bias-free" effects. We used $\hat{\pi}_{j0} + \hat{\pi}_{j1}z_{1t}$, where $\hat{\pi}_{j0}$ and $\hat{\pi}_{j1}$

[19] Specifically, in Panel A, *ulc* is significant at the 10 percent level, but not at the 5 percent level.
[20] In other words, these columns contain the IRGLS estimates of π_{j0} in (10).

are the IRGLS estimates of π_{j0} and π_{j1} in (10) respectively, as an estimator of the bias-free component of γ_{jt}. This means that we used $\sum_{d=2}^{3}\hat{\pi}_{jd}z_{dt} + \hat{\varepsilon}_{jt}$, where $\hat{\pi}_{jd}$ is the IRGLS estimate of π_{jd}, as an estimator of the sum of omitted-variables and measurement-error bias components of γ_{jt}. We report the means, $\hat{\pi}_{j0}$ + $\hat{\pi}_{j1}(1/T)\sum_{t=1}^{T} z_{1t}$, where T is the number of quarters in the period 1970:1-2000:4. The bias-free effects of lagged inflation are insignificant (on average) using all three measures of expected inflation, while the bias-free effects of expected inflation and marginal costs are significant (on average). Finally, column 5 presents average bias-free effects for the pure NKPC. In Panels B and C, (i.e., using *Greenbook* and consensus forecasts, respectively, for inflation), the hypothesis that in the pure NKPC, the average bias-free effect of expected inflation is unity cannot be rejected at the 5 per cent level of significance. In Panel A, the same hypothesis cannot be rejected at a significance level slightly lower than 5 percent in the sense that the estimate (0.73) of the average bias-free effect of $\hat{\dot{p}}_{t+1}$ on the dependent variable of the pure NKPC plus twice its standard error is equal to 0.994. In all three panels, the average bias-free effect of marginal costs is positive and, at least marginally significant.

Apart from the flexibility assigned (or not assigned) to the functional form by the TVC models in (4) and (9) (or models (1) and (2)), there is one major difference between the GMM specification and those estimated with TVCs. The former specification excludes a constant term on the plausible *analytic* presumption that a (positive) constant term in (1) would mean that the inflation rate is positive even with zero values for all the other determinants of inflation (since the *change* in the log-price is a positive number). The TVC procedure, however, includes an intercept (as in equation (4)) on the basis of the *econometric* presumption, derived under the TVC interpretation, that the intercept represents the sum of three terms: the “true” intercept, the net effect of the portions of excluded variables remaining after the effects of the true values of included explanatory variables have been removed, and the measurement error in the dependent variable. Consequently, omission of the intercept under TVC would subject the coefficients on the remaining included variables to specification biases.

Are the preceding results, whereby TVC estimations yield the bias-free effects of expected inflation that are close to unity on average (in the case of $\hat{\dot{p}}_{t+1}$ at a significance level slightly less than 5 per cent) and the average bias-free effect of lagged inflation that is not significantly different from zero, being driven by the inclusion of the intercept in the TVC regressions? To shed light on this issue, all four sets of TVC regressions were re-estimated without the intercept (γ_{0t}).[21] The results are reported in Table 2, which repeats the GMM results from Table 1 in the three panels. Consider columns 4 and 5, which show TVC bias-free effects for the hybrid model and the pure NKPC model, respectively. In the hybrid model, the lagged inflation term's average bias-free effect is insignificant under all three definitions of expected inflation while the hypothesis that the average bias-free effect of expected inflation equals unity cannot be rejected at the 5 per cent level under each of the three definitions of expected inflation. For the pure NKPC specification, the hypothesis that the average bias-free effect of expected inflation equals unity cannot be rejected again at the 5 per cent level, under each of formulations of expected inflation. Thus, our main findings - - (i) the pure version of the NKPC is an adequate representation of the actual data generating process, and (ii) the hybrid model reflects spurious correlation - - are not due to the inclusion of an intercept.

3.1 Discussion

What accounts for the differences in results obtained under GMM and TVC estimations? As stressed above, TVC estimation aims to deal with specification biases stemming from incorrect functional forms, omitted variables, and measurement errors. GMM, in contrast, does not address these biases. Consider the following implications of GMM in a TVC environment.

First, any proxies for $E_t\dot{p}_{t+1}$ and s_t are likely to contain measurement errors. Replacing $E_t\dot{p}_{t+1}$ and s_t by their respective proxies in equation (2) introduces measurement-error biases into the coefficients of equation (2) (see equations (6) and (7)). The coefficients on the proxies for $E_t\dot{p}_{t+1}$ and s_t are time-varying if their

[21] Despite the fact that most of the constant terms under TVC estimation are insignificant in Table 1, they nevertheless absorb specification errors from omitted variables. We drop the constants only to show what happens in their absence.

measurement-error bias components are time-varying. That is, the coefficients on these proxies - - coefficients each of which is the sum of three components, including a measurement-error bias - - are likely to exhibit time-varying behavior if the measurement error changes over time.

Second, excluding relevant explanatory variables from equation (2) introduces omitted-variable biases into the coefficients of that equation (see equations (6) and (7)). These omitted-variable biases will not be constant if the "true" model underlying the NKPC is nonlinear. As is the case with measurement-error bias, the coefficients of equation (2) are time-varying if their omitted-variables bias components are time-varying. If the coefficients of equation (2) are time-varying, then the instrumental variables needed to empirically implement the GMM do not exist and condition (3) will not be satisfied. For example, in a time-varying environment, each of the coefficients in equation (2) is made a function of coefficient drivers plus a random error term. Substituting into the TVC version of the hybrid NKPC the equations determining its coefficients - - that is, substituting equation (10) above into equation (9) - - gives a regression model. This regression involves both a regression part and an error part. Each of these parts, however, contains the included explanatory variables implying that it is impossible for any variables to be highly correlated with the included explanatory variables and uncorrelated with the error part. Therefore, if the coefficients are time varying, the instrumental variables do not exist; that is, we cannot obtain instrumental variables that are highly correlated with the regression part, but are uncorrelated with the error part.

Third, in equation (2), it is incorrect to assume that because the value of a lagged included variable $\dot{p}_{t-1}$ was determined before the value of the current joint effect η_{1t} of excluded variables, $\dot{p}_{t-1}$ is independent of η_{1t}. Lagged inflation may well have been influenced, for example, by a forecast of an excluded variable represented in η_{1t}. Also, both $\dot{p}_{t-1}$ and η_{1t} may have been affected by a third variable - - in the usual parlance, a 'common cause' (Pratt and Schlaifer, 1988, p. 47). By the same logic, the assumption that η_{1t} is mean independent of z_t may be incorrect. If the parameterization of the hybrid version of the NKPC in equation (2) is incorrect - - i.e., if the coefficients of equation (2), treated as constant parameters, are, in fact, time-varying - - then η_{1t} does not represent a sufficient set of excluded variables (defined in Pratt and Schlaifer (1988, p. 34)) that is independent of the explanatory variables included in equation (2). In other words, the value derived for η_{1t} depends, in part, on the assumed constancy of the coefficients on the proxies for $E_t \dot{p}_{t+1}$ and s_t. If the coefficients are not, in fact, constant, it can be shown that η_{1t}, generated from constant coefficients, is not independent of the explanatory variables included in equation (2) (Pratt and Schlaifer, 1988).

4. Conclusions

This paper has provided a clear-cut empirical experiment. Using GMM, we were able to replicate results typically found in the literature in which lagged inflation has a positive and significant coefficient in the NKPC framework, producing a hybrid NKPC. Under GMM, incorporating lagged inflation and, alternatively, one of three measures of expected inflation in the Phillips relation, the coefficients on the lagged inflation variable and expected inflation sum to near unity, yielding a long-run vertical Phillips relation. Are these results spurious, as McCallum (1999, p. 193) has suggested? TVC estimation provides a straightforward method of addressing this question. Our results strongly suggest that the role found by previous researchers for lagged inflation in the NKPC is the spurious outcome of specification biases. Moreover, our results are not dependent on a particular measure of inflation expectations. Each of the three measures used provided a similar set of results.

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Table 1					
Estimation of NKPC for USA 1970:1-2000:4					
Panel A: Actual (or estimated) inflation-based specification					
Variables	GMM (1)	TVC (2)	TVC (3)	TVC bias-free effect (4)	TVC bias-free effect (5)
Constant	-	1.512** [1.96]	0.812 [0.72]	1.873 [0.87]	0.961* [1.88]
$\dot{p}_{t+1}$	0.660*** [11.87]	-	-	-	-
$\hat{\dot{p}}_{t+1}$ from (11)	-	0.584*** [4.12]	0.712*** [6.81]	0.407*** [2.33]	0.730*** [5.54]
ulc_t (marginal costs)	0.037* [1.65]	0.236** [1.98]	0.184* [1.70]	0.254** [1.96]	0.234** [1.95]
$\dot{p}_{t-1}$	0.345*** [6.50]	-0.034 [-0.32]	-	0.069 [0.60]	-
$\bar{R}^2$	0.83	0.99	0.99	0.99	0.99
J-test	0.05				
Panel B: Greenbook forecasts-based specification					
	GMM (1)	TVC (2)	TVC (3)	TVC bias-free effect (4)	TVC bias-free effect (5)
Constant	-	0.529 [0.98]	-0.017 [-0.10]	0.945 [0.72]	0.037 [0.20]
Greenbook forecast of $\dot{p}_{t+1}$	0.616*** [32.46]	0.654*** [6.79]	0.948*** [20.10]	0.624*** [5.15]	0.967*** [20.55]
ulc_t (marginal costs)	0.116*** [6.33]	0.180** [2.24]	0.405 [0.86]	0.206** [2.11]	0.367** [2.49]
$\dot{p}_{t-1}$	0.307*** [11.49]	0.215*** [2.76]	-	0.121 [1.36]	-
$\bar{R}^2$	0.83	0.99	0.99	0.99	0.99
J-test	0.05				
Panel C: Consensus forecasts-based specification					
	GMM (1)	TVC (2)	TVC (3)	TVC bias-free effect (4)	TVC bias-free effect (5)
Constant	-	0.635 [1.20]	0.078 [0.35]	0.675 [0.24]	0.031 [0.13]
Consensus forecasts of of $\dot{p}_{t+1}$	0.793*** [8.97]	0.620*** [4.97]	0.916*** [15.12]	0.727*** [5.66]	0.925*** [14.85]
ulc_t (marginal costs)	0.310*** [4.50]	0.210** [2.51]	0.432*** [3.82]	0.227*** [2.81]	0.421*** [3.94]
$\dot{p}_{t-1}$	0.257*** [3.17]	0.215** [2.30]	-	0.125 [1.28]	-
$\bar{R}^2$	0.82	0.99	0.99	0.99	0.99
J-test	0.05				

Notes: Figures in brackets are t-statistics. ***, **, * indicate significance at 1%, 5%, and 10% level respectively. The estimates in columns (4) and (5) are obtained using four coefficient drivers: a constant term, the change in the t-bill rate in period t-1, the change in CPI inflation rate in period t-1 and the change in wage inflation in period t-1. The bias-free effects are estimated using the constant term and the change in the t-bill rate in the previous period.

Table 2					
Estimation of NKPC for USA 1970:1-2000:4					
Panel A: Actual (or estimated) inflation-based specification					
Variables	GMM (1)	TVC (2)	TVC (3)	TVC bias-free effect (4)	TVC bias-free effect (5)
Constant	-	-	-	-	-
$\dot{p}_{t+1}$	0.660*** [11.87]	-	-	-	-
$\hat{\dot{p}}_{t+1}$ from (11)	-	0.569*** [5.94]	0.973*** [30.10]	0.963*** [4.19]	0.981*** [18.13]
ulc_t (marginal costs)	0.037* [1.65]	0.148*** [3.18]	-0.055 [-0.02]	0.365** [2.42]	0.210*** [2.64]
$\dot{p}_{t-1}$	0.345*** [6.50]	0.457*** [5.28]	-	0.026 [0.23]	-
$\bar{R}^2$	0.83	0.99	0.99	0.99	0.99
J-test	0.05				
Panel B: Greenbook forecasts-based specification					
	GMM (1)	TVC (2)	TVC (3)	TVC bias-free effect (4)	TVC bias-free effect (5)
Constant	-	-	-	-	-
Greenbook forecast of $\dot{p}_{t+1}$	0.616*** [32.46]	0.808*** [11.61]	0.981*** [39.19]	0.987*** [11.04]	0.975*** [34.92]
ulc_t (marginal costs)	0.116*** [6.33]	0.298*** [3.89]	0.282*** [5.21]	0.673*** [7.53]	0.266*** [5.02]
$\dot{p}_{t-1}$	0.307*** [11.49]	0.185 [1.37]	-	-0.029 [-0.12]	-
$\bar{R}^2$	0.83	0.99	0.99	0.99	0.99
J-test	0.05				
Panel C: Consensus forecasts-based specification					
	GMM (1)	TVC (2)	TVC (3)	TVC bias-free effect (4)	TVC bias-free effect (5)
Constant	-	-	-	-	-
Consensus forecasts of of $\dot{p}_{t+1}$	0.793*** [8.97]	0.830*** [10.22]	0.948*** [38.68]	0.818*** [8.72]	0.950*** [36.72]
ulc_t (marginal costs)	0.310*** [4.50]	0.410* [1.92]	0.451*** [4.14]	0.212** [2.33]	0.485** [2.27]
$\dot{p}_{t-1}$	0.257*** [3.17]	0.099 [0.97]	-	0.160 [1.14]	-
$\bar{R}^2$	0.82	0.99	0.99	0.99	0.99
J-test	0.05				

Notes: Figures in brackets are t-statistics. ***, **,* indicate significance at 1%, 5%, and 10% level respectively. The estimates in columns (4) and (5) are obtained using four coefficient drivers: a constant term, the change in the t-bill rate in period t-1, the change in CPI inflation rate in period t-1 and the change in wage inflation in period t-1. The bias-free effects are estimated using the constant term and the change in the t-bill rate in the previous period.

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