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Unit Total Costs: An Alternative Marginal Cost Proxy for Inflation Dynamics

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Abstract

The conventional New Keynesian Phillips Curve (NKPC), driven by unit labor costs has been criticized for failing to match inflation dynamics and for explaining the duration of fixed price contracts. This paper extends recent attempts in the literature to find an alternative marginal cost proxy for the NKPC, by introducing a fuller marginal cost proxy, '*unit total costs*' that is derived from both *labor* and *non-labor unit costs*, where the latter includes, capital related costs and production taxes. Borrowing costs are also examined separately, as in the cost channel literature. *Unit total costs* are shown to improve the fit of the short-run variation in inflation and strengthen the empirical support for the role of expectations-based inflation persistence. They also imply a duration of fixed nominal contracts that is closer to those suggested by firm-level surveys. The *cost channel* becomes relatively less important when *unit total costs,* rather than *unit labor costs*, are used as a marginal cost proxy.

JEL: E5, E31, E32, E37

Keywords: New Keynesian Phillips curve; inflation; price rigidity; marginal cost proxy; production costs, borrowing costs; cost channel.

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1 The 'Unit Labor Cost' NKPC: A Brief Overview

Despite its recent popularity, there is still an ongoing debate as to whether the New Keynesian Phillips Curve (NKPC), can match the observed inflation persistence and the length of fixed nominal price contracts as implied by surveys at the micro level. The widely used hybrid NKPC (see Gali, Gertler and Lopez-Salido 2005) specifies log-linearized inflation around its steady state as,

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f E_t \widehat{\pi}_{t+1} + \lambda \widehat{mc}_t + \epsilon_t, \tag{1}$$

where, π_t is the inflation rate, $\widehat{mc}_t$ is real marginal cost; ϵ_t is a cost push shock; the coefficients are, $\gamma_b = \frac{\omega}{\psi+\omega(1-\psi(1-\beta))}$, $\gamma_f = \frac{\psi\beta}{\psi+\omega(1-\psi(1-\beta))}$, and $\lambda = \frac{(1-\omega)(1-\psi)(1-\psi\beta)}{\psi+\omega(1-\psi(1-\beta))}$, where ψ is a fraction (constant probability) of firms not adjusting prices, whereas ω is the fraction of backward price setting firms in this familiar Calvo-type sticky price setup. Gali and Gertler (1999), Gali, Gertler and Lopez-Salido (2001, 2005) and Sbordone (2002, 2005) suggest only a "modest" role for *intrinsic* inflation persistence (γ_b), whereas others find a very limited role for forward looking expected inflation (γ_f) in the NKPC, (see Fuhrer 1997 Rudd and Whelan 2005, 2007, Lindé 2005, Lawless and Whelan 2007 and Zhang, Osborn and Kim 2008). Real marginal cost in these studies, as with the bulk of this literature, is proxied by real *unit labor costs*, where the latter is measured in relation to the deviation of labor income share in the non-farm business sector from its mean,

$$\widehat{mc}_t = mc(\widehat{S}_{n,t}) \tag{2}$$

where $\widehat{S}_{n,t} = \hat{w}_t - (\hat{y}_t - \hat{n}_t)$; and $\hat{w}_t, \hat{y}_t$, and $\hat{n}_t$, are deviations of real wages, non-farm GDP, and labor from their steady states respectively. In estimating the NKPC, unit labor costs have been shown to be a better marginal cost proxy than the output gap, however, the degree of and the shifts in persistence using this proxy are still not a good fit to inflation. Fuhrer (2006), for example shows that most of the persistence found in US inflation data appears to be *intrinsic* from the lagged inflation term in the NKPC and thus cannot be attributed to unit labor costs. Rudd and Whelan (2002) and Lindé (2005) show that the labor share version of the NKPC explains a very small proportion of the variation in inflation; while Lawless and Whelan (2007), using both sectoral and aggregate data for EU-15 and the US, find negative coefficients on the effect of the labor share on inflation.[1] A further weakness is that the estimated coefficient on unit labor cost, as a proxy to real marginal cost, implies price rigidities that are not consistent with micro evidence. For the US for example, it implies price contracts of 6 quarters or much longer. This is inconsistent with a number of firm-level surveys which suggest that price rigidity ranges between 1.5 to 4 quarters.[2]

Following these findings and the contribution of Wolman (1999), there has been an effort to examine whether alternative marginal cost proxies can improve the fit of the NKPC.[3] Sbordone (2005) shows that incorporating adjustment costs, does not significantly improve the fit of the NKPC and a similar conclusion was recently reached by Lubik and Teo (2012), who examine whether inventory-specifications of produced goods can improve the fit of the unit labor costs NKPC. Other studies assume different production technologies and aggregation methods and express average marginal cost as a function of both labor unit costs and the output (or employment) gap (see Sbordone 2002, 2005, Gagnon and Khan 2005, Matheron and Maury 2004). These studies assume that capital does not change with changes in the relative price of firms, hence the resulting real marginal cost is still largely driven by labor unit costs. Gwin and VanHoose (2007, 2008) using data from 10,000 firms construct a measure of PPI-inflation and a growth rate of average variable costs, as proxies to average price and marginal costs respectively; although their PPI-inflation measure improves on the fit of inflation, their alternative marginal cost data does not differ significantly from Gali and Gertler (1999). More recently some studies focus on the effects of capacity utilization, but their results vary. Mazumder (2010) accounts for the effects of labor utilization in the marginal cost proxy, but finds a negative coefficient for the latter. McAdam and Willman, (2011) use a parameterized CES production to arrive at a 'full' real marginal cost measure of the NKPC which it is shown to improve the fit of inflation and be more consistent with micro studies. Their 'full' marginal cost, is derived from a parametric form of effective labor hours that allows for a covariation with capital utilization; hence, the main contribution of their paper comes from an augmented real marginal cost that incorporates the para-

[1] Lawless and Whelan (2007) also provide evidence that the widespread decline in labor shares across a broad range of sectors, has not been associated with large shifts in inflation, indicating that labor share may be an incorrect proxy for marginal cost in estimating the NKPC.

[2] See Blinder, Canetti, Lebow and Rudd (1998), Hall, Walsh and Yates (2000), Chevalier, Kashyap and Rossi (2003), Bils and Klenow (2004), De Walque, Smets and Wouters (2004), Gwin and VanHoose (2007), Coenen, Levin and Kai (2007) and Rotemberg and Woodford (1997).

[3] Another strand in the literature focus on refining proxies for the output gap. For example, using different approaches, Chadha and Nolan (2004), Neiss and Nelson (2005), and Bjørnland, Leitemo and Maih (2009) show that the use of theory consistent output gaps can be as good a proxy as real marginal cost. They suggest that the output gap proxies may not perform as well because output trends, that are largely used in the literature, are poor approximations to the output gap.

meterized costs associated with the degree of capacity utilization as the driving variable in the NKPC.[4]

2 'Unit Total Costs': A 'fuller' Marginal Cost Proxy

This paper builds on the existing literature by considering a fuller definition of marginal cost, that we define as "unit total costs". *Unit total costs*, consists of *labor* and *non-labor unit costs* data. We also consider the role of borrowing costs, which we examine separately, as in the cost channel literature. Using a standard New Keynesian model, where firms engage in borrowing and production is based on a CES function with capital and labour as inputs, we derive real marginal cost as a function of: labor costs, capital unit costs, capital utilization, capital depreciation, production taxes and borrowing costs (see section 3). The resulting NKPC is identical to that of Gali, Gertler and Lopez-Salido (2005), as in (1), but the theory-based marginal cost proxy (see 2), is replaced here with *unit total costs,*

$$\widehat{mc}_t = mc\left(\widehat{S}_{n,t}, \widehat{S}_{k,t}, \widehat{\tau}_t^Y\right) \tag{3}$$

or, with *unit total costs* and the *cost channel*, (see section 4.6),

$$\widehat{mc}_t = mc\left(\widehat{S}_{n,t}, \widehat{S}_{k,t}, \widehat{\tau}_t^Y, \hat{\imath}_t^{CB}\right) \tag{4}$$

where, $\widehat{S}_{n,t} = \hat{w}_t - (1-\chi)(\hat{y}_t - \hat{n}_t) - \chi\widehat{a}_t$, and $\widehat{S}_{k,t} = \hat{r}_t^k - (1-\chi)(\widehat{y}_t - \hat{k}_t) - \chi\hat{u}_t$ are the shares of *labor unit costs and capital unit costs* respectively; $\widehat{\tau}_t^Y$ are production-related taxes and $\hat{\imath}_t^{CB}$ captures firms' borrowing costs (i.e. the *cost channel* effect) which we examine separately as with the rest of the literature.[5]

2.1 Data

In contrast to previous studies which focus on *labour payments* in the *non-farm* GDP sector, we focus on *total operating payments* and in *all-sectors*, i.e. overall GDP. We construct our marginal cost proxy, *unit total costs*, using data on labor and non-labor costs in *all sectors* as published by the US Department of Commerce Bureau of Economic

[4]Note that both Mazumder (2010) and McAdam and Willman, (2011), also focus on the cyclical properties of the utilization rates and how these affect the cyclicality of the marginal cost. In this paper we do not address this issue. It is a well-documented fact that although, on average, real wages in the US tend to be weakly pro-cyclical, this depends on a number of factors induding the technology used, as well as the periods and shocks examined; a conclusion also reached in McAdam and Willman, (2011) and Amarasekara and Bratsiotis (2012).

[5]For details see section 4.6

Analysis.[6] In particular, *unit total costs* are constructed as the sum of the shares of *unit labor costs* ($\widehat{S}_{n,t}$) and other *non-labor costs* in overall GDP, that includes, consumption of fixed capital, net taxes on production (and imports) and business current transfer payments, (captured by $\widehat{S}_{k,t}$,and $\widehat{\tau}_t^Y$ respectively).[7] We also account for borrowing costs, as captured by the cost channel, through $\hat{\imath}_t^{CB}$.[8] As in the cost channel literature (see Ravena and Walsh 2006, Chowdhury, Hoffmann and Schabert 2006), we test separately for the contribution of firms' borrowing costs to estimating the NKPC, using three-month U.S. treasury bill rates, (captured by $\hat{\imath}_t^{CB}$), as a measure of short-run nominal interest rates, (see Chowdhury, Hoffmann and Schabert 2006). The effect of borrowing costs (cost channel) is examined in section 4.6, whereas throughout the paper *unit total cost* refers to all other production costs *excluding* the cost channel.

The paper compares the results from our *unit total cost* proxy, (with and without the cost channel) with those of the traditional *non-farm unit labor cost* and *unit labor cost* computed using *all sectors* of the economy. Consistent with most studies, inflation is measured as the change in the log of the *all-sector* GDP deflator. The period examined is 1966:Q1 to 2011:Q1.

[Figure 1]

Figure 1, compares annual inflation with the annual change in the marginal cost proxies. Abstracting from the oil price shocks, our measure of total cost more closely matches the dynamics of inflation, when compared to labor cost. Note, that as with the rest of the literature, marginal cost is measured as a deviation from a constant mean. This however can have some limitations, if inflation changes over different periods examined. We address these concerns in section 3.3, where we account for weak identification and structural breaks in our estimation of the NKPC.

[6] As published on 5 December 2013.

[7] For more details on the data used see in the Appendix.

[8] There is no available quarterly data for all firms' borrowing costs (in all sectors) in the BEA data series we use, (see Table 1.10 of BEA). Note that the item "Net Interest and Miscellaneous Payments" in that table, is excluded from our marginal cost proxy, Unit Total Cost (UTC), because it includes interest receipts and also net payments on mortgage and home improvement loans by households, as well as other items, that are not related to firms' borrowing costs. Although the inclusion of "Net Interest and Miscellaneous Payments" still shows UTC to perform better than the two measures of ULC examined in the paper, their inclusion, as expected, also weakens the results of the UTC as a marginal cost proxy in estimating the NKPC.

2.2 Some of the main findings

By replicating the methodology of Gali, Gertler and Lopez-Salido (2005), using non-linear GMM estimates on US data for the sample period 1966:Q1 to 2011:Q1, we show that in relation to unit labor costs (non-farm), the use of *unit total costs* (all sector), helps improve the fit of the short-run variation in inflation and the existing empirical support for the role of real marginal cost as the driving variable in the NKPC. The use of *unit total costs* as a marginal cost proxy is also shown to increase the importance of the forward looking or *expectations-based* inflation persistence γ_f. It is shown that this latter effect is stronger even in periods of relatively higher inflation volatility. [9] Moreover, *unit total costs* are shown to imply a duration of fixed nominal contracts of less than 5 quarters, which is much closer to the firm-level surveys based on micro data (1.5 to 4 quarters), than that implied purely by labor unit costs, (i.e. around 5-6 quarters or higher). The results suggesting that *unit total costs (all sector)* is a better proxy for inflation dynamics than unit labor costs (non-farm), are robust even when we account for a number of robustness tests including tests for weak identification and for structural breaks in inflation. Finally, although there is clearly a role for borrowing costs in estimating inflation dynamics, the contribution of the *cost channel* is shown to become relatively less important when *unit total costs,* rather than *unit labor costs*, are used as a marginal cost proxy in the estimation of the NKPC.

3 The Theoretical Framework

In this section we derive the NKPC, equation (1), with *unit total costs* (as shown in 3) and with *unit total costs* plus the *cost channel* (as shown in 4), as our marginal cost proxies. These are consistent with any general equilibrium model that features a CES production function with labor and capital, production taxes, but also with credit markets (for the cost channel).

[9] Using *unit labor cost* as a marginal cost proxy, Zhang, Osborn and Kim (2008) found that forward-looking behavior played a very small role during the volatile inflation period 1968-1981 in the U.S.

3.1 Households

Households maximize their expected present discounted value utility,[10]

$$E_t \sum_{s=0}^{\infty} \beta^s \left(\frac{c_{t+s}^{1-\sigma}}{1-\sigma} - \frac{\eta_n n_{t+s}^{1+\gamma}}{1+\gamma} \right), \tag{5}$$

where c_t is consumption, n is labor service hours; $\beta < 1$ is the subjective discount factor; σ, η_m, η_n are elasticities; $\gamma = 1/\delta$ is the marginal disutility of labor and δ the labor supply elasticity. The household's budget constraint is,

$$P_t(c_t + i_t) + D_t = P_t(w_t n_t + r_t^k u_t k_t) + R_{t-1}^D D_{t-1} + V_t + P_t \tau_t, \tag{6}$$

where, P_t is the price level, D_t, is nominal deposits; $R_t^D = (1 + i_t^D)$ and i_t^D is the nominal deposit rate; w_t is the real wage rate; r_t^k is the real rental price of capital, k_t, and u_t is capital utilization; $V_t = \int V_{j,t} + V_t^b$, are (net) profits from all firms and the banking sector, and $P_t \tau_t$ are nominal transfers. Investment, i_t, is related to the capital stock as follows,

$$i_t = k_{t+1} - (1 - \delta(u_t))k_t + \upsilon \left(\frac{k_{t+1}}{k_t} \right) k_{t+1}, \tag{7}$$

where, $\delta(u_t) = \delta u_t^{\varphi}$; $\delta^{'}(u) > 0$, is a depreciation function and $\upsilon \left(\frac{k_{t+1}}{k_t} \right) = \frac{b}{2}(\frac{k_{t+1}}{k_t} - 1)^2$ are quadratic costs related to capital investment; φ is the elasticity of marginal depreciation cost. Denoting the Lagrangian multiplier as λ_t, the first order conditions are,

$$c_t^{-\sigma} = \lambda_t P_t, \tag{8}$$

$$c_t^{-\sigma} = \beta E_t \left(\frac{R_t^D c_{t+1}^{-\sigma}}{P_{t+1}/P_t} \right), \tag{9}$$

$$\lambda_t P_t w_t = \eta_n n_t^{\gamma}, \tag{10}$$

$$r_t^k = \delta \varphi u_t^{\varphi - 1}, \tag{11}$$

$$P_t \lambda_t \left(1 + b(\tfrac{k_{t+1}}{k_t} - 1) \right) = \beta E_t P_{t+1} \lambda_{t+1} \left[r_{t+1}^k u_{t+1} + (1 - \delta u_{t+1}^{\varphi}) + \frac{b}{2} \left((\tfrac{k_{t+2}}{k_{t+1}})^2 - 1 \right) \right]. \tag{12}$$

Equation (8) and (9) determine the marginal utility of consumption and Euler equation, while equations (10)-(12) define the optimal allocations of labor and capital.

[10] Throughout the paper small Latin letters, x_t, indicate real variables of X_t, (except the nominal interest rates, i_t^X); and $\widehat{x}_t$ denotes the log-linearized value of x_t as a deviation from its steady state.

3.2 The Banking Sector

The banking sector is represented by a commercial bank, b, that accepts deposits from households, D_t, at the rate i_t^D, and makes loans, L_t, to firms at the loan rate i_t^L. The demand for loans is determined by firms, whereas the bank sets the interest rate on loans. If the credit market is short of liquidity, it can borrow from the central bank, L_t^{CB} at the refinance rate, i_t^{CB}.[11] The bank's balance sheet is, $L_t = D_t + L_t^{CB}$. The bank incurs intermediation costs, $\Phi_t(\cdot)$; these are decreasing with aggregate economic activity and banks' willingness to to lend, but can also be affected by shocks to credit market conditions, (ζ_t). In particular, $\Phi_t(\zeta_t, y_t) = \zeta_t \left(y_t/y\right)^{-\xi}$, where, y_t is output and y is its steady state and $\xi > 0$, (see also Cook 1999, Atta-Mensah and Dib 2008).[12] The bank's period profit function is,

$$V_t^b = i_t^L L_t - i_t^D D_t - i_t^{CB} L_t^{CB} - \Phi_t(\zeta_t, y_t) L_t. \tag{13}$$

From (13) and the above information and assuming normal profits we derive,

$$i_t^D = i_t^{CB} \qquad \text{and} \qquad i_t^L = i_t^{CB} + \zeta_t (y_t/y)^{-\xi} \tag{14}$$

hence with zero reserve requirements the deposit rate is equal to the refinance rate whereas the loan rate is a mark-up over the refinance rate driven by intermediation costs.[13]

3.3 Wholesale and Intermediate Firms

There is a continuum of imperfectly competitive firms, $j \in [0, 1]$, each engaging in the production of a differentiated good, $y_{j,t}$, which sells at the price $P_{j,t}$. The final goods firm bundles intermediate goods in a composite final good $y_t = \left(\int_0^1 y_{j,t}^{(\theta-1)/\theta} dj\right)^{\theta/(\theta-1)}$, by minimizing the cost, $P_t y_t = \int_0^1 P_{j,t} y_{j,t} dj$. The resulting demand for each intermediate differentiated good is,

$$y_{j,t} = \left(\frac{P_{j,t}}{P_t}\right)^{-\theta} y_t, \tag{15}$$

[11] We assume that extra liquidity is covered by the nominal lump sum tax so that, $L_t^{CB} = P_t \tau_t$.

[12] This assumption also ensures that loan spreads are countercyclical, as supported by empirical evidence. For a paper where this relationship is derived endogenously, see Agénor, Bratsiotis and Pfajfar, (2013).

[13] In these studies ζ_t evolves as, $\log(\zeta_t) = \rho_\zeta \log(\zeta) + (1 - \rho_\zeta) \log(\zeta_{t-1}) + \epsilon_{\zeta,t}$. Thus, at the steady state, $\Phi = \log(\zeta) = \overline{\zeta} > 0$, which captures the steady state mark-up over the policy rate due to imperfections in the credit market, whereas $\epsilon_{\zeta,t}$ captures innovations to such costs.

where, $P_t = \left(\int_0^1 P_{j,t}^{1-\theta} dj\right)^{1/(1-\theta)}$, is the average price index. The production of each intermediate good combines capital and labor according to the following CES technology,

$$y_{j,t} = \left[\alpha_k (u_t k_t)^{\chi} + \alpha_n (a_t n_t)^{\chi}\right]^{1/\chi}, \tag{16}$$

where $\chi = \frac{\rho-1}{\rho}$; $0 < \alpha_k$, $\alpha_n < 1$ are the corresponding input shares and a_t measures labor productivity. If $\chi \to 0$, and $\alpha_k + \alpha_n = 1$, equation (16) reduces to a Cobb-Douglas technology. The latter specification, however, assumes a unity elasticity of output with respect to labor which results to marginal cost being proportional to the labor share, (see Rotemberg and Woodford, 1999). The use of a CES production function allows the marginal product of labor and hence marginal cost to be affected by varying input shares, and so this specification is more appropriate for the purpose of this paper.[14]

In each period intermediate firms must borrow to cover their labor and capital costs, but they are required by lenders to hold some risk-free financial assets for risk diversification and collateral purposes. For simplicity we assume that all risk-free assets held by firms are summarized in the form of government bonds, $B_{j,t}$.[15] Hence, the existing stock of all government bonds satisfies, $B_t = \int_0^1 B_{j,t} dj$.[16] The firm's loan is equivalent to its *variable cost*,

$$L_t = P_t r_t^k k_t + P_t w_t n_t, \tag{17}$$

We assume that a portion ϑ of loans is collateralized by the firm's holdings of safe assets,[17]

$$\vartheta L_t = B_{j,t} \tag{18}$$

From (16), (17) and (18), the firm's period profits are,

$$V_{j,t} = P_{j,t} y_{j,t} (1 - \tau_t^Y) + i_t^{CB} B_{j,t} - R_t^L L_t \tag{19}$$

where, τ_t^Y is a *net* (i.e. less subsidies or business transfers) *production tax*, and $R_t^L = 1 + i_t^L$.

[14] For simplicity, we assume that employment and capital is common to all firms, which simplifies aggregation while still allowing for the average and marginal products to vary, (see Gali, Gertler and Lopez-Salido, 2007, Cantore, Levine and Yang, 2010). Assuming firm specific factor inputs within a CES production technology, implies further relative price and inflation effects, (see Gagnon and Khan 2005)

[15] Note that the role of risk is not essential for the purpose of this paper. For a recent paper that deals with endogenous idiosyncratic risk in marginal cost, see Agénor, Bratsiotis and Pfajfar, (2013).

[16] Households and commercial banks could also hold government bonds, but for the purpose of this paper we focus on bonds being held only by firms which, by assumption, are required by banks to back part of their loans by collateral.

[17] In Goodfriend and McCallum, (2007), loan makers construct collateral from goverenment bonds and firms' capital; Others show borrowing firms to have government bonds explicitly in their flow constraint, (Hnatkovska, Lahiri and Vegh, 2008).

Using (15)-(19), the period optimal real price of firm j is,

$$P_{j,t}^{*}/P_t = \mu_p mc_t \tag{20}$$

where $\mu_p = \theta/(\theta-1)$ is the price mark-up and real marginal cost is,[18]

$$mc_t = \left(\frac{1+i_t^L - \vartheta i_t^{CB}}{1-\tau_t^Y}\right)\left(\frac{r_t^k}{\alpha_k u_t^{\chi}(y_t/k_t)^{1-\chi}} + \frac{w_t}{\alpha_n a_t^{\chi}(y_t/n_t)^{1-\chi}}\right), \tag{21}$$

where, $\alpha_n a_t^{\chi}(y_t/n_t)^{1-\chi}$ and $\alpha_k u_t^{\chi}(y_t/k_t)^{1-\chi}$ are the marginal products of labor and capital, respectively.

3.4 The 'Unit Total Cost' New Keynesian Phillips Curve

Consider a Calvo-type price setting, where the price of each firm has a fixed probability, ψ, of remaining fixed at the previous period's price and a fixed probability of $1-\psi$ of being adjusted. Each firm setting a new price at time t will choose a price contract, X_t, to minimize current and future deviations of prices from optimal prices, $P_{j,t+s}^{*}$,

$$E_t \sum_{s=0}^{\infty} \psi^s \Delta_{t,t+s} \left(P_{j,t} - P_{j,t+s}^{*}\right)^2, \tag{22}$$

where, $\Delta_{t,t+s} = \beta^s c_{t+s}^{-\sigma}/c_t^{-\sigma}$, is the discount factor. Minimizing (22) with respect to $P_{j,t}$ and denoting percentage deviations around steady states by a *hat*, we obtain,

$$\widehat{X}_t = (1-\psi\beta)\sum_{s=0}^{\infty} \psi^s \beta^s E_t \widehat{P}_{j,t+s}^{*} = (1-\psi\beta)(\widehat{P}_{j,t}^{*}) + \psi\beta E_t \widehat{X}_{t+1}, \tag{23}$$

where $\widehat{X}_t$ is the optimal price contract chosen by all firms that adjust prices in each period t and $\widehat{P}_{j,t}^{*} = \widehat{P}_t + \widehat{mc}_t$ is the optimal price (see 20). The average price in the economy is,

$$\widehat{P}_t = \psi \widehat{P}_{t-1} + (1-\psi)\widehat{P}_t^N, \tag{24}$$

where newly set prices, $\widehat{P}_t^N = (1-\omega)\widehat{X}_t + \omega \widehat{P}_t^B$, are a weighted average of optimally set prices, $\widehat{X}_t$ and backward looking set price, $\widehat{P}_t^B = \widehat{X}_{t-1} + \pi_{t-1}$, (as in Gali and Gertler, 1999). Using equations (23), (24) and $\pi_t = \widehat{P}_t - \widehat{P}_{t-1}$, we derive the hybrid NKPC,

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f E_t \pi_{t+1} + \lambda \widehat{mc}_t, \tag{25}$$

[18] Note that here marginal cost also includes production taxes.

where, $\gamma_b = \frac{\omega}{\psi+\omega(1-\psi(1-\beta))}$; $\gamma_f = \frac{\psi\beta}{\psi+\omega(1-\psi(1-\beta))}$; $\lambda = \frac{(1-\omega)(1-\psi)(1-\psi\beta)}{\psi+\omega(1-\psi(1-\beta))}$; and the log-linearized marginal cost, or *unit total cost* (with no borrowing costs) is,

$$\widehat{mc}_t = \frac{S_n}{S_k + S_n}\widehat{S}_{n,t} + \frac{S_k}{S_k + S_n}\widehat{S}_{k,t} + \frac{\tau^Y}{(1-\tau^Y)}\widehat{\tau}_t^Y\,, \tag{26}$$

and *unit total cost* with the *cost channel* is,

$$\widehat{mc}_t = \frac{S_n}{S_k + S_n}\widehat{S}_{n,t} + \frac{S_k}{S_k + S_n}\widehat{S}_{k,t} + \frac{\tau^Y}{(1-\tau^Y)}\widehat{\tau}_t^Y + \lambda_i \hat{\imath}_t^L, \tag{27}$$

where, $\widehat{S}_{n,t} = \hat{w}_t - (1-\chi)(\hat{y}_t - \hat{n}_t) - \chi\widehat{a}_t$, and $\widehat{S}_{k,t} = \hat{r}_t^k - (1-\chi)(\widehat{y}_t - \hat{k}_t) - \chi\hat{u}_t$, are the shares of unit capital costs and unit labor costs, respectively; $S_k = \frac{r^k}{\alpha_k(y/k)^{(1-\chi)}}$ and $S_n = \frac{w}{\alpha_n(y/n)^{(1-\chi)}}$, are their respective steady states; $\lambda_i = \frac{(1-\vartheta)i^{CB}}{1+i^L-\vartheta i^{CB}}$ and $\hat{\imath}_t^L = \frac{i^{CB}}{i^L}\hat{\imath}_t^{CB} + \frac{\bar{\zeta}}{i^L}(\widehat{\zeta}_t - \xi\widehat{y}_t)$. From (25) and (26) we can express the NKPC as a $\widehat{mc}$-proxy of only *unit labor costs:* $\widehat{mc}_t = \widehat{ULC}_t = \widehat{S}_{n,t}$, so that (25) becomes,

$$\pi_t = \gamma_b\pi_{t-1} + \gamma_f E_t\pi_{t+1} + \lambda\widehat{ULC}_t. \tag{28}$$

With *unit total costs*, (and no cost channel) based on (26), the NKPC is,

$$\pi_t = \gamma_b\pi_{t-1} + \gamma_f E_t\pi_{t+1} + \lambda\widehat{UTC}_t, \tag{29}$$

and with *unit total cost* and the *cost channel,* based on (27), the NKPC is,[19]

$$\pi_t = \gamma_b\pi_{t-1} + \gamma_f E_t\pi_{t+1} + \lambda\widehat{UTC}_t + \lambda\lambda_i\hat{\imath}_t^{CB}, \tag{30}$$

where $\lambda\lambda_i$ is the coefficient capturing the *credit* or *cost channel* effect.

4 Empirical Estimation

In this section we replicate some of the key tests performed in the literature. The period examined, is 1966:Q1 to 2011:Q1. This sample covers the most recent period over where the divergence between unit labor cost and inflation has been cited as one of the reasons for the poor performance of the NKPC, (King and Watson 2012).[20] We first examine the role of *unit total cost,* as shown in equations (26) and (29). The role of the *cost channel* in the NKPC, (eq 30), is examined separately, in section 4.6.

[19] Here we set the loan rate markup to zero (i.e. $\bar{\zeta} = 0$) so that $\hat{\imath}_t^L = \hat{\imath}_t^{CB}$, as with the conventional cost channel literature.

[20] We thank an anonymous referee for pointing this out.

4.1 Structural Estimates

In this section we estimate the hybrid NKPC, equation (1), using non-linear instrumental variables (GMM, IV) with robust errors over the period 1966:Q1 to 2011:Q1. To deal with the small sample normalization problem we follow Gali and Gertler and Salido (2005) and others and use the following orthogonality condition,[21]

$$E_{t-1}\{(\pi_t - \lambda\widehat{mc}_t - \gamma_f\pi_{t+1} - \gamma_b\pi_{t-1})z_{t-1}\} = 0 \tag{31}$$

where z_{t-1} is a vector of variables dated t-1 and earlier and equation (25) is assumed to include an error term ε_t that is i.i.d.

[Table 1]

Table 1 gives non-linear instrumental variable estimates of the deep structural parameters in equation (1) using *labor unit costs* and *unit total costs* as proxies for marginal cost, respectively. The instrument set used is four lags of the measure of real marginal costs, inflation, output gap, wage inflation and commodity price inflation.[22] The results in Table 1 , suggest that adding *other operating costs* to the unit labor costs (for all-sectors data), improves on the existing empirical support for (a) the role of real marginal cost as the driving variable in the NKPC and (b) the forward looking expectations-based new Keynesian Phillips curve.

Focusing first on the real marginal cost coefficient, λ, Table 1 shows that unit total costs imply a higher λ, than the traditional measure of real unit labor cost, as well as real unit labor cost for all sectors. Further, t-statistics for the difference in these estimated coefficients, show that even when standard errors are taken into account the size of λ is significantly different when the unit total costs proxy is used as the measure of marginal cost, irrespectively of the restriction on β.[23] To further establish, independently of our structural model, whether the unit total costs NKPC is a better specification than the unit labor costs NKPC, we also conduct a non-nested test.[24] The test is conducted using

[21] See also Gagnon and Khan (2005) and Gali, Gertler and Salido (2001).

[22] Here we use the most parsimonious instrument set possible to avoid the estimation bias that arise in small samples with too many over-identifying restrictions (see Staiger and Stock 1987).

[23] These difference tests are available in Appendix B (working paper).

[24] Although the definition of unit total cost nests unit labor cost, equation (25) does not lend itself to the traditional F-tests for nested models, since it only includes one marginal cost variable. We therefore treat the unit labor cost NKPC and unit total labor cost NKPC as two different non-nested models focusing on the choice of regressors. In this regard we employ the Davidson and MacKinnon (1981) J-test which is based on the comprehensive approach and the Godfrey (1983) non-nested test for instrumental variable estimators.

all-sector total unit cost and all-sector unit labor cost. The results are summarized in Table 2.[25]

[Table 2]

Table 2, indicates that while we reject the null hypothesis for the labor unit cost NKPC model in favour of the unit total cost model, we cannot reject the null for the unit total costs NKPC model; hence *unit total costs* appear to be a better explanatory variable for inflation dynamics than the *unit labor costs*.

We also find that total unit costs imply a degree of price stickiness, ψ, that is closer to the values supported by micro data. Specifically, using unit total cost, ψ, is estimated at 0.79, implying an average price duration of 4.8 quarters, while the ψ values for the unit labor cost proxies are larger than 0.85, suggesting average price duration *in excess* of 6 quarters. Therefore, the duration of price contracts implied by total unit costs is much closer to the 3 to 4 quarters found by Blinder (1994) using micro data, than a duration greater than 5 quarters that is typically found in the empirical NKPC literature.

4.2 Unit Total Costs and Forward Looking Behavior

The results in Table 1 also suggest that when *unit total costs* are used as the driving variable in the NKPC, the coefficients on the structural parameters indicating backward looking behavior, (i.e. ω, ψ and γ_b) are generally lower, whereas γ_f, that indicates forward looking behavior is relatively higher, than their respective *unit labor cost* counterparts. To examine the robustness of this result we perform a number of tests, including different sample periods, applying a time varying trend and also test the implications of unit total costs for fundamental inflation and inflation persistence.

In this section, we test whether the relatively stronger forward looking behavior implied by unit total costs, holds in periods of high inflation volatility. Using *unit labor costs* on US data, Zhang, Osborn and Kim (2008) find very little empirical support for the role of forward expectations-based inflation persistence in the high and volatile inflation period 1968:1 to 1981:4.

[Table 3]

Table 3 shows that when we estimate the NKPC structural parameters for the same sample period, we find that the coefficient on unit labor costs (all sectors) is $\lambda = 0.044$ with $\gamma_b = 0.457$ and $\gamma_f = 0.542$. However, for the same sample period the use of *unit*

[25] For more details see in the Appendix.

total costs produces, $\lambda = 0.083$, with $\gamma_b = 0.364$ and $\gamma_f = 0.632$.[26] This, consistently with the results in Table 1, suggests that total unit costs indicate a larger role for forward looking behavior than that implied by unit labor costs. It also suggests, that much of the evidence supporting a backward NKPC might have been somewhat biased by the use of unit labor costs as a proxy for marginal cost.

4.3 Actual versus Fundamental Inflation

To assess the explanatory power of the NKPC using unit total cost as opposed to unit labor costs, we estimate the model-consistent or 'fundamental' inflation rate and compare this with the actual inflation rate. As Gali and Gertler (1999) show, the hybrid NKPC has the following closed form,

$$\pi_t = \delta_1 \pi_{t-1} + \frac{\lambda}{\delta_2 \gamma_f} \sum_{s=0}^{\infty} \delta_2^{-s} E_t\{\widehat{mc}_{t+s}|z_t\}$$

where $\delta_1 = \frac{1-\sqrt{1-4\gamma_b\gamma_f}}{2\gamma_f}$ and $\delta_2 = \frac{1+\sqrt{1-4\gamma_b\gamma_f}}{2\gamma_f}$ are the small and large roots of (25) respectively and z_t is a subset of the market's information set containing current and lagged values of inflation and real marginal cost i.e. $z_t = \{\pi_t, ..., \pi_{t-q+1}, \widehat{mc}_t, ..., \widehat{mc}_{t-q+1}\}'$. Accordingly, we derive the fundamental inflation, as in Gali and Gertler (1999), whereby z_t follows a VAR(3) process.[27] The resulting fundamental inflation for *unit total costs* and *unit labor costs* (for *non-farm* and *all-sector*) versus actual inflation are shown in Figure 2.

[Figure 2]

These figures show that the *unit total cost* driven NKPC matches actual inflation much better than its *unit labor costs* counterpart. Consistently with the observation of King and Watson (2012), the fundamental inflation based on both measures of unit labor cost is persistently below actual inflation since the 1990s. This is in contrast to the total unit cost based fundamental inflation which tracks actual inflation very closely.

4.4 Specification Tests

The main tools used thus far to evaluate the NKPC model is the J-test for overidentifying restriction and the goodness of fit. Bardsen et al (2004) suggest that the results of such

[26] The difference in the coefficients on γ_f between these two marginal cost proxies is statistically significant (t-stat for difference is 3.30).

[27] The Schwarz and Hannan-Quinn information criteria suggest a lag length of 2 for the VARs for both unit total costs and unit labor costs.

test may not be sufficient to establish robustness as they may have low power, particularly in the presence of weak instruments (see also section 4.6), and the fact that the sum of the coefficients on forward and backward looking inflation is close to unity could suggest that a model in the first difference of inflation could be just as good. In fact we have shown that wage share augmented by non-labor costs is a more appropriate driving variable. However it is also important to examine whether there are other variables that drive inflation as well and whether the omission of these variables contributes to autocorrelated residuals. Against this background, we conduct two specification tests suggested by Bardsen et al (2004).

The first test examines whether the presence of residual autocorrelation is due to omitted variables and as such the autocorrelation is not the result of the rational expectation hypothesis underlying the theory as Blake (1991) demonstrates but a symptom of misspecification. Here we present the two-stage least squares (2SLS) estimation which unlike GMM estimates does not correct for autocorrelated residuals. Following Bardsen et al (2004), two variables that are natural candidates in inflation models are measures of capacity utilization and additional lags of inflation. We therefore removed the lagged output gap and the fourth lag of inflation from the instrument set and included them as explanatory variables. If the model is correctly specified then these variables should be insignificant and there should be no change in the importance of the forward looking inflation variable. In this light Bardsen et al (2004) interprets this test as a test of richer dynamics.

Table 4 presents the reduced form 2SLS estimation of the NKPC using both unit labor cost and total unit cost, along with the inclusion of the additional variables (π_{t-4} and gap_{t-1}). The coefficient on the forward looking inflation is significantly different with the exception of unit total cost. In all cases, the forward looking variable is larger than the backward looking and remains highly significant both statistically and in absolute terms. There is still strong evidence of autocorrelated errors and the additional variables are insignificant. These results therefore suggest that with the exception of unit total cost, there could be some misspecification. arising from omitted variables as the coefficients on forward looking inflation are rather different.

[Table 4]

A complementary specification test uses an encompassing framework. The motivation is that other studies have found cointegrating or long run relationships between wages adjusted for productivity and prices (i.e. Mehra 1993). Bardsen et al (2004) suggest that these relations provide a basis to test the NKPC. They suggest the following procedure: (i)Using current set of variables and instruments used to identify the NKPC augment the model with the set of variables suggested by other models of inflation. (ii) Under the assumption that the forward looking NKPC is the correct model, the coefficients on the additional variables should be zero and the forward looking term should maintain its significance. Otherwise the encompassing property of the NKPC is refuted.

[Table 5]

Table 5 shows the results of this test, where we use the following cointegrating relation similar to Mehra (1993)[28]:

$$\begin{aligned} ecmw_t &= \ln ULC_{t,(nonfarm)} + 0.78 + 0.039 \cdot \ln P_t, \\ ecmw_t &= \ln ULC_{t,(all\text{-}sectors)} + 0.59 + 0.022 \cdot \ln P_t, \end{aligned}$$

where $ecmw_t$ is the error-correction from the cointegrating relation; P_t is the price level (i.e. implicit GDP deflator) and ULC is unit labor cost of the non-farm business sector. Estimating the reduced form model via GMM with these cointegrating relationships and the same instrument set as before yields interesting results (see Table 5). We find that the error correction terms are significant at the 5% level in the models with unit labor cost (both non-farm and all sectors) and λ is now negative. In contrast, the error correction term is insignificant in the model with unit total cost and there is very marginal change in the other coefficients. These results suggest a rejection of the encompassing principle for the NKPC using unit labor costs (similar to the results for the Euro area obtained by Bardsen et al (2004)) but there is not sufficient evidence to reject it using unit total cost here).

4.5 Identification Robust Estimation

We have so far replicated standard estimation methods, as proposed by Gali and Gertler (1999), and Gali, Gertler and Lopez-Salido (2001, 2005), to compare the conventional unit labor cost to our alternative marginal cost proxy, unit total costs. In this section we also compare these two marginal cost proxies, by taking into consideration two potential concerns raised recently in the literature: (i) weak identification of conventional GMM

[28]Similar to Mehra (1993) productivity adjusted wage is measured by unit labor cost. The cointegrating relations are estimated using FMOLS.

estimates and (ii) significant changes in the univariate inflation process over different periods.

Several recent papers argue that the traditional GMM estimates of the NKPC may be unreliable as the conventional GMM estimator may yield biased estimates in the presence of weak identification, (see for example Mavroeidis 2005 and Nason and Smith 2008). This literature also suggests that conventional inference after pre-testing for identification is unreliable if the size of the pre-testing procedure cannot be controlled (see Kleibergen and Mavroeidis 2009). We therefore re-estimate the model using the continuous updating (CUE) GMM estimator, that is the MQLR statistic recommended by Kleibergen and Mavroeidis 2009 for inference, which allows for the application of weak instrument robust statistics. Specifically, we use the 95% confidence derived from inverting the subset MQLR statistic using the same instrument set as before, which is widely used. The choice of the instrument set is important for the results here. The standard approach is the Hansen (1982) criterion which we also report (i.e. p-value).[29] We find that the output gap Granger-cause marginal cost, which should lead to a role for lagged inflation in the instrument set, (see Nason and Smith 2008) and also Granger-causes the real marginal cost proxies. Therefore, in Table 6, we also report the results for an instrument set which includes three lags of inflation and the output gap.[30]

[Table 6]

Given that β is close to 1, we focus on the results for $\beta = 1$.[31] Focusing firstly on the larger instrument set (instrument set A) for the full sample, the estimates of γ_f and λ for unit total costs are not significantly different form the conventional GMM estimate in Table 1. Thus the estimate of total unit cost NKPC (i.e.$\gamma_f \approx 0.7$ and of $\lambda \approx 0.03$) seems to be robust to the estimation method and instrument set. The estimates for price stickiness, ψ, for unit total costs are virtually unchanged from the conventional GMM estimate in Table 1. However the size of the confidence interval for γ_f in all cases using instrument set A suggests that there could be an identification issue, although the 95% confidence excludes values close to zero implying a role for forward looking behavior. The results using the smaller instrument set (instrument set B) provides a stronger support

[29] The application of this criterion to this estimator is also robust to the weak instrument problem.

[30] Identification requires that π_{t+1} can be predicted by at least one variable other than π_t, π_{t-1} and mc_t (see Nason and Smith, 2008).

[31] Many studies, impose the restriction that $\gamma_b + \gamma_f = 1$, (see for example Buiter and Jewitt 1989 and Fuhrer and Moore 1995, and Kleibergen and Mavroeidis, 2009). In this framework, the test of the null hypothesis $\gamma_b + \gamma_f - 1 = 0$, is generally accepted.

for the unit total cost NKPC and confirm the conclusion of the previous section, that is, compared to the coefficients using unit labor costs, the unit total costs measure of real marginal cost indicates a stronger role for forward looking inflation and a steeper slope for the Phillips curve, (i.e. a larger λ). Also, the fact that the confidence intervals for the unit total cost NKPC with instrument set B are relatively small around the point estimates, suggest that the coefficients are more accurately estimated.[32]

We also estimate over two-subsample periods, 1966-1983 and 1983-2011, to account for the inflation break at the end of 1983.[33] There is wide consensus that the US economy has become more stable since the latter half of the 1980s, with significant changes (statistical and economic) in the univariate inflation process. Following much empirical evidence on US inflation data, we estimate the NKPC over two subsamples, 1966:Q1 to 1983:Q4 and 1984:Q1 to 2011:Q1, (see for example Stock and Watson 2007, Roberts 2006, Kleibergen and Mavroeidis 2009).[34] These test again show that the forward looking term γ_f is stronger and λ is generally larger with unit total cost in the 1966 to 1983 period. Also the 95% confidence bands indicate that the forward looking variable is more accurately estimated for unit total cost than labor unit costs. In most cases, the estimate for λ is tight around zero with the exception of unit total costs, using instrument set B. Also, in the latter sample, unit total costs exhibit an increase in the size of λ, (or the slope of the NKPC), and the role of the forward looking inflation. Overall, unit total costs produces the most robust estimate, although the confidence band around γ_f, while indicating that forward looking variable is significantly different from zero and could include unity, raises also an issue of identification.

4.6 The Cost Channel

Much attention has been given recently to the role of the cost channel of monetary policy in inflation dynamics (see Barth and Ramey 2001, Ravenna and Walsh 2006 and Chowdhury et al 2006). Changes in interest rates directly affect firms' operating cost through the cost of working capital loans, (see 27 and 30). We follow the literature and test separately for the contribution of the cost channel, by estimating the interest rate augmented NKPC as given in 30, where $(\lambda\lambda_i)$ is the coefficient of the cost channel, and λ_i is a measure of its relative importance (see also Chowdhury et al 2006). Consistent

[32] The interval for λ, in particular, is noticeably smaller than those found in Kleibergen and Mavroeidis (2009)

[33] The subsample tests are provded in Appendix B and are also available in a working paper.

[34] This break point corresponds with estimates of the onset of the great moderation (see Stock and Watson 2007).

with this literature the interest rate used is the three-month US treasury bill rate.[35]

[Table 7]

The conventional GMM results are shown in Table 7. We find that the cost channel is significant in all cases except for non-farm unit labor cost. In particular, using unit total costs, the cost channel appears to be statistically significant, in terms of both the coefficient of the cost channel, $(\lambda\lambda_i)$ and in terms of its measure of its relative importance λ_i, suggesting that there is a role for the inclusion of borrowing costs. However, notice that when other, non-labor unit costs are taken into account, as in unit total costs, the cost channel appears to be relatively less important to estimating the NKPC, than other costs in the marginal cost. For example, the inclusion of the cost channel appears to moderate the coefficients λ and γ_f, in relation to their estimates without the cost channel (see earlier tables), thus suggesting that part of the effects of interest rates on inflation were partially captured in other non-labor costs, (i.e. such as investment and capital related factors).

5 Concluding Remarks

This paper builds on recent attempts in the literature to find an alternative marginal cost proxy that can explain inflation dynamics better than the conventional *output gap* or *unit labor costs,* that have been criticized as poor proxies. We construct our alternative real marginal cost proxy, *unit total costs,* by extending the data already used in the literature in two dimensions: first, by using both *labor* and *non-labor costs* as a proxy to marginal cost and second by extending the data from *non-farm* GDP, to *all-sector* GDP. *Unit total costs* are shown to, (i) improve on the fit of observed inflation and hence on the existing empirical support for real marginal costs as the driving variable in the NKPC; (ii) imply a duration of fixed nominal contracts that is much closer to those suggested by firm-level surveys, than that implied by merely unit labor costs; (iii) suggest a larger role for forward looking behavior and expectations-based inflation persistence than that implied by the conventional *unit labor costs.* These findings are robust when we account for the mean break in US inflation data, at the end of 1983, and they are also hold even in the relatively high and volatile inflation periods of the 1970's, where the use of unit labor costs has been reported in other studies to exhibit a very weak forward looking

[35] The relative importance of the cost channel depends on both the extent to which firms rely on external finance and the pass-through from the policy rate to market interest rates.

behavior. Intuitively, this might be because in periods of increased uncertainty and high inflation volatility, expectations about future inflation may be more relevant to firms' decisions about non-labor costs, such as borrowing costs and investment in new capital; which may also explain the following finding; (iv) Consistent with earlier studies there is a role for the cost channel, though when other non-labor unit costs are included in the marginal cost, as in our unit total cost proxy, the contribution of borrowing costs becomes relatively less important. This, as explained above, may be because other non-labor costs (such as investment and capital related costs) may partly capture the effects of interest rates and forward expectations on inflation.

Indeed, we believe that adding data that reflect information about key leading economic indicators, such as expectations about interest rates, investment and borrowing decisions, that until recently have been given relatively little attention in the empirical estimation of the NKPC, may substantially improve the existing empirical support for the role of forward looking behavior in price setting and inflation.

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APPENDIX

Data Definitions

All data, with the exception of nonfarm labor costs, commodity price index and the 3-month treasury bill rate, are sourced from the U.S. Department of Commerce Bureau of Economic Analysis and the US Bureau of Labor Statistics, as published on 05 December 2013. The *commodity price index* is the spot commodity index sourced from the Commodity Research Bureau at: http://www.crbtrader.com/crbindex/ and the *3-month treasury bill rate* is sourced from the US Federal Reserve.

Labor Cost (nonfarm): Source: US Bureau of Labor Statistics

Labor Costs (all sectors): Source: U.S. Department of Commerce Bureau of Economic Analysis, Table 1.10, compensation of employees

Non-Labor Costs (*all sectors*): Source: U.S. Department of Commerce Bureau of Economic Analysis, Table 1.10. These payments include: *consumption of fixed capital*, *taxes on production and imports* and *business current transfer payments*.

GDP deflator: Source: U.S. Department of Commerce Bureau of Economic Analysis, Table 1.1.9

Inflation = Change in the log of the *GDP deflator*.

Nominal GDP (nonfarm & all sectors): Source: US Bureau of Economic Analysis, Table 1.3.5

Output Gap: Log difference between real GDP and the Hodrick-Prescott filtered trend.

Total Costs (all sectors) = Labor Cost (all sectors) + *Non-Labor Costs* (all sectors)

Unit Labor Costs (nonfarm) = (log) Labor Cost (nonfarm) - (log) Nominal GDP (nonfarm)

Unit Labor Costs (all sectors) = (log) *Labor Cost (all sectors)* - (log) *Nominal GDP (all sectors)*

Unit Total Costs (all sectors) = (log) *Total Costs (all sectors)* - (log) *Nominal GDP (all sectors)*

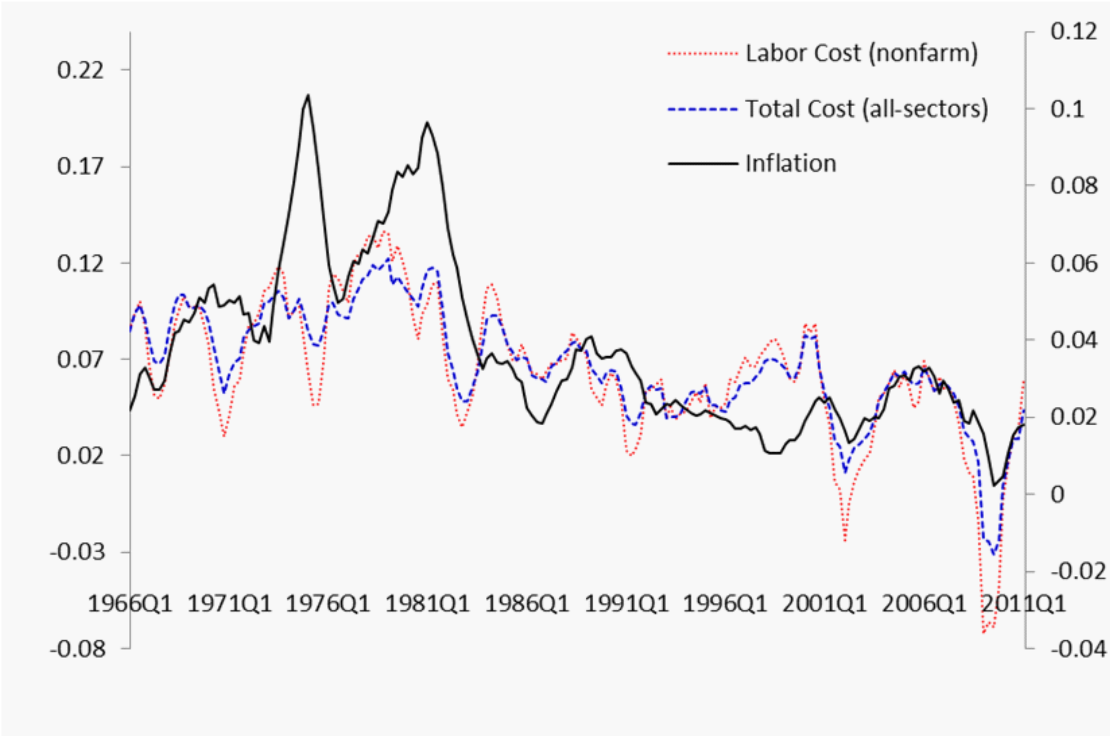

Figure 1: ULC (nonfarm), UTC (All Sector) and GDP Deflator (on the right axis)

Table 1: NKPC Estimates: Unit Labor Cost vs Unit Total Costs

	ω	ψ	β	γ_b	γ_f	λ	P(j-stat)
			Unit Labor Cost (Non-farm)				
Unrestricted	0.486	0.943	0.989	0.341	0.655	0.001	0.999
	(0.011)	(0.023)	(0.004)	(0.011)	(0.010)	(0.0005)	
Restricted	0.493	0.952	1.00	0.341	0.659	0.001	0.999
	(0.010)	(0.017)		(0.005)	(0.008)	(0.00007)	
			Unit Labor Cost (All Sectors)				
Unrestricted	0.408	0.879	0.988	0.318	0.677	0.007	0.997
	(0.049)	(0.020)	(0.007)	(0.029)	(0.029)	(0.002)	
Restricted	0.412	0.883	1.00	0.318	0.682	0.006	0.999
	(0.049)	(0.017)		(0.013)	(0.009)	(0.0001)	
			Unit Total Cost (All Sectors)				
Unrestricted	0.259	0.794	0.984	0.247	0.744	0.033	0.653
	(0.030)	(0.074)	(0.011)	(0.057)	(0.056)	(0.009)	
Restricted	0.289	0.783	1.00	0.270	0.729	0.031	0.983
	(0.024)	(0.063)		(0.017)	(0.043)	(0.002)	

Note: This table reports non-linear IV estimates (GMM) of the deep structural parameters in equation (25), using labor unit cost and unit total costs as proxies to marginal cost. The estimation uses quarterly data over the period: 1966:Q1-2011:Q1. The instrument set includes four lags of the real marginal cost proxy, inflation, output gap, wage inflation and commodity price inflation. Standard errors are shown in brackets. A 12-lag Newey-West estimate of the covariance matrix is used. The last column presents the Hansen's J-test for overidentifying restrictions.

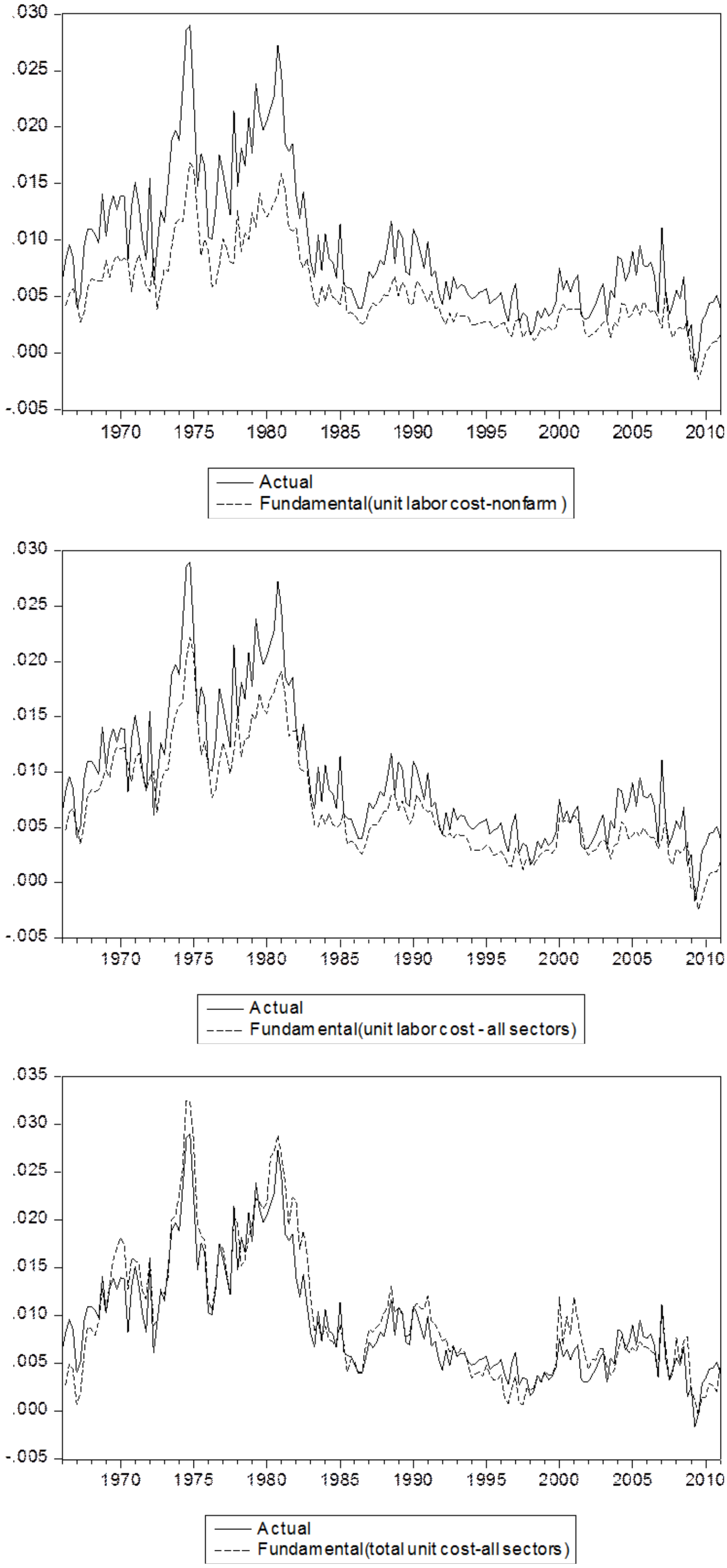

Figure 2: Actual vs Fundmanental Inflation

Table 2: NKPC Estimates: Non-nested Tests

	γ_b	γ_f	λ	*J-Test*	*Godfrey*
Unit Labor Cost (All Sectors)	0.272 (0.053)	0.725 (0.054)	0.04 (0.009)	2.66*	−4.34*
Unit Total Cost (All Sectors)	0.261 (0.057)	0.734 (0.055)	0.023 (0.012)	−0.89	1.11

Note: This table reports the GMM estimates of the reduced-form of equation (25), using quarterly data over the period 1966 Q1 to 2011 Q1. The instrument set includes four lags of the measure of the real marginal cost proxy, inflation, output gap, wage inflation and commodity price inflation. Standard errors are given in parenthesis below. A 12-lag Newey-West estimate of the covariance matrix is used. The last two columns give the Davidson –McKinnon J-test and Godfrey non-nested tests. Asterisks (*) denote significance at the 5% level.

Table 3: Comparative Estimates with Zhang Osborn and Kim (2008) Sample

	γ_b	γ_f	λ	*P(j-stat)*
Unit Labor Cost (Non-farm)	0.446 (0.013)	0.550 (0.012)	0.013 (0.005)	0.999
Unit Labor Cost (All Sectors)	0.457 (0.029)	0.542 (0.028)	0.044 (0.017)	0.995
Unit Total Cost (All Sectors)	0.364 (0.031)	0.632 (0.032)	0.083 (0.016)	0.906

Note: This table reports the GMM estimates of the reduced-form of equation (25), using labor unit cost and total unit costs as proxies for marginal cost. The estimation uses quarterly data over the period: 1968:Q1-1981:Q4. The instrument set includes four lags of the real marginal cost proxy, inflation, output gap, wage inflation and commodity price inflation. Standard errors are shown in brackets. A 12-lag Newey-West estimate of the covariance matrix is used. The last column presents the Hansen's J-test for overidentifying restrictions.

Table 4: NKPC, 2SLS Estimates: Unit Labor Costs vs Unit Total Costs

	γ_b	γ_f	λ	π_{t-4}	gap_{t-1}
Unit Labor Cost (Non-farm)	0.286 (0.095)	0.719 (0.131)	0.003 (0.009)	−0.007 (0.093)	−0.013 (0.021)
$\chi^2_{AR(1)}$=76.58 [0.00]; $\chi^2_{AR(2)}$=83.64 [0.00]; $F_{A,(1-4)}$(4,172)=15.89 [0.00] F_H(5,175)=2.67 [0.02]; F_{IR}(12,161)=5.39 [0.00]; χ^2_{IV}(17)=15.75 [0.26]					
Unit Labor Cost (All Sectors)	0.273 (0.092)	0.728 (0.121)	0.011 (0.015)	−0.005 (0.088)	−0.013 (0.018)
$\chi^2_{AR(1)}$=71.48 [0.00]; $\chi^2_{AR(2)}$=76.77 [0.00]; $F_{A,(1-4)}$(4,172)=15.54 [0.00] F_H(5,175)=2.87 [0.02]; F_{IR}(12,161)=5.41 [0.00]; χ^2_{IV}(17)=7.93 [0.85]					
Unit Total Cost (All Sectors)	0.273 (0.092)	0.753 (0.121)	0.032 (0.027)	−0.029 (0.090)	−0.011 (0.017)
$\chi^2_{AR(1)}$=67.74 [0.00]; $\chi^2_{AR(2)}$=72.42 [0.00]; $F_{A,(1-4)}$(4,172)=14.85 [0.00] F_H(5,175)=3.18 [0.01]; F_{IR}(12,161)=5.13 [0.00]; χ^2_{IV}(17)=8.21 [0.83]					

Note: This table reports the 2SLS estimates of the reduced-form of equation (25), using labor unit cost and unit total cost as proxies for marginal cost. The estimation uses quarterly data over the period: 1966 Q1 to 2011 Q1. The instrument set includes four lags of the measure of real marginal costs proxy, wage and commodity price inflation; three lags of inflation and lags two to four of the output gap. Standard errors are given in parenthesis below the coefficients.

Table 5: NKPC, Error-Correction GMM Estimates: Unit Labor Cost vs Unit Total Cost

	γ_b	γ_f	λ	$ecmw_{t-1}$	*P(j-stat)*
Unit Labor Cost (Non-farm)	0.278 (0.047)	0.711 (0.044)	−0.007 (0.004)	0.022 (0.007)	0.938
Unit Labor Cost (All Sectors)	0.263 (0.062)	0.726 (0.061)	−0.004 (0.009)	0.035 (0.018)	0.835
Unit Total Cost (All Sectors)	0.272 (0.066)	0.723 (0.049)	0.031 (0.021)	0.002 (0.019)	0.949

Note: This table reports the GMM estimates of the reduced-form of equation (25), using labor unit cost and unit total cost as proxies for marginal cost. The estimation uses quarterly data over the period: 1966 Q1 to 2011 Q1. The instrument set includes four lags of the measure of real marginal costs proxy, inflation, output gap, wage and commodity price inflation. Standard errors are given in parenthesis below the coefficients. A 12-lag Newey-West estimate of the covariance matrix is used. The last column presents the Hansen's J-test for overidentifying restrictions.

Table 6: Robust GMM CUE Estimates

Instruments (A,B)	ω	ψ	γ_f	λ	P(j-stat)
			Unit Labor Cost (Non-farm)		
A	0.530 [0.00, 1.00]	0.910 [0.85, 1.00]	0.986 [0.48, 1.50]	0.008 [−0.040, 0.028]	0.058
B	0.209 [0.00, 0.82]	0.840 [0.00, 1.00]	0.623 [0.45, 1.32]	0.002 [*n.a.*, *n.a.*]	0.507
			Unit Labor Cost (All Sectors)		
A	0.322 [0.00, 0.87]	0.974 [0.82, 1.00]	0.788 [0.55, 1.50]	0.010 [−0.004, 0.037]	0.287
B	0.460 [0.40, 1.00]	0.840 [0.00, 1.00]	0.648 [0.46, *n.a.*]	0.011 [−0.093, *n.a.*]	0.614
			Unit Total Cost (All Sectors)		
A	0.280 [0.00, 0.77]	0.790 [0.00, 0.93]	0.737 [0.51, *n.a.*]	0.031 [0.004, *n.a.*]	0.339
B	0.290 [0.00, 1.00]	0.790 [0.73, 1.00]	0.733 [0.50, 1.18]	0.028 [−0.009, 0.081]	0.986

Note: This table reports continuously updating GMM estimates of the parameters of equation (25) under the assumption that $\beta = 1$, with Newey and West (1987) weight matrix. The estimation uses quarterly data over the period 1966:Q1 to 2011:Q1. *Instruments* A: 4 lags of inflation, real marginal cost proxy, output gap, wage and commodity price inflation; *Instruments* B: 3 lags of inflation and output gap. The numbers in square brackets are the 95% confidence interval based on the subset MQLR test. (n.a. implies that the inverted MQLR statistic is below the 0.95 line).

Table 7: Interest Rate Augmented NKPC: UTC with Cost Channel

ω	ψ	β	γ_b	γ_f	λ	$\lambda\lambda_i$	λ_i	P(j-stat)
Unit Labor Cost (Non-farm)								
0.309	0.921	0.993	0.251	0.745	0.004	0.002	0.530	0.991
(0.057)	(0.086)	(0.007)	(0.043)	(0.044)	(0.006)	(0.005)	(2.270)	
Unit Labor Cost (All Sectors)								
0.452	0.932	0.985	0.328	0.666	0.002	0.003	1.34	0.999
(0.041)	(0.036)	(0.006)	(0.021)	(0.021)	(0.002)	(0.001)	(1.68)	
Unit Total Cost (All Sectors)								
0.349	0.799	0.985	0.306	0.688	0.024	0.002	0.066	0.871
(0.009)	(0.039)	(0.003)	(0.026)	(0.025)	(0.009)	(0.001)	(0.028)	

Note: This table reports non-linear IV estimates (GMM) of the deep structural parameters in equation (29), using labor unit cost and total unit costs as proxies for marginal cost. The estimation uses quarterly data over the period: 1966:Q1-2011:Q1. The instrument set includes four lags of the real marginal cost proxy, inflation, output gap, wage inflation, commodity price inflation and 3-mth treasury bill rate. Standard errors are shown in brackets. For nonfarm labor share the instrument set includes four lags of the real marginal cost proxy, inflation, commodity price inflation and 3-mth treasury bill rate. A 12-lag Newey-West estimate of the covariance matrix is used. The last column presents the Hansen's J-test for overidentifying restrictions.