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Overtime Labor, Employment Frictions and the New Keynesian Phillips Curve

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Abstract

This paper presents a New Keynesian (NK) model that is extended to differentiate between straight time and overtime work. The model proposes that the New Keynesian Phillips curve (NKPC) should be estimated with marginal cost measured in terms of overtime labor; the resulting coefficient estimates are in accordance with theory and statistically significant for the hybrid NKPC (which allows for backward-looking price setters) but not for the purely forward-looking NKPC. In the hybrid model, backward-looking behavior is found to be predominant. The paper also shows that the incorporation of employment frictions (predetermined employment and convex adjustment costs) in NK models helps reconcile the frequent price changes found in the microdata with the degree of sluggishness in inflation adjustment to output changes at the macro level.

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1 Introduction

New Keynesian (NK) models have, by combining price stickiness with monopoly power at the firm level, contributed greatly to a better understanding of inflation dynamics. Despite their popularity these models have also been subject to criticism. Noticeably, Rudd and Whelan (2007) question the ability of these models to fit the data (in particular statistically insignificant estimates of the overall slope coefficient on marginal cost) and the use of the labor share as the appropriate measure of real marginal cost (one would expect marginal cost to be procyclical, since workers require a higher real wage in order to be induced to supply extra hours, which does not seem to be the case for the labor share).[1]

To address these issues, this paper extends the NK model to differentiate between straight time and overtime work.[2] Several facts motivate the introduction of overtime labor as important for the study of business cycles, inflation and marginal costs. Hansen and Sargent (1988), using a vector autoregression (VAR) approach, find that overtime work appears to adjust more rapidly to output innovations than full time employment.[3] Also, the number of persons working overtime (defined as working 41 hours and over) represents about 29% of the US workforce. Since overtime is paid at a significant premium (which must be at least 50% of the straight time hourly wage as mandated in the Fair Labor Standards Act of 1938) such a large share suggests that it plays an important role in how firms react to unexpected shocks.[4] These facts indicate that many firms are likely to be constrained in the short run in adjusting their total employment and resort to overtime work in order to respond to unexpected fluctuations.[5]

As the model and evidence indicate that marginal cost should be measured in terms of overtime costs, I construct a marginal cost measure using data on overtime labor. Unlike the labor share, marginal cost measured in overtime is shown to be procyclical. I then use this overtime-based marginal cost measure to estimate the New Keynesian Phillips Curve (NKPC) via generalized method of moments (GMM). The resulting coefficient estimates for the slope coefficient on real marginal cost of the purely forward-looking NKPC are negative and thus at odds with NK theory. The coefficient estimates, however, become both positive and statistically significant once the NKPC is augmented (in order to capture the apparent inertia in inflation observed in the data) to include some dependence on lagged inflation (which is found to be quantitatively dominant, therefore implying that the purely forward-looking model cannot be seen as a good approximation to inflation dynamics).

Another important criticism is that standard coefficient estimates of New Keynesian models imply that firms reoptimize prices roughly once every six quarters (Galí and Gertler, 1999). This is inconsistent with an average of less than two quarters found in the microeconomic data (Klenow & Kryvtsov, 2005). I show how the incorporation of employment frictions (predetermined employment and convex adjustment costs) helps reconcile reduced form estimates of NK models with the frequent price changes found in the microdata.

In particular, I assume that firms must commit to the number of workers they will employ before observing shocks to the economy (and face convex adjustment costs in changing employment numbers) but are free to adjust the number of employees working overtime. The introduction of employment frictions allows a reinterpretation of econometric estimations of the NKPC. If employment frictions are taken into account then the sluggishness in inflation adjustment to output changes becomes compatible with frequent price adjustments by firms. This happens because the presence of employment frictions represent a real rigidity in the sense of Ball and Romer (1990) which strengthen the degree of strategic complementarity among the pricing decisions of different firms. The same effect can be seen in firm-specific capital models but to a much smaller extent (this happens because labor represents a much larger share of firms' costs than capital).

The model presented here builds on Hall's (1996) paper. Hall also assumes the number of workers to be predetermined (but not that firms face convex adjustment costs in changing workforce numbers) and that firms resort to overtime work in order to adjust to unexpected fluctuations. I differ from Hall by assuming that firms have monopoly power and are subject to Calvo price stickiness as in conventional New Keynesian models, thus allowing for a role for monetary policy that does not exist in Hall's model. Bils (1987) also considers marginal cost to be a function of overtime work, estimating a marginal wage schedule from average hours per worker (which includes part-time workers) in manufacturing. I compute marginal costs from actual data on overtime work in nonagricultural industries.

Other important empirical references are Mazumder (2010) and Ravenna and Walsh (2008) who estimated the NKPC with models that also allow for adjustment along both the intensive and extensive margin in hours and Batini, Jackson and Nickell (2005) who presented evidence of the importance of employment adjustment costs in NKPC estimation. The work in this paper is also related to the literature on firm-specific capital. Altig, Christiano, Eichenbaum and Linde (2011), Sveen and Weinke (2004) and Woodford (2005) also depart from the assumption of rental spot factor markets and studied the implications for sticky price models of standard restrictions to capital formation.

2 The models

In this section I describe two business cycle models with sticky prices. The baseline model consists of an otherwise standard New Keynesian model which is extended to differentiate between straight time and overtime employment. The model therefore allows for adjustment along both the intensive and extensive margin in hours. This change suggests that marginal cost may be better measured by costs with overtime labor and not by the labor share of income. In the next subsection I add employment frictions (firms must commit to the number of workers they will employ before observing shocks to the economy and face convex adjustment costs in changing their full time workers) to the baseline framework. In the last subsection I compare the two models implications with respect to inflation dynamics and price frequency adjustment.

2.1 A New Keynesian model with overtime labor

2.1.1 Households

Consider an economy with a continuum of identical infinitely-lived agents on the interval [0,1] who have preferences over consumption of a single nondurable good C_t and leisure L_t.

The utility of each agent is

$$\sum_{s=0}^{\infty} \beta^s \left(\frac{1}{1-\sigma} {C_{t+s}}^{1-\sigma} + v \frac{1}{1-\chi} L_{t+s}^{1-\chi}\right) \tag{1}$$

where $0 < \beta < 1$ is the subjective discount factor, v is the utility from leisure and is strictly greater than zero, σ is the intertemporal elasticity of substitution and χ is the labor supply elasticity.

Each household is endowed with T units of time each period. L can take one of three values:

-T if the agent is unemployed;

-$T - h_1$ if the agent is employed but works the straight shift only;

-$T - h_1 - h_2$ if the agent works both the straight and overtime shift.

I follow Hansen (1985) and Rogerson (1988) and employ lotteries to convexify the commodity space. The end result is the utility specification below (see the web appendix for details), which is similar to the one used by Hansen and Sargent (1988) and Hall (1996)

$$\sum_{s=0}^{\infty} \beta^s \left[\frac{1}{1-\sigma} {C_{t+s}}^{1-\sigma} - a_1 (N_{1,t+s} - N_{2,t+s}) - a_2 N_{2,t+s} - a_0 (1 - N_{1,t+s})\right], \tag{2}$$

where $a_0 \equiv -v \frac{1}{1-\chi}(T)^{1-\chi}, a_1 \equiv -v \frac{1}{1-\chi}(T - h_1)^{1-\chi}, a_2 \equiv -v \frac{1}{1-\chi}(T - h_1 - h_2)^{1-\chi}$, $N_{1,t}$ is the share of agents who work the straight time shift (full time employment) and $N_{2,t}$ is the share of workers who work both shifts (overtime employment). This representative agent chooses a set of stochastic processes $\{C_{t+s}, N_{1,t+s}, N_{2,t+s}\}_{s=0}^{\infty}$ to maximize (2) subject to the following sequence of budget constraints

$$C_t = (D_t + W_{1,t} h_1 N_{1,t} + W_{2,t} h_2 N_{2,t} + T_t + TR_t - E_t \{Q_{t,t+1} D_{t+1}\})/P_t, \tag{3}$$

where P_t is the price of the final good, $W_{1,t}$ is the nominal hourly wage of the straight shift, $W_{2,t}$ is the nominal hourly wage of the overtime shift, D_t is the nominal payoff of the portfolio held at the end of period t, $Q_{t,t+1}$ is the stochastic discount factor, TR_t are government transfers and T_t denotes firms profits. The price of a one period bond is given by $R_t^{-1} = E_t Q_{t,t+1}$ where R_t denotes the gross nominal interest rate.

The resulting first-order conditions (FOC) are

$$R_t^{-1} = \beta E_t \left\{ (C_{t+1}/C_t)^{-\sigma} (P_t/P_{t+1}) \right\}, \tag{4}$$

$$\frac{W_{1,t}}{P_t} h_1 C_t^{-\sigma} = (a_1 - a_0), \tag{5}$$

$$\frac{W_{2,t}}{P_t} h_2 C_t^{-\sigma} = (a_2 - a_1). \tag{6}$$

These conditions represent the optimal consumption/savings and labor supply decisions of the economy's representative agent (it is important to note that wages are assumed to be flexible in this model).

2.1.2 Firms

Final good firms The final consumption good, Y_t, is produced by a perfectly competitive representative firm. The firm produces the final good by combining a continuum of intermediate goods ($Y(i)$, $i \in [0,1]$) using a Dixit-Stiglitz technology

$$Y_t = [\int_0^1 Y_t^{(\epsilon-1)/\epsilon}(i) di]^{\epsilon/(\epsilon-1)}. \tag{7}$$

Profit maximization implies the following demand for the ith good:

$$Y_t(i) = (P_t/P_t(i))^{\epsilon} Y_t, \tag{8}$$

where P_t is an index cost of buying a unit of Y

$$P_t = [\int_0^1 P_t^{1-\epsilon}(i)di]^{1/(1-\epsilon)}. \tag{9}$$

Intermediate good firms Each intermediate good is produced by a monopolist firm according to the following production function

$$Y_t(i) = A_t(h_1 N_{1,t}^{1-\alpha}(i) + h_2 N_{2,t}^{1-\alpha}(i)), \tag{10}$$

where A_t represents the level of technology, assumed to be common to all firms and to evolve exogenously over time (according to an autoregressive process $\ln(A_t)=(1-\rho_A)\ln(A)+\rho_A\ln(A_{t-1})+\varepsilon_t^A$ where ε_t^A is a zero mean white noise process). The above production function is similar to the one used by Hansen and Sargent (1988) and Hall (1996).[6]

The i^{th} intermediate good firm chooses $P_t(i)$, $Y_{t+j}(i)$, $N_{1,t+j}(i)$, $N_{2,t+j}(i)$ to maximize profit subject to (8) and (10) as well as its price-setting constraints and takes P_{t+j}, Y_{t+j}, $W_{1,t+j}$, $W_{2,t+j}$ as given. Formally, it maximizes

$$\sum_{j=0}^{\infty} \theta^j E_t \left\{ Q_{t,t+j}[P_t(i)Y_{t+j}(i) - W_{1,t+j}h_1 N_{1,t+j}(i) - W_{2,t+j}h_2 N_{2,t+j}(i)] \right\}, \tag{11}$$

where θ is the probability the firm will not be able to optimally reset its price in a given period. The resulting first-order conditions are:

$$E_t \sum_{j=0}^{\infty} (\theta\beta)^j \Lambda_{t,j} \frac{P_t}{P_{t+j}} Y_{t+j}(i)[P_t(i) - \mu P_{t+j} MC_{t+j}(i)] = 0, \tag{12}$$

$$\frac{W_{1,t}/P_t}{(1-\alpha)A_t N_{1,t}^{-\alpha}(i)} = MC_t(i), \tag{13}$$

$$\frac{W_{2,t}/P_t}{(1-\alpha)A_t N_{2,t}^{-\alpha}(i)} = MC_t(i), \tag{14}$$

where $P_t MC_t(i)$ denotes the Lagrange multiplier with respect to the production function constraint and can be interpreted as the firm's marginal cost, $\Lambda_{t,j} = (\lambda_{t+j}/\lambda_t) = (C_{t+j}/C_t)^{-\sigma}$ and $\mu = \epsilon/(\epsilon - 1)$ is the steady state markup of price over marginal cost.

The first order condition for the firm's price setting behavior (equation 12) is similar to the standard New Keynesian model (price is a function of all future expected marginal costs). Equation (13) and (14) imply that inputs adjust to equalize the marginal cost across different factors, where the marginal cost of a factor is the ratio of the factor price to the marginal product. Equation (14) is particularly important since it suggests that overtime labor costs (and not the firm's total labor input costs) should be used to proxy marginal cost. In constrast, the empirical literature starting with Galí and Gertler (1999) has focused on the labor share or output gap to proxy marginal cost (an exception is Mazumder, 2010).

2.1.3 Market clearing and monetary policy rule

Market clearing in the goods market requires

$$Y_t = C_t \tag{15}$$

this equation represents the economy's aggregate resource constraint. Finally, when prices are sticky the equilibrium path of real variables cannot be determined independently of monetary policy. In other words: monetary policy is non-neutral. The model is closed by assuming the central bank follows a simple interest rule of the form:

$$r_t = \gamma_\pi \pi_t + \gamma_y y_t + s_t \tag{16}$$

where $\pi_t = p_t - p_{t-1}$ is inflation and lower case letters are used to denote variables in log deviation from the steady state. s_t is a monetary policy shock which follows an AR(1) process: $s_t = \rho_s s_{t-1} + \varepsilon_t^s$ where ε_t^s is a zero mean white noise process.

2.2 A New Keynesian model with overtime labor and employment frictions

In this section I introduce employment frictions to the New Keynesian model outlined previously.[7] The basic structure is identical to the model presented in section 2.1, the only differences are that firms must now choose $N_{1,t}(i)$ before the shocks to the economy are known and face convex adjustment costs when changing the number of full time employees. The adjustment cots function is

$$H_t(i) = H(\frac{N_{1,t+1}(i)}{N_{1,t}(i)})N_{1,t}(i), \tag{17}$$

where $H_t(i)$ represent purchases by the firm of the final good. The function $H(\cdot)$ is an increasing and convex function, of the usual kind assumed in neoclassical investment theory which satisfies, near a zero growth rate of employment, $H(1)i = \delta_{N1}$, $H'(1) = 1$ and $H''(1) = \epsilon_{\psi N1}$, where δ_{N1} is an exogenous separation rate and the parameter $\epsilon_{\psi N1}$ measures the employment adjustment costs in a log-linear approximation to the equilibrium dynamics. This implies that in the steady state to which the economy converges in the absence of shocks, the rate of hiring required to maintain the economy's employment is δ_{N1} times the steady state employment N_1. This allows δ_{N1} to be interpreted as the exogenous quit rate in employment. It also implies that near the steady state, a marginal unit in hiring expenses increases employment by an equal amount (as there are locally no adjustment costs). These assumptions are similar to those made by Woodford (2005) and Sveen and Weinke (2004) in a context of capital adjustment costs.

In this model the i^{th} intermediate good firm must choose $P_t(i)$, $Y_{t+j}(i)$, $N_{1,t+j+1}(i)$, $N_{2,t+j}(i)$ to maximize profit, which is now given by

$$\sum_{j=0}^{\infty} \theta^j E_t \left\{ Q_{t,t+j}[P_t(i)Y_{t+j}(i) - W_{1,t+j}h_1 N_{1,t+j}(i) - W_{2,t+j}h_2 N_{2,t+j}(i) - P_{t+j}H_{t+j}(i)] \right\} \tag{18}$$

subject to (8), (10) and (17) as well as its price-setting constraints and takes P_{t+j}, Y_{t+j}, $W_{1,t+j}$, $W_{2,t+j}$ as given. The first-order condition for the firm's price-setting behavior (12) and for $N_{2,t+j}$ (14) remain identical. Only the firm's optimal employment decision, previously given by (13), is changed. It is now given by

$$H'(\frac{N_{1,t+1}(i)}{N_{1,t}(i)}) = E_t \beta \Lambda_{t,1}[\rho_{t+1}(i) + \frac{N_{1,t+2}(i)}{N_{1,t+1}(i)} H'(\frac{N_{1,t+2}(i)}{N_{1,t+1}(i)}) - H(\frac{N_{1,t+2}(i)}{N_{1,t+1}(i)})], \tag{19}$$

with

$$\rho_{t+1}(i) = -\frac{W_{1,t+1}}{P_{t+1}} h_1 + \frac{W_{2,t+1}}{P_{t+1}} h_2 \frac{MPN_{1,t+1}(i)}{MPN_{2,t+1}(i)}, \tag{20}$$

$$\frac{MPN_{1,t+1}(i)}{MPN_{2,t+1}(i)} = N_{2,t+1}^{\alpha}(i) \frac{h_1}{h_2} N_{1,t+1}^{-\alpha}(i) = [\frac{1}{h_2} Y_{t+1}(i) A_{t+1}^{-1} - \frac{h_1}{h_2} N_{1,t+1}^{1-\alpha}(i)]^{\alpha/(1-\alpha)} \frac{h_1}{h_2} N_{1,t+1}^{-\alpha}(i), \tag{21}$$

where the second equality is obtained by using (10) to substitute out N_2.

(19) takes a similar form to the FOC for the firm's investment decision found in Sveen and Weinke (2004) or Woodford (2005). It should be noted that a firm's marginal return to N_1 is measured by the marginal savings in its overtime costs as opposed to its marginal productivity. This arises from firms being demand constrained, which implies that a firm's benefit from having an additional worker derives from the fact that this allows it to produce the quantity demanded with less overtime work.

It is also important to observe that while equation (12) which describes the firm's price-setting behavior remains unchanged, the firm's choices here are more complex than in standard sticky price models. Since a firm's choice of full time employment is among the determinants of its marginal product of labor, I cannot solve the price setting problem without considering the firm's optimal employment behavior. The reason for this is that N_1 is not purchased on a spot market. A firm's marginal cost therefore depends on its present full time employment numbers and these depend on the firm's decisions in previous periods, including its price-setting decisions. This problem, however, is very similar to the case of firm-specific capital solved by Woodford (2005). Following Woodford (2005), I solve this problem by means of an undetermined coefficients method.

The firm's optimality condition for N_2 given by (14) is also unaltered with respect to the previous model. However, when employment is predetermined overtime labor costs become the only way to measure marginal cost. For this reason, in the empirical section I will focus only on (14) as an alternative marginal cost measure to the labor share.

The economy's resource constraint (15) is also changed and is now given by

$$Y_t = C_t + H_t, \tag{22}$$

where

$$H_t = [\int_0^1 H_t(i)di], \tag{23}$$

stands for aggregate employment adjustment costs.

2.3 Inflation dynamics

In both models the economy's price inflation equation takes the form

$$\pi_t = \beta E_t \pi_{t+1} + \gamma mc_t, \tag{24}$$

where γ is a function of the model's structural parameters and lower case letters are again used to denote variables in log deviation from the steady state.[8] This equation is often referred to as the NKPC.

The dynamic relationship between inflation and average real marginal cost may be identical in structure for both models, but the magnitude of γ is different between the models. In the New Keynesian model with no employment frictions we have that

$$\gamma = \frac{(1-\theta)(1-\theta\beta)}{\theta}\Theta, \tag{25}$$

with $\Theta = \frac{1-\alpha}{1-\alpha+\alpha\epsilon} \leq 1$. This is identical to the Basic New Keynesian model (e.g., Galí, 2008), so the introduction of overtime employment in the model does not imply any important change in the dynamic relationship of inflation or on the numerical magnitude of γ. Notice, however, that γ is strictly decreasing in the index of price stickiness, θ, and in the measure of decreasing returns α (this occurs because under decreasing returns to scale ($\alpha > 0$), marginal cost is no longer independent of the level of production and, hence, is not common across firms). This means that for a given value of γ a larger α implies a smaller degree of price stickiness (a lower θ).

The introduction of employment frictions, however, does change the predicted slope of the Phillips curve trade-off to an extent that can be quantitatively significant. When employment frictions are present this slope is given by

$$\gamma = \frac{(1-\theta)(1-\theta\beta)}{\theta}\phi_{N1}^{-1}, \tag{26}$$

with

$$\phi_{N1}^{-1} = \frac{1-\alpha}{1-\alpha+\alpha\epsilon\left[1+\frac{h_1}{h_2}(\frac{N_1}{N_2})^{1-\alpha}\right]+\varphi(\alpha,\beta,\theta,h_{1,}h_{2,}N_{1,}N_{2,},\nu_1,\nu_2)},$$

where ν_1 and ν_2 are the coefficients to be determined using the method developed in Woodford (2005). Woodford (2005) shows that a non-explosive solution to the firm's decision problem exists in the case of large enough adjustment costs. Note that $\left[1+\frac{h_1}{h_2}(\frac{N_1}{N_2})^{1-\alpha}\right] > 1$ and $\varphi(\cdot) \geq 0$, so one can conclude that $\phi_{N1}^{-1} \leq \Theta \leq 1$ (these inequalities are strict if $\alpha > 0$). This happens because employment frictions consist of real rigidities in the sense of Ball and Romer (1990) which strengthen the degree of strategic complementarity among the pricing decisions of different firms.

3 Model estimation

This section describes the dataset used, how to construct a real marginal cost measure based on overtime labor and the GMM estimates of the reduced form Phillips curve.

3.1 Data

The data used will be quarterly (employment numbers and interest rates series were converted to quarterly by averaging monthly observations), seasonally adjusted, U.S. time series.[9] The endogenous regressors necessary to estimate the NKPC consist of inflation (the log difference of the GDP deflator) and a measure of real marginal cost. Two alternative real marginal cost measures will be used in the estimation. The labor share, which is also referred to as real unit labor cost (RULC), and a new marginal cost measure based on overtime costs. To construct the latter I make use of employment and hours data series from the BLS Current Population Survey as well as data on real GDP and real compensation per hour in the nonfarm business sector. The employment and hours series are: $N_{1,t}$ (persons who worked 35 hours and over per week), $N_{2,t}$ the share of persons working overtime (number of persons who worked 41 hours and over per week) and the average overtime hours shift ($h_{2,t}$).[10]

For the exogenous instruments I will make use of lagged variables of the endogenous regressors and also the output gap (obtained by quadratically detrending real GDP per capita), wage inflation (the log difference of real compensation per hour in the nonfarm business sector), commodity price inflation (the log difference of the commodities consumer price index) and the long-short interest rate spread (the log of the 10 year treasury rate minus the log of the 1 year treasury rate).

All data was obtained from either the BLS or the St. Louis Fed website.[11]

3.2 Constructing a marginal cost measure based on overtime labor

Equation (14) suggests that marginal cost should be a function of overtime labor. This is common to both models described in section 2. However, to compute it one needs a series for aggregate productivity (A_t). Fortunately, this can easily be estimated from the data at hand. Rearranging the production function (10) shows that A_t should equal $\frac{Y_t}{h_1 N_{1,t}^{1-\alpha} + h_2 N_{2,t}^{1-\alpha}}$. Assuming α to be 0.33 and h_1 equal to 516 (the quarterly value for the straight time shift if one assumes it to be 40 hours per week), it is then easy to construct a series for aggregate productivity

$$A_t = \frac{Y_t}{h_1 N_{1,t}^{1-\alpha} + h_{2,t} N_{2,t}^{1-\alpha}}. \tag{27}$$

by using data on real GDP per capita (Y_t), the average overtime hours shift ($h_{2,t}$), $N_{1,t}$ and $N_{2,t}$.[12] I then construct the following measure of real marginal cost, which I will refer to as real overtime labor cost (ROLC):

$$ROLC_t = \frac{(1 + pr)W_t}{(1 - \alpha)A_t N_{2,t}^{-\alpha}} \tag{28}$$

where W denotes real compensation per hour in the nonfarm business sector (in levels) and pr for the wage premium on overtime hours. This gives a measure of real marginal cost consistent with the model outlined in section 2 (see Eq., 14). Finally, since the NKPC is written in log deviations from the steady state, I take the log of the resulting series and de-mean it (this means that the end series is not affected by the choice of value of pr as this term effectively cancels out).

Figure 1 displays the ROLC series and the other two more commonly used measures of marginal cost in the literature: the demeaned log of the labor share (RULC) and H-P detrended real GDP per capita (y_t). Two observations are striking about this figure. The first observation is how much more volatile the ROLC is than the other two marginal cost measures. The second observation is that the ROLC series is characterized by large short run movements but with quick return to its mean (its persistence is considerably smaller than the other measures). This is not surprising since we already knew that the cyclical volatility of overtime labor is about twice that of real GDP and full time employment (see Hall, 1996) and, because it is paid with a significant premium, firms will choose to hire new workers for very persistent fluctuations. It is also clear that ROLC tends to comove positively with H-P detrended real GDP whereas RULC does not (this conclusion is robust if one uses quadratically detrended real GDP instead).

Table 1 displays some key statistics for the three marginal cost measures and confirms these observations. The ROLC is much more volatile than either RULC or H-P filtered real GDP per capita, and much less persistent. The labor share, with a correlation of -0.14 with H-P filtered real GDP per capita, does appear to be countercyclical. For this reason, several authors have argued that the labor share is not a good proxy for marginal cost.[13] Using overtime data to measure real marginal cost appears to address this criticism. The ROLC series has a clearly positive correlation (0.39) with the H-P detrended real GDP. This is consistent with Bils (1987) and Mazumder's (2010) results for the manufacturing industry whose marginal cost measures also rely on overtime costs.[14] All three series are positively correlated with current and future inflation (this is very relevant, because the most important reason why Mazumder's marginal cost measure proves to be incompatible with the NK model is that it is negatively correlated with inflation). This is consistent with the theory, as inflation in the NK model is equal to the expected discounted sum of future real marginal costs. Curiously, while the ROLC series is positively correlated with current and future inflation, it is essentially uncorrelated with past inflation. This could be an indication that it is correctly measuring firms' current costs at the margin as changes to these, from unanticipated shocks, would affect current and future pricing decisions but not prices previously set. Finally, both ROLC and H-P filtered real GDP have positive correlation with current and future inflation growth ($\Delta\pi_t = \pi_t - \pi_{t-1}$) whereas RULC does not.

3.3 GMM estimation of the NKPC

3.3.1 Reduced form estimates of the purely forward-looking NKPC

I estimate the NKPC for both RULC and ROLC for the period 1977Q3–2006Q3 with GMM, making use of the orthogonality condition

$$E_t \{(\pi_t - \gamma mc_t - \beta\pi_{t+1})z_t\} = 0, \tag{29}$$

where z_t is the instrument set. For robustness purposes, two sets of instruments are used. The first set of instruments is composed of four lags of inflation, the marginal cost variable (RULC or ROLC), the output gap (quadratically detrended output), the long-short interest rate spread, wage inflation and commodity price inflation. This is the same instrument set used by Galí and Gertler (1999). The second set of instruments is smaller in order to minimize the potential estimation bias that is known to arise in small samples when there are too many over-identifying restrictions (see, e.g., Staiger & Stock, 1997). It consists of only four lags of inflation and two lags of the marginal cost variable, the output gap, the long-short interest rate spread, wage inflation and commodity inflation (this is similar to the instrument set used in Galí, Gertler, & López-Salido, 2005). In all regressions a Newey-West heteroskedasticity and autocorrelation consistent (HAC) weighting matrix was used with the lag order selected by Newey and West's (1994) optimal lag-selection algorithm.

Table 2 displays the estimation results. For RULC with both sets of instruments γ is positive but not statistically significant at the 5% level. This is consistent with Rudd and Whelan (2007) and Ravenna and Walsh (2008) who also obtained positive but insignificant estimates for γ when using the labor share.[15] When ROLC is used to proxy for marginal cost the estimate of γ is negative with both sets of instruments (but only at a statistically significant level with the first instrument set).[16] This represents a rejection of the model (a marginal cost increase should be associated with an increase in inflation). The reason why γ is positive with RULC but negative with the ROLC measure is linked to the correlation with future inflation growth. This is easy to understand if one assumes $\beta = 1$ and rearranges the NKPC as $E_t\pi_{t+1} - \pi_t = -\gamma mc_t$. That is, the purely forward-looking NK model predicts that real marginal cost should be negatively related to future inflation growth, which is true for the RULC measure but not for the ROLC series (as seen in Table 1). For this same reason, negative estimates of γ were also obtained by Mazumder (2010) with a procyclical measure of marginal cost in manufacturing and Galí and Gertler (1999) with an output gap measure.

Table 2 also reports statistics that are indicative of the quality of the instruments used. A good instrument must be both correlated with the included endogenous variables and orthogonal to the error. The former condition may be tested by examining the fit of the first stage regressions.[17] One rule of thumb is that for a single endogenous regressor, an F statistic below 10 is cause for concern (Staiger & Stock, 1997). The Anderson and Rubin (1949) F test of the significance of the endogenous regressors (denoted as A-R test) in the structural equation being estimated readily rejects its null hypothesis. Also, both the conventional and the Angrist-Pischke (A-P) first stage F statistics for each endogenous regressor are included in Table 2.[18] In all regressions the first stage F statistic values reported are quite high, indicating that the endogenous regressors are relevant. Finally, to test the validity of the orthogonality conditions Table 2 includes the p-values of Hansen's J test of overidentifying restrictions (Prob. J). In all regressions the null hypothesis that the instruments used are exogenous is not rejected by the J test.

3.3.2 Reduced form estimates of the hybrid NKPC

One of the central criticisms (see page 205 of Woodford, 2003) of the purely forward-looking NK model estimated in the previous subsection is its inability to capture the apparent inertia in inflation (that is, lagged inflation values seem an important determinant of current inflation). To address this criticism Galí and Gertler (1999) extended the NK model to allow for a subset of firms that use a backward-looking rule of thumb. In this “hybrid” model a fraction ω of firms set its price equal to the average price chosen in the previous period, with a correction for inflation based on the lagged inflation rate. The remaining firms set prices optimally subject to Calvo constraints on price setting (as described in section 2).

Importantly, the rejection of the NK model in the previous subsection may have been caused by model misspecification arising from the absence of lagged values of inflation in the regressions of the purely forward-looking model (leading to omitted variable bias in the estimates). I estimate the hybrid NKPC for both RULC and ROLC according to the moment condition (for details see Galí & Gertler, 1999):

$$E_t \left\{ (\pi_t - \gamma_h mc_t - \gamma_f \pi_{t+1} - \gamma_b \pi_{t-1}) z_t \right\} = 0, \tag{30}$$

where

$$\begin{aligned} \gamma_h &= \frac{\theta}{\Upsilon}(1-\omega)\gamma, \\ \gamma_f &= \frac{\beta\theta}{\Upsilon}, \\ \gamma_b &= \frac{\omega}{\Upsilon}, \end{aligned} \tag{31}$$

with $\Upsilon = \theta + \omega[1 - \theta(1-\beta)]$. The instrument sets used are those described in the previous subsection and an identical methodology is used to correct for heteroskedasticity and autocorrelation. Table 3 displays the results. Just as in the purely forward-looking case, the coefficient on real marginal costs is positive (0.01 with the large instrument set and 0.02 with the reduced instrument set) but not statistically significant when the RULC series is used. Both the reduced form coefficients on lagged and expected inflation are statistically significant and of approximately similar size (with values varying between 0.4 to 0.6). These results are consistent with those in Rudd and Whelan (2007). The estimates differ quite significantly when the ROLC measure is adopted as a proxy for real marginal cost. In this case γ is both positive (and quantitatively about twice as large as when the RULC series is used, with estimates varying between 0.02 to 0.04) and statistically significant. There are equally striking differences with respect to the estimates for the reduced form coefficients on lagged versus expected future inflation. In the regressions with ROLC, lagged inflation is clearly predominant over expected future inflation (both are, however, statistically significant). With the large instrument set γ_b estimate is 0.65 (about twice that of γ_f which is 0.33) and with the reduced instrument set 0.76 (while γ_f is estimated to be only 0.22). The results with the ROLC also compare favorably with the marginal cost measures of Mazumder (2010) and Ravenna and Walsh (2008) since those series resulted in negative estimates of γ for both the forward-looking NKPC and the hybrid NKPC.

As in the purely forward-looking model, the J test confirms the validity of the overidentifying restrictions in all regressions. However, the low A-P first stage F statistics for future inflation indicate a potential weak instruments problem in the regressions.

4 Evidence on price frequency changes and the NK model

To infer the degree of price frequency adjustment from the reduced form estimates one needs first to calibrate several other parameters (see Eqs., 25, 26) which in the case of the model with employment frictions is all of the model's parameters apart from those related to the Taylor rule and exogenous shocks. However, values for the latter are also set in the calibration section in order to plot impulse response functions to illustrate the intuition for the results.

The first subsection describes the choice of parameter values, the second subsection explains the importance of employment frictions to reconcile NKPC estimates with the micro evidence on price adjustment and finally the last subsection presents results for the NK model's structural parameters obtained from the reduced form estimates of the last section under certain assumptions on factor specificity.

4.1 Calibration

The period length is one quarter and the discount rate is set at $\beta = 0.99$. I assume a value of one for σ, the intertemporal elasticity of substitution. The representative agent's leisure utility parameter υ and the labor supply elasticity χ are calibrated so that $N_1 = 0.46$ and $N_2 = 0.16$ (their time series means in per capita terms). The agents time endowment, T, is set at 1369, implying agent's have 15 hours per day available for work and leisure activities. I assume the straight time shift to be 40 hours a week, implying a quarterly value of 516 for h_1. I choose the overtime shift h_2 to be equal to 155, the mean of overtime hours.

I choose $\epsilon = 7.6667$ (which implies a frictionless steady state markup of 15%), α is set at 0.33, the quit rate in employment (δ_{N1}) is chosen to be 0.1 (consistent with the empirical evidence for the U.S., see Shimer, 2005) and $\epsilon_{\psi N1}$, the curvature on labor adjustment costs, to be 2 (the midpoint estimate of Cooper & Willis, 2002). The values of β, σ, ϵ and α are the same as in Woodford (2005).

For the stochastic shocks and interest rate rule I adopt the same calibration as Galí (2008). So ρ_A is set at 0.9 and ρ_s is assumed to be equal to 0.5. The inflation and output weights (γ_π, γ_y) of the Taylor rule are set at 1.5 and 0.125 respectively, which are consistent with observed variations in the Federal Funds rate over the Greenspan era (see Taylor, 1999).

4.2 Implications of employment frictions for the frequency of price adjustment

The small estimates of the slope of the NKPC, γ, in the literature imply a period of price stickiness much larger than that found using micro data. The Calvo price staggering assumption implies an average time period for which a price is fixed of $1/(1-\theta)$. The typical value estimated (e.g., Galí & Gertler, 1999), $\theta > 0.8$, then implies the average time period between price changes to be larger than five quarters. Table 4 reports estimates from Klenow and Kryvtsov (2005) for the mean monthly fraction of items changing prices, fr, using micro data (from New York, Los Angeles and Chicago). These estimates imply an average price duration (APD) of 3.4 months

($APD = 1/fr = \frac{3}{1-\theta}$) for all prices (4.3 months excluding sales) resulting in a value of θ of 0.12 (0.3 if one excludes sales).

In this subsection, I explore how introducing employment frictions helps reconcile this apparent discrepancy between macro and micro estimations. Table 5 shows the values of θ (and APD) implied by a given estimate of γ (which in the literature vary mostly between 0.02–0.05). Three different cases are considered. The Basic New Keynesian model (no employment frictions) under constant returns to scale (denoted as CRS, α is set to 0), the Basic New Keynesian model (no employment frictions) under decreasing returns to scale (DRS, α is set to 0.33), , and in the last column the New Keynesian model with overtime labor and employment frictions. Apart from the CRS case where α is equal to zero, all other parameters are set as described in previous subsection.

I begin by looking at the CRS case since it is the most commonly assumed in the literature. This is clearly not consistent with the micro evidence reported by Klenow and Kryvtsov (2005). Even for high values of γ the implied average price duration is higher than five quarters. We can see that under the DRS model there is a significant reduction in the implied price stickiness value (the values of θ vary between 0.7 and 0.6), yet it still falls very far behind the values in the micro estimations, especially for the lowest values of γ. These values are very close to those obtained by Woodford (2005) in a firm-specific capital model, which is not surprising since the DRS model is essentially a model with fixed capital.[19] Adding employment frictions has, however, a much larger effect, with θ varying between 0.4 and 0.3.[20] Even for the lowest values of γ the average price duration implied by the employment frictions model seems to be quite consistent with the micro evidence.

The difference in the frequency of price adjustment resulting from the introduction of employment frictions is well illustrated by the impulse response functions of the two models described in section 2. I set γ at 0.03 so that the two models are equivalent at the aggregate level. The remaining parameters are set as described in the calibration section. Figure 2 displays the responses of inflation and output for both models to a 1% productivity shock while figure 3 displays the responses for a 1% monetary policy shock. As can be clearly seen in both figures, for what are about the same changes in output the reaction of inflation to either shock is clearly larger in the model with employment frictions indicating significantly more frequent price adjustments.

The intuition is as follows: under decreasing returns to scale or in the presence of employment frictions, a firm's marginal cost is no longer independent of its own level of output (and a considerably steeper function of output under employment frictions). A firm that contemplates raising its price understands that this implies less demand and therefore less output. The reduced output implies a lower marginal cost. Other things being equal, the lower marginal cost induces a profit maximizing firm to post a lower price. The introduction of employment frictions then induces price-adjusting firms to keep their relative price close to the non-adjusters. Hence, the sluggishness of inflation responses to changes in output (low estimates of γ) can be reconciled with individual firms flexibility in changing prices.

Why is the effect of the introduction of employment frictions so strong (while capital is not)? The explanation seems to be in the output share of the constrained production factor. In the DRS model, the constrained factor share, α, is half of the unconstrained factor share (the labor input), whereas in the employment frictions model the constrained factor, full time employment, represents the most significant production factor ($h_1 N_1$ is about 4 times larger than $h_2 N_2$). Consider a value of γ of 0.02. If α were to be double it would imply a $\theta = 0.575$, a significantly smaller value. Alternatively, reducing the size of the straight time labor input relative to the overtime input in the employment frictions model leads to a substantial rise in the implied period between price adjustments. Lowering the steady state value of N_1 to 0.20 and the straight time shift (h_1) to 200 results in a value of θ equal to 0.632. Capital simply does not represent a large enough proportion of firms costs for the introduction of realistic levels of frictions in this factor to sufficiently reduce the elasticity of the desired price with respect to output.

4.3 Structural estimates of the NK model

The reduced form equation estimates are valid independently of the assumptions made regarding capital or employment rigidities. However, as noted by Woodford (2005) estimation of the NKPC "provides no direct evidence regarding the frequency of price adjustment, nor any way of testing which of the alternative possible assumptions about the specificity of factor markets is the correct one." Therefore, estimates of the structural parameters are highly conditioned by modelling assumptions and should be interpreted with care.

Structural parameters estimates for the two real marginal cost measures for both the purely forward-looking NKPC and hybrid NKPC are reported respectively in Tables 6 and 7 (the delta method was applied to find the standard errors). For the RULC series these estimates are obtained under the DRS case while for the ROLC the employment frictions model was used.

For the purely forward-looking model the estimated values of θ are close to 0.7 for the labor share with either instrument set. With the ROLC series the values found are nonsensical (not surprisingly since the theory requires $\gamma > 0$). For the hybrid model θ is found to be in the range 0.5–0.6 for the regressions with RULC while for the regressions with ROLC θ is between 0.2–0.3. The lower values for ROLC are the result of both a higher coefficient slope on marginal costs from the reduced form estimates and also of the assumption of employment frictions. Under the DRS assumption θ would be 0.42 with instrument set 1 and 0.26 with instrument set 2. The implied estimates of the fraction of backward-looking firms (ω) are in the 0.5–0.6 range for the ROLC series and in the 0.6–0.7 range for RULC. This is quite surprising given that the coefficients on lagged inflation are actually larger for the ROLC series. These results are in line with Rudd and Whelan's (2007) concerns on the difficulty of interpreting estimates on the relative importance of backward versus forward-looking behavior from hybrid models.

The estimation results (shown in the web appendix) in this and the prior section are robust to controlling for outliers and restricting β equal to unity (which implies $\gamma_b + \gamma_f = 1$ in the hybrid model).

5 Conclusion

This paper describes a NK model with straight time and overtime labor. The introduction of employment frictions allows the model to be consistent with both the micro evidence on the frequency of price adjustment and the reaction of inflation to movements in aggregate labor costs. Since firms are only allowed to change overtime hours to react to unexpected shocks, this model implies that firms' marginal costs should be measured by overtime work costs. I construct a marginal cost measure based on overtime costs which unlike the labor share is found to be procyclical. GMM estimation results using this new marginal cost measure are in accordance with theory (and statistically significant) for the hybrid NKPC but not for the purely forward-looking NKPC. Another important result is that lagged inflation is found to be quantitatively much more relevant than expected future inflation in estimates of the hybrid NKPC. The empirical results in this paper therefore suggest that overtime labor is important to obtain a more plausible measure of firms' marginal costs and that it is also necessary to include backward-looking behavior for a good description of inflation dynamics.

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Notes

[1]In chapter 3 Galí (2008) shows that log deviations in real marginal cost (mc_t) from steady state are positively related the log deviation of output from its flexible price counterpart, the *output gap* ($\tilde{y}_t$), in the basic NK model (that is $mc_t = \kappa\tilde{y}_t$ where $\kappa > 0$). Woodford (2003, p.181) shows this conclusion is not "special to the particular structure of production costs and demand assumed" and is true in a broad class of standard models. For real marginal cost to be countercyclical it would have to be the case that the business cycle is mostly driven by productivity shocks, since due to price stickiness output would not increase as much as its flexible counterpart. For all other conventional shocks (e.g, those considered in Smets and Wouters, 2007), even for other supply shocks such as wage-mark up shocks, the NK model predicts output to be positively correlated with the output gap. However the NK model also predicts a negative impact of productivity on hours worked. Given the strongly positive correlation between output and hours worked over the business cycle this implies that it would be hard to reconcile the NK model with a predominant role for productivity shocks over the cycle. The work of both Smets and Wouters (2007) and Galí and Rabanal (2004) confirms that productivity shocks do not seem to play a dominant role in driving output.

[2]The model allows for adjustment along both the intensive (changes in overtime employment) and extensive margin (changes in straight time employment) in hours. In the data, most fluctuations in aggregate hours worked come from the extensive margin. However, in standard versions of the NK model all fluctuations in aggregate hours are made along the intensive margin (that is, all the variation is in hours per worker). In this context it is relevant to make reference to the search-match literature which has also introduced fluctuations in aggregate hours worked resulting from the extensive margin in NK models, e.g., Walsh (2005), Trigari (2009) and Blanchard and Galí (2010).

[3]This is consistent with the work of Hamermesh (1993) which shows that hours per worker adjust more rapidly than employment.

[4]For a reference on the effects of overtime pay regulation see Trejo (1991).

[5]The fact that Hodrick-Prescott (H-P) filtered overtime employment is about twice as volatile as real GDP or straight time labor (see Hall, 1996) confirms there is an important business cycle dimension to it.

[6]This "shift work" production function was developed by Lucas (1970) and shown to be more "consistent with observed cyclical patterns in production and real wages" than the standard neoclassical and the fixed factor proportions production functions. Other papers which also make use of this production function are Sargent and Wallace (1974) and Sargent (1978).

[7]Studies using aggregate quarterly data, summarized in Hamermesh (1993), show the average lag in adjusting employment demand to be three to six months. At the micro level, employment adjustment costs are also found to be significant (for a survey see Hamermesh & Pfann, 1996), with some studies suggesting they amount to as much as one year payroll for the average worker.

[8]Please see the web appendix for details, concerning this subsection.

[9]The X-12-ARIMA filter was adopted whenever seasonally adjusted data was not available, except for the interest rate series which were left unadjusted.

[10]The series for $N_{1,t}$ was obtained by subtracting the number of part time workers (persons working less than 35 hours a week) from the total number of workers. A series for total overtime hours was obtained by removing total part time hours and straight time hours (assuming the straight time shift to be 40 hours per week) from the total number of hours worked in nonagricultural industries. This series was then divided by $N_{2,t}$ to obtain the average overtime shift series ($h_{2,t}$) which was then converted to quarterly by assuming a month to be equal to 4.3 weeks and summing the resulting monthly observations. The necessary data to obtain $N_{1,t}$, $N_{2,t}$ and $h_{2,t}$ has only been collected by the BLS since June 1976.

[11]The labstat codes of the BLS series used are: LNU02033235, LNU02033241, LNS12032197, LNU02033182, LNS12033120, LNS12035019 and LNU02033116. The series ID for the St. Louis Fed data are: CNP16OV, COMPRNFB, CUSR0000SAC, GDPC1, GDPDEF, GS1, GS10 and PRS85006173.

[12]In the model considered here the overtime shift is fixed, but since this represents another means by which firms can also vary overtime labor, I make use of the data available in this

aspect as well (the empirical results obtained are robust to either using a fixed or variable overtime shift).

[13]Rudd and Whelan (2007), point out that "the labor share tends to jump upward and reach a local peak near the onset of the NBER recessions." For the labor share to be a good proxy for real marginal cost and for real marginal cost to have a positive correlation with the output gap (which is implied by NK theory, as shown in chapter 3 of Galí, 2008), would imply that output was actually above potential during economic recessions.

[14]There are however several differences between ROLC and the marginal cost measure considered by Bils (1987) and Mazumder (2010). Bils and Mazumder's methodology is dependent on estimating a marginal wage schedule from average hours per worker (and on the function assumed for the marginal wage schedule). Also, Bils and Mazumder's marginal cost measure can only be computed for the manufacturing sector since the data used is not available at the aggregate level. On the other hand, Bils (1987) and Mazumder (2010) do not assume that the marginal product of overtime labor is independent from the amount of straight time labor hired by the firm, which is assumed in the production function (10) used here and in Hall (1996). It is therefore not clear that one methodology is preferable to the other.

[15]Ravenna and Walsh (2008) explain why Galí and Gertler's (1999) result is no longer obtained in updated samples (Galí & Gertler's, 1999, estimates were obtained with data from 1960Q1 to 1997Q4): "The cross-correlation between inflation and unit labor cost (Fig. 5) shows why the very fact of extending the sample up to 2007 causes the relationship to break down. Inflation is positively correlated with contemporaneous and future values of unit labor cost up to 1994—as predicted by the theory—while the cross-correlation is reversed in the sample 1995–2007."

[16]Mazumder (2010) and Ravenna and Walsh (2008) obtained similar results (negative coefficient estimates) when estimating the New Keynesian Phillips Curve with models that also allowed for adjustment along both the intensive and extensive margin in hours.

[17]These statistics were obtained by using an extension to Stata's ivregress command developed by Baum, Schaffer and Stillman (2010).

[18]The conventional first stage F statistic can be misleading with multiple endogenous variables, since it would have high values in cases when some instruments are strongly correlated with several endogenous variables while others are weak predictors. To correct for this Angrist and Pischke (2009) developed a modification of the first-stage F statistic.

[19]Sveen and Weinke (2004) when comparing the DRS model with the firm-specific capital model had already previously observed that: "The functional form of the inflation equation itself is only affected to some negligible extent by the feature of endogenous capital accumulation at the firm level."

[20]These results are robust to different values of the employment adjustment cost function ($\epsilon_{\psi N1}$ and δ_{N1}). For $\gamma = 0.02$, lowering the value of the separation rate (δ_{N1}) to 0.03 does not change the implied value of θ. For this same γ estimate, increasing the curvature on employment adjustment costs ($\epsilon_{\psi N1}$) from 2 to 3 would only raise θ from 0.456 to 0.458. Lowering $\delta_{N1}$to 0.03 and $\epsilon_{\psi N1}$ to 0.5 would make θ equal to 0.439.

6 Tables

Table 1: Comparison of marginal cost measures (1977Q3–2006Q3)

	Stand. Dev.	Correlation with								
		π_{t-1}	π_t	π_{t+1}	$\Delta\pi_t$	$\Delta\pi_{t+1}$	y_t	$RULC_{t-1}$	$ROLC_{t-1}$	y_{t-1}
$RULC_t$	0.021	0.59	0.57	0.55	-0.05	-0.05	-0.14	0.91		
$ROLC_t$	0.031	0.00	0.05	0.13	0.10	0.17	0.39		0.69	
y_t	0.014	0.13	0.18	0.22	0.11	0.09	1.00			0.86

Table 2: GMM reduced form estimates of the purely forward-looking NKPC (1977Q3–2006Q3)

	Instrument set 1				Instrument set 2			
	coef. est.	st. err.	F test	A-P F test	coef. est.	st. err.	F test	A-P F test
π_{t+1}	0.958	(0.024)	65.36	50.83	0.968	(0.061)	27.32	22.89
$RULC_t$	0.037	(0.019)	168.09	58.24	0.039	(0.049)	127.32	60.03
	Prob. J	0.980	A-R test	120.79	Prob. J	0.777	A-R test	124.62
π_{t+1}	0.992	(0.017)	70.63	73.44	1.003	(0.037)	29.06	29.84
$ROLC_t$	-0.034	(0.015)	39.95	38.43	-0.021	(0.023)	30.98	27.42
	Prob. J	0.993	A-R test	164.02	Prob. J	0.709	A-R test	122.67

Inst. set 1: four lags of inflation, the marginal cost variable, detrended output, the long-short interest rate spread, wage inflation and commodity inflation. Inst. set 2: four lags of inflation and two lags of the marginal cost variable, detrended output, the long-short interest rate spread, wage inflation and commodity inflation. In all regressions a Newey-West heteroskedasticity and autocorrelation consistent (HAC) weighting matrix was used with lag order selected by Newey and West's (1994) optimal lag-selection algorithm. HAC standard errors are shown in brackets.

Table 3: GMM reduced form estimates of the hybrid NKPC (1977Q3–2006Q3)

	Instrument set 1				Instrument set 2			
	coef. est.	st. err.	F test	A-P F test	coef. est.	st. err.	F test	A-P F test
π_{t-1}	0.544	(0.037)	437.95	30.02	0.583	(0.050)	398.79	33.72
π_{t+1}	0.441	(0.042)	189.03	14.20	0.396	(0.055)	89.56	6.43
$RULC_t$	0.011	(0.009)	418.15	174.72	0.018	(0.011)	310.76	173.92
	Prob. J	0.999	A-R test	200.46	Prob. J	0.846	A-R test	243.02
π_{t-1}	0.648	(0.057)	434.65	16.34	0.757	(0.079)	314.55	18.23
π_{t+1}	0.334	(0.061)	206.71	5.72	0.222	(0.082)	97.05	6.08
$ROLC_t$	0.023	(0.010)	108.03	92.78	0.042	(0.017)	62.19	27.33
	Prob. J	0.999	A-R test	184.93	Prob. J	0.832	A-R test	184.17

Inst. set 1: four lags of inflation, the marginal cost variable, detrended output, the long-short interest rate spread, wage inflation and commodity inflation. Inst. set 2: four lags of inflation and two lags of the marginal cost variable, detrended output, the long-short interest rate spread, wage inflation and commodity inflation. In all regressions a Newey-West heteroskedasticity and autocorrelation consistent (HAC) weighting matrix was used with lag order selected by Newey and West's (1994) optimal lag-selection algorithm. HAC standard errors are shown in brackets.

Table 4: Micro evidence on the frequency of price adjustment

Sample	fr	implied APD	implied θ
1. All Items			
All prices	0.293	3.413	0.121
Regular prices	0.233	4.292	0.301
2. Core Items			
All prices	0.26	3.846	0.220
Regular prices	0.207	4.831	0.379

The first column is from Klenow and Kryvtsov (2005) and gives the mean fraction of changing monthly prices, fr. APD is the implied mean number of months for which a price remains fixed. The last column gives us the implied probability of a price being fixed for a quarter ($APD = 1/fr = \frac{3}{1-\theta}$).

Table 5: Implications for average price duration of alternative assumptions about factor markets

	CRS ($\alpha = 0$)		DRS ($\alpha = 0.33$)		Employment Frictions	
γ	θ	APD	θ	APD	θ	APD
0.05	0.804	15.268	0.619	7.867	0.308	4.335
0.04	0.823	16.916	0.651	8.588	0.344	4.570
0.03	0.845	19.345	0.689	9.651	0.390	4.919
0.02	0.872	23.468	0.738	11.454	0.456	5.514

θ is the implied probability of a price being fixed for a quarter. APD is the implied mean number of months for which a price remains fixed ($APD = \frac{3}{1-\theta}$).

Table 6: Structural estimates of the purely forward-looking NKPC (1977Q3–2006Q3)

	RULC	ROLC
	θ	θ
Inst. set 1	0.672	1.034
	(0.069)	(54.530)
Inst. set 2	0.660	1.016
	(0.169)	(18.127)

Inst. set 1: four lags of inflation, the marginal cost variable, detrended output, the long-short interest rate spread, wage inflation and commodity inflation. Inst. set 2: four lags of inflation and two lags of the marginal cost variable, detrended output, the long-short interest rate spread, wage inflation and commodity inflation.

Table 7: Structural estimates of the hybrid NKPC (1977Q3–2006Q3)

	RULC			ROLC		
	ω	β	θ	ω	β	θ
Inst. set 1	0.660	0.908	0.590	0.547	0.892	0.316
	(0.173)	(0.166)	(0.057)	(0.172)	(0.171)	(0.135)
Inst. set 2	0.654	0.868	0.512	0.584	0.815	0.210
	(0.162)	(0.175)	(0.035)	(0.168)	(0.168)	(0.225)

Inst. set 1: four lags of inflation, the marginal cost variable, detrended output, the long-short interest rate spread, wage inflation and commodity inflation. Inst. set 2: four lags of inflation and two lags of the marginal cost variable, detrended output, the long-short interest rate spread, wage inflation and commodity inflation.

7 Figures

Figure 1: Marginal Cost Measures (1977Q3–2006Q3)

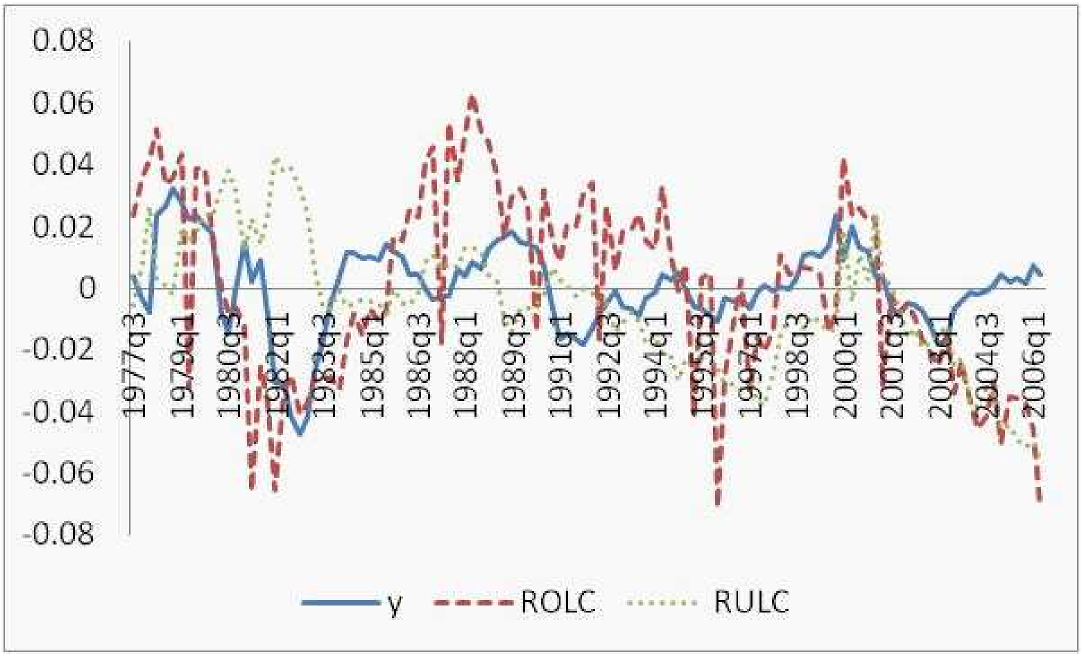

Figure 2: Inflation and output responses to a 1% Productivity Shock

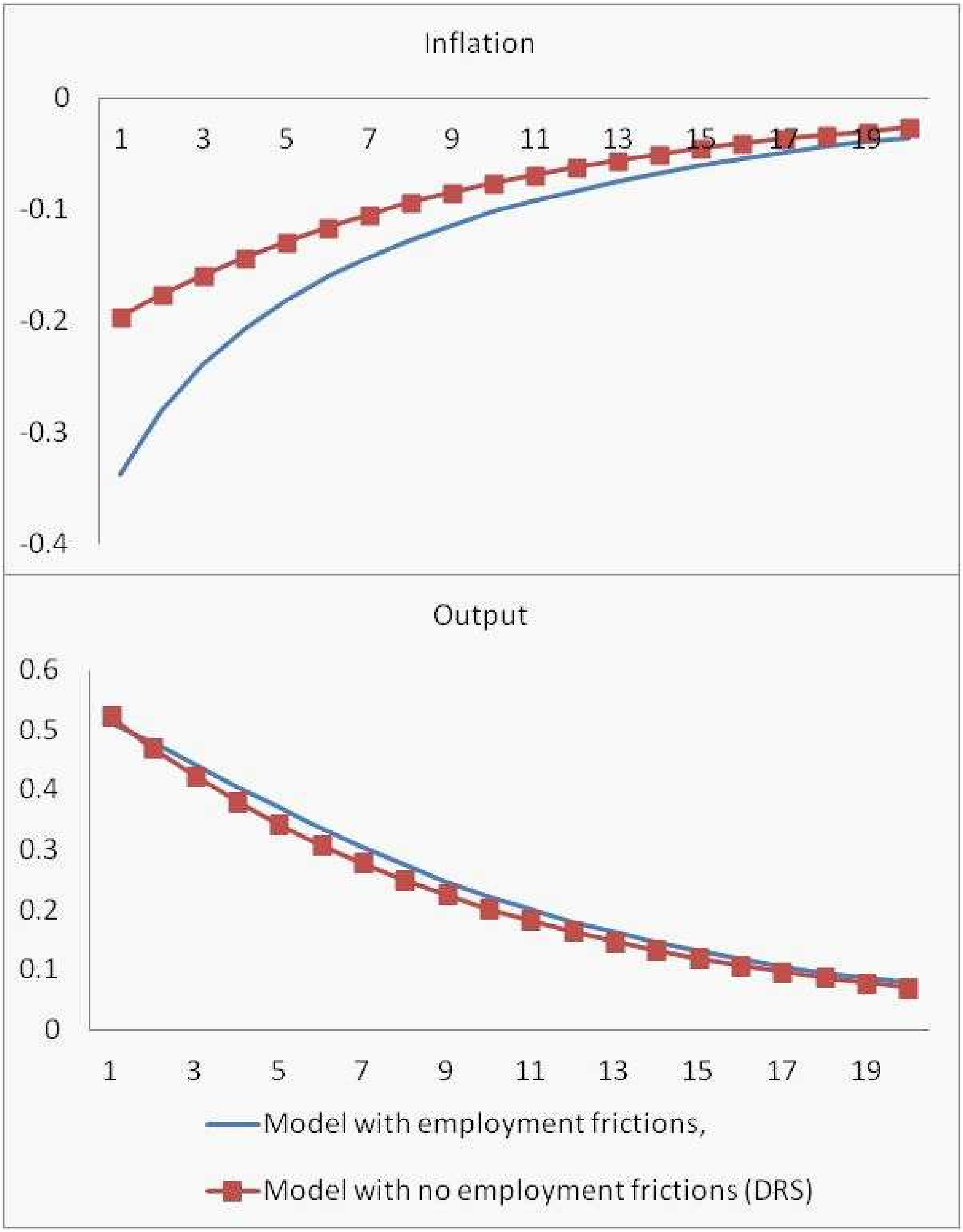

Figure 3: Inflation and output responses to a 1% Monetary Policy Shock