Estimation of New Keynesian Phillips Curve. The Case of Austria, France, Germany, Italy and UK

By

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Abstract:

This paper's focus is on the estimation of the baseline and hybrid model of the New Keynesian Phillips Curve for five European countries, using quarterly data for the period 1991 to 2005. The method employed here is GMM, using nonlinear specifications and instrument list, and also the weighting matrices are calculated in a consistent manner to heteroskedasticity and autocorrelation of unknown form. The results indicate that, although the coefficients have the desired sign, the labor share measuring the marginal cost of firms, under the Cobb-Douglas production function and constant returns to scale assumptions, is not the best choice for the driving force of inflation given these data, as it is significant only for two out of five countries. Thus, further research could improve the model fit by focusing on more precise measures of marginal cost under assumptions more consistent with the economic reality. Another feature of the results is that the forward looking behavior is significantly more important than the backward looking behavior for all five countries under consideration, but still the backward looking behavior cannot be neglected, as the coefficient on the lagged inflation is significant in all cases except for Germany.

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1. Introduction

After gathering a significant amount of work on the issue of the traditional Phillips curve, the modern literature now also focuses on the New Keynesian Phillips Curve (hereafter NKPC), which explains current inflation by expected future inflation and a measure of real economic activity. Information about the inflation dynamics is essential not only from the theoretical point of view, but it also has applicability in practice, with deep implications on the monetary policy conduct a country may choose to run. From this perspective, it is important that the policy makers should focus on the behavior of firms in setting their prices and on the inflation persistence[1], as these could give important hints on how to handle the monetary policy instrument to reach the desired target. Moreover, as the NKPC indicates, the policy makers should look into and check the existence of a relationship between short-run dynamics of inflation and real economic activity and how the expectations of future economic activity might affect the current price setting behavior.

The literature in the direction of the New Keynesian economy is mainly built on the early work of Taylor (1980), Fischer (1997) and Calvo (1983). In this framework, with monopolistic imperfect competition and nominal rigidities, the optimizing problem is characterized by costly price adjustments. More precisely, as Galí (2007) broadly points out, the first feature of the New Keynesian economy, as opposed to the classical economy, is the imperfect competition introduced in the goods market, where each firm has a constant elasticity of demand and sets the prices of the goods, instead of taking them as given. The

[1] According to Dossche and Everaert (2005), inflation persistence is defined as the speed with which inflation approaches slowly, rather than suddenly, to the central bank's target level after the occurrence of shocks in the economic activity or in the production costs.

second important feature and key assumption in this type of economy is the nominal rigidity encountered in the form of limitations on the regularity with which firms can adjust their nominal prices. The immediate implication of this characteristic is that the price setting becomes forward looking, since firms realize that their prices will stay effective for a certain time beyond the current period.

This paper contributes to the existing literature by combining both theoretical and empirical research into an analysis of the sustainability of NKPC for Austria, Germany, France, Italy and UK. I test the baseline model of the NKPC, as well as the hybrid model, which allows a fraction of backward looking firms in their decision of price setting. The method employed here is the Generalized Method of Moments (henceforth GMM), an instrumental variable technique which allows controlling for simultaneity caused by measurement error, an often argued issue associated with the using of the real marginal cost as a driving variable for inflation. Indeed, a persistent guidance is given in the relevant literature for further investigation into data measurement and more particularly in the measurement of the real marginal cost and its steady state.

The approach taken in this paper has the following features, common with those of Galí and Gertler (1999). First, I use a measure of real marginal cost instead of the output gap, since the natural level of output is unobservable. Second, the baseline model is accompanied by the hybrid model which allows a subset of firms to set their prices in a backward looking manner, this way accounting for inflation persistence. Thus, this extension of the baseline model permits an assessment of the departure from a pure forward looking model. Third, using the key model variables – the degree of price stickiness and the fraction of firms that use a simple rule of thumb to set their prices in a backward looking fashion – I derive all the structural parameters of the model.

The results of this paper indicate that the forward looking behavior is significant for all countries. Nevertheless, I find evidence of backward looking behavior as well, though the point estimates are not significant in all cases. The average duration in which prices remain unchanged is the lowest for Germany and UK and highest for France. The labor share as a measure of the marginal cost of firms turns out not to be the best choice for a driving variable of inflation. The problems stem mainly from measurement error and assumptions not fully in line with the reality of the economy.

The next section depicts the theoretical framework of the New Keynesian Phillips curve, presenting the baseline model, the unit labor cost as a measure of the real marginal cost and the hybrid model of the NKPC. Section 3 contains data description and methodology employed, while section 4 moves on to reporting the results of the estimation for each of the countries under analysis. The next section is about other empirical findings in the relevant literature, while the final section concludes.

2. Theoretical Framework

2.1. Price setting and Phillips Curve

The usual starting point for the derivation of the NKPC is an economy of monopolistically imperfect competitive firms which produce differentiated goods, but use the same technology which changes exogenously in time.

Following Calvo's (1983) model described in detail in Galí and Gertler (1999), in a particular period each firm can either change its price with a probability $1-\theta$ to a price p_t^* or keep it fixed with a probability θ. The probability of changing the price is independent of the time passed since the last price adjustment. Thus, the average duration in which a price remains fixed is given by $\frac{1}{1-\theta}$ and the degree of price stickiness is represented by θ. Given this setup, it can be shown that the aggregate price level p_t is a convex combination of the lagged price level which the share of firms not changing their prices will keep for the current period and the optimal price level chosen by firms which reset their prices in period t [2]. Thus,

$$p_t = \theta \cdot p_{t-1} + (1-\theta) \cdot p_t^* \tag{1}$$

Assuming that the steady state of inflation is zero and taking a log linear approximation around that steady-state, the aggregate inflation is given by:

$$\pi_t = (1-\theta) \cdot (p_t^* - p_{t-1})$$

[2] For a more extensive derivation, see Gali (2007) or the appendix of this paper.

This setup implies that inflation only appears because in any given period, firms adjusting their prices choose a different level of price from the aggregate price of the previous period.

Letting mc_t^n be the deviation of the log nominal marginal cost from its log steady state value and β the subjective discount factor, then a firm maximizes expected discounted profits taking into account the constraint implied by the cost of adjusting prices. Thus, the expression for the reset price can be written as follows:

$$p_t^* = \mu + (1 - \beta \cdot \theta) \cdot \sum_{k=0}^{\infty} (\beta \cdot \theta)^k \cdot E_t \left\{ mc_{t+k}^n \right\} \quad (2)$$

When setting the price at time t, a firm takes into account the expected future path of nominal marginal cost, knowing that it is possible that the prices remain fixed for multiple periods. A special case emerges from the formula above, the case of full flexible prices or in terms of the formula given, the case when θ is equal to zero. This implies that firms will only account the movements in the current marginal costs.

Continuing the notations and derivation from Galí (2007), letting inflation rate at time t be $\pi_t \equiv p_t - p_{t-1}$, mc_t the deviation of the firm's real marginal cost from its steady state value and combining equations (1) and (2), we get the following inflation equation:

$$\pi_t = \lambda \cdot mc_t + \beta \cdot E_t \left\{ \pi_{t+1} \right\} \quad (3)$$

where the coefficient on marginal cost depends on the proportion of firms which keep their prices fixed θ and the subjective discount factor β and is given by the relation:

$$\lambda = \frac{(1-\theta) \cdot (1 - \beta \cdot \theta)}{\theta}$$

Most of the empirical work on the literature of NKPC uses a measure of output gap as the driving variable of inflation instead of the marginal cost. In the standard framework of sticky prices without variable capital employed by Rotemberg and Woodford (1997) cited in Rubene and Guarda (2004), there is an approximate relationship between marginal cost and output gap. Denoting y_t the log of output and y_t^* the log of natural level of output, i.e. the level of output under full flexible prices, we can create one more notation for the output gap:

$$x_t \equiv y_t - y_t^*$$

Then, the relation between the marginal cost and the output gap can be written as:

$$mc_t = \kappa \cdot x_t \tag{4}$$

where κ is the output elasticity of marginal cost.

Combining equations (3) and (4) yields one of the main building blocks in the New Keynesian model:

$$\pi_t = \lambda \cdot \kappa \cdot x_t + \beta \cdot E_t \left\{ \pi_{t+1} \right\} \tag{5}$$

As in the traditional Phillips curve, inflation depends positively on the output gap. But, as opposed to the traditional Phillips curve and as mentioned in Galí and Gertler (1999), the relation employs $E_t \left\{ \pi_{t+1} \right\}$ instead of $E_{t-1} \left\{ \pi_t \right\}$ and the model is derived from a theoretical model with rational expectations which relies on microeconomic foundations.

2.2. *Unit labor cost as a measure of marginal cost*

Galí and Gertler (1999) show that output gap is not a good choice in estimating NKPC, since the natural level of output is unobservable. The NKPC employing the output gap indicates that the inflation leads the output gap, and so an increase in current inflation should imply a future rise in the output gap. However, Galí and Gertler (1999) show that the data suggests the opposite – the output gap leads inflation. Furthermore, the natural level of output constructed with Hodrick-Prescott filter does not provide the best measure for the theoretical level. The alternatives of this variable are the gap variables the Congressional Budget Office (CBO) estimate or a measure of the capacity utilization, as Galí and Gertler (1999) point out. Nonetheless, it is generally recognized that these alternatives suffer from serious measurement error. The second issue, mentioned also in Neiss and Nelson (2002), is that even in the case of observable output gap, its connection with the marginal cost under the relation emphasized above is most likely not valid. The relationship would only hold in the context of perfect competitive labor market, with no frictions.

Given these difficulties, and following other papers in the literature[3], I use a measure of the marginal cost instead of output gap as the driving variable of inflation. Although the marginal cost is not observable, using certain assumptions and macroeconomic variables generates an observable measure for the marginal cost.

Assuming a Cobb-Douglas technology with labor N_t and technology A_t as inputs, the formula for the output Y_t is given by:

[3] Some few examples are given by Gali and Gertler (1999), Genberg and Pawels (2003) and Guay and Pelgrin (2004).

$$Y_t = A_t \cdot N_t(i)^{1-\alpha}$$

By cost minimization we obtain the marginal cost (the ratio of the wage rate to the marginal product of labor):

$$MC_t = \frac{W_t / P_t}{\partial Y_t / \partial N_t}$$

The labor income share is given by $S_t \equiv \frac{W_t \cdot N_t}{P_t \cdot Y_t}$ and so the marginal cost is equal to

$$MC_t = S_t$$

Letting the lower case letters denote the deviation from the steady state, we find the final formula for marginal cost:

$$mc_t = s_t \tag{6}$$

The combination between equations (3) and (6) gives the formula for the inflation equation, which is at the base of my empirical analysis:

$$\pi_t = \lambda \cdot s_t + \beta \cdot E_t\left\{\pi_{t+1}\right\} + u_t \tag{7}$$

where $\lambda = \frac{(1-\theta)\cdot(1-\beta\cdot\theta)}{\theta}$ and u_t represents a stochastic error or "cost-push" shock, as it is referred to in the literature.

2.3. *A hybrid model of New Keynesian Phillips Curve*

Due to authors such as Fuhrer (1997) cited in Galí and Gertler (1999), who suggest that the New Keynesian model with sticky prices fails because of the fact that a part of the market sets prices using a backward looking rule of thumb which captures the persistence in inflation, a hybrid version of NKPC has emerged. The setting remains the same as before; i.e. the assumptions made in Calvo's (1983) model hold. The extension from the model is that this time there are two types of firms which reset prices. A proportion of $1-\omega$ set their prices in a forward looking manner as before, using all available information in order to forecast future marginal costs, while the rest ω use, as specified by Galí and Gertler (1999), a simple rule of thumb that accounts for the recent history of aggregate price.

The aggregate price level is now given by the formula below:

$$p_t = \theta \cdot p_{t-1} + (1-\theta) \cdot p^*_{hyb,t} \tag{8}$$

The prices newly set in period t are represented by the formula:

$$p^*_{hyb,t} = (1-\omega) \cdot p_t^f + \omega \cdot p_t^b \tag{9}$$

The forward looking firms have the same behavior as before, setting their prices p_t^f according to the formula:

$$p_t^f = \mu + (1-\beta \cdot \theta) \cdot \sum_{k=0}^{\infty} (\beta \cdot \theta)^k \cdot E_t \left\{ mc_{t+k}^n \right\} \tag{10}$$

As for the backward looking firms, the rule followed in setting prices has the characteristic that it only depends on previous information from period $t-1$ and earlier. An additional assumption of this model is that the firms do not know about each other's type, which competitor is forward looking and which is backward looking. Given these features, the formula for the backward looking firms can be written as follows:

$$p_t^b = p_{hyb,t-1}^* + \pi_{t-1} \tag{11}$$

Intuitively, the firms which use the backward looking rule set their prices accounting for the inflation one period before and the average optimal price set in $t-1$.

One interesting case to follow, which has been presented by the same authors mentioned above, is the case in which the backward looking firms are a small fraction of the total population of firms. In this instance, the average price $p_{hyb,t}^*$ recently set is dominated by the forward looking firms. Given that the price set by the backward looking firms p_t^b directly follows the average optimal price set one period before $p_{hyb,t-1}^*$, the backward looking price will be close on average to the forward looking price.

The combination of formulas (8) - (11) results in the formula for the hybrid NKPC:

$$\pi_t = \lambda \cdot mc_t + \gamma_f \cdot E_t\{\pi_{t+1}\} + \gamma_b \cdot \pi_{t-1} + u_t \tag{12}$$

where the parameters are given by:

$$\lambda \equiv \frac{(1-\omega)\cdot(1-\theta)\cdot(1-\beta\cdot\theta)}{\phi},$$

$$\gamma_f = \frac{\beta\cdot\theta}{\phi},$$

$$\gamma_b = \frac{\omega}{\phi},$$

and $\phi = \theta + \omega \cdot \left[1 - \theta \cdot (1-\beta)\right]$.

It is worth noting that all coefficients are explicit functions of the main three parameters of the model: θ measuring the degree of price stickiness, the subjective factor β used by firms in discounting their profits and the proportion of firms using backward looking rule of thumb in setting their prices or in other words, the degree of "backwardness", ω.

There are two special cases emerging from the above formulas. First, when ω=0, all firms are forward looking and the model turns into the pure NKPC discussed in the previous subsection or, differently put, $\gamma_b = 0$ and $\gamma_f = \beta$. Second, when the discount factor is restricted, β=1, we get that $\gamma_f + \gamma_b = 1$, in other words, the coefficients on the expected inflation and the lagged inflation add up to one.

In the next sections, I present the data used, the methodology employed and the results of the empirical analysis of both baseline model and hybrid version of the NKPC for the five countries.

3. Data description and Methodology

I use quarterly data for each of the countries under analysis, taken mostly from Eurostat (n.d.) in the form of seasonally adjusted data. The main variables which I employ are the GDP in nominal and real form, the nominal compensation to the employees[4] and the world commodity price index[5]. The latter is used in the instrument list, in order to capture the effect of the world commodity on internal inflation. The time span for which I am conducting the empirical analysis covers the same period for all countries, more specifically it runs from 1991Q1 to 2005Q1. Subsequently, I repeat the steps in my estimations for a longer time frame for each country, in order to check the robustness of the model. For comparison, these results are reported in Table 3 and Table 4 in Appendix A.

The measure capturing the nominal GDP is the GDP in current prices, which shows the valuation of stocks and flows in the current accounting period. The real GDP is illustrated by the GDP in volumes, chain-linked series with 2000 as the base year[6]. Having these two variables at hand, inflation is then measured as the log difference of the GDP deflator, which is given by the ratio of the nominal and real GDP. The Augmented Dickey-Fuller test for unit root rejects the null hypothesis of a unit root in the case of inflation for all countries even at the 1% level of significance. The only exception is Austria, for which I could reject the null hypothesis of a unit root at 10% significance level.

[4] The compensation to the employees is defined, according to Eurostat (n.d.), as the total compensation in the form of cash or in kind paid by an employer to the employee as a reward for his work. It also includes the social contributions paid by the employer.

[5] Taken from Korosi (2008).

[6] For a more detailed description of the methodology under which these variables are computed, visit Eurostat (n.d.).

The real marginal cost, the forcing variable in my econometric specification, is not an observable variable, is sensitive to the model assumptions and thus it is represented by the unit labor cost (this measure holds only under the assumption of constant returns to scale). The latter is calculated as the ratio between the nominal compensation to the employees and the nominal GDP. The unit root test for the log deviation from the mean indicates that the labor share gap is a stationary variable and so enters in the equation specifications without further differencing. The log departure from the mean was computed using the Hodrick-Prescott (HP) filter with the recommended smoothing parameter, of 1600, for quarterly data.

The method employed in my estimations is the Generalized Method of Moments (hereafter, GMM) which presents the advantages of being a robust estimator in the sense that it does not require a clear-cut information of the distribution of the disturbances. As also explained in Eviews 5 User's Guide (2004), the parameters should satisfy a theoretical relation expressed usually as orthogonality conditions between a certain (occasionally nonlinear) function of the parameters $f(\theta)$ and a set of instrumental variables z_t: $E(f(\theta)' Z) = 0$. GMM estimator selects parameter estimates such that the sample correlations between the utilized instruments and the function are as close to zero as possible.

One property needed to be met in using GMM, mentioned also by Guay and Pelgrin (2004), is identification, which generally can be achieved by using important explanatory variables as instruments. As it is well known, the valid instrument set contains variables strongly correlated with the explanatory variables in the equation and at the same time uncorrelated with the disturbances. In the NKPC model, instruments are needed to account for the expected value of inflation in the NKPC equation, which is clearly endogenous and possibly also for the driving variable of inflation, the marginal cost, which most likely presents measurement error. Technically, there is no limit to the number of instruments which can be included, but one should pay attention to including too many in small samples as it could over-identify the equation and in the end result in biased estimators. On the other hand, more lags and instruments improve capturing the changes of the variables under analysis. It is advisable, as argued by many authors such as Hall and Peixe (2003) cited in Guay and Pelgrin (2004), that the “desirable” set of instruments have the following characteristics: orthogonality, identification, efficiency and non-redundancy. Guay and Pelgrin (2004) then explain that the inclusion of redundant instruments leads to deterioration of the finite sample performances of GMM estimator. As shown by Tauchen (1986) also cited in Guay and Pelgrin (2004), after conducting Monte Carlo simulations, the most dependable estimates are the ones obtained with small instrument sets, because the confidence intervals are more reliable.

In an attempt to come up with the best possible instrument list given the variables at hand, I excluded the output gap as one of the instruments, as it violates the basic orthogonality conditions of GMM and is likely to be correlated with the measurement error of the real marginal cost. Therefore, accounting also for the fact that the best instrument for a variable is its own lag, the final list of instruments which I used in all my regressions is composed of the first lag of inflation (measured by the first difference of the log GDP deflator), the first lag of the labor share gap and the world commodity price index. The same instrument list and specifications were used across all countries in order to get comparable results.

The correlations between inflation and the labor share are in all cases positive, the strongest one being for France and the weakest for UK. Therefore, the preliminary analysis is consistent with the theoretical framework of inflation being positively correlated with a measure of real economic activity.

4. Specifications and Results

The basis for estimating the model through GMM is formed by the orthogonality conditions between a function of the parameters of interest and the instruments set. In the baseline model, plugging in the expression for λ in equation (7) results in the equation specification. Since the nonlinear GMM estimation is sensitive to the moment conditions, a good way to account for those is to specify two alternative sets of conditions. Thus, for the baseline model, the equation specifications are given by the following:

$$E_t\left\{\left(\theta\cdot\pi_t-(1-\theta)\cdot(1-\beta\cdot\theta)\cdot s_t-\theta\cdot\beta\cdot\pi_{t+1}\right)\cdot z_t\right\}=0 \tag{13}$$

$$E_t\left\{\left(\pi_t-(1-\theta)\cdot(1-\beta\cdot\theta)\cdot\theta^{-1}\cdot s_t-\beta\cdot\pi_{t+1}\right)\cdot z_t\right\}=0 \tag{14}$$

The equation specifications are nonlinear estimations of the parameters θ and β and z_t is the set of instruments mentioned before. For robustness, I also consider the case where the discount factor is β=1 in order to get a better understanding of the sensitivity of the estimates with the specifications (13) and (14). In this case, the specifications are, respectively:

$$E_t\left\{\left(\theta\cdot\pi_t-(1-\theta)^2\cdot s_t-\theta\cdot\pi_{t+1}\right)\cdot z_t\right\}=0 \tag{15}$$

$$E_t\left\{\left(\pi_t-(1-\theta)^2\cdot\theta^{-1}\cdot s_t-\pi_{t+1}\right)\cdot z_t\right\}=0 \tag{16}$$

For the hybrid model, the equation specification is given below, as well as the case when β=1.

$$E_t\left\{\left((\theta+\omega\cdot(1-\theta\cdot(1-\beta)))\cdot\pi_t-(1-\omega)\cdot(1-\theta)\cdot(1-\beta\cdot\theta)\cdot s_t-\theta\cdot\beta\cdot\pi_{t+1}-\omega\cdot\pi_{t-1}\right)\cdot z_t\right\}=0 \tag{17}$$

$$E_t\left\{\left((\theta+\omega)\cdot\pi_t-(1-\omega)\cdot(1-\theta)^2\cdot s_t-\theta\cdot\beta\cdot\pi_{t+1}-\omega\cdot\pi_{t-1}\right)\cdot z_t\right\}=0 \tag{18}$$

Next, I present the results of the baseline model and the hybrid version of the NKPC for Austria, Germany, France, Italy and UK using GMM method based on the same sample size for all countries. With the purpose of checking further for the robustness, I then report in the Appendix in Table 3 and Table 4 the results of the baseline NKPC and the hybrid version respectively, for a longer time period for each of the five countries under analysis. Thus, after adjustments, the data for Austria in this case is from 1988Q3 to 2005Q1, for France is from 1978Q3 to 2005Q1, for Germany is from 1991Q1 to 2005Q1, for Italy is from 1981Q4 to 2005Q1 and finally, for UK, is from 1971Q4 to 2005Q1.

4.1. The results of the baseline model

The results of the baseline NKPC for the same period for all five countries analyzed are reported in Table 1 in the Appendix. The first three columns report the structural parameters of the baseline model, while the fourth indicates the implied number of quarters during which prices remain fixed, according to each specifications. The last column indicates the J-statistic, the minimized value of the objective function, which helps in performing the overidentifying restrictions when the number of instruments is higher than the number of endogenous variables.

As Table 1 shows, the implied value of λ is always positive, which confirms the theory behind NKPC. However, the coefficient on the marginal cost turns out statistically significant only in the case of Germany and Italy. The overall view indicates that the model performs best in case of Germany and has less performance in case of Italy and UK. Still, the results are generally in line with other findings of the existing literature[7], but the coefficient estimates prove to be quite sensitive to the normalization.

For Austria, using the first specification, the coefficient λ is within the range of 0.10-0.15 and the coefficient θ is around 0.75, which implies that the prices remain fixed on average for about a year. Specification 2 yields a slightly higher coefficient θ representing the price stickiness, and since λ depends inversely on θ, the estimation produced a lower impact of marginal cost of inflation λ of 0.06-0.1. The estimates also imply that the share of firms keeping their prices fixed in a given period seems to be quite significant, both in size and from the statistical point of view. The subjective discount factor β is quite low for the first unrestricted specification, indicating a significant sensitivity of the parameter to the specification. In this sense, the second specification performs better.

The results for France are comparable with the ones obtained in case of Austria even if the θ coefficient proves to be more sensitive across specifications. The subjective discount factor is higher than in Austria's case and much closer to the reference values in the relevant literature[8]. The implied number of quarters during which the prices remain fixed ranges from 4 to 7. This is due to the higher value of the θ coefficient of around 0.87 in the second specification.

The results for Germany prove to be the most consistent across specifications and restrictions imposed on the subjective discount factor. They show that approximately half of

[7] My results in terms of the size of the coefficients are generally comparable with those obtained by Jondeau and Le Bihan (2005).

[8] Usually, the reference value for β is 0.99.

the existing firms keep their prices fixed over a certain period and thus the number of quarters during which prices will remain unchanged is around 2. The β coefficient remains basically unchanged from one specification to another and the same can be said about the impact of marginal cost on inflation which stays within the range of 0.35-0.42, only this time the coefficients are also statistically significant at 10% level of significance.

In the case of Italy, the model does not seem to behave very consistently, as the θ coefficient changes significantly across specifications and the β coefficient is much higher than 1. Obviously, the λ coefficient also changes significantly. One possible explanation for the underperformance of the model might be the structural breaks in the inflation observed at the beginning of 1992 and 1995.

Finally, the model for UK also presents instability and sensitivity to the specifications. In the first non-restricted specification, the β coefficient is again greater than 1. However, the second specification gives much better results, indicating that the fraction of firms not changing the prices in a given period varies only slightly, between 0.65-0.71. The implied number of quarters in which the prices remain the same is around 3.

There are several reasons, as pointed out in Galí and Gertler (1999), why to suspect that the estimates for the price stickiness and implicitly for the coefficient on labor share are biased. The first and most obvious one, which would induce an upward bias on the degree of price stickiness, is the fact that the labor share as a measure of marginal cost is not exact, it was obtained after several assumptions which are not always applicable in reality or in the exact form. One of the assumptions made in order to identify θ from estimates of λ was that the markup of price over marginal cost is constant when there are no price rigidities. Another issue likely to arise is the relatively small sample which, although has the advantage of offering the base for comparability among countries, it comes with the cost of a greater sensitivity of the model under GMM method and thus less reliable estimates.

Since the number of instruments is higher than the endogenous variables in the equation specification, the J-test for the over-identifying restrictions was also performed and in all cases the null that the over-identifying restrictions are satisfied was accepted. This entails that the list of instruments can be acknowledged as valid.

4.2. The results of the hybrid model

The results for the hybrid model of the NKPC are reported in Table 2 in the Appendix A. The first three columns give the estimated structural parameters: price stickiness, degree of "backwardness" and discount factor, while the next three columns give the implied values of the reduced form coefficients and the fifth column shows the number of quarters during which prices remain unchanged. Again, the last column reports the J-statistic. Table 4 in the Appendix A reports the results using the same methodology and instrument list as before, only for a larger sample.

The estimates are in harmony with the underlying theory in terms of the sign they are expected to show in the equation. However, although the share of backward looking firms is within reasonable boundaries for all countries, the coefficient is significant only for Austria and France, while for the other countries it is statistically insignificant even at the 15% level of significance. The coefficient of the lead of inflation is significant in all cases, whereas the coefficient on the lagged inflation is insignificant for Germany in both specifications. These coefficients constitute preliminary signals that the forward looking model remains important for all countries under consideration. The β coefficient is again higher than 1 in the case of

Italy and UK in the unrestricted specifications. Restricting β to 1 gives little impact on the estimates of other coefficients, which is a good sign in terms of the sensitivity of the model.

Looking at the results for Austria, the ω coefficient is around 0.4, which suggests that the share of backward looking firms is fairly quantitatively and statistically significant and thus the pure forward looking model is rejected by the data. The coefficients on lagged and lead inflation are in this case around 0.35 and 0.57 respectively. The implied value for the price duration indicates that the prices stay fixed for roughly 3 quarters. As mentioned before, restricting the discount factor to one does not change the results that much.

For France, forward looking behavior is much more important than backward looking behavior, with a coefficient of the lead of inflation of approximately 0.73, while the coefficient on lagged inflation is only around 0.26. The share of backward looking firms is thus both statistically and quantitatively insignificant. The impact of marginal cost on inflation is little: the λ coefficient is only about 0.02. The average price duration indicates that the prices remain unchanged for approximately 6 quarters.

In Germany's case, the share of backward looking firms is extremely low and insignificant: only 0.06 in the unrestricted specification. In this case, the model clearly tends to be in favor for the pure forward looking version of NKPC. The impact of marginal cost on the inflation seems to be the greatest for this country among the five under consideration. The duration of prices is low, showing that they stay fixed for about 2 quarters.

For Italy, the hybrid version of the NKPC indicates that a share of 0.15 of total firms is backward looking, but the coefficient is statistically insignificant. The impact of marginal cost on inflation is within the range of 0.15-0.19. Again, the price duration for Italy is around 2 quarters, similar to Germany's case.

Finally, in the case of UK, roughly one fifth of the firms changing prices is backward looking, and the coefficient becomes significant in the restricted specification.

On the whole, some interesting features arise from the results of the hybrid model of the NKPC. First, as previously mentioned, the forward looking behavior is significantly more important than the backward looking behavior, as the estimates of the coefficients on the expected inflation are highly above the ones on the lagged inflation. This is also consistent with the evidence found by Paloviita (2004) cited in Angeloni et al. (2005) of inflation being more forward-looking in the recent years, especially in the case of the countries with low inflation rates such as the ones under analysis. Second, the impact of marginal cost on inflation is positive in all cases and extremely high in case of Germany, but it turns out to be statistically insignificant for all the other countries. Given that the analysis was carried out for the same sample across countries, the different results must stem from different local conditions in the economy.

One of the reasons for which the results are sensitive and not much reliable is the possibility of weak identification of the instrument list. This follows from the fact that, as also pointed out in Benati (2008), the quality of the instruments and implicitly the consistency of the estimates depend in great detail on the quality of the monetary policy. Especially in the Euro zone, where the monetary policy has great success at keeping the inflation low, these instruments are expected to be weak, as the policy makers already extracted the necessary information these variables may contain on future behavior of inflation. Another concern is the measurement error of the marginal cost which was proxied by the labor share, under assumptions which are not always applicable in practice.

A further potential limitation of the model, highlighted also by Galí and Gertler (2003), is that a constant time interval was assumed over the whole sample in between price modifications. This is because we also assumed that the potential shocks affecting the economy are not sufficiently large so as to generate a change in the time interval in which prices remain fixed. One way to check this more specifically, as done by Galí and Gertler (2003) is to check the degree of price rigidity over several sub-sample sizes and the stability of the parameters over these estimations. They found that the coefficients are quite stable, which implies that the time-dependent assumption fits quite well to the countries in which inflation is not volatile, such as the countries I have under consideration.

One way of improving the model would be that further effort could be put in modeling factor markets. As Chadha and Nolan (2004) point out, doing this accounts for the omitted variables, in direct reference to wages, capital stock and total factor productivity. Additionally, modeling the factor markets will reveal the reason why simply adding a shock term to the NKPC equation does not improve the fit of the data with the model specification. Galí ang Gertler (2003) also draw attention to the modeling of the marginal cost, as it seems that much of the persistence in the marginal cost expressed as the labor share comes from the staggered wages. They find that the empirical model with wages which are allowed to be indexed to past inflation is performing quite well.

An important source in interpreting the coefficients in the hybrid model of the NKPC is looking at inflation persistence – the reason for including the lag in the equation – and its determinants, and the price setting behavior. This is what the next subsection in this paper does, with reference to the studies conducted by specialists in the central banks of the countries part of the Eurosystem.

4.3. *Some notes on inflation persistence and price setting behavior*

This section looks at the results in my estimation of the hybrid model of the NKPC and relates them with some of the findings of the Inflation Persistence Network team (hereafter IPN) of the European Central Bank and the National Central Banks of the Eurosystem, which conducted an intense and ample study on the matter of inflation persistence and price setting behavior for the euro zone countries.

Angeloni et al. (2004) point out the main sources for inflation persistence. Among those, first to be mentioned is the extrinsic persistence which shows that due to the nominal rigidities inflation inherits persistence from its determinants such as marginal cost or output gap. In addition, an increase in the share of backward-looking firms generates an increase in the γ_b coefficient and thus, in the intrinsic persistence of inflation. When it comes to inflation expectation, under rational expectations, this term in itself does not contribute to the inflation persistence. Nevertheless, imperfect information about the type of the shocks affecting the economy and about the monetary policy regime brings a non-stationary element in the observed inflation series and thus alters the expectations-based persistence. In this sense, the degree of commitment from the central bank is important in forming the inflation expectations. Communication of the intentions of the Central Bank to the public has a central role in this type of models and assures a credible commitment, in which the expectations of the agents about inflation are not different from the real target.

As many papers indicate, the degree of intrinsic persistence showed by the γ_b coefficient drops significantly in more stable monetary regimes. This seems to be the case also with the countries under analysis in this paper, where Germany has the lowest intrinsic inflation which can be associated with the credible monetary policy the Bundesbank has been conducting for many years and the good communication they prove to have in revealing their policy to the private agents in the economy. As suggested by Angeloni et al. (2005), in the case of stable monetary policy regimes, the main source of inflation persistence comes from the persistence in its near determinants, such as the marginal cost.

Until very recently, the results on the degree of price stickiness have been relying mostly on macroeconomic evidence. Currently, within the work of the IPN team, a large variety of surveys have been carried out in euro area countries, which considers the consistency of micro foundations of the macroeconomic models with the stylized facts in the European price setting behavior. These surveys are focused on the price behavior of firms in the euro area, as well as the information set they use in setting their prices, the reasons behind the price stickiness and the asymmetries observed in pricing decisions.

The main findings of these surveys pointed out in Fabiani at al. (2005) imply that the perfect competition assumption of the classical economy and the law of one price do not hold nowadays, as the dominant practice in setting prices is the mark-up pricing and price discrimination situations, which account for roughly 80% of the cases, depending on the quantity of goods sold. All these features are in favor of the applicability and value of the New Keynesian model, which gives a better description of the current reality.

In light of the framework presented above and looking at the results presented in Table 2 for the hybrid version of the NKPC, some interesting observations can be made about the results obtained here and which are presented in the coming paragraphs.

Kwapil et al. (2005) find evidence for Austria that approximately 70% of firms follow a time-dependent price setting policy in normal circumstances, when there are no large shocks in the economy. Also, Austria is found to be a country where the real effects of monetary policy should have a bigger effect, as the share of firms following state-dependent pricing rules is quite small and thus the central bank has more power to influence real economic activity by using the real interest rate. The main source for price stickiness in Austria seems to be the fear of affecting the customer relationships by changing the contracts. Price changes occur for a share of over 54% just once every year, which is pretty much consistent with my results indicating that prices remain the same for around 3 quarters in the case of the restricted sample and around 4 quarters in the larger sample results.

Loupias and Ricart (2004) found that in France, 39% of the firms are using time-dependent pricing policy. My result of firms changing prices once in every approximately 5-7 quarters are less consistent with the authors' findings that on average, the French firms change their prices once in 7 months. In this case, the macro evidence does not seem to fit the micro evidence.

For Germany, Stahl et al. (2004) show that only 26% of the firms are using mainly time-dependent rules in setting their prices and 44% of the total number of firms change their prices less than once in a given year and thus the median firm changes its price once per year. According to my data, for a German firm the prices remain fixed for roughly 2 quarters, which implies that firms change their prices twice per year.

The studies for Italy, and in particular the study of Fabiani et al. (2004), find that around 40% of the firms are time-dependent in setting their prices and a firm keeps its price fixed for 1 year. In this paper, the model for Italy shows a high sensitivity to the specifications and the approximate period during which prices remain unchanged is around 2 quarters in the hybrid model.

Because of the importance of the consistency of macro models with micro evidence, much more work needs to be done in building such macro models. The IPN team found serious challenges to the assumptions made by micro-founded macro models such as the

NKPC and also raises the issue of separating the micro features needed to be captured in the model from those which are not so important for monetary policy and macro-economics.

5. Other empirical evidence on the NKPC and suggestions for further research

The NKPC has been the focus of many empirical analyses, some of which gave valuable insights about inflation persistence, price rigidities and the connection of real economic activity and inflation. I only mention a few of those which used the same GMM method of estimation as I did.

Galí and Gertler (2001) cited in Neiss and Nelson (2002), estimate the baseline and the hybrid model of the NKPC for a data set from 1970 to 1998 of the euro area. Their results indicate that the marginal cost, as a driving force of inflation, is positive and significant and the λ coefficient is around 0.35, while the β coefficient is around 0.91. The duration in which prices remain unchanged is around 3-5 quarters in the euro area.

Using marginal cost as the driving variable, Jondeau and Le Bihan (2005) obtain a ω coefficient of 0.26 for the euro area data. The degree of backward-lookingness shows a somewhat different situation for the European countries. For Germany and UK, the authors obtain a very low coefficient ω, whereas in case of France and Italy, firms seem to have a strong backward looking behavior. Their results are consistent with the results I obtain, in which France and Italy present higher ω coefficients and Germany and UK very low ω coefficients. Nevertheless, in the case of France and Italy, they are statistically insignificant. Jondeau and Le Bihan (2005) also obtain that the coefficient on the driving variable is insignificant for most of the European countries they analyzed. This seems to be the case with my results as well, in which, except for Germany, the coefficient is economically significant, but statistically insignificant. The point estimates for the marginal cost is very low for France according to the authors' results and my results support this finding as well.

6. Conclusions

This paper analyzed the short-term relation of inflation with a measure of real economic activity, specifically the real marginal cost of firms, and future inflation expectations for a set of five European countries, four of which are members of the European Union. The topic is important not only from a theoretical point of view, but also has deep implications in the monetary policy decisions and an even increasing relevance, since the European Union is in the process of expanding. The model of the NKPC is built on micro-foundations, one of the main advantages of this approach, and relies on rational expectations.

The starting point in my empirical approach was the estimation of the baseline model of the NKPC, using first difference of GDP deflator as a measure of inflation and labor share as the measure of the real marginal cost. The results indicated that the marginal cost is a significant driving force of inflation only in the case of Germany and Italy. The fraction of firms keeping their prices unchanged was significant in all cases, the highest for Austria and France and the lowest for the case of UK. The average duration of prices seems to be in line with previous findings in the literature.

In order to account for inflation persistence, I followed Galí and Gertler's (1999) specification of a hybrid model of the NKPC, in which one lag of inflation was added to the right hand side of the equation. In this model specification, a part of the firms in the economy behave in a backward looking fashion when setting their prices in a given period. The fraction of firms keeping their prices fixed remained significant both statistically and in size, while the backward looking share of firms is significant only in the case of Austria and UK. The marginal cost as a driving force of inflation came out significant only in Germany's case.

The coefficient on the expected inflation was in all cases significant, while the point estimates on the lagged inflation turned out to be significant for all countries, but Germany. The data seems not to be in favor of the hybrid model in Germany's case. Again, the average price duration was consistent with previous findings in the relevant literature.

Overall, the model performed the best for Germany, for which the estimates were the least sensitive to the specification and clearly supporting the pure forward looking model of the NKPC. One possible interpretation relates to the crucial role held by the long tradition and reputation of Deutsche Bundesbank of conducting a consistent monetary policy, assuring an increased credibility which then helps anchoring the inflation expectations and in the end reducing the inflation volatility. This is just one example of how important is the central bank's degree of commitment in controlling its monetary policy and getting the desired trade-offs between inflation and output.

The investigation in this paper was conducted over the same time span for all five countries, in order to get a higher degree of comparability. This suggests that the differences observed across countries might be due to local conditions and in this respect I refer to the importance of the labor market on the inflation differentials. More specifically, as Campolmi and Faia (2006) also get from their analysis, the labor market frictions are significant determinants of the dynamics of the marginal costs of firms, which in sequence affects the inflation dynamics. Thus, as argued by the authors, different replacement rates have an impact on the real wage dynamics, which in turn has an impact on the marginal costs and therefore on the inflation as well. Weber (1997), the President of the Deutsche Bundesbank, mentions in his speech held at a Symposium in Kiel that the bargaining power of the trade unions is another significant labor market determinant for inflation differentials. In this sense, he argues that the globalization process weakened the bargaining power of such trade unions, since it is much easier for firms to access labor supply in the low-cost countries.

As rightfully pointed out by Van der Ploeg (2006), further research needs to be done in order for the NKPC to capture more features of the real world economy, at the firm level behavior in particular, such as credit constraints, bankruptcies, equity constraints and other market features induced by imperfect information.

The current period of low inflation rate and stabile monetary policy regimes came from well-learned lessons from the past, in particular those learned from the Phillips curve. As the president of the Deutsche Bundesbank mentioned is his speech in 2007, the results of the Eurosystem's Inflation Persistence Network are of great added value, by using micro data in its study and also demonstrating that the moderate inflation as it is nowadays in the euro area is generated to a certain degree by the real wage rigidities. Regarding this particular topic, it is of interest to inspect the results of the Eurosystem's Wage Dynamic Network.

The topic of estimating New Keynesian Phillips Curve for the European countries is far from being a settled issue and my results confirm the fact that more investigation had to be done on the relation of inflation with measures of real economic activity.

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Appendix A: Tables with results

Table 1. The baseline model of the NKPC for all 5 countries (equation 7) for the 1991Q1-2005Q1 sample

			θ	β	λ	Duration	J Stat
Austria	**GDP Defl**	spec 1	0.7534*	0.7888*	0.1328	4.0547	0.0843
			[0.1551]	[0.1324]	[0.1734]		
		spec 2	0.7867*	0.9497*	0.0686	4.6884	0.0970
			[0.1091]	[0.1385]	[0.0880]		
	Restr β	spec 1	0.7306*	1.0000	0.0993	3.7124	0.0873
			[0.1467]		[0.1281]		
		spec 2	0.7304*	1.0000	0.0995	3.7087	0.1105
			[0.0841]		[0.0736]		
France	**GDP Defl**	spec 1	0.7683*	0.9560*	0.0801	4.3153	0.0162
			[0.2182]	[0.0917]	[0.1611]		
		spec 2	0.8703*	0.9497*	0.0259	7.7089	0.0147
			[0.4069]	[0.0885]	[0.1504]		
	Restr β	spec 1	0.7428*	1.0000	0.0890	3.8882	0.0198
			[0.2032]		[0.1651]		
		spec 2	0.8426*	1.0000	0.0294	6.3547	0.0188
			[0.3798]		[0.1551]		
Germany	**GDP Defl**	spec 1	0.5322*	0.9688*	0.4258**	2.1377	0.0273
			[0.0861]	[0.2024]	[0.2443]		
		spec 2	0.5544*	0.9668*	0.3729***	2.2443	0.0293
			[0.0964]	[0.1966]	[0.2413]		
	Restr β	spec 1	0.5333*	1.0000	0.4084*	2.1427	0.0283
			[0.0861]		[0.2165]		
		spec 2	0.5565*	1.0000	0.3534**	2.2550	0.0305
			[0.0969]		[0.2160]		
Italy	**GDP Defl**	spec 1	0.4141*	1.5413*	0.5118	1.7068	0.0172
			[0.1458]	[0.3999]	[0.4582]		
		spec 2	0.4672*	1.4525*	0.3665	1.8769	0.0169
			[0.1625]	[0.3408]	[0.3925]		
	Restr β	spec 1	0.5185*	1.0000	0.4473**	2.0767	0.0602
			[0.1003]		[0.2727]		
		spec 2	0.6298*	1.0000	0.2176	2.7014	0.0630
			[0.1592]		[0.2421]		
UK	**GDP Defl**	spec 1	0.3703**	1.4728*	0.7732	1.5880	0.0528
			[0.2046]	[0.6338]	[0.8381]		
		spec 2	0.7118**	0.8599*	0.1571	3.4693	0.0603
			[0.4006]	[0.3155]	[0.3851]		
	Restr β	spec 1	0.4949*	1.0000	0.5154	1.9799	0.0599
			[0.1261]		[0.3888]		
		spec 2	0.6548*	1.0000	0.1820	2.8969	0.0555
			[0.2343]		[0.3121]		

***Notes*: Spec 1 corresponds to eq. 13 and spec 2 corresponds to eq. 14. Restr β is the case of β =1. The instrument list is: one lag of inflation, one lag of labor share gap and the world commodity price index. The weighting matrix is robust to heteroskedasticity and autocorrelation of unknown form (HAC).**

Table 2. The hybrid model of the NKPC (equation 12) for the 1991Q1-2005Q1 sample

		θ	ω	β	λ	γ_b	γ_f	Duration	J stat
Austria	**GDP Defl**	0.6456*	0.3215*	0.8146*	0.1225	0.3461*	0.5664*	2.8247	0.0499
		[0.1342]	[0.1279]	[0.1811]	[0.1225]	[0.0960]	[0.1242]		
	Restr β	0.6071*	0.3291*	1.0000	0.1107	0.3515*	0.6485*	2.5450	0.0513
		[0.1336]	[0.1282]		[0.1040]	[0.0938]	[0.0938]		
France	**GDP Defl**	0.8305*	0.2918	0.9814*	0.0199	0.2611***	0.7291*	5.8980	0.0017
		[0.4584]	[0.3567]	[0.1343]	[0.1224]	[0.1805]	[0.1649]		
	Restr β	0.8253**	0.3041	1.0000	0.0188	0.2693**	0.7307*	5.7245	0.0020
		[0.4726]	[0.3503]		[0.1213]	[0.1631]	[0.1631]		
Germany	**GDP Defl**	0.5141*	0.0624	0.8654*	0.4419**	0.1091	0.7775*	2.0582	0.0200
		[0.0919]	[0.1254]	[0.3142]	[0.2530]	[0.2012]	[0.4006]		
	Restr β	0.5256*	0.0354	1.0000	0.3870**	0.0630	0.9370*	2.1079	0.0253
		[0.0895]	[0.0981]		[0.2253]	[0.1650]	[0.1650]		
Italy	**GDP Defl**	0.4474*	0.1539	1.6480*	0.1902	0.2382	1.1416*	1.8095	0.0087
		[0.1912]	[0.2281]	[0.5637]	[0.3798]	[0.2239]	[0.4504]		
	Restr β	0.5852*	0.2592	1.0000	0.1509	0.3070*	0.6930*	2.4109	0.0365
		[0.2137]	[0.2145]		[0.2615]	[0.1276]	[0.1276]		
UK	**GDP Defl**	0.4549**	0.1876	1.0458*	0.3591	0.2902*	0.7360*	1.8346	0.0430
		[0.2734]	[0.1349]	[0.5177]	[0.4500]	[0.1362]	[0.3213]		
	Restr β	0.4703*	0.1927*	1.0000	0.3416	0.2906*	0.7094*	1.8879	0.0418
		[0.1393]	[0.1143]		[0.2784]	[0.1339]	[0.1339]		

***Notes*: The specifications correspond to eq. 17 and eq. 18 respectively. Restr β is the case of β =1. The instrument list is: one lag of inflation, one lag of labor share gap and the world commodity price index. The weighting matrix is robust to heteroskedasticity and autocorrelation of unknown form (HAC).**

Table 3. The baseline model of the NKPC for all 5 countries (equation 7) for the longer sample

			θ	β	λ	Duration	J Stat
Austria	**GDP Defl**	spec 1	0.7813*	0.8639*	0.0910	4.5728	0.0772
			[0.1692]	[0.0773]	[0.1355]		
		spec 2	0.5523*	0.9315*	0.3937*	2.2334	0.1414
			[0.0568]	[0.1746]	[0.1507]		
	Restr β	spec 1	0.7050*	1.0000	0.1235	3.3893	0.0919
			[0.1257]		[0.1272]		
		spec 2	0.6288*	1.0000	0.2191*	2.6942	0.1219
			[0.0640]		[0.0978]		
France	**GDP Defl**	spec 1	0.8184*	0.9857*	0.0429	5.5057	0.0177
			[0.3099]	[0.0647]	[0.1540]		
		spec 2	0.9504*	0.9752*	0.0038	20.1641	0.0192
			[0.2198]	[0.0644]	[0.0282]		
	Restr β	spec 1	0.8034*	1.0000	0.0481	5.0871	0.0184
			[0.2700]		[0.1483]		
		spec 2	0.8913	1.0000	0.0132	9.2026	0.0165
			[0.6485]		[0.1678]		
Germany	**GDP Defl**	spec 1	0.5322*	0.9688*	0.4258**	2.1377	0.0273
			[0.0861]	[0.2024]	[0.2443]		
		spec 2	0.5544*	0.9668*	0.3729***	2.2443	0.0293
			[0.0964]	[0.1966]	[0.2412]		
	Restr β	spec 1	0.5333*	1.0000	0.4084*	2.1427	0.0283
			[0.0861]		[0.2165]		
		spec 2	0.5565*	1.0000	0.3534**	2.2550	0.0305
			[0.0969]		[0.2160]		
Italy	**GDP Defl**	spec 1	0.6781*	1.0564*	0.1347	3.1065	0.0177
			[0.2271]	[0.0961]	[0.2377]		
		spec 2	0.9400	1.0299*	0.0020	16.6783	0.0155
			[2.1237]	[0.0917]	[0.2137]		
	Restr β	spec 1	0.7149*	1.0000	0.1137	3.5079	0.0206
			[0.2232]		[0.2135]		
		spec 2	0.9161	1.0000	0.0077	11.9258	0.0174
			[1.3103]		[0.2508]		
UK	**GDP Defl**	spec 1	0.6586*	1.0995*	0.1430	2.9291	0.0278
			[0.1358]	[0.1497]	[0.1490]		
		spec 2	0.7923*	1.0531*	0.0434	4.8152	0.0249
			[0.2644]	[0.1445]	[0.1363]		
	Restr β	spec 1	0.6784*	1.0000	0.1525	3.1094	0.0316
			[0.1257]		[0.1475]		
		spec 2	0.8264*	1.0000	0.0365	5.7594	0.0060
			[0.2960]		[0.1374]		

***Notes*: Spec 1 corresponds to eq. 13 and spec 2 corresponds to eq. 14. Restr β is the case of β =1. The instrument list is: one lag of inflation, one lag of labor share gap and the world commodity price index. For Italy and UK, I also used the second lag of inflation in the instrument list. The weighting matrix is robust to heteroskedasticity and autocorrelation of unknown form (HAC).**

Table 4. The hybrid model of the NKPC (equation 12) for the longer sample

		θ	ω	β	λ	γ_b	γ_f	Duration	J Stat
Austria	**GDP Defl**	0.7505*	0.3963*	0.9399*	0.0393	0.3511*	0.6248*	4.0076	0.0156
		[0.2366]	[0.1616]	[0.1367]	[0.0824]	[0.0820]	[0.0874]		
	Restr β	0.7066*	0.3986*	1.0000	0.0468	0.3607*	0.6393*	3.4086	0.0178
		[0.1994]	[0.1540]		[0.0833]	[0.0783]	[0.0783]		
France	**GDP Defl**	0.8526*	0.1659***	1.0327*	0.0144	0.1621**	0.8606*	6.7859	0.0114
		[0.1887]	[0.1157]	[0.0959]	[0.0420]	[0.0978]	[0.0853]		
	Restr β	0.8482*	0.1388***	1.0000	0.0201	0.1406**	0.8594*	6.5882	0.0185
		[0.1551]	[0.0970]		[0.0450]	[0.0845]	[0.0845]		
Germany	**GDP Defl**	0.5141*	0.0624	0.8654*	0.4419**	0.1091	0.7775*	2.0582	0.0200
		[0.0920]	[0.1253]	[0.3142]	[0.2530]	[0.2012]	[0.4005]		
	Restr β	0.5256*	0.0354	1.0000	0.3870**	0.0630	0.9370**	2.1079	0.0253
		[0.0895]	[0.0981]		[0.2253]	[0.1650]	[0.1650]		
Italy	**GDP Defl**	0.8947*	0.2670***	1.0673*	0.0030	0.2267*	0.8108*	9.4992	0.1071
		[0.4230]	[0.1783]	[0.2975]	[0.0545]	[0.0729]	[0.2133]		
	Restr β	0.8243*	0.2327*	1.0000	0.0224	0.2202*	0.7798*	5.6929	0.0403
		[0.1804]	[0.1133]		[0.0519]	[0.0803]	[0.0803]		
UK	**GDP Defl**	0.7609*	0.1834***	1.0110*	0.0476	0.1939*	0.8133*	4.1821	0.0043
		[0.2474]	[0.1180]	[0.1728]	[0.1149]	[0.0848]	[0.1556]		
	Restr β	0.7650*	0.1854**	1.0000	0.0473	0.1951*	0.8049*	4.2548	0.0043
		[0.2381]	[0.1132]		[0.1146]	[0.0822]	[0.0822]		

***Notes*: The specifications correspond to eq. 17 and eq. 18 respectively. Restr β is the case of β =1. The instrument list is: one lag of inflation, one lag of labor share gap and the world commodity price index. For Italy and UK, I also used the second lag of inflation in the instrument list. The weighting matrix is robust to heteroskedasticity and autocorrelation of unknown form (HAC).**

Appendix B: Derivation of the baseline model of the NKPC

In this appendix I am briefly deriving the baseline version of the NKPC, following the notations and derivation of Galí (2007).

The New Keynesian economy departs from the classical economy with two main assumptions, also emphasized in Galí (2007). First, this time there is imperfect competition in the goods market, in which firms set their prices and not take them as given. Second, there are constraints on the price adjustment behavior in the sense that only a fraction of firms adjust their prices in a given period, as it is costly to do so. This model follows Calvo's (1983) model of staggered prices.

Focusing on the supply-side of the economy, the model assumes firms which employ an identical technology to produce differentiated goods. The production function is

$$Y_t = A_t \cdot N_t(i)^{1-\alpha}$$

where A_t is the technology presumed to evolve exogenously in time and N_t represents employment.

According to the assumptions in Calvo's (1983) model, there is a probability $1-\theta$ that a firm will change its price, independently of the time passed since the last adjustment, and thus a probability θ that the price will remain unchanged. Assuming that the number of firms is large enough, this implies that a share of θ firms keep their prices fixed, while a share of $1-\theta$ firms reset their prices in a given period. As a result, the average duration of a price is given by $\frac{1}{1-\theta}$.

The above mentioned conditions imply that the aggregate price can be written as a combination of newly set price and the previous period's optimal price:

$$P_t = \left[\int P_{t-1}(i)^{1-\varepsilon} di + (1-\theta)\cdot\left(P_t^*\right)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}} = \left[\theta\cdot\left(P_{t-1}\right)^{1-\varepsilon} + (1-\theta)\cdot\left(P_t^*\right)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}$$

where ε is the demand elasticity, which is the same for all firms.

Continuing the derivation, the relation from above is divided by P_{t-1} and the inflation rate between $t-1$ and t is denoted by $\Pi_t = \frac{P_t}{P_{t-1}}$. From this, results

$$\Pi_t^{1-\varepsilon} = \theta + (1-\theta)\cdot\left(\frac{P_t^*}{P_{t-1}}\right)^{1-\varepsilon}$$

P_t^* represents the newly set price and it is the same across firms. The steady-state of zero inflation, which is one of the assumptions of the model, implies that $\Pi_t = 1$ and $P_t^* = P_{t-1} = P_t$. Log-linearization of the above equation around $\Pi_t = 1$ and $\frac{P_t^*}{P_{t-1}} = 1$ gives:

$$\pi_t = (1-\theta)\cdot(p_t^* - p_{t-1}) \tag{1}$$

This equation shows that inflation stems from the fact that firms are reoptimizing in a given period by choosing a price different from the average price set one period before. Thus, a firm changing price in time t chooses P_t^* which maximizes the current value of the profits during the time in which this price is in effect. The equation behind this is:

$\max\limits_{P_t^*} \sum\limits_{k=0}^{\infty} \theta^k \cdot E_t \left\{ Q_{t,t+k} (P_t^* Y_{t+k/t} - \Psi_{t+k}(Y_{t+k/t})) \right\}$ subject to the constraints of the demand $Y_{t+k/t} = \left(\frac{P_t^*}{P_{t+k}} \right)^{-\varepsilon} \cdot C_{t+k}$, in which $Q_{t,t+k} \equiv \beta^k \cdot \left(\frac{C_{t+k}}{C_t} \right)^{-\sigma} \cdot \left(\frac{P_t}{P_{t+k}} \right)$ is defined to be the stochastic discount factor for nominal payoffs, $\Psi_t(\cdot)$ is the cost function and finally $Y_{t+k/t}$ represents the output in period $t+k$ for a firm which most recently reset its price in period t.

The first order condition for this optimal price setting is given by the following relation:

$$\sum_{k=0}^{\infty} \theta^k \cdot E_t \left\{ Q_{t,t+k} \cdot Y_{t+k/t} \cdot (P_t^* - \mathrm{M} \cdot \psi_{t+k/k}) \right\} = 0 \tag{2}$$

where $\psi_{t+k/k} \equiv \Psi'_{t+k}\left(Y_{t+k/t}\right)$ represents the nominal marginal cost for a firm which has not changed its price since period t and $\mathrm{M} \equiv \frac{\varepsilon}{\varepsilon - 1}$ is the gross desired markup[9].

Next, we can rewrite (2) so as to contain variables which have a well defined value in the zero inflation steady state. More specifically, dividing by P_{t-1}, noting $\Pi_{t,t+k} = \frac{P_{t+k}}{P_t}$ and

[9] In a frictionless environment, with no price adjustment constraint.

also denoting $MC_{t+k/t} \equiv \frac{\psi_{t+k/t}}{P_{t+k}}$ as the real marginal cost in period $t+k$ of a firm which has last adjusted its price in period t, the equation becomes:

$$\sum_{k=0}^{\infty} \theta^{k} \cdot E_{t}\left\{Q_{t,t+k} \cdot Y_{t+k/t} \cdot (\frac{P_{t}^{*}}{P_{t-1}} - \mathrm{M} \cdot MC_{t+k/t} \cdot \Pi_{t-1,t+k})\right\} = 0 \qquad (3)$$

A zero inflation steady state implies that $\frac{P_{t}^{*}}{P_{t-1}} = 1$, $\Pi_{t-1,t+k} = 1$, $Q_{t,t+k} = \beta^{k}$ and additionally, from the constancy of prices, $P_{t}^{*} = P_{t+k}$ which immediately gives $Y_{t+k/t} = Y$ and $MC_{t+k/t} = MC$ implying that firms are producing the same quantity of output. Accordingly, $MC = 1/\mathrm{M}$. A first order Taylor approximation of (3) around a zero inflation steady-state gives:

$$p_{t}^{*} - p_{t-1} = (1-\beta \cdot \theta) \cdot \sum_{k=0}^{\infty} (\beta \cdot \theta)^{k} \cdot E_{t}\left\{\hat{mc}_{t+k} + (p_{t+k} - p_{t-1})\right\} \qquad (4)$$

where $\hat{mc}_{t+k} \equiv mc_{t+k/t} - mc$ is the log departure of the marginal cost from its steady-state value $mc = -\mu$ and $\mu = \log \mathrm{M}$ is the log of the gross desired mark-up.

For a better understanding of the factors in optimal price setting, (4) can be rewritten in the following manner:

$$p_{t}^{*} = \mu + (1-\beta \cdot \theta) \cdot \sum_{k=0}^{\infty} (\beta \cdot \theta)^{k} \cdot E_{t}\left\{\hat{mc}_{t+k} + p_{t+k}\right\} \qquad (5)$$

Moving on to the equilibrium, for a clearing in the goods market we have $Y_t = C_t$. In the labor market, the clearing condition implies $N_t = \int_0^1 N_t(i)di$. Using the formula of the production function, we can rewrite this as

$$N_t = \int_0^1 \left(\frac{Y_t(i)}{A_t}\right)^{\frac{1}{1-\alpha}} di = \left(\frac{Y_t}{A_t}\right)^{\frac{1}{1-\alpha}} \int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{\frac{-\varepsilon}{1-\alpha}} di$$

Taking logs and accounting for the fact that $\int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{\frac{-\varepsilon}{1-\alpha}} di$ is equal to zero up to a first order approximation around a zero inflation steady state, we get a relation between output, technology and employment: $y_t = a_t + (1-\alpha) \cdot n_t$.

The real marginal cost for a particular firm can be written in terms of the average marginal cost of the economy from the following relation:

$$mc_{t+k/t} = (w_{t+k} - p_{t+k}) - mpn_{t+k/t}$$

or after accounting for the log version of the production function given above,

$$mc_{t+k/t} = (w_{t+k} - p_{t+k}) - \frac{1}{1-\alpha} \cdot (a_{t+k} - \alpha \cdot y_{t+k/t}) - \log(1-\alpha)$$

And so, from the equation above, from the demand of $C_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon} \cdot C_t$ and accounting for the fact that in the market clearing we have $c_t = y_t$, we get the expression of the marginal cost for a firm as a function of the average marginal cost of the entire economy.

$$mc_{t+k/t} = mc_{t+k} - \frac{\alpha \cdot \varepsilon}{1-\alpha} \cdot (p_t^* - p_{t+k}) \tag{6}$$

Under the assumption of constant returns to scale, $\alpha = 0$ and $mc_{t+k/t} = mc_{t+k}$, meaning that the marginal cost is the same across firms.

By substituting (6) into (4), making the assumption of constant returns to scale and reorganizing the terms, we get

$$p_t^* - p_{t-1} = \beta \cdot \theta \cdot E_t \left\{ p_{t+1}^* - p_t \right\} + (1 - \beta \cdot \theta) \cdot \hat{mc}_t + \pi_t \tag{7}$$

In the final stage, combining equations (7) and (1) we get the formula of the NKPC with marginal cost as the driving force of inflation:

$\pi_t = \beta \cdot E_t \left\{ \pi_{t+1} \right\} + \lambda \cdot \hat{mc}_t$ where $\lambda = \dfrac{(1-\theta) \cdot (1 - \beta \cdot \theta)}{\theta}$.