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Abstract

In this paper we provide evidence on the fit of the New Phillips Curve (NPC) for Spain over the most recent disinflationary period (1980-1998). Some of the findings can be summarized as follows: (a) the NPC fits the data well; (b) yet, the backward looking component of inflation is important; (c) the degree of price stickiness implied by the estimates is plausible; (d) the use of independent information about prices on imported intermediate goods (which is influenced by the exchange rate) affects the measure of the firm's marginal costs and so inflation dynamics; and finally, (e) labor market frictions, as manifested in the behavior of the wage markup, appear to have also played a key role in shaping the behavior of marginal costs.

1 Introduction

In recent years much research has been devoted to the integration of Keynesian features into the class of dynamic stochastic general equilibrium models generally associated with Real Business Cycle theory. Two important ingredients of the resulting New Keynesian models are the presence of imperfect competition and nominal rigidities. The resulting framework has implied a new view on the nature of short run inflation dynamics. In particular, these New Keynesian models have given rise to the so called New Phillips Curve (NPC, henceforth). Two distinct features characterize the relationship between inflation and economic activity in the NPC. First, the forward looking character of inflation, which is a consequence of the fact that firms set prices on the basis of their expectations about the future evolution of demand and cost factors. Second, the link between inflation and real activity comes through the potential effects of the latter on real marginal costs.

In this paper, we follow recent work by Sbordone (1999), Galí and Gertler (1999), and Galí, Gertler and López-Salido (2000). Those authors have found supporting evidence for the NPC, and have shown that real marginal costs provide important information to understand inflation dynamics in both the US and the Euro area. The objectives of the present paper are twofold. First, we provide evidence on the fit of the NPC for a small open economy like Spain, and use it as a tool to understand the recent Spanish disinflation process (1980-1999). That exercise also allows us to compare the characteristics of Spanish inflation dynamics with those observed for the Euro area.

The NPC framework assigns a central role to movements in marginal cost as a source of inflation changes. Hence, understanding the behavior of marginal costs should shed light on the behavior of inflation itself. This motivates the second part of the paper, in which we characterize the joint behavior of Spanish inflation, output, and marginal cost over the past two decades, in order to assess quantitatively the contribution of different factors to the recent disinflationary period.

The structure of the paper is as follows. In Section 2 we describe the main differences between the traditional Phillips curve and the NPC. Section 3 presents the main theoretical ingredients underlying the NPC. In Section 4 we provide extensive evidence supporting the new Phillips Curve paradigm. Finally, in Section 5 we analyze the factors underlying inflation inertia by examining in detail the determinants of the marginal costs.

2 Phillips Curves, Old and New

2.1 he Traditional Phillips Curve

The traditional Phillips curve relates inflation to some cyclical indicator plus lagged values of inflation. For example, let π_t denote inflation and $\widehat{y}_t$ the log deviation of real GDP from its long run trend. A simple, largely atheoretical specification of the traditional Phillips curve takes the form:[1]

$$\pi_t = \sum_{i=1}^{h} \varphi_i \, \pi_{t-i} + \delta \, \widehat{y}_{t-1} + \varepsilon_t \tag{1}$$

where ε_t is a random disturbance.

Instead of the direct estimations of expressions like (1), most of the available evidence on a Phillips curve relationship in Spain was based upon the estimation of wages and prices equations. Given the nature of such a relationships, the emphasis of the literature shifted from analyzing the link between inflation and unemployment (or output) in terms of a relationship like (1) to a relationship between real wages and unemployment (i.e. the so called wage equation).[2] Pioneers work on that analysis in Spain are Sanchez (1977), Espasa (1982), Dolado and Malo de Molina (1985), Dolado, Malo de Molina and Zabalza (1986), Dolado and De Lamo (1991), Andrés and García (1993) and recently Estrada, Hernando and López-Salido (2000).

Nevertheless, it is still possible to find some evidence of a Phillips curve relationship which explicitly emphasizes the link between inflation and unemployment and/or inflation and output. Pioneer are the works of Dolado and Malo de Molina (1985), and specially Baiges, Molinas and Sebastián (1987). The latter constitutes a clear example of estimates of Phillips curve relationship like (1).

Nevertheless, since the mid-seventies, traditional Phillips curves have been the object of intense scrutiny on different grounds. First, their lack of rigorous microfoundations has made them subject to the Lucas critique, and questioned their validity as a building block of any model used for the evaluation of alternative monetary policies. This issue is of particular concern in Spain, to the extent that the *Banco de España* has switched between different policy regimes in the past two decades.[3]

Second, its empirical performance has been rather unsatisfactory in many instances. Thus, the traditional Phillips curve seemed incapable of accounting for the combination of high inflation and output losses experienced by industrial economies in the 70s.[4] More recently it has failed to explain why the expansion of the late 90s has not been accompanied by any significant inflationary pressures–at least until the recent hike in oil prices. The recent Spanish experience has not been an exception from this point of view. Figure 1 displays the time series for inflation and detrended

[1]For example, Rudebusch and Svensson (1999) show that a variant of equation (1) with four lags of inflation fits well quarterly U.S. data over the period 1980-1998. Galí, Gertler and López-Salido (2000) compare this evidence with the one obtained for the Euro area.

[2]See for details on the relationships between the wage equation and the Phillips curve the recent paper by Blanchard and Katz (1999). Essentially the Phillips curve analysis for the Spanish economy was pursued under the approach described by Layard, Nickell and Jackman (1991).

[3]For a detailed discussion, see Ayuso and Escrivá (1999).

[4]This was already emphasized by Dolado and Malo de Molina (1985) and Baiges, Molinas and Sebastián (1987).

output over the period 1980-1998. As can be easily seen in the Figure, low and steady inflation characterizing the late part of the sample has not been perturbed despite the robust expansion in economic activity (reflected in positive and growing detrended output estimates). In such an environment a traditional Phillips curve would over-predict inflation.[5]

2.2 The New Phillips Curve

Recent developments in monetary business cycle theory have led to the development of a so called New Phillips Curve (NPC). The NPC arises in a model based on staggered nominal price setting, in the spirit of Taylor's (1980) seminal work. A key difference with respect to the traditional Phillips curve is that price changes are the result of optimizing decisions by monopolistically competitive firms subject to constraints on the frequency of price adjustment.

A common specification is based on Calvo's model (1983) of staggered price setting with stochastic time dependent rules. The first building block is an equation that relates inflation, π_t, to anticipated future inflation and real marginal cost:

$$\pi_t = \beta \; E_t\{\pi_{t+1}\} + \lambda \; \widehat{mc}_t \tag{2}$$

where $\widehat{mc}_t$ is average real marginal cost, in percent deviation from its steady state level, β is a discount factor, and λ is a slope coefficient that depends on the primitive parameters of the model, and in particularly the one measuring the degree of price rigidity. As we will show below, equation (2) can be obtained by aggregating across the optimal pricing decisions of individual firms.

Equation (2) is the first of two building blocks for the NPC. The second is an equation that relates marginal cost to the output gap. Under a number of assumptions typically found in standard optimization-based models with nominal price rigidities, it is possible to derive a simple relationship between real marginal costs and an *output gap* variable:[6]

$$\widehat{mc}_t = \delta \; (y_t - y_t^*) \tag{3}$$

where y_t and y_t^* are, respectively, the logarithms of real output and the natural level of output. The latter variable has a theoretical counterpart: it is the level of output that would be observed if prices were fully flexible.

Combining (2) with (3) yields the standard output gap-based formulation of the NPC:[7]

$$\pi_t = \beta \; E_t\{\pi_{t+1}\} + \kappa \; (y_t - y_t^*) \tag{4}$$

where $\kappa \equiv \lambda\delta$.

[5] There is an extensive evidence for the US. Recent contributions include Lown and Rich (1998) and Gordon (1998).

[6] See Rotemberg and Woodford (1997).

[7] See Yun (1996), Woodford (1996), and King and Wolman (1997).

2.3 Implications and Criticisms

The NPC, as exemplified by equation (4), has been the subject of considerable controversy.[8] Like the traditional Phillips curve, inflation is predicted to vary positively with the output gap. Yet, in the NPC inflation is an entirely forward looking, as can be easily seen by iterating equation (4) forward:

$$\pi_t = \kappa \sum_{k=0}^{\infty} \beta^k \, E_t\{(y_{t+k} - y^*_{t+k})\} \tag{5}$$

Hence, past inflation is irrelevant in determining current inflation under this new paradigm. As a result, an economy may achieve a disinflation without the need for the central bank to engineer a recession, to the extent that it can commit to stabilizing the output gap. In other words, there is no longer a trade off between price and output gap stability. Many authors have pointed to that prediction as being in conflict with the evidence of substantial output losses associated with disinflations (e.g. Ball (1994)).

Furthermore, and as emphasized by Fuhrer and Moore (1995) and others, the joint dynamics of inflation and output implied by equation (5) appear to be at odds with the empirical evidence. In particular, (5) implies that inflation should anticipate movements in the output gap, but the evidence appears suggests that the opposite relationship holds: the output gap tends to lead inflation instead, at least when detrended log GDP is used as a proxy for the former variable. In this sense, the evidence is consistent with the traditional Phillips curve.

2.4 Recent Evidence

The previous criticisms notwithstanding, recent work by Sbordone (1999), Galí and Gertler (1999), and Galí, Gertler and López-Salido (2000) has provided evidence favorable to the forward-looking nature of inflation, and the link between the latter variable and real marginal cost, and suggested that equation (2) is largely consistent with the data. These results support the idea that it is the failure of equation (3) -the hypothesized link between real marginal cost and the output gap- that may be behind the claimed poor performance of the NPC.

Galí and Gertler (1999) put forward two possible explanations for this finding. One is that conventional measures of the output gap may be poor approximations. To the extent that there are significant real shocks to the economy (e.g., shifts in technology growth, fiscal shocks, etc.), using detrended log GDP as a proxy for y_t^* in expression (4) may not be appropriate. Second, even if the output gap is correctly measured, it may not be the case that real marginal cost moves proportionately to it, as assumed. In particular, as we discuss in section 5, with frictions in the labor

[8] See also Galí and Gertler (1999) for a discussion of some of the issues involved.

market, either in the form of real or nominal wage rigidities, equation (3) is no longer valid. These labor market rigidities, further, can in principle offer a rationale for the inertial behavior of real marginal cost.[9] Indeed, in section 5 we provide evidence that labor market frictions were an important factor in the dynamics of marginal cost in Spain.

In the next section we sketch the derivation of the structural relation between inflation and real marginal cost. This will be the base of our estimates in section 4. We do so under alternative assumptions regarding the technology available to firms. We also consider a variant of the baseline model which allows for a fraction of backward-looking firms. In Section 4 we estimate the different specifications of the inflation equation using Spanish data. Section 5 provides some evidence regarding the sources of variations in marginal costs.

3 The New Phillips Curve: Basic Theory and Alternative Specifications

We assume a continuum of firms indexed by $j \in [0,1]$. Each firm is a monopolistic competitor and produces a differentiated good $Y_t(j)$, that it sells at nominal price $P_t(j)$. Firm j faces an isoelastic demand curve for its product, given by $Y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon} Y_t$, where Y_t and P_t are aggregate output and the aggregate price level, respectively. Suppose also that the production function for firm j is given by $Y(j)_t = A_t N_t(j)^{1-\alpha}$, where $N_t(j)$ is employment and A_t is a common technological factor. Notice that allowing for decreasing returns to labor will imply on the one hand increasing marginal costs, and on the other that marginal costs will differ across firms producing different output quantities. This is not the case under constant returns to labor (i.e., $\alpha = 0$).

Firms set nominal prices in a staggered fashion, following the approach in Calvo (1983). Thus, each firm resets its price only with probability $1-\theta$ each period, independently of the time elapsed since the last adjustment. Thus, each period a measure $1-\theta$ of producers reset their prices, while a fraction θ keep their prices unchanged. Accordingly, the expected time a price remains fixed is $\frac{1}{1-\theta}$. Thus, the parameter θ provides a measure of the degree of price rigidity. It is one of the key structural parameters we seek to estimate.

After appealing to the law large numbers and log-linearizing the price index around a zero inflation steady state, we obtain the following expression for the evolution of the (log) price level p_t as function of (the log of) the newly set price p_t^* and the lagged (log) price p_{t-1}.

[9] As we discuss in detail in section 5, inertial behavior of marginal cost opens up the possibility of a short run tradeoff between inflation and output. See also Erceg, Henderson and Levin (2000).

$$p_t = (1-\theta)\, p_t^* + \theta\, p_{t-1} \tag{6}$$

Because there are no firm-specific state variables, all firms that change price in period t choose the same value of p_t^*. A firm that is able to reset in t chooses price to maximize expected discounted profits given technology, factor prices and the constraint on price adjustment (defined by the reset probability $1-\theta$). It is straightforward to show that an optimizing firm will set p_t^* according to the following (approximate) log-linear rule:

$$p_t^* = \mu + (1-\beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k\, E_t\{mc_{t,t+k}^n\} \tag{7}$$

where β is a subjective discount factor, $mc_{t,t+k}^n$ is the logarithm of nominal marginal cost in period $t+k$ of a firm that last reset its price in period t, and $\mu \equiv \log(\frac{\varepsilon}{\varepsilon-1})$ is the firm's desired markup. Intuitively, the firm sets price as a markup over a discounted stream of expected future nominal marginal cost. Note that in the limiting case of perfect price flexibility ($\theta = 0$), $p_t^* = \mu + mc_t^n$: price is just a fixed markup over current marginal cost. As the degree of price rigidity (measured by θ) increases, so does the expect time the price is likely to remain fixed. As a consequence, the firm places more weight on expected future marginal costs in choosing current price.

The goal now is to find an expression for inflation in terms of an observable measure of aggregate marginal cost. Cost minimization implies that the firm's real marginal cost will equal the real wage divided by the marginal product of labor. Given the Cobb-Douglas technology, the real marginal cost in $t+k$ for a firm that optimally sets price in t, $MC_{t,t+k}$, is given by:

$$MC_{t,t+k} = \frac{(W_{t+k}/P_{t+k})}{(1-\alpha)\ (Y_{t,t+k}/N_{t,t+k})}$$

where $Y_{t,t+k}$ and $N_{t,t+k}$ are output and employment for a firm that has set price in t at the optimal value P_t^*. Individual firm marginal cost, of course, is not observable in the absence of firm level data. Accordingly it is helpful to define the observable variable "average" marginal cost, which depends only on aggregates, as follows:[10]

$$MC_t \equiv \frac{(W_t/P_t)}{(1-\alpha)(Y_t/N_t)} \tag{8}$$

Following Woodford (1996) and Sbordone (1999), we exploit the assumptions of a Cobb-Douglas production technology and the isoelastic demand curve introduced to obtain the following log-linear relation between $MC_{t,t+k}$ and MC_t:

[10]Note that this measure allows for supply shocks (entering through A_t in the production). An adverse supply shock, for example, results in a decline in average labor productivity, Y_t/N_t. Also, the specificaton is robust to the addition of other variable factors (e.g. imported imports), so long as the elasticity of output with respect to labor is constant, firms take wages as given, and there are no labor adjustment costs.

$$\widehat{mc}_{t,t+k} = \widehat{mc}_{t+k} - \frac{\varepsilon\alpha}{1-\alpha}\,(p_t^* - p_{t+k}) \tag{9}$$

where $\widehat{mc}_{t,t+k}$ and $\widehat{mc}_{t+k}$ are the log deviations of $MC_{t,t+k}$ and MC_{t+k} from their respective steady state values. Intuitively, given the concave production function, firms that maintain a high relative price will face a lower marginal cost than the norm. In the limiting case of a linear technology ($\alpha = 0$), all firms will be facing a common marginal cost.

We obtain the primitive formulation of the new Phillips curve that relates inflation to real marginal cost by combining equations (6), (7), and (9),

$$\pi_t = \beta\ E_t\{\pi_{t+1}\} + \lambda\ \widehat{mc}_t \tag{10}$$

with

$$\lambda \equiv \frac{(1-\theta)(1-\beta\theta)(1-\alpha)}{\theta\ [1+\alpha(\varepsilon-1)]} \tag{11}$$

Note that the slope coefficient λ depends on the primitive parameters of the model. In particular, λ is decreasing in the degree of price rigidity, as measured by θ, the fraction of firms that keep their prices constant. A smaller fraction of firms adjusting prices implies that inflation will be less sensitive to movements in marginal cost. Second, λ is also decreasing in the curvature of the production function, as measured by α, and in the elasticity of demand ε. The larger α and ε, the more sensitive is the marginal cost of an individual firm to deviations of its price from the average price level: everything else equal, a smaller adjustment in price is desirable in order to offset expected movements in average marginal costs.

3.1 A Hybrid Model

Equation (10) is the baseline relation for inflation that we estimate. An alternative to equation (10) is that inflation is principally a backward looking phenomenon, as suggested by the strong lagged dependence of this variable in traditional Phillips curve analysis. As a way to test the model against this alternative, we follow Galí and Gertler (1999) and Galí, Gertler and López-Salido (2000) by considering a hybrid model that allows a fraction of firms to use a backward looking rule of thumb. Accordingly, a measure of the departure of the pure forward looking model from the data in favor of the traditional approach is the estimate of the fraction of firms that are backward looking.

All firms continue to reset price with probability $1-\theta$. However, only a fraction $1-\omega$ resets price optimally, as in the baseline Calvo model. The remaining fraction ω choose the (log) price p_t^b according to the simple backward looking rule of thumb:

$$p_t^b = p_{t-1}^* + \pi_{t-1}$$

where p^*_{t-1} is the average reset price in $t-1$ (across both backward and forward looking firms). Backward looking firms see how firms set price last period and then make a correction for inflation, using lagged inflation as the predictor. Note that though the rule is not optimization based, it converges to the optimal rule in the steady state.[11]

We defer the details of the derivation to Galí, Gertler and López-Salido (2000) and simply report the resulting hybrid version of the marginal cost based Phillips curve:

$$\pi_t = \gamma_b \, \pi_{t-1} + \gamma_f \, E_t\{\pi_{t+1}\} + \lambda \, \widehat{mc}_t \tag{12}$$

with

$$\tilde{\lambda} \equiv \frac{(1-\omega)(1-\theta)(1-\beta\theta)(1-\alpha)}{\phi \, [1+\alpha(\varepsilon-1)]} \quad ; \quad \gamma_b \equiv \omega\phi^{-1} \quad ; \quad \gamma_f \equiv \beta\theta\phi^{-1}$$

where $\phi \equiv \theta + \omega[1-\theta(1-\beta)]$.

As in the pure forward looking baseline case, relaxing the assumption of constant marginal cost (i.e. $\alpha = 0$) affects only the slope coefficient on average marginal cost. The coefficients γ_b and γ_b are the same as in the hybrid model of Galí and Gertler (1999). In this regard, note that the hybrid model nests the baseline model in the limiting case of no backward looking firms (i.e., $\omega = 0$).

3.2 Alternative Measures of Marginal Costs

In this section we keep the assumption that firms face identical constant marginal costs, which greatly simplifies aggregation, but relaxing the linear specification of the technology. We consider various technologies to generate different measures of marginal cost. We take as a baseline technology a simple Cobb-Douglas production function; we then allow for overhead labor, as well as labor adjustment costs. Finally, we consider a CES production function and we also allow for labor adjustment costs.

Let Y_t be output, A_t be technology, K_t capital and N_t total labor. Thus output is given by:

$$Y_t = A_t K_t^{\alpha} N_t^{1-\alpha} \tag{13}$$

Real marginal cost is given by the ratio of the wage rate to the marginal product of labor, i.e., $MC_t = \frac{W_t}{P_t}\frac{1}{\frac{\partial Y_t}{\partial N_t}}$. Hence, given equation (13), we have the following expression for the real marginal costs:

$$MC_t = \frac{(W_t/P_t)}{(1-\alpha)(Y_t/N_t)} = \frac{s_t^n}{1-\alpha}$$

[11]Note also that backward looking firms free ride off of optimizing firms to the extent that p^*_{t-1} is influenced by the behavior of forward looking firms. In this regard, the welfare losses from following the rule need not be large, if the fraction of backward looking firms is not too dominant.

where $s_t^n \equiv \frac{W_t N_t}{P_t Y_t}$ is the labor income share (or, equivalently, real unit labor costs). Equivalently, in terms of percent deviations from steady state we have:

$$\widehat{mc}_t = \widehat{s}_t \tag{14}$$

Consider next the case where technology is isoelastic in non-overhead labor: $Y_t = F(K,N) = A_t K_t^{1-\alpha}(N_t - \overline{N_t})^{\alpha}$ yields the following expression for the marginal costs is:[12]

$$\widehat{mc}_t = \widehat{s}_t + \delta\, \widehat{n}_t \tag{15}$$

where $\delta = \frac{\overline{N}/N}{1-\overline{N}/N}$, depends on the ratio of overhead labor to total labor in steady state. Thus, from expression (15) it is straightforward to see that allowing for overhead labor makes more procyclical the real unit labor costs.

Let us assume next a CES production function:

$$Y_t = F(K,N) = [\alpha_K\, K_t^{1-\frac{1}{\sigma}} + \alpha_N\, (Z_t N_t)^{1-\frac{1}{\sigma}}]^{\frac{\sigma}{\sigma-1}}$$

In this case the expression for the real unit labor cost has to be modified as follows:

$$\widehat{mc}_t = \widehat{s}_t + \eta\, \widehat{yk}_t \tag{16}$$

where $\widehat{yk}_t$ is the deviation from its steady state of the productivity of capital, and $\eta = (\frac{1-\mu s}{\mu s})(\frac{1-\sigma}{\sigma})$, with μ as the steady state markup, s the steady state labor income share and σ the elasticity of substitution between labor and capital.

Finally, we consider the effect of labor adjustment cost on the computation of the real marginal costs. In that case, the marginal costs take the following form:

$$\widehat{mc}_t = \widehat{s}_t - \widehat{\gamma}_t + \xi\, (\widehat{g_{N}}_t - \zeta\, E_t\{\widehat{g_{N}}_t\}) \tag{17}$$

where $\widehat{\gamma}_t = -\delta \widehat{n}_t$, $\widehat{g_{N}}_t \equiv \log(N_t/N_{t-1})$ and ξ is a constant that depends upon the curvature of the adjustment costs (see Appendix for details).

4 How Well Does the New Phillips Curve Fit Spanish Data?

As a first pass on the data Figure 2 plots the evolution of inflation (based on GDP Deflator), as well as the labor income share which we take as our baseline measure of real marginal costs, $\widehat{mc}_t$. Both variables move closely together, at least at medium frequencies. The relation appears to hold throughout the three key phases of the sample: (i) the disinflation of the 1980s; (ii) the steady inflation of the late 1980s

[12] Overhead labor is represented by $\overline{N_t}$. The technical details of this section are left to a technical Appendix.

and early 1990s; and (iii) the recent disinflationary period and current period of low inflation during the late 1990s. That apparent positive comovement of marginal cost and inflation suggests that, as was the case for the U.S. (Galí and Gertler (1999)) and the Euro area (Galí, Gertler, and López-Salido), the new Phillips curve may also fit the Spanish inflation data well, and thus may provide a useful tool for understanding the dynamics of its differential vis a vis the rest of Europe.

In order to confirm such an intuition, we now proceed to provide formal reduced form evidence of this conjecture.[13]The estimated inflation equation for Spain during the period 1980:I-1998:IV is given by:

$$\pi_t = \underset{(0.077)}{0.760}\, E_t\{\pi_{t+1}\} + \underset{(0.052)}{0.151}\, \widehat{mc}_t \tag{18}$$

where standard errors are shown in parentheses.[14] The main predictions of the model appear to be satisfied. The slope coefficient on marginal cost is positive, as implied by the theory, and significantly different from zero. The estimate of coefficient affecting the expected inflation (the discount factor) is a bit low, but has the right sign and order of magnitude. We view Figure 2 and the previous results as *prima facie* evidence of the potential merits of the new inflation paradigm.

In Figure 3 , we plot the real marginal costs under the different assumptions about technology. In particular, in the left hand right panel we plot the Cobb-Douglas case against two cases: the first allows for overhead labor, and the second for adjustment cost in labor. In the right hand side panel we compare the Cobb-Douglas case with the CES and the CES with labor adjustment costs. It is clear that there are few noticeable differences in the evolution of the alternative measures of real marginal costs. The most remarkable feature can be observed in the specification that allows for labor adjustment costs. In that case, the marginal costs present a higher volatility over the period 1984-1992, induced by the large fluctuations in employment experienced in Spain after the introduction of the fixed term contracts among other structural reforms.[15]

In a recent paper, Wolman (1999) suggests that allowing for features such as:

[13]We begin by presenting estimates of the coefficients in equation (2). We refer to these estimates as "reduced form" since we do not try to identify the primitive parameters that underlie the slope coefficient λ. In the next section we proceed to relate these coefficients with a structural model with sticky prices. The aim will be to identify the degree of price rigidities behind the observed evoution of inflation and real marginal costs.

[14]We estimates this equation by GMM. The method will be described in detail in section 4, where we present our structural estimates of the model. Our instruments set includes four lags of inflation, detrended output, wage inflation and real marginal costs. We performed a number of diagnostic tests to evaluate the regression. To check for potential weakness of the instruments, we perform an F-test applied to the first-stage regression; the results clearly suggest that the instruments used are relevant (F statistic = 15.7, with a p-value = 0.00). Next we test the model's overidentifying restrictions. Based on the Hansen test, we do not reject the overidentifying restrictions (J statistic = 7.59, with associated p-value of 0.91).

[15]See, e.g. Bentolila and Saint Paul (1992).

overhead labor, labor adjustment costs and variable capital utilization would increase the empirical viability of sticky price models. The analysis here tends to suggest that such extensions may have very little impact on the estimates of the degree of price stickiness, as it will be clear in the next section.

4.1 Structural Estimates

In this section, we present estimates of the structural parameter θ, which measures the extent of price rigidity. As expression (11) indicates, the reduced form coefficient λ is a function not only of θ and β, but also of the technology curvature parameter α and the elasticity of demand ε. Our main aim is to use the model's restrictions to identify only two primitive parameters: β, the slope coefficient on expected inflation in equation (10), as well as one other parameter among θ, α, and ε. Our strategy is to estimate the degree of price rigidity, θ, and the discount factor β, conditional on a set of plausible values for α and ε. Let's define the constant $\xi \equiv \frac{1-\alpha}{1+\alpha(\varepsilon-1)} \in (0,1)$, which is conditional on the calibrated values for α and ε. Given this definition, we can express the slope coefficient on real marginal cost, λ in equation (10), as follows: $\lambda \equiv \theta^{-1}(1-\theta)(1-\beta\theta)\ \xi$.

In our baseline we report estimates under the assumption of constant marginal costs across firms, which corresponds to $\xi = 1$. In this case identification of θ does not require the calibration of any parameter. Nevertheless, under increasing marginal cost, to estimate the parameters β and θ, we treat ξ as known with certainty. We obtain measures of ξ, i.e. of α and ε, based on information about the steady values of the average markup of price over marginal cost, μ_t and of the labor income share $S_t \equiv W_t N_t / P_t Y_t$. By definition, the average markup equals the inverse of average real marginal cost (i.e., $\mu_t = 1/MC_t$). It thus follows from our assumptions about technology that: $\alpha = 1 - \frac{S_t}{\mu_t}$. We can accordingly pin down α using estimates of steady state (sample mean) values of the labor income share and the markup. Given an estimate of the steady state markup μ we can obtain a value for ε by observing that, given our assumptions, the steady state markup should correspond to the desired or frictionless markup, implying the relationship which allows us to identify ε, i.e. $\varepsilon = \frac{\mu}{\mu-1}$.We estimate the models (10) and (12) by GMM using the following two orthogonality conditions, respectively:

$$E_t\{(\pi_t - \beta\ \pi_{t+1} - \theta^{-1}(1-\theta)(1-\beta\theta)\xi\ \widehat{mc}_t)\ \mathbf{z}_t\} = 0$$

$$E_t\{(\pi_t - \omega\ \pi_{t-1} - \beta\theta\ \pi_{t+1} - \phi^{-1}(1-\omega)(1-\theta)(1-\beta\theta)\xi\ \widehat{mc}_t)\ \mathbf{z}_t\} = 0$$

where $\phi \equiv \theta + \omega[1-\theta(1-\beta)]$. Notice that in the hybrid model we can estimate an additional parameter: ω, the fraction of backward looking price setters. As in the previous case, we use calibrated values of α and ε to calibrate ξ. This again allow us to identify ω, as well as the price rigidity parameter θ.

In our empirical analysis we use instruments dated $t-1$ or earlier for two reasons: First, there is likely to be considerable error in our measure of marginal cost. Assuming this error is uncorrelated with past information, it is appropriate to use lagged instruments. Second, not all current information may be available to the public at the time they form expectations. Our instruments set include a constant, and four lags of price and wage inflation, detrended output and the real marginal costs.

Table 1 reports estimates of the model under constant returns to labor, i.e. under constant marginal costs across firms, which corresponds to $\xi = 1$, as discussed above. In addition, we proxy the real marginal costs using the real unit labor costs. The first row (labelled (1)) corresponds to the estimates of the structural parameters of the forward looking model. The row (2) reports the structural estimates for the hybrid model. The first two columns report the estimates of the two primitive parameters, θ and β. The third column reports the implied estimate for λ, the reduced form slope coefficient on real marginal cost. Next we report the average duration of a price remaining fixed (in quarters), corresponding to the estimate of θ (i.e. $D = 1/(1-\theta)$). Standard errors (with a Newey-West correction) for all the parameter estimates are reported in brackets.

The first row of Table 1 reports the baseline estimates of the purely forward looking model using Spanish data from 1980.I to 1998:IV. The estimated parameter θ is a bit high leading to an average duration of prices around ten quarters. The estimate of the discount factor β is again a bit low, but not terribly so is we take into account the uncertainty surrounding the estimates. The combination of this two parameters imply a low value for the slope of the Phillips curve, λ, positive and significant.[16] Thus, although the results suggest that real marginal cost is indeed a significant determinant of inflation, imposing a pure forward looking model jointly with the assumption of constant returns to labor yields a high estimate of the price stickiness parameter and so a high duration of fixed prices.

In the second row of Table 1 we report estimates for the hybrid model. In this case, we report the estimates for the primitive parameters ω, θ and β, as well as the reduced form parameters, γ^b, γ^f and λ, while the last column again gives the implied average duration of price rigidity.

The estimates imply that backward looking price setters, measured by the size of ω, have been a relatively important factor behind the dynamics of Spanish inflation. The estimate of ω, the fraction of backward looking price-setters, is around 0.7 leading to estimates of $\gamma^b$and γ^f around 0.5. The estimates of the other structural parameters, β and θ are much more plausible under the hybrid specification. Again, after accounting for standard errors, we get sound estimates, being now the estimated average duration around 6 quarters, lower than the obtained in the purely forward

[16]Although not reported to save space, the overidentifying restrictions are not rejected under any specification. The results are available from the authors upon request.

looking specification. Thus, using the hybrid model prices are more flexible (i.e., the average duration of price rigidity is shorter), but the backward looking behavior is more important.

We have thus far tested our forward looking model against the hybrid model under the hypothesis of constant marginal costs and using the real unit labor costs as our measure of real marginal costs. In the next two section we extend our analysis in two directions. First, we analyze the effect of alternative measures of marginal costs on the estimates of the structural parameters. Second, we focus on the effects of allowing for increasing marginal costs in order to estimate our parameters, paying special attention to the degree of price rigidity.

Table 2 presents the results for the constant marginal costs model, i.e. $\xi = 1$, under alternative specifications of marginal costs. We report, for each definition of marginal costs, the estimates of the forward looking model (row (1)) as well as the hybrid model (row (2)). Overall, it appears that the previous results holds. Thus, as anticipated from Figure 3, alternative specification of the marginal costs have no significant effects on the estimation of the structural parameters.. The forward looking specification tends to overestimate the degree of price rigidity. The hybrid model seems to work better. The estimates confirm that backward looking price setting, measured by the size of ω, is around 0.7, and that this corresponds to estimates of $\gamma^b$and γ^f of around 0.5. The duration is estimated around 6 quarters.

We now extend the analysis to the model where we allow for increasing marginal costs (i.e. $\xi \neq 1$). Table 3 reports the structural parameters under two different calibration of the labor income share. In the first two rows we set $s = 0.75$, while in the second we set $s = 0.70$ corresponding to the average over the estimation period. We fix the steady state markup $\mu = 1.2$ within the range of the empirical estimates (see, for instance, Rotemberg and Woodford (1995) and Basu and Fernald (1997)). Below we will show how the structural estimates depend upon the calibration of those parameters. From Table 3 two main features are worth noting. First, as anticipated in the theoretical section 3, the existence of increasing marginal costs, allow us to estimate a more plausible degree of price stickiness. This value leads to a estimated duration between 3 and 4 quarters, in line with the estimates for the US and the Euro area (see, Galí, Gertler and López-Salido(2000)). Moreover, these estimates are quite robust to the existence of backward looking firms (i.e. the estimation of the hybrid model yields only slightly lower values). Second, allowing for decreasing returns to labor yields lower estimates of both the degree of price rigidity and the fraction of backward looking price setters than those obtained under the constant returns assumption (corresponding to $\xi = 1$).

These latter estimates, although theoretically appealing, render its identification to the calibration of the parameters α and ε using information on the steady state labor income share, s, and the markup, μ. We have carried out a robustness check of the increasing marginal costs model, by analyzing how the estimates of the parameter of price stickiness, θ, depends upon changes in the steady state of both s and μ. Thus, we have estimated the parameters of the model for different values of s and μ, both in the purely forward looking model and in the hybrid model. The results are presented in Figures 4a and 4b.

The top panels of Figure 4a present the estimates of the parameter θ with the 95% confidence intervals, for both the forward looking and the hybrid model under different values of the steady state labor income share (the values ranged from 0.61 to 0.75 which cover the evolution of the variable over the sample period we use in our analysis, see right hand side scale of Figure 2). For these exercises we keep $\mu = 1.2$ as in the estimates of previous Table 3. The bottom panels present the estimates (and the 95% confidence interval) of the duration associated to the values of θ. These figures tend to support the results previously discussed. Overall, changes in the labor income share of 15 percentage points slightly affect the estimates of the parameter θ, so the estimated duration ranges from 3 to 4 quarters. Nevertheless, a higher steady state labor income share leads to a higher estimates of the price stickiness parameter. In the hybrid model, the differences, across different values of the labor share, in the point estimates of θ are even lower than in the forward looking model. In addition, under the hybrid model we tend to estimated a lower degree of price rigidity.

Figure 4b carries out a similar exercise. Now we fix $s = 0.7$, but allowing changes in the steady state markup, μ. Values of the steady state markup near one (perfect competition) tend to reduce significantly the estimates of the price stickiness. Nevertheless, for values of the markup between 20% to 50%, there is no significant effects in the estimation of parameter θ, and so on the duration. Again this is true for both models, although under the hybrid specification we tend to estimate a lower degree of price rigidities across different values of μ.

4.2 A Measure of Fundamental Inflation

In this section we follow Galí and Gertler (1999), Sbordone (1999) and Galí, Gertler and López-Salido (2000), to assess the extent to which our estimates of the model constitutes a good approximation to the dynamics of inflation in Spain. We consider both the pure forward looking and the hybrid model given by equations ((10) and (12)), since the hybrid model does yield estimates that are slightly different.

Those authors define the concept fundamental infiation π_t^*, as the one obtained by iterating equations (10) and (12). for simplicity, we focus on the pure forward looking case. In this case, solving forward yields:[17]

$$\pi_t = \lambda \sum_{k=0}^{\infty} \beta^k \; E_t\{\widehat{mc}_{t+k}\} \equiv \pi_t^* \tag{19}$$

Fundamental inflation π_t^* is a discounted stream of expected future real marginal costs, in analogy to the way a fundamental stock price is a discounted stream of

[17]The hybrid case can be found in Galí and Gertler (1999). We leave all the technical details of this section to the previous paper.

expected future dividends. To the extent our baseline model is correct, fundamental inflation should closely mirror the dynamics of actual inflation. The question we address in this section is: to what extent observed fluctuations in inflation can be accounted for by our measure of fundamental inflation, i.e., how far is our model from reality?.

Figure 5a displays our measure of fundamental inflation for Spain together with actual inflation in the forward looking model. The measure of fundamental inflation is constructed using the estimated structural form presented in Table 3. Overall, fundamental inflation tracks the behavior of actual inflation quite well, especially at medium frequencies. In particular, it seems to succeed in accounting for the high inflation in the early 80s and the subsequent disinflation in the mid 1980s, and the 90's. Nevertheless, the recent episode of low inflation, in the late nineties, is overestimated. Thus, as expected, the purely forward looking model fails to fully capture the short run movements of inflation. In Figure 5b we present the fundamental inflation calculated for the hybrid model. In this case, the model seems to work very well both at the medium and high frequencies. Again, as expected allowing for such an inertial behavior (backward looking price setters) in inflation improves the previous model as to capture the short terms movements of inflation over the sample period.

4.3 Measuring Marginal Costs in an Open Economy: The Role of Imported Materials

Openness of the economy may affect the dynamics of inflation, because movements in the exchange rate can fuel domestic inflation behavior through import prices. It is important to stress here, however, that neither the derivation of equation (10), relating domestic inflation to real marginal costs, nor the relationship between the latter variable and the labor income share (given a Cobb-Douglas technology), did rely at all on any assumption on the degree of openness of the economy. But, as we will show next, once we depart from the assumption of a constant elasticity of output with respect to labor, the labor income share may no longer be a suitable indicator of real marginal costs when other non-labor inputs are used. In particular, if some of the intermediate inputs are imported information about their relative price (which is influenced by the exchange rate) may be needed to measure the firm's marginal costs.

For concreteness, let us assume the following CES production function:

$$Y_t = F(N, M) = [\alpha_N \, (Z_t N_t)^{1-\frac{1}{\sigma}} + \alpha_N \, (M_t)^{1-\frac{1}{\sigma}}]^{\frac{\sigma}{\sigma-1}}$$

where M_t represents imported materials (i.e. intermediate goods), and σ is the elasticity of substitution between the two inputs. From cost minimization we know that the following equilibrium condition holds:

$$\frac{N_t}{M_t} = \left(\frac{P_{M,t}}{W_t} \right)^{\sigma} \tag{20}$$

where $P_{M,t}$ is the price of imported materials, and W_t is the nominal wage. In that case, and as described in the Appendix, one can derive the following expression for the real marginal costs is:

$$mc_t = \frac{s_t}{1 - \kappa \left(\frac{Y_t}{M_t}\right)^{\frac{1}{\sigma}-1}} \tag{21}$$

Substituting expression (20) into expression (21), and log-linearizing the resulting expression yields the following specification for the real marginal costs:

$$\widehat{mc_t} = s_t + \phi\ (p_{M,t} - w_t) + const \tag{22}$$

where $\phi = (\frac{1-\mu s}{\mu s})(\sigma - 1)$. Notice that now real marginal costs depend upon real unit labor cost and an additional term related to the relative price of the two inputs.. The parameter ϕ determines how changes in the ratio of relative prices would translate into movements in the marginal costs, and so on inflation. Thus, when $\sigma > 1$ an increase in the prices of imported materials below the increase in the nominal wage will increase the marginal costs.[18] Finally, it is worth pointing that movement in the exchange rate would affect the evolution of the import prices, and so the dynamic of the marginal costs.

In Figure 6 we plot the evolution of the (log) relative price of imports $(p_{M,t} - w_t)$ together with domestic annual inflation. As the Figure makes clear the two variables display a similar pattern. This evolution anticipates that this component can be an additional and independent source of movements in the marginal costs that it is relevant to understand the recent Spanish disinflation. But, what is behind this downward trend in the relative prices?. To answer that question we have decompose this variables in terms of the real import prices and the real wages:

$$p_{M,t} - w_t = (p_{M,t} - p_t) - (w_t - p_t)$$

Figure 6b presents the evolution of these two components. As it can be seen from that Figure, the downward trend that dominates the behavior of relative input prices during the eighties was the result of a decrease in the real import prices (i.e., a real exchange rate apreciation), as well as the increase in real wages. Interestingly, the nominal depreciation of the *peseta* in 1992 and subsequent years was not fully translated into real import prices and, in addition, it was offset by a reduction in real wages. These two factors are behind the evolution this second component of the marginal cost.

As a first approximation we proceed to estimate the importance of the open economy factor as a source of variations in marginal cost and, thus, on the dynamics of inflation by estimating the following reduced form equation:

[18]Notice that when $\sigma \to 1$ the production function is Cobb-Douglas so the marginal costs are independent of the movements in the relative prices of labor and imported materials.

$$
\begin{aligned}
\pi_t &= \beta\, E_t\{\pi_{t+1}\} + \lambda\, \widehat{mc}_t \\
&= \beta\, E_t\{\pi_{t+1}\} + \lambda_1\, s_t + \lambda_2\, (p_{M,t} - w_t)
\end{aligned}
$$

where parameters λ_1 and λ_2 are functions of the structural parameters.

The GMM estimates of the previous equation is:[19]

$$
\pi_t = \underset{(0.058)}{0.561}\, E_t\{\pi_{t+1}\} + \underset{(0.009)}{0.032} s_t + \underset{(0.083)}{0.442} (p_{M,t} - w_t)
$$

Notice that the estimated sign of the relative import price coefficient is positive and highly significant. Given the observed behavior of that variable, we can conclude that Spanish disinflation of the past two decades can be partly accounted for by decrease in the relative price of imported inputs (as we describe in Figures 6a and 6b).

Given (22), the estimates also imply an elasticity of substitution between employment and imported materials is significantly larger than one ($\sigma > 1$). Finally, the coefficients on expected inflation and real unit labor costs are still clearly significant, as predicted by the theory.

We now turn to estimate our structural parameters for different values of the elasticity of substitution. In particular, in Figure 7 we plot how different values of σ affect the behavior of the marginal costs. Thus, in the three panels of Figure 7 we plot the evolution of inflation and three measures of marginal costs that have been obtained for: $\sigma = 0.8$, $\sigma \to 1$ (the Cobb-Douglas case), and $\sigma = 1.5$. Overall, the medium run behavior of the marginal costs is very similar to the baseline case, i.e. the Cobb-Douglas. Nevertheless, in the short run there are some differences, specially during the period 1989-1994. In particular it is worth noting that a higher elasticity of substitution leads to a less volatile behavior of the marginal cost, i.e. the marginal costs remain essentially flat over that period, hence contributing to the reduction of the inflation. Finally, in Table 4 we present the corresponding structural estimates for these two values of σ. The estimates confirm the previous assessment that accounting for the movements in the relative price of inputs in a non-Cobb-Douglas setting does not affect much the basic results of the paper regarding the value of the structural parameters (θ and ω).

[19]In the GMM estimation we are adding four lags of the relative price of imputs as instruments. The coefficient affecting the relative price of imputs has been multiplied by 100. These reduced form estimates corresponds to the model with constant marginal costs across firms.

5 Marginal Cost Dynamics: The Role of Labor Market Frictions

5.1 Measuring Wage Markup

In this section we decompose the movement in real marginal cost in order to isolate the factors that drive this variable.[20] Our results suggest that labor market frictions are likely to play a key role in the evolution of real marginal cost in Spain. Our decomposition requires some restrictions from theory. Suppose the representative household has preferences given by $\sum_{t=0}^{\infty}\beta^t U(C_t, N_t)$, where C_t is non-durable consumption and N_t is labor, and where usual properties on the utility are assumed to hold. Without taking a stand on the nature of the labor market (e.g. competitive versus non-competitive, etc.), we can without loss of generality, express the link between the real wage and household preferences in the following log-linear way:

$$(\widehat{w_t - p_t}) = \widehat{mrs}_t + \widehat{\mu}_t^w \tag{23}$$

where $\widehat{mrs}_t = \log(-\frac{U_{N,t}}{U_{C,t}})$ is the log of marginal rate of substitution between consumption and labor. Because that variable is the marginal cost to the household in consumption units of supplying additional labor, the variable $\widehat{\mu}_t^w$ can be interpreted as the wage markup (in analogy to the price markup over marginal cost, $\widehat{\mu}_t$). Assuming that the household cannot be forced to supply labor tc the point where the marginal benefit $(\widehat{w_t - p_t})$ is less than the marginal cost $\widehat{mrs}_t$, we have $\widehat{\mu}_t^w \geq 0$.

Conditional on measures of $(\widehat{w_t - p_t})$ and $\widehat{mrs}_t$, equation (23) provides a simple way to identify the role of labor market frictions in the wage component of marginal cost. If the labor market were perfectly competitive and frictionless (and there were no measurement problems), we should observe $\mu_t^w = 0$ ($\widehat{\mu}_t^w = 0$), i.e., the real wage adjusts to equal the household's true marginal cost of supplying labor. With labor market frictions present, we should expect to see $\mu_t^w > 0$ and also possibly varying over time (i.e. $\widehat{\mu}_t^w \neq 0$). Situations that could produce tbis outcome include: households' having some form of monopoly power in the labor market, staggered long term nominal wage contracting, distortionary taxes, and informational frictions that generate efficiency wage payments.

Using equation (23) to eliminate the real wage in the measure of real marginal cost yields the following decomposition:

$$\log(MC_t) = \log\frac{(W_t/P_t)}{(1-\alpha)(Y_t/N_t)} = \log(-\frac{U_{N,t}/U_{C,t}}{(1-\alpha)Y_t/N_t}) + \mu_t^w \tag{24}$$

According to equation (24), real marginal cost has two components: (i) the wage markup μ_t^w, and (ii) the ratio of the household's marginal cost of labor supply to the marginal product of labor, $\frac{-U_{N,t}/U_{C,t}}{(1-\alpha)Y_t/N_t}$. In this section, we analyze in detail the

[20] We follow here the analysis of Galí, Gertler and López-Salido (2000).

determinants of the wage markup, leaving for the next section the analysis of the ratio of the marginal rate of substitution to the marginal product of labor, $\frac{-U_{N,t}/U_{C,t}}{(1-\alpha)Y_t/N_t}$, and its implications to measure the "output gap" in a economy with both price and wage rigidities.

In this paper, we extend the analysis of Galí, Gertler and López-Salido (2000) considering a type of preferences that imply the absence of income effect on the labor supply decisions.[21] This model has been proved to do a good job in understanding some monetary business cycle features. In particular, we use the following specification for preferences

$$U(C_{it}, N_{it}) \ = \log\left(C_t - \frac{A_t}{1+\varphi} N_t^{1+\varphi}\right) \tag{25}$$

as anticipated this specification implies that the MRS_t is independent on consumption. Following King and Wolman (1999) A_t can be understood as a random preference shifter that also acts as a productivity shock so guarantying balanced growth. Log-linearizing equation (24) and ignoring constants, yields an expression for marginal cost and its components that is linear in observable variables:

$$\widehat{mc}_t = \widehat{\mu}_t^w + [(\widehat{a}_t + \varphi\, \widehat{n}_t) - (\widehat{y}_t - \widehat{n}_t)] \tag{26}$$

with the wage markup defined as follows:

$$\widehat{\mu}_t^w = (\widehat{w}_t - \widehat{p}_t) - (\widehat{a}_t + \varphi \widehat{n}_t)$$

Figure 8 present the evolution of the marginal costs and the wage markup for Spain under alternative parameterization of the labor supply elasticity, respectively. We take three values for φ, 1, 5 and 10 implying a labor supply elasticity $(1/\varphi)$ of 1, 0.2 and 0.1.[22] The top panel in each case illustrates the behavior of the (log) inefficiency wedge relative (log) real marginal cost and the bottom panel does the same for the (log) wage markup.

In general a robust feature is that over the whole period there is a steady decline in the wage markup behind the decline in marginal cost. This circumstance is robust across the different values we us for the labor supply elasticity. Perhaps most striking feature is the change in the wage markup, from the high values at the beginning of the eighties to an apparent downward drift from 1985 to 1999. This behavior seems consistent with the popular notion that labor union pressures produced a steady rise in the real wage late in the 70's and during the beginning of the 80's. The impact of this labor market distortion is mirrored in the steady increase in the inefficiency wedge over the same period.

[21] Among othres, see Christiano, Eichenbaum and Evans (1997) and Dotsey, King and Wolman (1999).

[22] A low value of the labor supply elasticity is more in line with the microeconomic empirical evidence (see for example Pencavel (1986)). In the analysis, the variable z_t is a measure of the productivity trend obtained from a regression of productivity on a time trend.

The increase in the wage markup during the latest recession is consistent with the idea that workers change their expectations slowly in responses to changes in the economic conditions. Finally, the reduction in the marginal costs we observe during the nineties is mostly due to the reduction in the wage markup.

6 Conclusions

In this paper we provide evidence on the fit of the New Phillips Curve (NPC) for Spain over the most recent disinflationary period (1980-1998). Some of the findings can be summarized as follows: (a) the NPC fits the data well; (b) yet, the backward looking component of inflation is important; (c) the degree of price stickiness implied by the estimates is plausible; (d) the use of independent information about prices on imported intermediate goods (which is influenced by the exchange rate) affects the measure of the firm's marginal costs and so inflation dynamics; and finally, (e) labor market frictions, as manifested in the behavior of the wage markup, appear to have also played a key role in shaping the behavior of marginal costs.

Table 1

Structural Estimates: Baseline Marginal Costs

	Parameters						
	θ	β	λ	ω	γ_b	γ_f	D
$\xi = 1$							
(1)	0.905 (0.011)	0.759 (0.077)	0.033 (0.011)	-	-	-	10.5 (0.116)
(2)	0.835 (0.029)	0.850 (0.124)	0.010 (0.005)	0.709 (0.065)	0.487 (0.017)	0.487 (0.037)	6.1 (0.176)

Note: Sample Period: 1980-1999. Instruments include: a constant term, inflation, wage inflation, detrended output and marginal costs from t-1 to t-4.

Table 2

Structural Estimates: Alternative Marginal Costs

$\xi = 1$				*Parameters*			
Technology	θ	β	λ	ω	γ_b	γ_f	D
Cobb-Douglas (CD)							
(1)	0.905 (0.011)	0.759 (0.077)	0.033 (0.011)	-	-	-	10.5 (0.116)
(2)	0.835 (0.029)	0.850 (0.124)	0.010 (0.005)	0.709 (0.065)	0.487 (0.017)	0.487 (0.037)	6.1 (0.176)
CD with Overhead Labor							
(1)	0.912 (0.012)	0.781 (0.064)	0.028 (0.010)	-	-	-	11.1 (0.133)
(2)	0.839 (0.032)	0.846 (0.161)	0.009 (0.005)	0.725 (0.085)	0.493 (0.017)	0.483 (0.047)	6.2 (0.200)
CES							
(1)	0.902 (0.011)	0.745 (0.078)	0.035 (0.012)	-	-	-	10.2 (0.112)
(2)	0.835 (0.027)	0.829 (0.0129)	0.011 (0.005)	0.700 (0.067)	0.488 (0.017)	0.482 (0.041)	6.1 (0.165)
CD with Labor Adjust. Costs							
(1)	0.904 (0.011)	0.757 (0.074)	0.034 (0.011)	-	-	-	10.4 (0.114)
(2)	0.835 (0.027)	0.859 (0.120)	0.009 (0.004)	0.719 (0.068)	0.489 (0.017)	0.488 (0.036)	6.1 (0.164)
CES with Labor Adjust. Costs							
(1)	0.912 (0.013)	0.788 (0.058)	0.027 (0.009)	-	-	-	11.1 (0.144)
(2)	0.836 (0.038)	0.860 (0.189)	0.010 (0.006)	0.737 (0.098)	0.496 (0.017)	0.483 (0.053)	6.1 (0.227)

Table 3

Structural Estimates: Increasing Marginal Costs

	Parameters						
$\xi \neq 1$	θ	β	λ	ω	γ_b	γ_f	D
$\mu = 1.2$, $\alpha = 0.375$							
(1)	0.743 (0.032)	0.759 (0.078)	0.151 (0.052)	-	-	-	3.9 (0.125)
(2)	0.671 (0.031)	0.887 (0.102)	0.044 (0.022)	0.596 (0.063)	0.488 (0.017)	0.487 (0.034)	3.0 (0.094)
$\mu = 1.2$, $\alpha = 0.417$							
(1)	0.723 (0.035)	0.759 (0.077)	0.173 (0.060)	-	-	-	3.6 (0.126)
(2)	0.654 (0.033)	0.890 (0.100)	0.051 (0.025)	0.582 (0.064)	0.487 (0.017)	0.487 (0.034)	2.9 (0.095)

Note: The parameter α was calibrated so (1-α) is equal to the average labor income share divided by the chosen markup (μ). The average labor income share takes two values 0.75 and 0.70.

Table 4

Structural Estimates: The Effects of Imported Materials

$\xi = 1$				*Parameters*			
Technology	θ	β	λ	ω	γ_b	γ_f	D
$\sigma = 0.8$							
(1)	0.915 (0.018)	0.855 (0.065)	0.020 (0.010)	-	-	-	11.7 (0.21)
(2)	0.810 (0.036)	0.906 (0.131)	0.010 (0.005)	0.724 (0.067)	0.490 (0.018)	0.496 (0.035)	5.3 (0.19)
$\sigma = 1.5$							
(1)	0.919 (0.004)	0.557 (0.069)	0.043 (0.007)	-	-	-	12.3 (0.114)
(2)	0.877 (0.028)	0.819 (0.117)	0.007 (0.003)	0.719 (0.066)	0.485 (0.017)	0.484 (0.037)	8.1 (0.23)

Figure 1. Inflation and Detrended Output

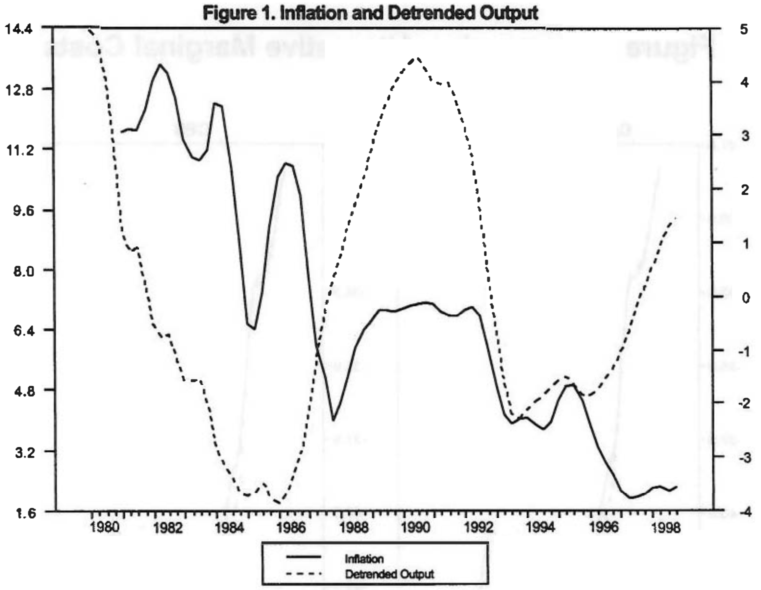


Figure . Inflation and Marginal Cost

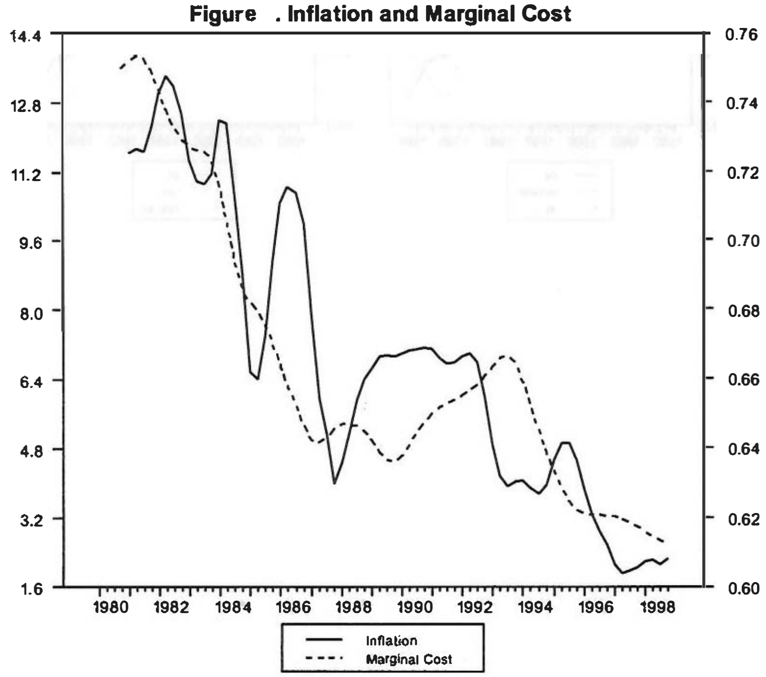


Figure 3. Comparing Alternative Marginal Costs

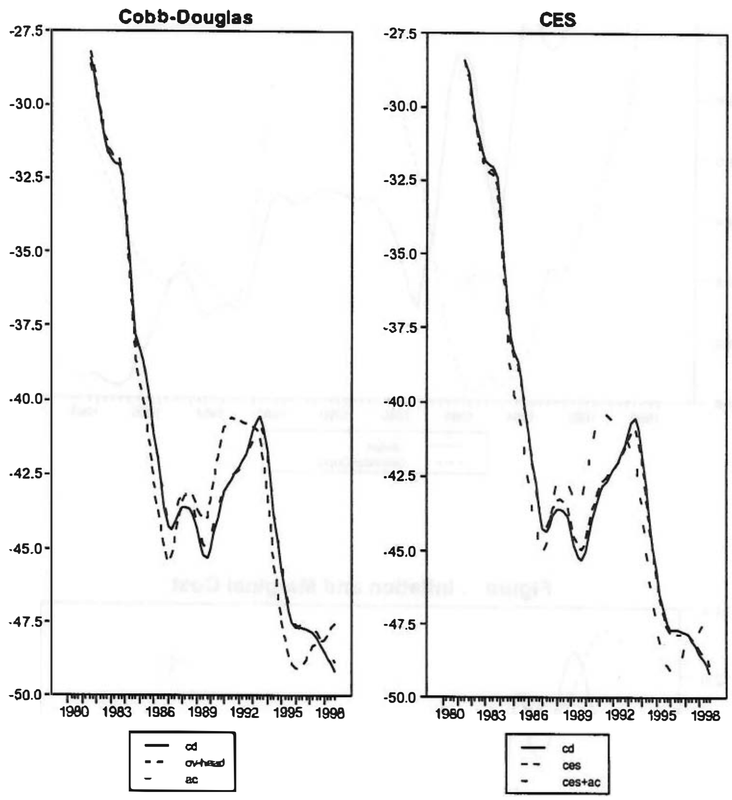


FIGURE 4(a). THE INFLUENCE OF LABOR SHARE ON THE ESTIMATED PRICE STICKINESS

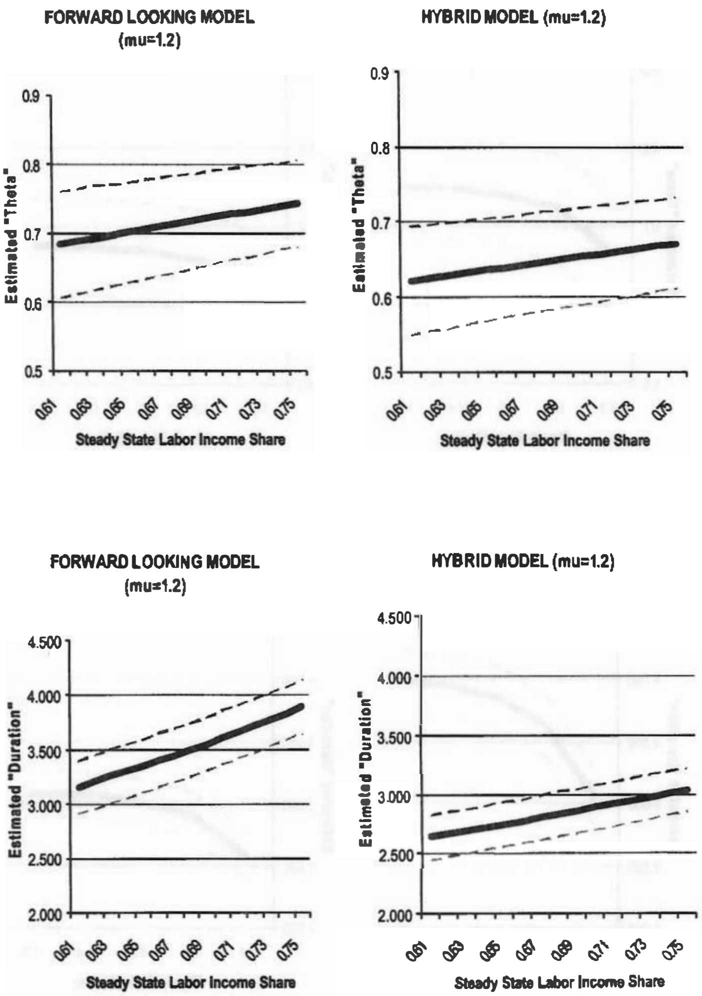


FIGURE 4(b). THE INFLUENCE OF MARKUPS ON THE ESTIMATED PRICE STICKINESS

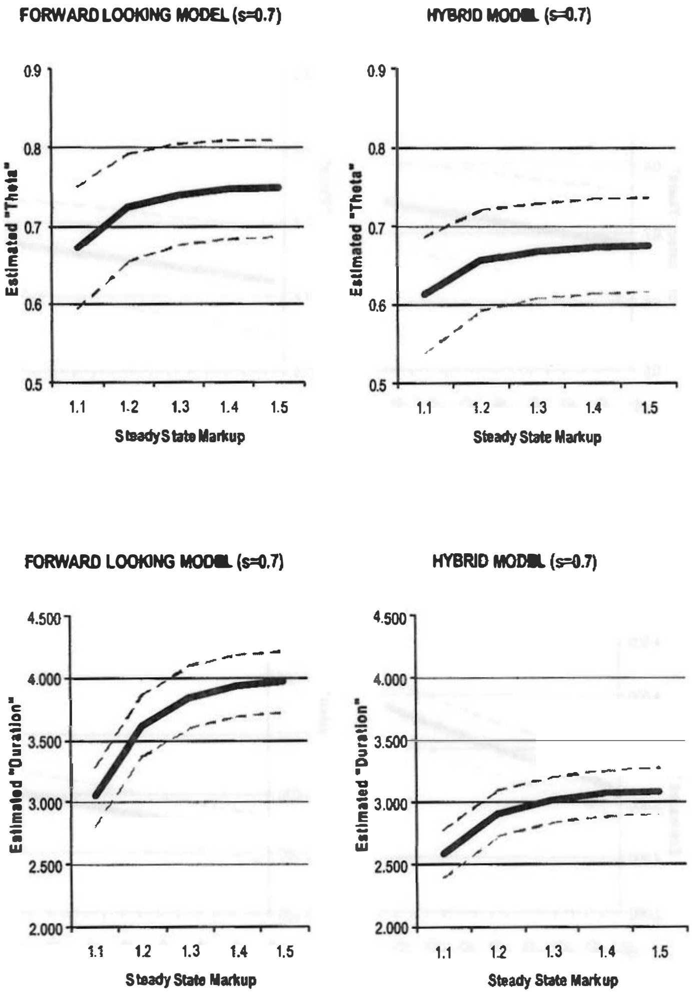


Figure 5a. Inflation: Actual vs. Fundamental

Forward Lookig Model

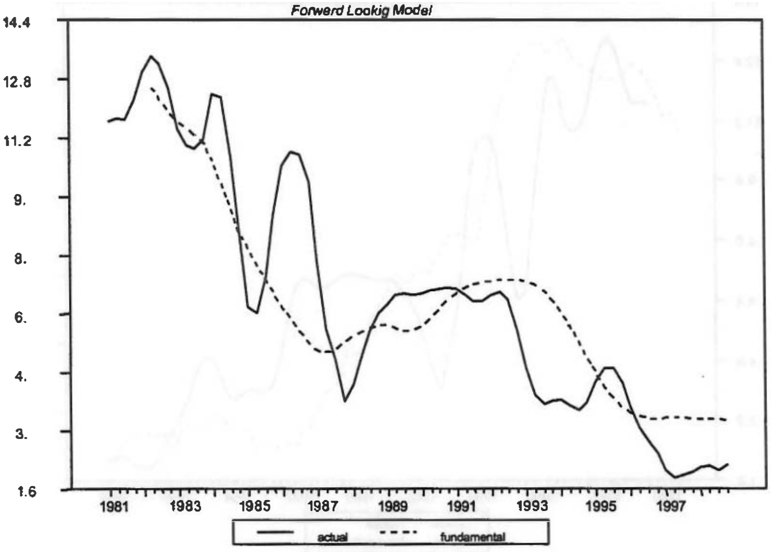


Figure 5b. Inflation: Actual vs. Fundamental

Hybrid Model

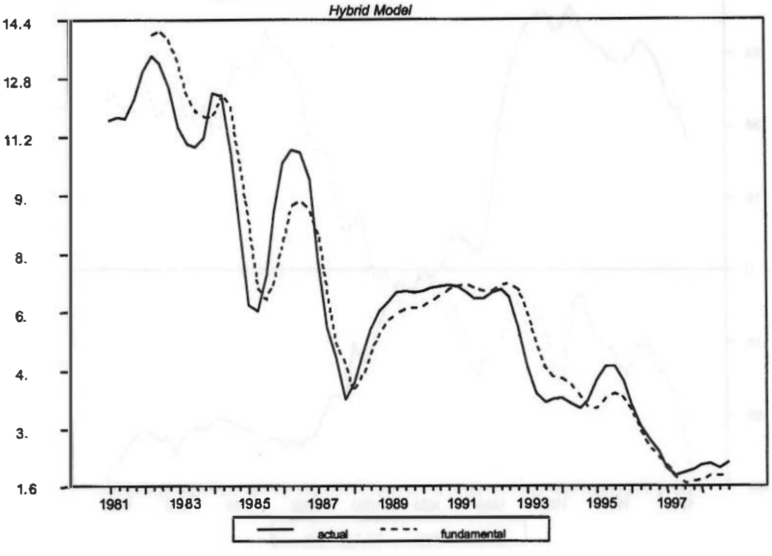


Figure 6a. Inflation and Relative Imput Prices

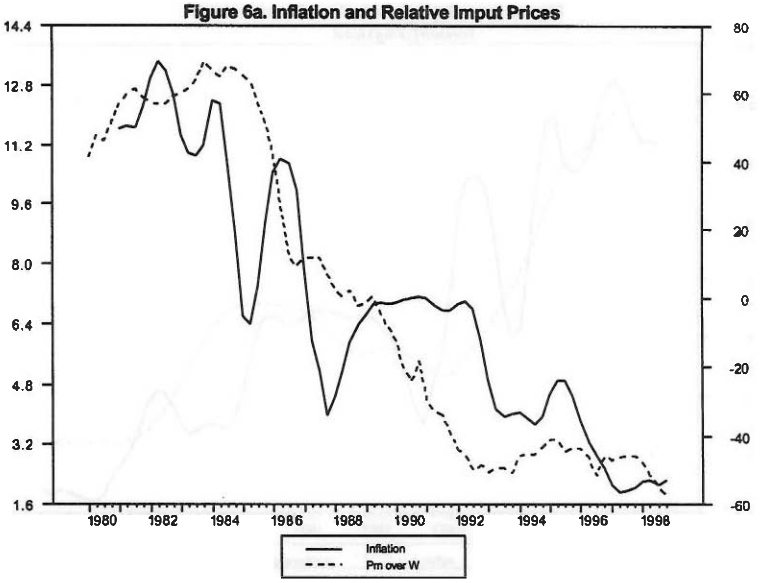


Figure 6b. Real Wages and Real Import Prices

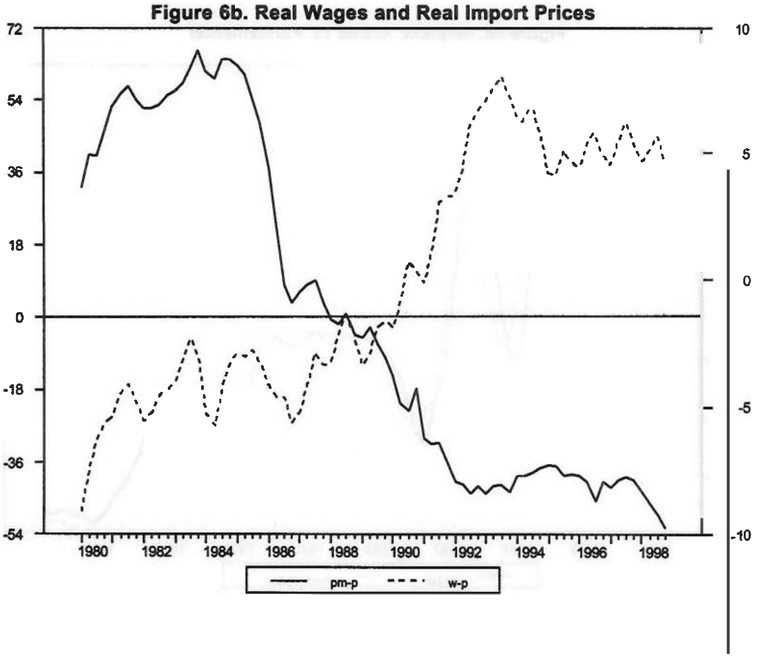


Figure 7. Inflation and Alternative Marginal Cost

The Effect of Substitutability between Imported Materials

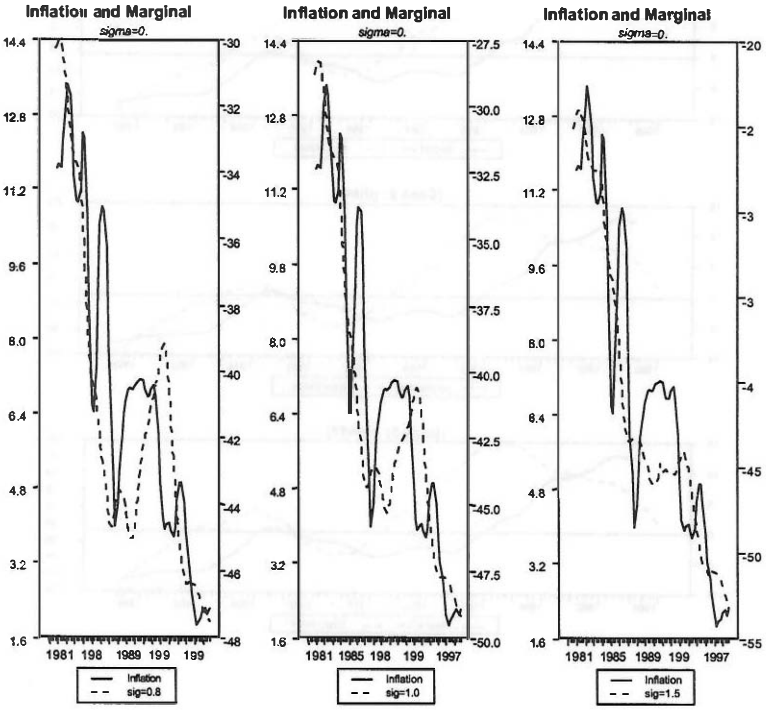
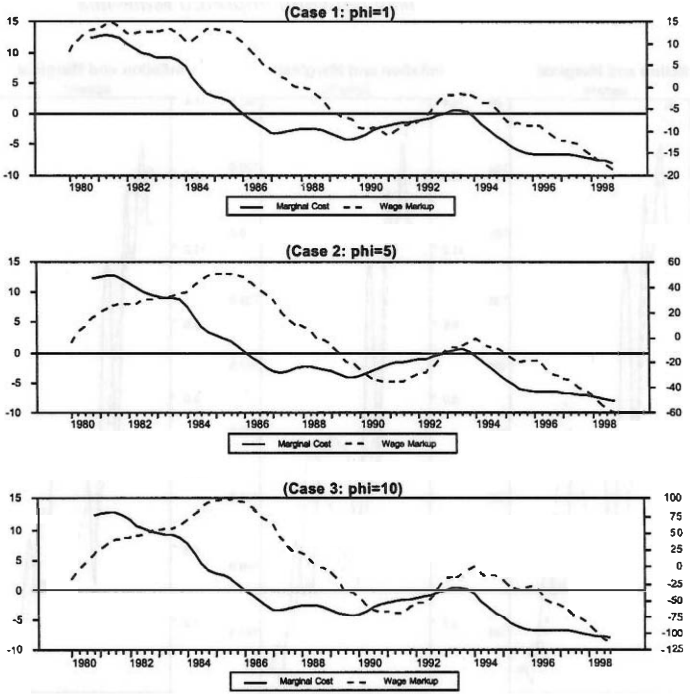


Figure 8. Marginal Cost and Wage Markup



Appendix - Derivation of various marginal cost measures

The purpose of this appendix is to derive alternative measures of firm's marginal costs. In this case, the real marginal costs, mc_t, (i.e. the inverse of the markup) is given by: $mc_t = \frac{w_t}{F_{N_t}}$, where w_t is the real wage and F_{N_t} is the partial derivative of the production function (i.e. of output) with respect to labor. Under the previous assumptions, the real marginal costs can be expressed as follows:

$$mc_t = \frac{w_t}{F_{N_t}} = \frac{s_t}{\gamma_t}$$

where s_t is the labor income share, and γ is the elasticity of output with respect to labor. In log-deviations from steady state ($mc = \frac{1}{\mu} = \frac{s}{\gamma}$, where μ is the steady state markup), the previous expression is just:

$$\widehat{mc_t} = \widehat{s_t} - \widehat{\gamma_t} \tag{27}$$

The benchmark case used in this paper is based upon the assumption of no adjustment costs, and a Cobb-Douglas production function (i.e. $Y_t = F(K,N) = Z_t K_t^{1-\alpha} N_t^{\alpha}$). In this case, $\gamma_t = \alpha$, thus expression (27) collapses to: $\widehat{mc_t} = \widehat{s_t}$.

Assuming a CES production function: $Y_t = F(K,N) = [\alpha_k K_t^{1-\frac{1}{\sigma}} + \alpha_N (Z_t N_t)^{1-\frac{1}{\sigma}}]^{\frac{\sigma}{\sigma-1}}$, the elasticity of output with respect to labor can be written as a function of the average productivity of capital $(YK_t \equiv Y_t/K_t)$: $\gamma_t = 1 - \kappa (YK_t)^{\frac{1}{\sigma}-1}$. Log-linearizing around steady state this yields to: $\widehat{\gamma_t} = -\eta\, \widehat{yk_t}$, with $\eta = (\frac{1-\mu s}{\mu s})(\frac{1-\sigma}{\sigma})$. Using expression (27) we get:

$$\widehat{mc_t} = \widehat{s_t} + \eta\, \widehat{yk_t} \tag{28}$$

We calibrate the model following Rotemberg and Woodford (1999). Thus, $s = 0.7$, $\mu = 1.25$, $\frac{1}{\sigma} = 2$, which implies a value of $\eta = 0.14$.

Rotemberg and Woodford (1999) also considers the case where technology is isoelastic in non-overhead labor: $Y_t = F(K,N) = Z_t K_t^{1-\alpha}(N_t - \overline{N_t})^{\alpha}$. In this case, $\gamma_t = \alpha \frac{N_t}{N_t - \overline{N}}$, and in log-deviations from the steady state: $\widehat{\gamma_t} = -\delta \widehat{n_t}$, where $\delta = \frac{\overline{N}/N}{1-\overline{N}/N}$, so the new expression for the marginal costs is:

$$\widehat{mc_t} = \widehat{s_t} + \delta \widehat{n_t} \tag{29}$$

To calibrate the model we follow Rotemberg and Woodford (199) using a zero profit condition in steady state. In particular, it can be shown that the ratio of average costs to marginal costs can be written as follows: $\frac{AC_t}{MC_t} = [\chi + \alpha(\frac{\overline{N}}{N_t - \overline{N}})]$. This implies the following steady state relationship: $AC = \frac{\chi}{\mu} + \frac{\delta}{1+\delta}s$. Non-negative profits require $AC_t \leq 1$, implying that $0 \leq \delta \leq \frac{\mu - \chi}{\chi - \mu(1-s)}$. We calibrate δ in expression (29) following Rotemberg and Woodford (1999). Under zero profits, and using that $s = 0.7$, $\mu = 1.25$, and $\chi = 1$ this implies $\delta = 0.4$.

Finally, we consider the effect of having cost of adjusting labor. These costs take the form: $U_t N_t \phi(N_t/N_{t-1})$, where U_t is the price of the input required to make the adjustment. In this case, the real adjustment costs associated with hiring an additional worker for one period is given by:

$$(U_t/P_t)\{\phi(N_t/N_{t-1})+(N_t/N_{t-1})\phi'(N_t/N_{t-1})\}-E_t[q_{t,t+1}\{(U_{t+1}/P_{t+1})(N_{t+1}/N_t)^2\phi'(N_{t+1}/N_t)\}]$$

letting $\zeta_t \equiv \frac{q_{t-1,t}(U_t/P_t)}{(U_{t-1}/P_{t-1})}$, and $g_{N_t} \equiv (N_t/N_{t-1})$, we can approximate the previous expression by:

$$(U_t/P_t)\phi''(1)\{\widehat{g_{N_t}} - \zeta E_t[\widehat{g_{N_{t+1}}}]\}$$

Assuming that the ratio U_t/W_t is stationary, the real marginal costs are given by:

$$mc_t = (\frac{s_t}{\gamma_t})[1 + (U/W)\phi''(1)\{\widehat{g_{N_t}} - \zeta E_t[\widehat{g_{N_{t+1}}}]\}]$$

which, in terms of deviations from steady state yields

$$\widehat{mc_t} = \widehat{s}_t - \widehat{\gamma}_t + \xi\{\widehat{g_{N_t}} - \zeta E_t[\widehat{g_{N_{t+1}}}]\} \tag{30}$$

where $\xi = \mu^{-1}(U/W)\phi''(1)$. Under the assumption that the employment follows a random walk, then

$$\widehat{mc_t} = \widehat{s}_t - \widehat{\gamma}_t + \xi\{\widehat{g_{N_t}}\}$$

References

[1] Andrés, J. and J. García (1993): "Factores Determinantes de los Salarios: Evidencia para la Industria Española", en J.J. Dolado, C. Martín and L. Rodriguez Romero (eds.): *La Industria y el Comportamiento de las Empresas Españolas. Ensayos en Homenaje a Gonzalo Mato.* Alianza Editorial Madrid.

[2] Ayuso, J. and J.L. Escrivá (1999): "La Evolución de la Estrategia del Control Monetario en España", en *La Política Monetaria y la Inflación en España*, Alianza Editorial

[3] Baiges, J, C. Molinas and M. Sebastián (1987): "The short-run Phillips Curve of the Current Spanish Economy", Documento de Trabajo 8715, Facultad de Ciencias Económicas y Empresariales, Universidad Complutense.

[4] Ball, L. (1994): "What Determines the Sacrifice Ratio?", in N.G. Mankiw, *Monetary Policy*, Chicago University Press.

[5] Basu, S. and Fernald, J.G. (1997): "Returns to Scale in US Production: Estimates and Implications", *Journal of Political Economy*, 105, 249-283.

[6] Blanchard, O.J. and L. Katz (1999): "Wage Dynamics: Reconciling Theory and Evidence", *American Economic Review, Papers and Proceedings,* Vol. 89, No. 2, 69-74.

[7] Calvo, Guillermo A. (1983): "Staggered Prices in a Utility Maximizing Framework", *Journal of Monetary Economics*, 12, 383-398.

[8] Del Amo, A.R. and Dolado, J.J. (1991): "Un Modelo de Mercado de Trabajo y la Restricción de la Economía Española" *Investigaciones Económicas*, vol.XVIII (1), 87-118.

[9] Christiano, Lawrence, Martin Eichenbaum and Charle Evans, (1997), "Sticky Price and Limited Participation Models: A Comparison," *European Economic Review*, 41, 1201-1249.

[10] Dolado, J.J. and J.L. Malo de Molina, (1985): "Desempleo y Rigidez del Mercado de Trabajo en España" *Boletín Económico, Banco de España, Septiembre 1985*, 22-40.

[11] Dolado, J.J. and J.L. Malo de Molina, and A. Zabalza (1986): "Spanish Industrial Unemployment: Some Explanatory Factors" *Economica*, vol.53, Supplement 1986, 313-335.

[12] Dotsey, M, R. King and A. Wolman, (1999):"State-dependent pricing and the general equilibrium dynamics of money and output", *Quarterly Journal of Economics, Vol. 114 (2), 655-690.*

[13] Espasa, T. (1982): "Un Estudio Econométrico de la Tasa de Variación del Empleo en la Economía Española", en *El Mercado de Trabajo en España,* Secretaria General Técnica, Ministerio de Economía y Comercio.

[14] Erceg C., Dale Henderson, and Andrew Levin, (2000), "Optimal Monetary Policy with Staggered Wage and Price Contracts," *Journal of Monetary Economics*

[15] Fuhrer, Jeffrey, Geoffrey Moore (1995): "Inflation Persistence", *Quarterly Journal of Economics*, 110(1), 127-159.

[16] Galí, J. and Mark Gertler (1999), "Inflation Dynamics: A Structural Econometric Analysis", *Journal of Monetary Economics,* 44, 195-222.

[17] Galí, J. and M. Gertler and J.D. López-Salido(2000), "European Inflation Dynamics", *European Economic Review,* forthcoming.

[18] Goodfriend, Marvin and Robert King, (1997), "The New Neoclassical Synthesis," *NBER MacroAnnual,* Ben Bernanke and Julio Rotemberg, eds., MIT Press.

[19] Gordon, Robert J. (1998) "Foundations of the Goldilocks Economy," *Brookings Papers on Economic Activity,* 2, 297-346.

[20] King, R. and Wolman, A. (1997): "Optimal Monetary Policy in a XXI Century St. Louis Model", Federal Reserve Bank of St. Louis.

[21] Lown Cara S. and Robert W. Rich (1997): "Is There and Inflation Puzzle?", *Federal Reserve Bank of New York Quarterly Review*, 51-69.

[22] Pencavel, J. (1986): "Labor Supply of Men: A Survey", *Handbook of Labor Economics, Vol. 1*, 3-102.

[23] Rotemberg, Julio, and Michael Woodford (1997), "An optimization-based Econometric Framework for the Evaluation of Monetary Policy", in *NBER Macroeconomic Annual 1997*, Ben Bernanke and Julio Rotemberg, eds., 297-346, MIT Press.

[24] Rotemberg, Julio, and Michael Woodford (1995), "Dynamic General Equilibrium Models with Imperfectly Competitive Product Markets", in *Frontiers of Business Cycle Research*, Thomas F. Cooley, ed., 243-293, Pinceton University Press, Princeton New Jersey.

[25] Rotemberg, Julio, and Michael Woodford (1999), "The Cyclical Behavior of Pices and Costs", in *Handbook of Macroeconomics*, Vol. 1, J.B. Taylor and M. Woodford (eds.), 1050-1135.

[26] Rudebusch, Glenn D. and Lars E.O. Svensson (1999): "Policy Rules for Inflation Targeting", in *Monetary Policy Rules*, John Taylor (ed.), 203-246, The University of Chicago Press.

[27] Sanchez, Ana. (1977), "Relaciones Econométricas sobre Precios y Salarios en la Economía Española", Estudios Económicos Serie A. n^o.8, Banco de España.

[28] Sbordone, Argia, M. (1999), "Prices and Unit Labor Costs: A New Test of Price Stickiness". mimeo, Rutgers University.

[29] Taylor, John B. (1980): "Aggregate Dynamics and Staggered Contracts," *Journal of Political Economy*, 88, 1-23.

[30] Wolman, A. (1999): "Sitcky Prices, Marginal Cost, and the Behavior of Inflation", *Economic Quarterly*, Ferederal Reserve Bank of Richmond, Fall 1999.

[31] Woodford, Michael (1996): "Control of the Public Debt: A Requirement for Price Stability?", *NBER Working Paper No. 5684*, July .

[32] Yun, Tack (1996): "Nominal Price Rigidity, Money Supply Endogeneity, and Business Cycle", *Journal of Monetary Economics, 37,* 345-370.

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