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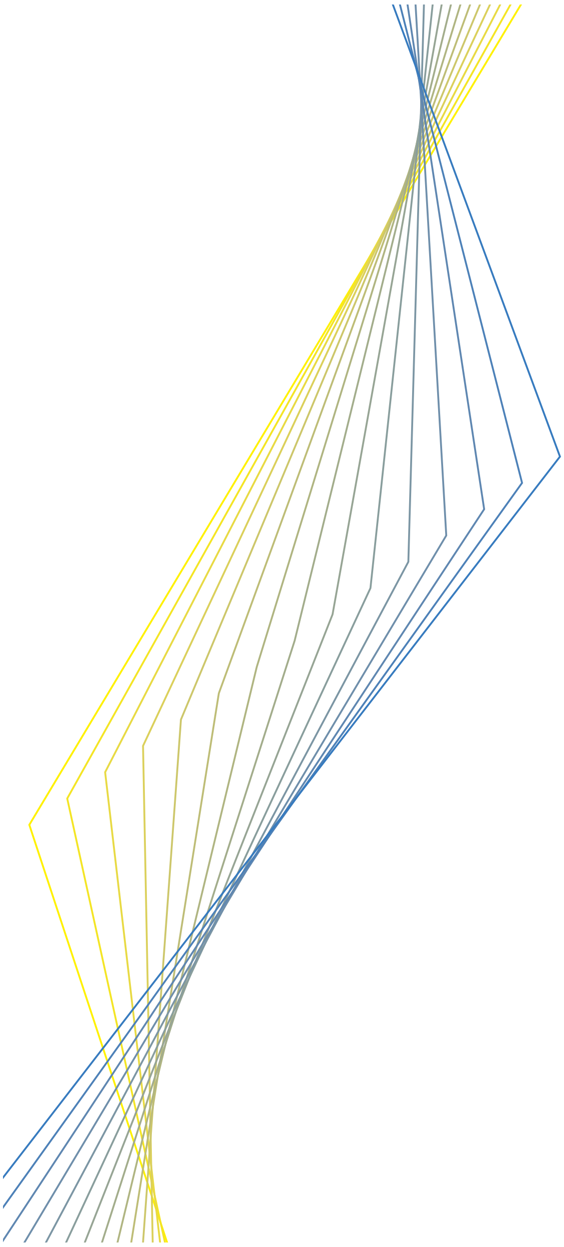

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NEW KEYNESIAN PHILLIPS CURVES: A REASSESSMENT USING EURO-AREA DATA[1]

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Contents

Abstract:

Using euro-area data, we re-examine the empirical success of New Keynesian Phillips Curves (NKPCs). The nature of our re-evaluation relies on the actual empirical underpinnings of such estimates: we find existing estimates un-robust and – given that key parameters are generally calibrated rather than estimated – potentially at odds with the data. We re-estimate with a well-specified optimizing supply-side (which attempts to treat non-stationarity in factor income shares and mark-ups) and this allows us to derive estimates of technology parameters and marginal costs. Our resulting estimates of the euro-area NKPCs are robust, provide reasonable estimates for fixed-price durations and discount rates and embody plausible dynamic properties. Our method for identifying and estimating New Keynesian Phillips curves has general applicability to a wide set of countries and might also be used in identifying sectoral NKPCs.

Keywords: Phillips Curves, Inflation Dynamics, Supply-Side, Euro-Area.

JEL classification: E31.

Non Technical Summary

New Keynesian Phillips curves (NKPCs) have become increasingly popular for analyzing inflation persistence. They differ from traditional forms by replacing measures of cyclical pressures (e.g., output gaps) with real marginal cost indicators and further assume that prices are set optimally subject to Calvo staggered-price assumptions. Recently NKPCs have also been estimated for the euro-area with some authors claiming that the NKPC fits euro-area data better than the US with a lesser role for backward-looking expectations in the euro area. Common criticisms of the NKPC approach include: whether they capture actual inflation persistence, the plausibility of their implied dynamics and their estimation methodology and power to discriminate backward and forward looking weights.

Our paper takes a more fundamental, empirical perspective. For instance, a well-documented stylized fact in many European countries is the “hump-shaped” labor income share in GDP; after increasing strongly in the 1970s, the share of labor income in the euro area decreased continuously in the two subsequent decades. This seems to be in apparent contradiction to the Cobb Douglas production function (implying stationary factor income shares), which has been the maintained supply-side hypothesis in the NKPC literature. Failure to account for these (stylized fact) supply-side developments implies an incorrect gap measure for the fundament driving inflation and thus spurious estimation of nominal persistence since cointegration between the fundament and the dependent price variable is unlikely to hold. We attempt to synthesize these long-run structural and short-run dynamic aspects. From an empirical point of view, the specification and estimation of a realistic, data-consistent but theoretically well-founded supply-side, to determine technology parameters and real marginal costs, is crucial. We re-estimate with a well-specified optimizing supply-side (which attempts to treat non-stationarity in factor income shares and mark-ups) and this allows us to derive estimates of technology parameters, marginal costs and “price gaps”. Our resulting estimates of the euro-area NKPCs are robust, provide reasonable estimates for fixed-price durations and discount rates and embody plausible dynamic properties. Our method for identifying and estimating New Keynesian Phillips curves has general applicability to a wide set of countries and might also be in identifying sectoral NKPCs.

1. Introduction

New Keynesian Phillips curves (NKPCs) have become increasingly popular for analyzing inflation persistence. They differ from traditional forms by replacing measures of cyclical pressures (e.g., output gaps) with real marginal cost indicators and further assume that prices are set optimally subject to adjustment constraints. Enthusiasm for the New (over the Old) might be thought to stem from at least four sources. First, whilst old style Phillips curves fit the data robustly, their recent forecasting performance appears to have weakened.[1] This might reflect such things as measurement errors in output gap estimates (Orphanides *et al.*, 2000); *new economy* effects or, the failure of backward-looking expectations to capture improved policy credibility. Second, many have argued that inflation persistence is better matched by real marginal cost indicators than cyclical measures such as traditionally-defined output gaps (see the discussions in Galí and Gertler, 1999, Neiss and Nelson, 2002).[2] Third, in using real marginal costs as the fundamental determinant of inflation, they potentially provide a richer description of and justification for the inflationary process than output gaps (given their decomposition into wage and productivity components). Finally, being micro-founded, they provide a more theoretically satisfying model of inflation dynamics.

Conventional Phillips curves use the form, $\pi_t = \sum_{i=1}^{I} \alpha_i \pi_{t-i} + \eta \tilde{y}_t$ with the priors $\sum_i \alpha_i = 1$ and $\eta > 0$. Where π_t is the contemporaneous inflation rate and $\tilde{y}_t$ is, typically, an output gap. Thus, a positive output gap increases inflation subject to there being no long-run trade off. The NKPC, by contrast, posits: $\pi_t = \delta E_t(\pi_{t+1}) + \lambda x_t$ where x is the assumed fundament: $\pi_t = \lambda \sum_{j=0}^{\infty} \delta^j x_{t+j}$. Inflation, thus, becomes a jump process and inflation persistence or sluggishness derives directly from that in the fundament. The fundament may be either the output gap or the log deviation of marginal costs from steady state. Under certain proportionality conditions, both measures are perfectly correlated. That further allows the interpretation that marginal costs may in fact capture the "true" output gap better than conventional de-trended measures.

Although the literature has mostly focused on US data, recently NKPCs (as here) have also been estimated for the euro-area (e.g. Amato and Gerlach, 2000, Jondeau and Le Bihan, 2001,

1 See Gordon (1998), Anderson and Wascher (2000).

2 Galí and Gertler (1999) suggest that in recent US data, output gaps and marginal costs have moved in opposite directions.

Bårdsen *et al.*, 2002, Galí *et al*. 2001). Indeed, the latter claim that the New Phillips curves fits euro-area data better than the US with a lesser role for backward-looking expectations in the euro area. In spite of the recent success, however, common criticisms of the NKPC approach include: whether they capture actual inflation persistence (Fuhrer, 1997, Fuhrer and Moore, 1995), the plausibility of their implied dynamics (Ball, 1994, Mankiw, 2001) and their estimation methodology.[3] Notably, on this last point, Rudd and Whelan (2003) suggest that hybrid model suffers low power against the backward-looking one. Also Bårdsen *et al.* (2002) argue that, as a statistical model, both the pure and hybrid NKPC are inadequate, and the significance of the forward term in the hybrid model of Galí *et al*.(2001) in the euro area is therefore misleading. Likewise they show that, applying the encompassing principle also to UK and Norwegian inflation, leads to clear rejection of the NKPC.

Our paper takes a more fundamental, empirical perspective. For instance, a well-documented stylized fact in many European countries (e.g. Blanchard, 1997 Caballero and Hammour, 1998) is the "hump-shaped" labor income share in GDP; after increasing strongly in the 1970s, the share of labor income in the euro area decreased continuously in the two subsequent decades, see Figure 1.

This seems to be in apparent (and drastic) contradiction to the Cobb Douglas production function (implying stationary factor income shares), which has been the maintained supply-side hypothesis in the NKPC literature.[4] Failure to account for these (stylized fact) supply-side developments implies an incorrect gap measure for the fundament driving inflation and thus spurious estimation of nominal persistence since cointegration between the fundament and the dependent price variable is unlikely to hold. We attempt to synthesize these long-run structural and short-run dynamic aspects. From an empirical point of view, the specification and estimation of a realistic, data-consistent but theoretically well-founded supply-side, to determine technology parameters and real marginal costs, is crucial. Indeed it is perhaps surprising that, in a literature that emphasizes both clear micro foundations, properly-measured production costs and long-run inflation determinants, the derivation of the supply side has been by passed so lightly – being largely calibrated (neglecting data compatibility) and indeed based on either short-run production functions omitting the capital stock or where capital is determined outside the optimization framework.

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3 For instance, well-known problems with GMM estimation such as those related to orthogonality conditions and instrument choice (e.g., Fuhrer *et al*., 1995).

4 Developments in the United States, however, remain broadly in line with the stable labour income share (and, in turn, in line with the common Cobb-Douglas prior).

Our theoretical framework contains a multi-sector model of imperfect competition, where the two-factor value-added production function with capital and labor as inputs is otherwise same across firms except for the sectorally-differentiated scale and technological progress parameters of the production function. We first aggregate the first order conditions of optimization of firms, which are sectorally differentiated and face sectorally differentiated demand curves. We show that these relaxations to standard assumptions introduce sectoral production shares as determinants of the aggregate level markup. Thereafter, utilizing a simple demand system with sectorally differentiated income elasticites we show that the long-run development of sectoral production shares can be reduced to trend. We also show that the relaxation of the assumption of constant price elasticity of demand introduces competitors' price into pricing equation. When applied to the open sectors of the economy this offers an avenue to incorporate the adverse supply side shocks of the 1970s into our framework in the spirit presented by Bruno and Sachs (1985) and later Blanchard (1997), which is essential to be able to explain the hump of in the labor income share in the latter half of 1970's and early 1980's. The specification and estimation of this supply-side system is then used to operationalize the fundament (marginal cost) terms in the NKPC.

After incorporating a data-consistent fundament derived from our favored supply-side system, we find NKPC estimates that compare favorably with others in the literature: discount factors insignificantly different from unity (with annualized discount rates of around 4%), reasonable periods of price fixedness and plausible dynamics. On the issue of discriminating between the different forms of the curve, our estimates of the backward looking component were numerically high (e.g., 0.3-0.5) although often not significant (depending on normalization). Accordingly, we sought a higher degree of robustness by re-estimating using the Net Present Value approach (Rudd and Whelan, 2003). When the present value was calculated assuming that the fundament to be real marginal cost, the backward-looking component was estimated to be high and significant (around 0.9); however, when using nominal marginal costs (which we argue is the correct fundament) we derived a more balanced view on the relative merits of backward- and forward-looking components – which are broadly compatible with our first results.

We use euro-area data from 1970q1-1997q4, Fagan *et al*. (2001).[5] Applications of this data include: Coenen and Wieland (2000), Stock *et al*. (2000), Coenen and Vega (2002), Smets and Wouters (2003) as well as the aforementioned Amato and Gerlach (2000), Jondeau and

[5] The raw data can be downloaded from www.ECB.int. Longer data are now available but, for comparability purposes, we retain that used in the earlier studies.

Le Bihan (2001), Galí *et al*. (2001), Bårdsen *et al.* (2002). Appendix 4 explains additions to and transformation of the database necessary to estimate the supply side: a correction to include self-employed in labor income, consistent treatment of capital income, a correction to real euro-area interest rates (controlling for 1970s financial repression) and the derivation of price competitive index.

The paper proceeds as follows: Sections 2 reviews the Calvo staggered-price model and its evolution to the NKPCs. Section 3 highlights some issues with existing NKPC studies. The next section discusses and presents our favored supply-side system. Section 5 is our empirical section for the NKPC and Section 6 concludes.

2. The Calvo Staggered Price Model

A cornerstone of the New Keynesian Phillips Curve literature is price staggering. A simple way to capture this is to assume that in any given period each firm has a fixed probability $1-\theta$ that it may adjust its price during that period and, hence, a probability θ that it will keep its price unchanged, Calvo (1983). The expected time between price adjustments (*duration*) is thus $\frac{1}{1-\theta}$. Because these adjustment opportunities occur randomly, the interval between price changes for an individual firm will be a random variable. The aggregate price level can then be presented as the weighted sum of the prices of the firms which do not change their prices (equaling the previous period price level) and the price p_t^v selected by firms that are able to change price at time t. Denoting by lowercase letters the logarithm of variables, the aggregate price level can be expressed as:

$$p_t = \theta p_{t-1} + (1-\theta) p_t^v \quad (1)$$

Following Galí and Gertler (1999) we assume that in each sector *j* a fraction $1-\omega$ of the firms are 'forward looking' (p^f) and set prices optimally given the constraint on timing of adjustments and using all the available information in order to forecast future marginal costs:

$$p_t^v = \omega p_t^b + (1-\omega) p_t^f \quad (2)$$

The rest of the firms are 'backward looking' and follow a rule of thumb in their price setting, (p^b). Backward looking firms follow the price setting of their competitors and are unable to identify whether any competitor is backward- or forward-looking. Depending on whether there is or is not a lag in the information set available for the backward looking firms the following two backward looking price-setting rules are specified. If the latest information of the backward looking firms is dated on t-1, (a situation we refer to as *information lag*) as assumed by Galí and Gertler (1999), then the backward looking rule is:

$$p_t^b = p_{t-1}^v + \pi_{t-1} \tag{3a}$$

In (3a) the lagged inflation proxies current inflation π_t. As this kind of constraint on the available information seems unconventionally constrained, we assume alternatively that no information lag exist and backward looking firms set their prices following the rule (*no information lag*):

$$p_t^b = p_{t-1}^v + \pi_t \tag{3b}$$

Alternative pricing rules (3a) and (3b) can also be interpreted in terms of Mankiw and Reis's (2001) "sticky-information" model; the main difference to their formulation is that they assume that in each period only a fraction of firms updates information. In our formulation all firms, which reset their prices, update their information with, at most, one period information lag.

Following Rotemberg (1987), we assume that forward looking firms set their prices to minimize a quadratic loss function that depends on the difference between the reset price over the period it is expected to remain fixed and the optimal price in the absence of restrictions in price setting. Hence, the representative firm *j* minimizes

$$\frac{1}{2}\sum_{i=0}^{\infty}(\delta\theta)^i E_t\left(p_{j,t}^f - p_{j,t+i}^*\right)^2 \tag{4}$$

Where δ is (as before) a subjective discount factor and $p_{j,t+i}^*$ is the optimal price, i.e. the latter is the profit-maximizing price for firm in the absence of any restrictions or costs associated with price adjustment. It equals the mark-up over nominal marginal costs, i.e. in logarithms $p_{j,t+i}^* = mcn_{j,t+i}^f + \mu$, where $mcn_{j,t+i}^f$ is the marginal costs of the forward-looking firm *j* and $\mu \geq 0$ is the mark-up. The minimization of (4) implies the following relation for the optimal reset price of firm *j*,

$$p_{j,t}^{f}=(1-\delta\theta)\sum_{i=0}^{\infty}(\delta\theta)^{i}\left(mcn_{j,t+i}^{f}+\mu\right) \tag{5}$$

If, in addition, firms are assumed to share common production technology and labor markets are homogenous, then marginal costs are same for all firms adjusting the price at t, i.e. $mcn_{j,t+i}^{f}=mcn_{t+i}^{f}\ \ \forall j$, and, hence, also the optimal reset price is the same, $p_{j,t}^{f}=p_{t}^{f}\ \forall j$, for all forward-looking firms adjusting their price at t. Accordingly, at the aggregate, we can write:

$$p_{t}^{f}=(1-\delta\theta)\sum_{i=0}^{\infty}(\delta\theta)^{i}\left(mcn_{t+i}^{f}+\mu\right) \tag{6}$$

Equations (1)-(2), (3a) and (6), when written in terms of aggregate inflation (where $\pi_t=p_t-p_{t-1}$), imply,

$$\pi_t=\gamma_0^f E_t(\pi_{t+1})+\gamma_0^b\pi_{t-1}+\lambda_0\left(mcn_t^f+\mu-p_t\right) \tag{7}$$

where $\gamma_0^f=\delta\theta\phi^{-1}$, $\gamma_0^b=\omega\phi^{-1}$, $\lambda_0=(1-\omega)(1-\theta)(1-\delta\theta)\phi^{-1}$ and $\phi=\theta+\omega[1-\theta(1-\delta)]$.

The adoption of the backward looking rule (3b) results in:

$$\pi_t=\gamma_1^f E_t(\pi_{t+1})+\gamma_1^b\pi_{t-1}+\lambda_1\left(mcn_t^f+\mu-p_t\right) \tag{8}$$

where $\gamma_1^f=\delta\theta[1-\omega(1-\theta)]\varsigma^{-1},\gamma_1^b=\omega\theta\varsigma^{-1},\lambda_1=(1-\omega)(1-\theta)(1-\delta\theta)\varsigma^{-1}$ and $\varsigma=\theta(1+\delta\theta\omega)$.

An interesting feature of equations (7) and (8) is that, although the assumed underlying pricing rules of backward looking firms differ, they are, in fact, observationally equivalent. It can be shown that that between the parameter values of ω associated with the rule (3a) (denote by ω_0) and the rule (3b) (denote by ω_1) the following relation prevails: $\omega_1=\dfrac{\omega_0}{\theta+\omega_0(1-\theta)}$. By substituting this relation into (8) we end up with (7) or vice versa and, hence, for the composite parameters $\gamma_1^f = \gamma_0^f$, $\gamma_1^b = \gamma_0^b$ and $\lambda_1 = \lambda_0$. This also suggests that time series techniques are not able to identify pricing rules (3a) and (3b) from each other. However, parameter estimates of θ and δ are unaffected by this indeterminacy. On the positive side, we may conclude that this indeterminacy increases the generality of the specified equations (7) and (8). Indeterminacy concerns only the identification of ω; different estimates are obtained conditional on the assumption concerning the information lag.

The only situation where this indeterminacy disappears is in the limiting case of completely flexible price setting, i.e. $\theta = 0$. In the context of the one period information lag backward looking rule (3a), equation (7) reduces to the backward-looking error correction form: $\pi_t = \omega \cdot \pi_{t-1} + (1-\omega)\left(mcn_t^f + \mu - p_{t-1}\right)$, while in the context of no information lag backward looking rule, we end up with $p_t = mcn_t^f + \mu$, i.e. prices are set optimally although part of the firms do not base their price-setting behavior on optimization.

When the share of the backward looking firms is zero, $\omega = 0$, then both (7) and (8) reduce to,

$$\pi_t = \delta E_t(\pi_{t+1}) + (1-\theta)(1-\delta\theta)\theta^{-1}\left(mcn_t^f + \mu - p_t\right) \tag{9}$$

Notably, specifications (7)-(9) cannot be estimated before operationalizing the marginal cost variable mcn_t^f. We define two approaches. The first – what might be called the *standard approach* – derives (and calibrates) marginal cost from a highly simplified production framework. In the second – the one followed here – the fundament is determined by a fully-specified firms-based supply-side system based on aggregation across sectors. We relax many of the constraints typically found in this literature and allow key parameters on both the supply and demand side to differ across sectors and goods. In the following (Section 3), we first review this standard approach (as in Galí *et al*., 2001) and, in particular, we show that marginal costs, as typically calibrated, do not pass the standard requirements of cointegration in euro-area data.

3. NKPCs: Existing Studies (The Standard Approach)

Here, we argue that the reasonableness of (especially euro-area) NKPC estimates are conditional upon two factors. The first is the scaling parameter linking the firm-level marginal cost to the aggregate. We argue that the grounds for a non-unit value for this scaling parameter are not well founded and require unrealistic assumption about capital. Whether the scaling parameter is unity or not has a large bearing on the NKPC estimates. When (euro-area) NKPCs are estimated when the scaling parameter is constrained to be non-unity, results deteriorate markedly. The second factor is the common practice of including a freely-estimated constant in the NKPC regression. Since such a constant is not implied by theory, we discuss its role and interpretation. The sensitivity of estimation results with respect to both factors (i.e., scaling parameter and constant) is a fact that we associate with the basic problem non-stationarity of the euro-area labor income share.

3.1. Treatment of the Capital Stock

The *standard approach* derives (and calibrates) the marginal cost from a highly simplified production framework where either labor is the only factor (Galí *et al*., 2001) or where capital is included but determined outside the optimization framework (Sbordone, 2002). Given Cobb-Douglas technology $Y_t = A_t N_t^{1-\alpha} K_t^{\alpha}$ and assuming that each firm is a monopolistic competitor producing a differentiated good and faces the iso-elastic demand curve for its products, given by, $Y_{jt} = Y_t \left(P_{jt} / P_t \right)^{-\varepsilon}$, the real marginal cost ($mc_t^f = mcn_t^f - p_t$), specified in terms of aggregate marginal cost, is:

$$mc_t^f - mc_t = -\left(y_t^f - y_t\right) + \left(n_t^f - n_t\right) = -\frac{\alpha}{1-\alpha}\left[\left(y_t^f - y_t\right) - \left(k_t^f - k_t\right)\right] \qquad (10)$$

Thus, (10) shows that, if capital is exogenous, an assumption as to how the capital stock is allocated across firms is required. To end up with a formula without capital, the term $\left(k_t^f - k_t\right)$ must vanish. Two simple but unrealistic cases are: [6]

(a) $k^f = k = 0$: capital is not included in the theoretical framework, e.g., Galí *et al.*(2001).

(b) $k^f = k$: all capital is held by those forward-looking firms able to reset their prices at period *t*.

In both cases, capital disappears and after inserting the demand function into (10) we derive:

$$mc_t^f + \mu = \frac{1-\alpha}{1+\alpha(\varepsilon-1)}\left[mc_t + \mu\right] = \xi\left[mc_t + \mu\right] \quad ; \quad \xi = \frac{1-\alpha}{1+\alpha(\varepsilon-1)} \tag{11}$$

where typically α and ξ are calibrated to ensure a pre-set mark up. In the case where $\alpha = 0$ we have $\xi = 1$ and thus $mc_t^f = mc_t$.

Two other (more realistic) assumptions about the allocation of the exogenously-deteremined capital stock, is to assume that the capital-output (c) or capital-labor ratio (d) is equal across all firms:

(c) $k_t^f - y_t^f = k_t - y_t$

It is then straightforward to show that (10) collapses to $mc_t^f = mc_t$. Hence, independent of α , no scaling of ξ different from unity is needed. Similarly for,

(d) $n_t^f - n_t = k_t^f - k_t$

after substituting into the production function:

$$y_t^f - y_t = (1-\alpha)(n_t^f - n_t) + \alpha(k_t^f - k_t) = k_t^f - k_t$$

again, we see this implies $mc_t^f = mc_t$ and that $\xi = 1$ with $\alpha \in [0,1]$. [7] In fact, we derive the same result when capital is endogenous and part the optimization framework.[8] The difference is that in the capital-endogenous case, this holds for all future values, whereas when the capital stock is exogenously given, this identity between aggregate and dis-aggregated marginal cost does not hold for expected future values. However, from the point of view of estimated specification (7) or (8) does not matter, whilst this is not the case if one tries to estimate in present-value form, (Rudd and Whelan, 2003).

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[6] Sbordone (2000) suggests that for the disappearance of the capital stock, it is sufficient to say that it is exogenous. However, equation (10) shows that this is not a sufficient condition.

[7] Thus, the deviation of ξ from unity requires that the production function exhibits non-constant returns to scale.

[8] Thus, the Capital-labour ratio is determined by the relative price of inputs, which is common across firms with homogenous labour and capital.

To conclude, the motivation for introducing this scaling parameter, ξ, to be different from unity, is not well founded. On one hand, if capital is treated exogenously and constant returns are assumed, this requires unrealistic assumptions about the allocation of capital, (a) or (b). On the other, for non-constant returns, pinning down a value for ξ is difficult because there is no straightforward way to calibrate the size of the returns to scale and, due to the difficulties to disentangle the speed of technical progress from non-unitary returns to scale, its estimation is very problematic.

3.2. Estimation Issues: Labor Share Identities and Regression Constant

Our second issue highlights that the inclusion a freely-estimated constant is not neutral with respect to the NKPC's empirical success. We see, for instance, from equation (7 or 8) that, the markup μ can be estimated using the level of real marginal cost as the fundamental variable. Then, the equation includes a constant, which is directly interpretable: namely that of the steady-state markup. However, a typical way to operationalize the fundamental variable is, using Cobb-Douglas, to express the markup over real marginal costs in terms of the deviation of labor income-share from the steady state (i.e., sample average). In the following, we show that in this context, the markup term disappears and equation does not allow any freely-estimated constant.

Using the fact that in the steady-state (denoted by a bar): $\overline{mc}_t = \log(1+\mu)$. This implies that $mc_t + \log(1+\mu) - \overline{mc}_t + \log(1+\mu) = mc_t - \overline{mc}_t = s_t - \bar{s}$, where $s = \log\left(\frac{wN}{PY}\right)$ denotes the log labor income share. Hence, with the scaling parameter ξ in (11), linking the firm-level marginal cost to the aggregate, equaling to unity, equation (7) can be written as:

$$\phi\pi_t - \theta\delta\pi_{t+1} - \omega\pi_{t-1} - (1-\omega)(1-\theta)(1-\delta\theta)(s_t - \bar{s}) = 0 \tag{12}$$

Specification (12) has the advantage that no assumption concerning the production function parameters or markup is needed.

Clearly there is no role for a constant in this equation (i.e., it is not implied by theory). Nevertheless, when equilibrium inflation deviates from zero, the question arises as to the requirement for a constant to account for non-zero sample average (steady-state) inflation. This argument would imply the following specification, where the dependent variable (inflation), as well as the driving variable, is measured as deviation from sample average, $\overline{\pi}$ (which is the operational measure for equilibrium inflation, π^*):

$$\phi(\pi_t - \overline{\pi}) - \theta\delta(\pi_{t+1} - \overline{\pi}) - \omega(\pi_{t-1} - \overline{\pi}) - (1-\omega)(1-\theta)(1-\delta\theta)(s_t - \overline{s}) = 0 \qquad (13)$$

Thus, this equation includes a constant. It is not, however, freely estimated but is given in absolute terms by $(\phi - \theta\delta - \omega)\overline{\pi}$. Consequently, one objection might be that specification (13) is open to the *Lucas Critique* since, instead of π^* being constant (zero, for example), it is effectively dependent on the monetary policy regime.

In fact, our derivation of equations (7) and (12) did not contain any constraining assumption concerning the inflation regime. If the estimated equation is regime dependent as (13) states, why does the theoretical derivation not capture it? To answer this, equation (6), $p_t^f = (1-\delta\theta)\sum_{i=0}^{\infty}(\delta\theta)^i\left(mcn_{t+i}^f + \mu\right)$, is key. It states that the forward-looking firms, which reset their price level at period t is the markup over weighted average of future nominal marginal costs. In the regime of zero steady-state inflation, equation (6) implies, independently from the price fixing parameter θ, $p_t^f = \mu + mcn_t^f$. However, more generally in the equilibrium inflation regime $\pi_t = \pi^*$, price setting follows the rule $p_t^f = \mu + mcn_t^f + \frac{\delta\theta}{(1-\delta\theta)^2}\pi^*$. Hence, with values of the price fixing parameter $\theta > 0$, the reset price depends positively on the equilibrium inflation rate and the new fixed price may be well above the markup over current nominal marginal costs. This reflects, however, the fact that the price-resetting firms expect their prices to be fixed over the period $1/(1-\theta)$. That, in turn, implies that half of the time of expected price fixing, their price will be above and half of the time below the markup over marginal costs prevailing at each future point in time.

Therefore in aggregating across both the price-resetting and non-price re-setting firms, the equality of the current price level and the markup over current nominal marginal costs holds independently from the steady state inflation regime. All of this is contained by the derived equation (12) and, therefore, the equilibrium inflation rate does not appear in that equation. On this basis, we prefer specification (12) to (13).

In next section, we estimate equations (12) and (13) and show that results are sensitive with respect to which alternative is chosen. Although estimation results based on either specification are not good, results based on specification (13) appear more reasonable. They also resemble those presented by, for example, Galí *et al.* (2001). However, besides being open to Lucas Critique as argued above, their robustness can be criticized: for instance, the magnitude of estimated parameters (e.g., price durations, discount factors) can be economically unreasonable. Consequently, we conclude that such weak results may highlight the problem that there is no apparent cointegration between the euro-area actual price level and the long-run equilibrium price level (when the latter is assumed to be determined by the labor-income share). This, we argue, suggests mis-specification of the underlying supply side.

3.3. Empirical Results: The Standard Approach

Using the same data, instruments and normalizations as in Galí *et al*. (2001) we present the estimated forms of equations (12) and (13); Table 1 presents estimates of the hybrid NKPC when $\xi = 1$ in un-normalized and normalized (with respect to inflation) forms. We see (Columns 1 and 3) based on equation (13), where all the structural parameters are estimated, results are very close to those in Galí *et al*. (2001).

However, from an economic viewpoint the (average) price durations appear unreasonably long (11 and 13 quarters) and, especially, the implied annualized discount rates are unreasonably high: 50 % and 36% respectively. Constraining the discount rate to the common annual prior of 4%, in columns 2 and 4, did not improve estimates since the implied duration increased further to 15 and 58 quarters, respectively.

Estimates based on (12), in columns 5 and 6, fared no better except for estimates of the discount factor, which were close to unity. The implied durations of price fixing, in turn, were longer than in estimations based on equation (13), i.e. 18 and 527 periods respectively. We also see that results, especially with respect to the lagged inflation coefficient, are very sensitive to normalization. The unnormalized forms of (13) and (12) strongly favors the pure NKPC whilst normalizing them with respect to inflation favors the hybrid case.

Overall, therefore, the estimates appear weak and unrobust. This may emphasize the basic problem that there is no apparent cointegration between the actual price level and its constructed long-run equilibrium. This failing of stationarity essentially points to and highlights the mis-specification of the underlying supply side.

4. Aggregate Prices and Factor Demand in a Frictionless and Staggered-Price Economy

In this section, we first explain a frictionless model of the economy which is equivalent to a model of long-run supply based on static optimization of the firm[9] but consistent with observed movements in euro-area aggregate mark-ups. This allows us to revise the theoretical framework underlying the NKPC in a more realistic direction. This model defines output price and factor demands as a three-equation system with cross-equation parameter constraints. After having derived our frictionless optimal price determined by the aggregated supply-side system, we then incorporate it into the NKPC framework.

4.1. Supply Side Considerations: Accounting for Observed Non-Stationary Markups

Here, we illustrate the approach of deriving a data consistent system of long-run supply (Willman, 2002). Our long-run system allows price, income elasticities, markups and output shares between sectors to differ. This implies, for instance, secular developments in the aggregate labor-income share that are an observed feature of the euro area aggregated data, e.g., Blanchard (1997). This phenomenon cannot be satisfactorily explained by deviation of substitutions of capital and labor from unity. Thus, it should be clear that, though we use euro-area data, the concerns of stationarity and proper supply modeling refer to many large constituent countries (e.g., Germany, France) as well as potentially to the sectoral modeling of NKPCs.

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9 Thus, we maximise the decisions of the firm sector whilst household behaviour (thus decisions on the optimal labour-leisure trade off) is outside the scope of our framework.

As mentioned, the maintained hypothesis in the literature is that of Cobb-Douglas technology – this implies that marginal labor cost is proportional to nominal unit labor costs. Coupled with a constant price elasticity of demand, this means that the output price should depend on nominal unit labor cost with a unit elasticity. This, in turn, implies, as a tautology, that real unit labor costs (or labor income share) should be stationary (or at least trendless). Hence, the humped-shaped (non-stationarity) pattern of the labor-income share (Figure 1) that has been observed at the euro-area level (e.g., Blanchard, 1997, Caballero and Hammour, 1998) lies in contradiction to that theoretical framework.

Though not required, our approach also applies Cobb-Douglas technology but accounts directly for this non-stationarity in the aggregate markup (resulting from the aggregation across heterogeneous sectors), which then implies co-integration between the actual and optimal price in the frictionless economy.[10] Note further that in our framework – unlike Galí *et al*. (2001) and Sbordone (2002) – the optimal capital stock is included and determined endogenously. This long-run (as opposed to short-run, capital exogenous) optimizing framework has important implications for the estimation of NKPCs.

4.2. Model of Long-Run Supply

We first aggregate the FOCs of optimization of firms, which are sectorally differentiated and face sectorally-differentiated demand curves. We show that these relaxations of standard assumptions introduce sectoral production shares as determinants of the aggregate markup. Thereafter, utilizing a simple demand system with sectorally-differentiated income elasticites, we show that the long-run development of sectoral production shares can be reduced to trend. We also show that relaxing the assumption of constant price elasticity of demand, introduces competitors' price into the pricing equation. When applied to the open sectors of the economy, this offers an avenue to incorporate the adverse supply-side shocks of the 1970s into our framework in the spirit of Bruno and Sachs (1985) and Blanchard (1997), which is essential to explain the hump in the labor income share in the late 1970's and early 1980's. The interpretation runs that, due to less flexible labor markets in the euro area (relative to competing non-area ones), the effects of the oil price shocks were passed more fully onto labor costs. The dependence of open-sector price setting behavior on competing foreign prices

[10] Our theoretical framework (Sections 4.2) is written in terms of a general neo-classical framework, although in empirical work we apply Cobb-Douglas. Willman (2002) also estimated using CES and found that a unitary elasticity of substitution between capital and labor could not be rejected.

implies that part of the effects of adverse supply-side shocks are transmitted into lower markups in the open sector and, through aggregation, to the whole economy.

4.2.1. *Aggregation of the long-run supply side of the firm*

Consider an economy with *m* sectors. Firms in each sector produce differentiated goods, which are close substitutes within each sector, but not for one another across sectors. Except for the differences in the technological level and the growth of technological progress in each sector, all firms use the same production technology. This assumption allows us to specify the optimization framework in terms of the value-added concepts, which simplifies the notation. As our aim is to model the aggregated long-run supply, no frictional elements are accounted for and the time index *t* in the context of variables is suppressed unless necessary for clarity. Hence, the production and demand of firm *i* in sector *j* are determined by:

$$Y_i^j = A^j e^{\gamma^j t} F\left(K_i^j, N_i^j\right) = A^j e^{\gamma^j t} f\left(k_i^j\right) N_i^j \tag{14}$$

$$\frac{Y_i^j}{Y^j} = D^j\left(\frac{P_i^j}{P^j}\right); \; \frac{\partial \log D^j}{\partial \log P_i^j} = \varepsilon^j < -1 \tag{15}$$

where Y_i^j, N_i^j K_i^j and k_i^j is output, labor, capital and capital-labor ratio, of firm *i* in sector *j*. There are *m* sectors in the economy and n^j firms in each sector *j*. Y^j is output of sector *j* and D^j is the demand function faced by firms in sector *j*. Parameter γ^j is technological change and ε^j is the price elasticity of demand in sector *j*.

Assume that, in each sector, a fixed share of firms are profit maximizers, while the rest minimize their costs.[11] As factor markets are assumed competitive, each firm *i* in each sector *j* faces the same nominal wage rate *w* and nominal user cost of capital *q*. Hence,

$$\begin{cases} \max\limits_{Y_i^j, N_i^j, K_i^j} \prod_i^j = P_i^j \cdot Y_i^j - w \cdot N_i^j - q \cdot K_i^j \\ \text{s.t. equations (14) and (15)} \end{cases} \tag{16a}$$

[11] This partition of decision-makers into profit maximisers and cost minimisers reflects our earlier division of price setters; since a share of agents use rule-of-thumb (i.e., backward-looking) pricing rules they cannot be profit maximisers; we therefore make the alternative operational assumption that they are costs minimisers.

$$\begin{cases} \min\limits_{N_i^j, K_i^j} C_i^j = w \cdot N_i^j + q \cdot K_i^j \\ \text{s.t. equation (14)} \end{cases} \tag{16b}$$

The FOCs of profit maximisation imply the following 3-equation system, which determines the price of output, marginal rate of substitution between capital and labor and the production function:

$$P_i^j = \left(1+\mu^j\right)\left[\frac{w}{A^j e^{\gamma^j t}\left(f\left(k_i^j\right)-k_i^j f'\left(k_i^j\right)\right)}\right] \quad ; 1+\mu^j = \frac{\varepsilon^j}{\varepsilon^j+1} \geq 1 \tag{17}$$

$$\frac{\partial Y_i^j / \partial N_i^j}{\partial Y_i^j / \partial K_i^j} = \frac{f\left(k_i^j\right)-k_i^j f'\left(k_i^j\right)}{f'\left(k_i^j\right)} = \frac{w}{q} \tag{18}$$

$$\frac{Y_i^j}{N_i^j} = A^j e^{\gamma^j t} f\left(k_i^j\right) \tag{19}$$

The FOCs of cost minimization, in turn, implies the 2-equation system of (18)-(19). As the relative factor price w/q in (18) is the same across firms, that implies that the capital-labor ratio is also the same across firms equaling the aggregate capital-labor rate: $k_i^j = k^j = k, \forall i, \forall j$.

Aggregating first within and then across sectors and after some linearization (see Appendix 1) we derive:

$$\log\frac{Y}{N} = \log f(k) + \log A + \gamma_A \cdot t - \sum_{j=1}^{m} A\left(A^j\right)^{-1}\left(s_t^j - s_0^j\right) \tag{20}$$

$$\frac{f(k)-kf'(k)}{f'(k)} = \frac{w}{q} \tag{21}$$

$$\log P = \log w - \underbrace{\left\{ \log\left[f(k) - k \cdot f'(k) \right] + \log A + \gamma_A \cdot t - \sum_{j=0}^{m} A\left(A^j\right)^{-1}\left(s_t^j - s_0^j\right) \right\}}_{\text{Log of the marginal product of labour}} \tag{22}$$

$$\underbrace{+ \log(1+\mu_A) + \sum_{j=1}^{m} \frac{A\left(A^j\right)^{-1}\left(\mu^j - \mu_A\right)}{1+\mu_A}\left(s_t^j - s_0^j\right) - \sum_{j=1}^{m} b^j\left(\gamma^j - \gamma_A\right) \cdot t}_{\text{Log of the mark-up}}$$

where $s_t^j = \frac{Y_t^j}{Y_t}$, $A = \left(\sum_{j=0}^{m} s_0^j \left(A^j\right)^{-1} \right)^{-1}$, $\mu_A = \sum_{j=1}^{m} A\left(A^j\right)^{-1} s_0^j \mu^j$, $b^j = \frac{A\left(A^j\right)^{-1} s_0^j \left(1+\mu^j\right)}{\sum_{j=1}^{m} A\left(A^j\right)^{-1} s_0^j \left(1+\mu^j\right)}$,

$\sum_{j=1}^{m} b^j = 1$, $\gamma_A = \sum_{j=1}^{m} A\left(A^j\right)^{-1} s_0^j \gamma^j$.

An important difference of the aggregated supply-side system (20-22) compared to the firm-level system (17)-(19) is that the price equation (22) allows for the time-varying markup. If the sectoral markups, although constant, differ across sectors and, in addition, sectoral output shares change, then the aggregate markup contains a secular component. This development can be reinforced (or compensated) by sectoral differences in efficiency and technical progress. For instance, if the output share of less competitive sectors with slower technical development (e.g., Services) grows, this introduces a positive trend in the aggregate markup.[12]

Our next relaxing assumption is that the price elasticities $\varepsilon^j \; \forall j$ (and hence markups) need not be constant. This is the case, if in some sectors, assume e.g. in the export sector (j=x), firms face the following AIDS demand function. [13]

$$\kappa = \frac{P^x \cdot Y^x}{P_f \cdot D_f} = a + \theta \cdot \log\left(\frac{P_f}{P^x} \right) \qquad ; a, \theta > 0 \tag{23}$$

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[12] A stylized fact in the euro area development has been a strong increase in the output of the Services sector. From 1970-1999, this share increased from 51.5% to 61.3%. In the US, by contrast, the output share of Services has remained roughly constant: i.e., from 64.7% to 63.0%.(Source: OECD)

[13] In terms of the AIDS expenditure system, the share of country i exports in world imports (at current prices) is: $\kappa_i = \frac{P_i^x \cdot X_i}{P_f \cdot D_f} = a_i - \theta_{ii} \cdot \log P_i^x + \sum_j \theta_{ij} \log P_{ij}^x$, where $\sum_i a_i = 1$, $\theta_{ii} = \sum_j \theta_{ij}$ and P_f is a weighted index of export prices P_j^x, i.e. the competing foreign price (see Deaton and Muellbauer, 1980).

where η is the market share of exporting sector in nominal terms, D_f is world market demand and P_f is the competing foreign price level. Compared to the world market the size of the exporting firm is very small, which allows us to treat both world market demand D_f and the price level P_f as exogenous.

As is shown explicitly in Appendix 2, equation (23) implies time varying price elasticity and the markup in the export sector and the log of the markup can be presented in the form:

$$\log\left(1+\mu^x\right) \approx \log\left(1+\bar{\mu}^x\right) + \frac{1}{1+\bar{\mu}^x}\log\left(\frac{P_f}{P^x}\right); \bar{\mu}^x = \frac{a}{\theta} \tag{24}$$

The fact that the export-sector markup depends on the competitive pressure of foreign prices allows us to write the economy markup in (22) as:

$$\log\left(1+\mu_A\right) + \sum_{j=1}^{m} \frac{A\left(A^j\right)^{-1}\left(\mu^j - \mu_A\right)}{1+\mu_A}\left(s_t^j - s_0^j\right) - \sum_{j=1}^{m} b^j\left(\gamma^j - \gamma_A\right)\cdot t =$$

$$\log\left(1+\bar{\mu}_A\right) + \frac{s_0^x}{1+\bar{\mu}^x}\log\left(\frac{P_f}{P^x}\right) + \sum_{j=1}^{m} \frac{A\left(A^j\right)^{-1}\left(\mu^j - \bar{\mu}_A\right)}{1+\bar{\mu}_A}\left(s_t^j - s_0^j\right) - \sum_{j=1}^{m} b^j\left(\gamma^j - \gamma_A\right)\cdot t \tag{25}$$

where $\bar{\mu}_A$ is the value of μ_A calculated in terms of $\bar{\mu}^x$ and s_0^x is production share of the export (or open) sector in the base (reference) period.

4.2.2. Determination of sectoral output shares

Here, we show that, with help of a simple demand system, that the sectoral output shares can be reduced to trend, which essentially alleviates the data requirements of estimation.

There are *m* sectors in the economy, of which *m-1* are closed and the last is the export sector. Hence, the aggregate output is the sum of closed sectors' output $\left(YD = \sum_{j=1}^{m-1} Y^j\right)$ and export sector's output Y^x. Assuming no cross-sector substitutability between goods produced by closed sectors, the aggregate demand for closed sector goods is determined by the demand system,

$$\frac{Y^j}{YD} = e_t^j = e_0^j + \tau^j \log\left(\frac{YD/YD_0}{N/N_0}\right), \quad \sum_{j=1}^{m-1} e_t^j = 1, \quad \sum_{j=1}^{m-1} \tau^j = 0 \tag{26}$$

where e_t^j represents the output share of sector j $(j = 1,..,m-1)$ in the aggregated closed sector output, $\frac{Y^j}{YD}$, and *0* refers to the starting (or reference) period values of variables. Equation (24) expresses the demand system for the goods of closed sectors in per capita terms. Values of parameter $\tau^j > 0 \; (\tau^j < 0)$ imply greater (smaller) than unitary income elasticity of demand. As, by definition, $YD = (1 - s^x)Y$, we derive for the output share $s^j = Y^j/Y$

$$s_t^j = (1 - s_t^x)e_t^j \approx s_0^j + (1 - s_0^x)(e_t^j - e_0^j) - e_0^j(s_t^x - s_0^x) \tag{27}$$

where $s_0^j = (1 - s_0^x)e_0^j$

In Appendix 3 we show that in a growing economy, utilizing the demand system (26) and export equation (23), equation (27) can be transformed into the form,

$$s_t^j - s_0^j = \left[(1 - s_0^x)\tau^j - s_0^x(g_f - g)e_0^j\right] \cdot t + \nu_t^j \tag{28}$$

where g and g_f are long-run equilibrium growth rates of domestic and foreign demand, respectively. The term ν_t^j is the deviation of production share from its long-run growth trend in the sector j, which can reasonably be assumed to be stationary. Therefore, the important implication of equation (28) is that the long-run development of sectoral production shares are reduced to (linear) trend, the coefficient of which is determined by two components, i.e. the deviation of sectoral income elasticity from unity $(\tau^j \neq 0)$ and the long-run growth difference of equilibrium foreign demand.[14]

Substituting (28), as well as equation (25), into the supply side system of (20) - (22), we end up with the system,

$$\log \frac{Y}{N} = \log f(k) + \log A + \Gamma \cdot t + v_{1,t} \tag{29}$$

$$\frac{f(k) - kf'(k)}{f'(k)} = \frac{w}{q} \tag{30}$$

$$\log P = \log w - \log\left[f(k) - k \cdot f'(k)\right] + \log A + \Gamma \cdot t + \log(1 + \bar{\mu}_A) + \chi \log\left(\frac{P_f}{P^x}\right) + \eta \cdot t + v_{2,t} \tag{31}$$

where

$$\Gamma = \left[\underbrace{\gamma_A - (1 - s_0^x) g \sum_{j=1}^{m-1} A (A^j)^{-1} \xi^j - s_0^x (g_f - g)\left(\sum_{j=1}^{m-1} A (A^j)^{-1} e_0^j - A (A^x)^{-1}\right)}_{\Gamma}\right], \qquad \chi = \frac{s_0^x}{1 + \bar{\mu}^x},$$

$$\eta = \left[\frac{(1 - s_0^x) g}{1 + \bar{\mu}_A} \sum_{j=1}^{m-1} A (A^j)^{-1} (\mu^j - \bar{\mu}_A) \xi^j - \frac{s_0^x (g_f - g)}{1 + \bar{\mu}_A}\left(\sum_{j=1}^{m-1} A (A^j)^{-1} (\mu^j - \bar{\mu}_A) e_0^j - A (A^x)^{-1} (\bar{\mu}_x - \bar{\mu}_A)\right) - \sum_{j=1}^{m} b_j (\gamma^j - \gamma_A)\right]$$

Since $v_{1,t}$ and $v_{2,t}$ are stationary, they are absorbed by the residuals of the estimated long-run aggregated supply system.

4.2.3. Specification of aggregated supply side system with the Cobb-Douglas technology

Before being able to estimate the aggregated supply-side system, the underlying technology must be specified. From the point of view of estimation, Cobb-Douglas and CES would be natural candidates. However, we constraint our analysis to the former since, using euro-area data, the estimated CES function effectively reduces to the Cobb-Douglas. (Willman, 2002).

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14 Note our use of a linear time trend rather than, say, a quadratic since the former is implied by theory. Changing sectoral output shares requires that income elasticities across sectors differ from unity, so if technical progress is the driving variable for long-term growth, then this, associated with *permanent* deviation of elasticity from unity, implies a linear trend. We are aware of the possible problems involved since in the very long-run equilibrium, elasticities different from unity imply in a growing economy the infinite expansion of some sectors and the infinite contraction of others in terms of output shares. Over an empirical horizon, constant deviations from unity elasticity is both reasonable and empirically supported.

Using Cobb-Douglas, $f(k)=\left(\frac{K}{N}\right)^{\alpha}$, the aggregated supply system can be written as:

$$\log\frac{Y}{N}=\alpha\log\left(\frac{K}{N}\right)+\log A+\Gamma\cdot t \tag{32}$$

$$\frac{qK}{wN}=\left(\frac{\alpha}{1-\alpha}\right) \tag{33}$$

$$\begin{aligned}\log P = \log w - &\underbrace{\left\{\log(1-\alpha)+\alpha\log\left(\frac{K}{N}\right)+\log A+\Gamma\cdot t\right\}}_{\text{Log (MPL)=Log of the marginal product of labour}} \\ &+\underbrace{\log(1+\bar{\mu}_A)+\chi\log\left(\frac{P_f}{P^x}\right)+\eta\cdot t}_{\text{Log of the mark-up}}\end{aligned} \tag{34}$$

For notational simplicity, stationary terms $v_{1,t}$ and $v_{2,t}$ are abstracted from equations (32) and (34).

Aggregate Cobb-Douglas technology (32), implies that the marginal product of labor in equation (34) can be expressed alternatively in the form $MPL=(1-\alpha)\cdot(Y/N)$. This implies that (34) can also be written in that form, where the (inverted) income share is the lhs variable:

$$\log\left(\frac{pY}{wN}\right)=-\log(1-\alpha)+\log(markup) \tag{35}$$

Equation (35) shows that the aggregated labor income share $\frac{wN}{pY}$ is inversely related to the changes in the markup and, hence, non-stationarity of the total economy markup also implies non-stationarity of the aggregated labor income share – even assuming Cobb-Douglas technology. However, simultaneously, equation (33) states that the relative factor income, $\frac{qK}{wN}$, has to be constant (stationary) for the assumption of the aggregate Cobb-Douglas production function to be true. That implies that the GDP share of capital income, excluding profits, is also inversely related to the aggregate markup, which may be time-varying, although sectoral markups would be constant. In estimating the long run supply-side, the markup equation could be expressed alternatively in terms of capital-to-labor (34) or output-to-labor ratio (35). However, both alternatives give practically identical estimates of supply-side parameters. In calculating our marginal cost, we preferred (34) because the implied marginal cost is not open to the critique made by Roberts (2001) that due to e.g. labor hoarding, typically, the output-labor ratio is found to be pro- instead of counter-cyclical as theory would suggest. The capital-labor ratio, in turn, behaves counter-cyclically if the adjustment of capital to equilibrium is slower than that of labor (commonly considered a stylized fact).[15]

5. Structural Estimates

5.1. Estimates of the Supply Side

Estimates of our 3-equation supply-side (32-34) are given in Table 2.[16] The results appear reasonable, significant at the 1% level and in line with our priors. Specifically, we see that the elasticity of output with respect to Capital (β) is around 0.3, the estimate of technical progress (γ) implies an annual growth of technical factor progress of 2% and η (the parameter capturing the trend in the mark up) deviates significantly from zero.[17] The foreign competing price to export price (i.e., parameter χ) also plays a significant role especially in the behavior of the mark up in the 1970s (e.g., the two oil shocks). Note also the significance of the interest rate dummy capturing real financing costs. [18]

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[15] Preliminary examinations suggested that the NKPC estimates were not sensitive to whether (34) or (35) was applied in estimating the supply-side. Importantly, however, in the policy field, simulations of models incorporating NKPCs, might produce quite different dynamic results depending on the definition used. Nevertheless, theory favors the use of a marginal product measure that behaves counter-cyclically.

[16] In our GMM estimations, we use as instruments two and four period lags of inflation, two, four and five periods lags of the mark-up over real marginal costs and the fit of the one period lead of inflation and the mark-up over real marginal costs on the lags of: capacity utilisation rate (as defined by our supply side), unemployment rate, nominal short term interest rate, terms of trade, change of terms of trade, real marginal cost, residual of price equation excluding terms of trade component. The rational behind the formulation of the composite instruments was an attempt in a parsimonious way to maximise the information contained by history. The dataset and (Rats) programmes used to derive our estimates are available.

[17] Our interpretation of this parameter is that it reflects the rise of the output share of the (essentially less competitive) services sector in the euro area and its constituent members.

[18] This term plays an essential role in our estimation since otherwise the production function parameters (whether Cobb-Douglas or CES) would not capture the correct relative factor income ratio. This dummy thus provides a link from the period of financial regulation of the 1970s, when persistently negative ex-post real interest rates probably did not properly measure true financing costs, and post 1980s more liberalised period associated with positive real interest rates. For a more elaborate discussion, see Appendix 4.

Furthermore, Figure 2 shows our supply-side system estimate of the mark-up over real marginal cost and that from that implied by the Galí *et al*. (2001) calibration. Notably, the mark-up calculated by our system estimation are stationary around zero (ADF t-test = -3.8) whilst the calibrated variant is non-stationary (ADF t-test = -0.42) and of a relatively higher standard error (0.4 versus 0.2). [19]

5.2. Estimation of Inflation Equations [20]

We consider two cases: *Information Lag* (7) and *No-Information Lag* (8) across normalizations. [21] As is well known, non-linear estimation using GMM can be sensitive to the way orthogonality conditions are imposed and the choice of instruments. (e.g. Fuhrer *et al*., 1995). In line with this, we consider five alternative normalizations – un-normalized (A), normalized with respect to inflation (B), one-period ahead inflation (C), the fundament (D), and, finally, with respect to a weighted average of the fundament and inflation (E): [22]

Information Lag (Equation (7)):

(A) $E_t\{(\phi\pi_t - \theta\delta\pi_{t+1} - \omega\pi_{t-1} - (1-\omega)(1-\theta)(1-\delta\theta)(mcn_t + \mu_t - p_t))z_t\} = 0$

(B) $E_t\left\{\left(\pi_t - \frac{\delta\theta}{\phi}\pi_{t+1} - \frac{\omega}{\phi}\pi_{t-1} - \frac{(1-\omega)(1-\theta)(1-\delta\theta)}{\phi}(mcn_t + \mu_t - p_t)\right)z_t\right\} = 0$

(C) $E_t\left\{\left[\frac{\phi}{\delta\theta}\pi_t - \pi_{t+1} - \frac{\omega}{\delta\theta}\pi_{t-1} - \frac{(1-\omega)(1-\theta)(1-\delta\theta)}{\delta\theta}(mcn_t + \mu_t - p_t)\right]z_t\right\} = 0$

(D) $E_t\left\{\left[\frac{(\phi\pi_t - \delta\theta\pi_{t+1} - \omega\pi_{t-1})}{(1-\omega)(1-\theta)(1-\delta\theta)} - (mcn_t + \mu_t - p_t)\right]z_t\right\} = 0$

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19 Phillips-Perron tests show the same and are available.

20 For estimation, two composite instruments were constructed, namely the best fits of inflation and the mark-up over real marginal costs on the following variables (lagged at least by two periods): the residual of long-run system of estimated potential output, the unemployment rate, short-term nominal interest rates, relative foreign-to-competing export price, terms-of-trade, mark-up including residual component implied by the supply-side system and real marginal costs. In addition to these composite instruments, in estimating NKPC equations, two and four period lags of inflation and two, four and five period lags of the mark-up over real marginal costs were used.

21 For robustness, within each case we also considered the auxiliary cases of imposing $\omega = \gamma_b = 0$ and $\delta = 0.99$ (i.e., 4% annual discount factor). Details available.

22 Thus, as made clear earlier, our framework embodies a time varying mark-up, μ_t.

(E) $$E_t\left\{\left[\begin{pmatrix} \pi_t - \dfrac{1}{\phi}(\theta\delta\pi_{t+1} - \omega\pi_{t-1} + (1-\omega)(1-\theta)(1-\delta\theta)(mcn_t + \mu_t - p_t)) \\ + \dfrac{\sigma_{\pi_t/(mcn_t+\mu_t-p_t)}}{(1-\omega)(1-\theta)(1-\delta\theta)}(\phi\pi_t + \theta\delta\pi_{t+1} - \omega\pi_{t-1}) - (mcn_t + \mu_t - p_t) \end{pmatrix} z_t\right]\right\} = 0$$ [23]

Where parameters are defined as before, where Z_t is a vector of instruments and $\sigma_{\pi/(mcn_t+\mu_t-p_t)} = \dfrac{\sigma_\pi}{\sigma_{(mcn_t+\mu_t-p_t)}} = \dfrac{0.0085}{0.0250} = 0.34$.

And, equivalently, for *No-Information Lag (*Equation (8)):

(A) $$E_t\{[\varsigma\pi_t - \theta\delta(1-\omega(1-\theta))\pi_{t+1} - \theta\omega\pi_{t-1} - (1-\omega)(1-\theta)(1-\delta\theta)(mcn_t + \mu_t - p_t)]z_t\} = 0$$

(B) $$E_t\left\{\left[\pi_t - \frac{\delta\theta[1-\omega(1-\theta)]}{\varsigma}\pi_{t+1} - \frac{\omega\theta}{\varsigma}\pi_{t-1} - \frac{(1-\omega)(1-\theta)(1-\delta\theta)}{\varsigma}(mcn_t + \mu_t - p_t)\right]z_t\right\} = 0$$

(C) $$E_t\left\{\left[\frac{\varsigma}{\delta\theta[1-\omega(1-\theta)]}\pi_t - \pi_{t+1} - \frac{\omega}{\delta[1-\omega(1-\theta)]}\pi_{t-1} - \frac{(1-\omega)(1-\theta)(1-\delta\theta)}{\delta\theta[1-\omega(1-\theta)]}(mcn_t + \mu_t - p_t)\right]z_t\right\} = 0$$

(D) $$E\{[(\varsigma\pi_t - \delta\theta[1-\omega(1-\theta)]\pi_{t+1} - \omega\theta\pi_{t-1})/(1-\omega)(1-\theta)(1-\delta\theta) - (mcn_t + \mu_t - p_t)\ ]z_t\}_t = 0$$

(E) $$E_t\left\{\left[\begin{pmatrix} \pi_t - \dfrac{1}{1+\delta\theta\omega}\left(\omega\pi_{t-1} - \delta(1-\omega(1-\theta))\pi_{t+1} - (1-\omega)\dfrac{(1-\theta)}{\theta}(1-\delta\theta)(mcn_t + \mu_t - p_t)\right) \\ + \sigma_{\pi/mcn_t+\mu_t-p_t}\dfrac{\theta}{(1-\omega)(1-\theta)(1-\delta\theta)}[(1+\delta\theta)\pi_t + \theta\delta\pi_{t+1} - \omega\pi_{t-1}] - (mcn_t + \mu_t - p_t) \end{pmatrix} z_t\right]\right\} = 0$$

[23] Case (E) is motivated by some previous discussion of GMM estimators (e.g., Fuhrer, 1997). Our own justification for this weighted experiment is that in minimising the objective function GMM tends to choose parameter estimates so that weight of the variable which has greatest variance and smallest covariance with other variables tends towards zero. Potentially this is problem if no objective criterion exist about how estimated equation should be normalised. That is why, in models containing leads and lags of endogenous variables (and which is auto-correlated), we may bias the coefficient of the error correction variable towards zero if parameter constraints of the estimated equation allow that. However, if the equation is normalised with respect to the error-correction term that is not possible. Hence, there are two natural ways to normalise the estimated equation, i.e. with respect to the current-period dependent variable or in terms of error correction term. The essential difference between these two is that, in the first case, the objective function is minimised conditional on the variance of inflation and, in the latter, conditional on the variance of error correction term (which is also an endogenous variable). A third possibility is to leave the equation un-normalised. However, in

5.3. Results

In Tables 3-4, we document our alternative estimates for the euro-area NKPC. For robustness, we present our five different normalizations across the conventional *information lag* case and our alternative of *No-Information Lag*. We estimate in terms of the price level equation - rather than the inflation equation and derive recursively the composite parameters (e.g., γ_b). We also solve for the roots of the characteristic equation of each Phillips curve – this gives us information on the dynamic properties of each equation and thus provides a further check on its plausibility. We estimate the hybrid ($\omega \neq 0$) and purely forward looking cases ($\omega = 0$).[24]

As in Section 3.3, inflation was alternatively measured in unadjusted and adjusted (i.e. in terms of deviation from sample average). Only the unadjusted results are reported because, broadly speaking, estimated parameter remained quite robust.[25]

Our conclusions are:

The discount factor (δ) does not deviate significantly from unity or from 0.99 implying an annual discount rate of 4%. [26] This is a robust result and certainly in line with theory. The parameter of price adjustment, θ, (excluding the fundament and weighted cases) is to be found in a narrow range of 0.80-0.85 and significantly different from zero and unity. This parameter of course determines the duration of price fixing. Over the full sample, using the Hybrid model we find average fixed-price duration of 4.7 quarters and a slightly higher average for the purely forward-looking case of 5.4. However, normalization with respect to *fundament* and *weighted* normalization tend to give relatively smaller durations. Excluding these, we find a slightly higher average duration at 5.3 and 6.4 periods respectively. [27] In the light of standard errors, the data supports the Hybrid specification , when estimated equation is un-normalized and normalized with respect to lead inflation and inflation. No-information

that case there is perhaps a risk that parameters become estimated such that the variable with smallest (largest) variance gets the highest (smallest) weight within the range that parameter constraints allow.

24 Note that we estimated the equations over various sub-samples to test for structural instability of the parameters. Since this was effectively not found, we have suppressed the various results for brevity. Details available.

25 Most importantly, when this inflation deviation from average was used, the estimates of the discount factor was not as precise and varied around unity depending on the normalisation – although it never deviated significantly from unity. In addition, when the discount factor was constrained to a 4% annual rate, estimation results were practically the same in both cases (i.e., adjusted and unadjusted inflation measures).

26 By contrast, the Galí *et al*. (2001) estimates of the (euro area) discount rate (δ) are rather high – in the range of 7.5%-19.6% implying an annual range of 33.5%-105%. Overall, their average figure for δ is around 0.88 for both specifications (implying a 57% annualised discount factor).

27 This is to be compared to duration estimates from Galí *et al*. (2001) of 10 (sic) – 12.8 (Hybrid case) and 10.4 – 12.2 (Purely forward-looking case).

lag equations (Table 4) give slightly higher estimates and t-test values for lagged inflation than corresponding information lag equations (Table 3). In the former case estimates of ω are in the range of 0.39-0.59 and in the latter case in the range of 0.34-0.53. Under normalization with respect to fundament and under weighted normalization these estimates are somewhat smaller and statistically insignificant.

The tables also show the characteristic roots in each specified case – these give us information about stability and dynamic adjustment. For instance, in the case of the hybrid price equation, (7) solved in terms of the deep parameters, we have, the characteristic equation $p_{t+1} - \left[\frac{1}{\delta\theta} + 2\omega + (1-\omega)\theta\right] p_t + \left[\frac{1}{\delta} + \frac{2\omega}{\delta\theta} - \frac{\omega}{\delta} + \omega\right] p_{t-1} - \frac{\omega}{\delta\theta} p_{t-2} = 0$ with roots $\frac{1}{2}\left[\theta(1-\omega) + 2\omega \pm \sqrt{(\theta(1-\omega)+2\omega)^2 - 4\omega}\right]$, $\frac{1}{\delta\theta}$.

Saddle-path stability requires one un-stable and two stable roots. The third root is clearly unstable for $\delta \cdot \theta < 1$, and it can be shown that the first two roots fulfil the stability condition if inside the open interval, $\lambda_i \in (\omega, 1)$, $i = 1, 2$[28]. In addition, the discount factor (δ) affects only the forward-looking (unstable) root and the backward-looking parameter (ω) only affects the backward-looking (stable) root(s). Note also there are two separate backward-looking roots when θ is sufficiently high and ω is sufficiently low. In the opposite case, the root tends to become complex. This pattern can be seen in our estimates, where high ω produces cyclical adjustment. In cases A, B and C, results suggest a range for the unstable roots between 1.18 to 1.26. (Normalizations D and E, however, give somewhat higher roots, i.e., between 1.32 and 1.43).

Finally, results across the *Information Lag* and *No-Information Lag* cases, except estimates of lagged inflation parameter ω, are identical, as anticipated in section 2. In un-normalized form estimations this is not exactly the case, but there differences reflect the fact that normalization constraints do not match exactly each other. Hence in other normalization alternatives the estimated price dynamics are not sensitive with respect to the information lag assumption. To conclude, our results appear reasonable and in line with our priors. All specifications pass the orthogonality test (Hansen's *J*) and the regressions display durations of price stickiness roughly 5 quarters. Under conventional normalization (i.e., with respect to current and lead inflation and the unnormalized case), alternatives estimated results supported the hybrid NKPC with estimates ω (for lagged inflation) in the neighborhood of 0.5.

5.4. The Present Value Approach [29]

Rudd and Whelan (2003) criticized the estimation approach typically taken in the literature. They claim that instrumental variable estimates (like GMM) tend to be strongly biased towards forward-looking inflation formation even if the true model contains no such behavior. This situation occurs when the set of instruments contains variables that belong in the true model for inflation and are erroneously omitted from the estimated specification. In addition, in the case where the lagged value of the dependent variable is (correctly) included in the specification, the inclusion of the lagged inflation also in the set of instruments causes similar bias. Our estimations presented in the previous section are not, however, open to this criticism since all the instruments we used were lagged at least by two periods. [30] However, although our estimates for the lagged inflation were not always very precise in absolute terms, the point estimates for the lagged inflation parameter were quite high.[31]

To discriminate between the competing hypothesis of backward- and forward-looking behavior in expectation formation, Rudd and Whelan (2003) recommend tests based on correlations summarized by the reduced-form Phillips curve, where the lead of inflation is reduced to the sum of the fundament:

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[28] For the first two roots, we have the product $\lambda_1 \cdot \lambda_2 = \omega$ and the sum $\lambda_1 + \lambda_2 = \theta(1-\omega) + 2\omega < 1 + \omega$. Since both roots must be positive, $\lambda - (1+\omega)\lambda + \omega < 0$ this implies that $\omega < \lambda < 1$, where λ denotes both λ_1 and λ_2.

[29] In our "Present Value" estimates, we used as instruments, the fit and its one period lag of the difference of the weighted present value of the fundament (the mark-up over real marginal costs) and the lagged price level on lagged values of the fundament and lagged price level, on, two, five and seven periods lags of the short tem interest rate, one period lag of the long-term interest rate, one and three periods lags of relative foreign-to-competing export price, and one and two periods lags of the residual of long-run system of estimated potential output.

[30] In this respect, we deviate from Galí and Gertler (1999) and Galí *et al*. (2002), who included also the one period lag of inflation into the set of instruments.

[31] Also in our estimations (not reported here but available), when the lagged inflation was included by the set of instruments the sizes of the point estimates for the lagged inflation dropped dramatically. Also Roberts (2001) in US data, found that estimates of NKPC are sensitive to the inclusion of lagged inflation in the instrument set.

$$\pi_t = \sum_{j=1}^{J} \omega_j \pi_{t-j} + \left(1 - \sum_{j=1}^{J} \omega_j\right) \gamma \sum_{i=0}^{\infty} \beta^i E_t x_{t+i}$$
$$\approx \sum_{j=1}^{J} \omega_j \pi_{t-j} + \left(1 - \sum_{j=1}^{J} \omega_j\right) \gamma_n \sum_{i=0}^{n} \beta^i E_t x_{t+i} + const \tag{36}$$

where x refers to the fundament (e.g., either output gap or real marginal costs). In their empirical application – as in ours – the infinite sum was approximated by a finite sum of 12 periods. As in case of structural forms, the reduced form (36) can also estimated by instrumental variables. The difference between (36) and the original form is that instead of the lead of the dependent variable (inflation), the instrumented variable is the weighted sum of the leads of the fundament.

If the NKPC is correctly specified, the present value estimates (36) should give similar results as those based on the structural specification. However, Rudd and Whelan (2003) claim that (36) is less likely to spuriously indicate the presence of forward-looking behavior. This is because in this case, the term being instrumented for will not have high correlation with variables that have been omitted from the inflation equation. Hence, if the NKPC or its hybrid form were true, then in (36) at most one lag of inflation would be relevant and the parameter estimate on the lagged inflation should equal to the estimate of the structural NKPC.

Rudd and Whelan (2003) estimated (36) on US data conditional on predetermined values of β while γ_n and ω_j were estimated freely. The fundamental variable x was alternatively either the output gap or the labor income share (real marginal cost). A drawback of this application is that the structural deep parameters are not identified. We show later in this section that the hybrid form of the NKPC can be presented in the Present Value form corresponding to equation (36), where also the structural parameters are identifiable with the gap defined as: $x_{t+i} = \left(p^*_{t+i} - p_{t-1}\right)$, i.e. the gap is defined in terms of nominal marginal costs and (predetermined) lagged price level instead of real marginal costs. Hence, the driving variable of inflation is instead of the present value of real marginal costs, the present value of nominal costs. Consequently, we estimate applying both interpretations. Notably, if the nominal and real marginal cost interpretations are simultaneously correct, empirical results should be similar. If not, we argue that the more general nominal marginal cost interpretation should be favored.

We do not find results similar: in contrast to our earlier results, using the Present Value method and real marginal costs as the fundament, we find the backward-looking component dominating in line with Rudd and Whelan's (2003) findings for US data. However, when using present value of nominal marginal costs as the driving variable, we get a more balanced view on the relative importance of backward- and forward-looking components. All in all, these latter results are well in line with our earlier estimates in the context of estimating the structural-form. We conjecture that these results can be interpreted as indirect evidence in favor of the present value of the mark-up over *nominal* marginal costs as being the correct driving variable of inflation.

5.4.1. Real marginal cost interpretation

First, we considered the standard real marginal cost interpretation. Table (5) summarizes the results obtained from fitting equation (36) conditional on two alternative values of β (which equals to the discount factor in the basic (non-hybrid) specification). If the New-Keynesian interpretation of the reduced-form, Phillips curve is correct, then the inclusion of the present value should result in a substantial reduction in the coefficients on lagged inflation relative to those obtained from purely backward-looking specifications (e.g. the simple regression of inflation on its own lags only as in the bottom row). The results are quite similar to those of Rudd and Whelan (2003) using US data. The introduction of the present-value term into regression, although statistically significant, only marginally lowers the importance of the lagged inflation. (close to 0.9), suggesting a very limited role for expected future values of the real marginal cost variable. In addition, these results are not compatible with our earlier results based on estimation the structural specification – where the weight on lagged inflation was at most only slightly above 0.5. However, as these results are conditional on the assumption that the present value of real marginal costs is the true driving variable, the conclusion that the forward-looking behavior plays only marginal role price setting is not necessarily correct.

5.4.2. Nominal marginal cost interpretation

We next show that the present value term can be expressed as well in terms of nominal marginal costs as real marginal costs. The former practice corresponds to the more general interpretation that rather than being inflation equation, equation (36) is price setting equation.

By denoting $p_t^* = mcn_t + \mu_t$ and expressing the parameters of our structural NKPCs in terms of their roots, the present value form of our NKPCs can be written as,

$$[1-(\lambda_1+\lambda_2)L+\lambda_1\lambda_2]p_t = \sum_{i=0}^{\infty}\left(\frac{1}{\lambda_3}\right)^i(1-\omega)(1-\theta)(1-\delta\theta)E_t p_{t+i}^* \tag{37}$$

As shown in section 5.3, where the backward looking price setting rule contains information lag, we derive the roots as $\lambda_3 = 1/\delta\theta$, $\lambda_1+\lambda_2 = \theta(1-\omega)+2\omega$ and $\lambda_1\lambda_2 = \omega$. Equation (37) can therefore be transformed into,

$$\pi_t = \omega\cdot\pi_{t-1} + (1-\omega)(1-\theta)(1-\delta\theta)\sum_{i=0}^{\infty}(\delta\theta)^i E_t\left(p_{t+i}^* - p_{t-1}\right) \tag{38}$$

Let us approximate the infinite sum by the finite sum, $\sum_{i=0}^{\infty}(\delta\theta)^i E_t\left(p_{t+i}^* - p_{t-1}\right) \approx \frac{1}{1-(\delta\theta)^{n+1}}\sum_{i=0}^{n}(\delta\theta)^i E_t\left(p_{t+i}^* - p_{t-1}\right) + const$. Now the estimated form corresponding to (38) can be written as,

$$\pi_t = \omega\cdot\pi_{t-1} + (1-\omega)\left\{\frac{(1-\theta)(1-\delta\theta)}{1-(\delta\theta)^{n+1}}\sum_{i=0}^{n}(\delta\theta)^i E_t\left(p_{t+i}^* - p_{t-1}\right)\right\} + const \tag{39}$$

Consistent with our earlier results, setting $\delta = 0.99$ equation (39) contains two estimated structural parameters θ and ω. We have allowed the specification to include also an additional constant (*cons*) to take into account the fact that the weighted finite sum of the fundament is only an approximation of the infinite sum. For completeness, we estimate with and without a constant.

As can be seen (Table 6) when estimating (39) without a constant, ω is somewhat higher (0.63) than in the corresponding structural NKPC equation (when normalized on current inflation) (0.53) and is highly significant.

The estimate for θ, in turn is slightly smaller (0.77 as opposed to 0.80), implying that average fixed-price duration is 4.3 quarters. Moreover, when a constant is included, ω and θ estimates are very close to the earlier corresponding structural NKPC equation. (0.48 and

0.83 respectively). Again both parameter estimates were highly significant. Overall, these reduced form estimation results are very supportive of our structural form estimates.

For reference, Figure 3 shows actual inflation, the fitted value (the rhs) of equation (39) and the driving variable (i.e., the present value of the nominal value of marginal costs). As we see the fundamental variable tracks well the downward profile of inflation over the sample (upper panel) and the fit of the equation captures the major part of the short-run dynamics (lower panel).

The above estimations do not, however, account for the possibility that more than one lag of inflation plays an important role in explaining current inflation. Therefore, for further testing, corresponding to the generalized specification (40), we also estimate:

$$\pi_t = \sum_{j=1}^{m} \omega_j \cdot \pi_{t-j} + \left(1 - \sum_{j=1}^{m} \omega_j\right) \left\{ \frac{(1-\theta)(1-\delta\theta)}{1-(\delta\theta)^{n+1}} \sum_{i=0}^{n} (\delta\theta)^i E_t \left(p_{t+i}^* - p_{t-1}\right) \right\} + \text{constant} \quad (44)$$

As before, we pre-set $\delta = 0.99$. In Table 7, we see that additional lags of inflation (beyond one) are insignificant and, rather than increasing the importance of lagged inflation, it marginally decreases it. Our estimate for θ – the parameter governing price duration – is very stable across the lag structure at a value of around 0.82.

Overall, two conclusions emerge: first, it would thus implicitly appear that the point estimate of γ_f (i.e., the forward-looking inflation coefficient) is numerically insensitive to the lag specification because introducing more lags, largely speaking, does not affect the sum of point estimates, $\sum \omega$, second, the present-value approach gives the same point estimates of ω (around 0.5) but by diminishing their standard errors, provides statistical support in favor of the Hybrid model.

6. Conclusions

In this paper, we pursued a holistic approach to evaluating and estimating New-Keynesian Phillips curves. A firm-based supply side has been estimated to provide estimates (rather than calibrates) of key supply parameters and marginal cost indicators. Different normalizations and present-value estimations have been used to check robustness. In addition, the adjustment paths of the resulting estimates have then been compared.

The inclusion of a realistic, data-consistent, supply-side to determine technology parameters and marginal cost proved essential. Indeed, estimation on euro-area data emphasizes many key but latent issues such as the stability of factor shares, correct identification of supply parameters, markups and marginal costs. We showed that a standard supply-side approach could not adequately capture the trends and characteristics of the euro-area data (and, by implication, member countries).[32] Overall, we sought a synthesis between the estimation of euro-area NKPCs and the underlying structural features of the supply side. Failure to proceed on this basis, risks non-cointegration between the fundament and the dependent price variable and consequently spurious estimation.

After incorporating a data-consistent fundament derived from our supply-side system, we find NKPC estimates that compare favorably with others in the literature: discount factors insignificantly different from unity (with annualized discount rates of around 4%), reasonable periods of price fixedness and plausible dynamics. On the issue of discriminating between the different forms of the curve, our estimates of the backward looking component were numerically high (e.g., 0.3-0.5) although not always significant (depending on normalization). Accordingly, we sought robustness by re-estimating using the Net Present Value approach (Rudd and Whelan, 2003). When the present value was calculated in terms of real marginal cost, the backward-looking component was estimated to be high (around 0.9) and significant; however, when the present value was presented in terms of nominal marginal costs (which we argue is the correct driving variable) we derived a more balanced view on the relative merits of backward- and forward-looking components – which are broadly compatible with our first results. Notably, if both alternative ways to define the driving variable (i.e., in terms of the nominal or real marginal cost) are simultaneously correct, empirical results should be similar. If not, we argue that the more general nominal marginal cost interpretation should be favored.

[32] Notably, our new supply-side system approach cannot capture all factors that may explain movements in income shares, mark-ups, profitability etc. For instance, to explain the developments of the 1970s might also require hypotheses concerning the wage-productivity nexus, technology biases (e.g. Bruno and Sachs, 1985, Blanchard 1997) etc. However, these could be seen as complementary explanations to our framework.

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Appendix 1

The economy-wide aggregates are determined by the identities:

$$X \equiv \sum_{j=1}^{m} X^{j} \equiv \sum_{j=1}^{m}\sum_{i=1}^{n_j} X_i^j \quad , \; X_i^j = Y_i^j , K_i^j \text{ and } N_i^j \tag{A1.1}$$

$$PY = \sum_{j=1}^{m} P^{j} Y^{j} = \sum_{j=1}^{m}\sum_{i=1}^{n_j} P_i^j Y_i^j \tag{A1.2}$$

We assume that, in each sector, a fixed share of firms are profit maximisers, while the rest minimise their costs.[1] As factor markets are assumed competitive, each firm *i* in each sector *j* faces the same nominal wage rate *w* and nominal user cost of capital *q*. Hence, the optimisation problems of the profit maximising, on one hand, and the cost minimising firm, on the other, can be defined as:

$$\begin{cases} \max\limits_{Y_i^j, N_i^j, K_i^j} \prod_i^j = P_i^j \cdot Y_i^j - W \cdot N_i^j - q \cdot K_i^j \\ \text{s.t. equations (13) and (14)} \end{cases} \tag{A1.3a}$$

$$\begin{cases} \min\limits_{N_i^j, K_i^j} C_i^j = W \cdot N_i^j + q \cdot K_i^j \\ \text{s.t. equation (13)} \end{cases} \tag{A1.3b}$$

The FOC of profit maximisation imply the following 3-equation system, which determines the price of output and the demand for capital and labour conditional on the demand-determined output are:

$$P_i^j = \left(1+\mu^j\right)\left[\frac{w}{A^j e^{\gamma^j t}\left(f\left(k_i^j\right)-k_i^j f'\left(k_i^j\right)\right)}\right] \quad ; \; 1+\mu^j = \frac{\varepsilon^j}{\varepsilon^j+1} \geq 1 \tag{A1.4}$$

$$\frac{\partial Y_i^j / \partial N_i^j}{\partial Y_i^j / \partial K_i^j} = \frac{f\left(k_i^j\right)-k_i^j f'\left(k_i^j\right)}{f'\left(k_i^j\right)} = \frac{w}{q} \tag{A1.5}$$

---

[1] This partition of decision-makers into profit maximisers and cost minimisers reflects our earlier division of price setters; since a share of agents use rule-of-thumb (i.e., backward-looking) pricing rules they cannot be profit maximisers; we therefore make the alternative operational assumption that they are costs minimisers.

$$\frac{Y_i^j}{N_i^j} = A^j e^{\gamma^j t} f\left(k_i^j\right) \tag{A1.6}$$

The first order conditions of cost minimisation in turn, implies the 2-equation system of (A1.5)-(A1.6). As the relative factor price w/q in the rhs of equation (A1.5) is the same for all firms that implies that also the capital-labour ratio is also the same across firms equalling the aggregate capital-labour rate: $k_i^j = k^j = k, \forall i, \forall j$. Hence aggregated production (or labour demand) and the profit maximising price in sector *j* are determined by:

$$\frac{Y^j}{N^j} = f(k) A^j e^{\gamma_j t} \tag{A1.7}$$

$$P^j = \left(1+\mu^j\right)\left[\frac{w}{A^j e^{\gamma^j t}\left(f(k)-kf'(k)\right)}\right] \tag{A1.8}$$

Aggregation across sectors, as defined by identity (A1.1), implies that the aggregate level supply-system, corresponding to the firm level supply system (A1.4)-(A1.6), can be written as,

$$\frac{Y}{N} = f(k)\left[\sum_{j=1}^{m} s_t^j A^{j^{-1}} e^{-\gamma^j t}\right]^{-1} \tag{A1.9}$$

$$\frac{q[f(k)-kf'(k)]}{wf'(k)} = 1 \tag{A1.10}$$

$$P = \sum_{j=1}^{m} s_t^j P^j = \frac{w}{f(k)-kf'(k)} \sum_{j=1}^{m} s_t^j \left(1+\mu^j\right) A^{j^{-1}} e^{-\gamma^j t} \tag{A1.11}$$

Equation (A1.11) is obtained straightforwardly aggregating by (A1.8) and (A1.9) can be derived as follows:

$$\text{(A1.7)} \Rightarrow N^j = Y^j \left[A^j e^{\gamma^j \cdot t} f(k)\right]^{-1} \quad \Rightarrow \quad N = \sum_{j=1}^{m} N^j = [f(k)]^{-1} \sum_{j=1}^{m} Y^j A^{j^{-1}} e^{-\gamma^j t}$$

Thus, $\frac{Y}{N}=\frac{f(k)Y}{\sum_{j=1}^{m}Y^{j}A^{j^{-1}}e^{-\gamma^{j}\cdot t}}=f(k)\left[\sum_{j=1}^{m}\frac{Y^{j}}{Y}A^{j^{-1}}e^{-\gamma^{j}\cdot t}\right]^{-1}$ ■

Equations (A1.9) and (A1.11) become more transparent after transforming them into logarithmic form and then linearising the logarithms of the summation terms around the values $s_t^j = s_0^j$ and *t=0*:

After transforming (A1.9) into logarithmic form, take the linear approximation of the term:

$$\log\left[\left(\sum_{j=1}^{m}s_t^j A^{j^{-1}}e^{-\gamma^{j}\cdot t}\right)^{-1}\right]=h(s_t^j,t)\approx h(s_0^j,0)+\frac{\partial h(s_0^j,0)}{\partial t}t+\sum_{j=1}^{m}\frac{\partial h(s_0^j,0)}{\partial s^j}(s_t^j-s_0^j)$$

where

$$h(s_0^j,0)=\log\left[\left(\sum_{j=0}^{m}s_0^j A^{j^{-1}}\right)^{-1}\right]=\log A$$

$$\frac{\partial h(s_0^j,0)}{\partial t}t=\sum_{j=1}^{m}\frac{s_0^j A^{j^{-1}}}{\sum_{j=1}^{m}s_0^j A^{j^{-1}}}\gamma^j t=\sum_{j=1}^{m}AA^{j^{-1}}s_0^j\gamma^j=\gamma_A\cdot t$$

$$\sum\frac{\partial h(s_0^j,0)}{\partial s^j}(s_t^j-s_0^j)=\frac{-\sum_{j=1}^{m}A^{j^{-1}}(s_t^j-s_0^j)}{\sum_{j=1}^{m}s_0^j A^{j^{-1}}}=-\sum_{j=1}^{m}AA^{j^{-1}}(s_t^j-s_0^j)$$

Now the log of equation (A1.9) can be written as

$$\log\frac{Y}{N}=\log f(k)+\log A+\gamma_A\cdot t-\sum_{j=1}^{m}AA^{j^{-1}}(s_t^j-s_0^j) \tag{A1.12}$$

Equation (A1.12) corresponds to equation (20) in the text. Likewise the log of the summation term in (A1.11) can be linearised into following form:

$$\log\left(\sum_{j=1}^{m} s_t^j A^{j-1}\left(1+\mu^j\right)e^{-\gamma^j t}\right)=u\left(s_t^j,t\right)\approx u\left(s_0^j,0\right)+\frac{\partial u\left(s_0^j,0\right)}{\partial t}+\sum_{j=1}^{m}\frac{\partial u\left(s_0^j,0\right)}{\partial s^j}\left(s_t^j-s_0^j\right)t$$

where $u\left(s_0^j,0\right)=\log\left(\sum_{j=1}^{m} A^{j-1}s_0^j\left(1+\mu^j\right)\right)=\log\left(\underbrace{\sum_{j=1}^{m} AA^{j-1}s_0^j\left(1+\mu^j\right)}_{=1+\mu_A}\right)-\log A$

$$\frac{\partial u\left(s_0^j,0\right)}{\partial t}t=\sum_{j=1}^{m}\frac{AA^{j-1}s_0^j\left(1+\mu^j\right)\left(-\gamma^j\right)}{\sum_{j=1}^{m}AA^{j-1}s_0^j\left(1+\mu^j\right)}t=-\left(\sum_{j=1}^{m}b_j\gamma^j\right)\cdot t=-\left(\gamma_A+\sum_{j=1}^{m}b_j\left(\gamma^j-\gamma_A\right)\right)\cdot t$$

where $\sum_j b_j=1$.

$$\sum_{j=1}^{m}\frac{\partial u\left(s_0^j,0\right)}{\partial s^j}\left(s_t^j-s_0^j\right)=\frac{\sum_{j=1}^{m}AA^{j-1}\left(1+\mu^j\right)\left(s_t^j-s_0^j\right)}{\underbrace{\sum_{j=1}^{m}AA^{j-1}s_0^j\left(1+\mu^j\right)}_{1+\mu_A}}$$

$$=\sum_{j=1}^{m}AA^{j-1}\left(s_t^j-s_0^j\right)+\sum_{j=1}^{m}\frac{AA^{j-1}\left(\mu^j-\mu_A\right)}{1+\mu_A}\left(s_t^j-s_0^j\right)$$

Accordingly, the log of (A1.11) can be written as:

$$\log P=\log w-\underbrace{\left\{\log\left[f(k)-k\cdot f'(k)\right]+\log A+\gamma_A\cdot t-\sum_{j=0}^{m}AA^{j-1}\left(s_t^j-s_0^j\right)\right\}}_{\text{Log of the marginal product of labour}}$$

$$+\underbrace{\log\left(1+\mu_A\right)+\sum_{j=1}^{m}\frac{AA^{j-1}\left(\mu^j-\mu_A\right)}{1+\mu_A}\left(s_t^j-s_0^j\right)-\sum_{j=1}^{m}b^j\left(\gamma^j-\gamma_A\right)\cdot t}_{\text{Log of the mark-up}}\qquad\text{(A1.13)}$$

which corresponds to equation (22) in the text.

Appendix 2—*AIDS demand function, foreign competition and the markup*

Although the demand function (15) faced by firms is written in general form, the implicit assumption has been that the price elasticities $\varepsilon^j\ \forall j$ (and hence markups) are constant. We now relax that and instead assume that exporting firms face the AIDS demand function. We show that, in the export (or, more generally, open) sector of the economy, this assumption implies that the markup also depends on foreign competitiveness, i.e., the ratio of competing foreign to open sector prices. For simplicity, the export sector is treated as if there were only one exporting firm in the economy (the *m*th sector, indexed by *x*). However, compared to the world market the size of the exporting firm is very small, which allows us to treat both world market demand D_f and the price level P_f as exogenous.

Let us approximate the AIDS export demand function as, [2]

$$\kappa = \frac{P^x \cdot Y^x}{P_f \cdot D_f} = a + \theta \cdot \log\left(\frac{P_f}{P^x}\right); a, \theta > 0 \tag{A2.1}$$

where κ is the market share of exporting sector in nominal terms. Equation (A2.1) implies the following price elasticity and the markup in the export sector:

$$\varepsilon^x = -1 - \frac{\theta}{\eta} = -1 - \frac{\theta}{a + \theta \log\left(P_f / P^x\right)} \tag{A2.2}$$

$$1 + \mu^x = \frac{\varepsilon^x}{\varepsilon^x + 1} = 1 + \frac{a}{\theta} + \log\left(\frac{P_f}{P^x}\right) \tag{A2.3}$$

Equation (A2.2) states that, with $\theta > 0$, the price elasticity of exports is $\varepsilon^x < -1$. We also see that the price elasticity is not constant, but depends on the relative price P_f / P^x and thus that the export-sector markup depends positively on competing world market prices. For estimation purposes, it is useful to log-linearize (A2.3) around the point $\log\left(P^x / P_f\right) = 0$:

$$\log\left(1 + \mu^x\right) \approx \log\left(1 + \overline{\mu}^x\right) + \frac{1}{1 + \overline{\mu}^x} \log\left(\frac{P_f}{P^x}\right) \quad \overline{\mu}^x = \frac{a}{\theta} \tag{A2.4}$$

The fact that the export-sector markup depends on the competitive pressure of foreign prices allows us to write the economy markup in (22) as:

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[2] In terms of the AIDS expenditure system, the share of country *i* exports in world imports (at current prices) is: $\kappa_i = \frac{P_i^x \cdot X_i}{P_f \cdot D_f} = a_i - \theta_{ii} \cdot \log P_i^x + \sum_j \theta_{ij} \log P_{ij}^x$, where $\sum_i a_i = 1$, $\theta_{ii} = \sum_j \theta_{ij}$ and P_f is a weighted index of export prices P_j^x, i.e. the competing foreign price (see Deaton and Muellbauer, 1980).

$$\log(1+\mu_A)+\sum_{j=1}^{m}\frac{A(A^j)^{-1}(\mu^j-\mu_A)}{1+\mu_A}(s_t^j-s_0^j)-\sum_{j=1}^{m}b^j(\gamma^j-\gamma_A)\cdot t=$$

$$\log(1+\bar{\mu}_A)+\frac{s_0^x}{1+\bar{\mu}^x}\log\left(\frac{P_f}{P^x}\right)+\sum_{j=1}^{m}\frac{A(A^j)^{-1}(\mu^j-\bar{\mu}_A)}{1+\bar{\mu}_A}(s_t^j-s_0^j)-\sum_{j=1}^{m}b^j(\gamma^j-\gamma_A)\cdot t \quad \text{(A2.5)}$$

where $\bar{\mu}_A$ is the value of μ_A calculated in terms of $\bar{\mu}^x$ and s_0^x is production share of the export (or open) sector in the base (reference) period.

Appendix 3—*Determination of sectoral output shares*

Here, we show that, with help of a simple demand system, that the sectoral output shares can be reduced to trend, which essentially alleviates the data requirements of estimation.

There are *m* sectors in the economy, of which *m-1* are closed and the last is the export sector. Hence, the aggregate output is the sum of closed sectors' output $\left(YD=\sum_{j=1}^{m-1}Y^j\right)$ and export sector's output Y^x. Assuming no cross-sector substitutability between goods produced by closed sectors, the aggregate demand for closed sector goods is determined by the demand system,

$$\frac{Y^j}{YD}=e_t^j=e_0^j+\tau^j\log\left(\frac{YD/YD_0}{N/N_0}\right) \text{, where } \sum_{j=1}^{m-1}e_t^j=1 \text{ and } \sum_{j=1}^{m-1}\tau^j=0 \quad \text{(A3.1)}$$

where e_t^j represents the output share of sector j $(j=1,..,m-1)$ in the aggregated closed sector output, $\frac{Y^j}{YD}$, and *0* refers to the starting (or reference) period values of variables. Equation (A3.1) expresses the demand system for the goods of closed sectors in per capita terms. Values of parameter $\tau^j>0$ $(\tau^j<0)$ imply greater (smaller) than unitary income elasticity of demand. As, by definition, $YD=(1-s^x)Y$, we derive for the output share $s^j=Y^j/Y$

$$s_t^j=(1-s_t^x)e_t^j\approx s_0^j+(1-s_0^x)(e_t^j-e_0^j)-e_0^j(s_t^x-s_0^x) \quad \text{(A3.2)}$$

where $s_0^j=(1-s_0^x)e_0^j$. We next show that in a growing economy, with demand system (A3.1), the long-run development of sectoral production shares are reduced to trend. Assume that, on the equilibrium growth path, output per capita grows at a constant rate g. Equation (A3.2) implies that, on this path, the production shares $\bar{e}_t^j$ are determined as,

$$\bar{e}_t^j = \bar{e}_0^j + \tau^j g \cdot t \tag{A3.3}$$

Using (A3.3), equation (A3.1) can be written as

$$e_t^j - e_0^j = \tau^j g \cdot t + \tau^j \left[\underbrace{\log\left(\frac{YD/YD_0}{N/N_0} \right) - g \cdot t}_{u_t} \right] = \tau^j g \cdot t + \tau^j u_t \tag{A3.4}$$

where u_t can be assumed stationary around zero. Regarding the development of the output share of the export sector, equation (23) implies the following relation,

$$s_t^x = \left(\frac{P_f}{P^x} \right) \left(\frac{D_f}{Y} \right) \left(a + \theta \log\left(\frac{P_f}{P^x} \right) \right) \approx s_0^x + \left(s_0^x + \theta \right) \log\left(\frac{P_f}{P^x} \right) + s_0^x \log\left(\frac{aD_f}{s_0^x Y} \right) \tag{A3.5}$$

where $s_0^x = a\left(\frac{D_f}{Y} \right)_0$.

Assuming that in a common currency denominated equilibrium, inflation rates are equal and, denoting the equilibrium growth of foreign demand by g_f, we derive the following relation for the long-run development of the export share:

$$s_t^x - s_0^x = s_0^x \left(g_f - g \right) \cdot t + v_t^x \tag{A3.6}$$

where $v_t^x = s_0^x \left[\log\left(\frac{aD_f}{s_0^x Y} \right) - \left(g_f - g \right) \cdot t \right] + \left(s_0^x + \theta \right) \cdot \log\left(P_f / P^x \right)$, which is assumed to be stationary.

According to equation (A3.6) the output share of the export sector increases and the output share of the aggregated closed sector decreases, if $g_f > g$. Substituting (A3.4) and (A3.6) into (A3.2) we obtain for $j = 1, \ldots, m-1$:

$$s_t^j - s_0^j = \left[\left(1-s_0^x\right)\tau^j - s_0^x\left(g_f - g\right)e_0^j\right]\cdot t + \underbrace{\left(1-s_0^x\right)\tau^j u_t + e_0^j v_t^x}_{v_t^j} \qquad \text{(A3.7)}$$

Appendix 4—*The description of the data used in estimating the supply side system*

The principal source for the euro area data we use is that of the Area-Wide Model (Fagan et al, 2001). The empirical counterparts offered by this data set for production, labour input, capital input and prices are: Y = real GDP at factor cost, N = total employment, K = the gross capital stock, P = GDP deflator at factor cost

Employment Income

Employment Income is not directly available from the data of the area-wide model and, hence, some additions to the original data must be done. In the case of labour income, the problem is that, at the area-wide level, no data on the income of self-employed workers are available. Based on the OECD Labour force Statistics (Labour Force Statistics 1977-1997, OECD 1998) (e.g. Blanchard, 1997) we use the sample average of the labour share of paid self-employed and the average compensation per employee in calculating the imputed income of self-employed individuals. The rest of the entrepreneurial income of self-employed is interpreted as belonging to capital income. Hence, average labour income per employed person is calculated as:

$$W = 1.193\frac{Employees\,Compensation}{Total\,Employment}$$

Capital Stock Definitions

In calculating the capital income component of qK, we need, in addition to the capital stock series K, an operational counterpart for the user cost of capital q. However, regarding the capital stock, there are two different capital stock concepts available, i.e. gross and net capital stocks. The gross capital stock can be described as a capacity concept, i.e. it measures the potential volume of capital services which can be produced by the existing capital stock at a given point of time (e.g. Biorn and Olsen, 1989 and OECD, 1992). The net capital stock can be described as a wealth concept; capital has a value, which is derived from its ability to produce capital services today and in the future. Accordingly, the recommended practice in calculating the consumption of capital in national accounting statistics is to use the net capital stock.

The above argument supports the view that the net capital stock and the respective depreciation rate should be used in calculating the capital income component, while the gross capital stock should be used in the production function. To reconcile these views, we resort to the fact that, in practice, the ratio of net to gross capital stock is quite stable and, in the equilibrium growth path, this ratio should equal to the ratio of the respective depreciation rates. Hence, on the basis of the steady state condition $\frac{K_{net}}{K_{gross}} = \frac{\delta_{gross}}{\delta_{net}} < 1$ we can write

$$K = P_I(r + \delta_{net})K_{net} = P_I(r \cdot \frac{\delta_{gross}}{\delta_{net}} + \delta_{gross})K_{gross}$$

where P_I = investment deflator and K = gross capital stock.

Typically estimates of the net to gross capital stock ratio lie within a quite narrow range of 0.5 to 0.7 (see e.g. Steele, 1980).[3] According to OECD statistics, for instance, the ratio of net to gross capital stock in 1990 was 0.64 in Germany, 0.58 in France, 0.69 in Italy 0.64 in Belgium and 0.63 in Finland (OECD 1996).[4] In the following we use value 0.64 as a "median" estimate for the euro area ratio of net to gross capital stock. With the annual depreciation rate of 4% in the data of the ECB area-wide model, the estimate for the capital income is defined as:

$$qK = \frac{P_I\left[(i - 4 \cdot \pi^e) \cdot 0.64 + 4\right]}{400} \cdot K$$

where P_I = investment deflator, i = long-term interest rate, π^e = inflation expectations = the HP-filter fit for one period P_I -inflation

Interest Rate

We can observe two regimes in the ex post real interest rate; a negative level covering most of 1970s and a shift in the late 1970s and early 1980s to a markedly higher level covering the rest of the sample period. To take into account the possibility that our data for the euro area real interest rate do not measure correctly the marginal cost of financing in the 1970s, a level shift dummy was constructed to correct the interest rate upwards in the 1970s.[5] The dummy-corrected interest rate could be interpreted as a shadow interest rate $\left(i^n\right)$, measuring the marginal cost of financing.[6] As shown below, the dummy takes a hyperbolic form:

$$i^n = i + h \cdot DUM = i + h \cdot \left(1 - \frac{1}{1 + \exp\left(2 - 0.3\left(time - 35\right)\right)}\right)$$

Variable DUM is 1 in the early 1970s and starts deviating from unity in around 1976 and converging to zero in around 1983, after which i^n in practice equals to the observable long-term interest rate (i). Now, after replacing i by i^n in the above relation defining capital income *qK*, we can rewrite (assuming a 4% annual depreciation rate):

$$qK = P_I\left\{\left(i - 4\pi^e\right) \cdot 0.64 + 4\right\} \cdot \frac{K}{400} + h \cdot 0.64 \cdot P_I\left(\frac{K}{400}\right) \cdot DUM \quad ,$$

where parameter h can be estimated jointly with the other parameters of the system.

Price Competitiveness

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3 Steele's (1980) simulation experiments suggest that the relevant range could be even narrower.

4 For other euro area countries, data were not available. The French figure does not include the housing stock as an estimate for the gross housing stock was not available. However, assuming that the ratio of net to gross housing stock is around 0.7, as is the case very uniformly in other countries, this would imply that in France, too, the ratio of (total) net to (total) gross capital stock would be around 0.64.

5 This is in line with Coenen and Wieland (2000) who found a strong and significant negative dependence of euro area aggregated demand on the German real interest rate, whilst the dependency of the weighted average of the euro area real interest rate was markedly weaker and statistically insignificant.

6 This would, of course, presuppose the existence of a rather well functioning "grey" financial market. Then, when regulation is binding, the marginal cost of financing can be markedly above the average cost of financing, which the interest rate LTN measures. After financial deregulation, under the Modigliani-Miller theorem, as our user cost definition assumes, the marginal and average costs of financing are equal. For a more detailed analysis of a credit-rationed economy, e.g. Tarkka (1985).

In constructing a series for the price competitiveness of open sector production, the deflator of euro area exports proxies the price of the total open sector production as constructed in the area-wide model data. As a measure for the competing foreign price of the open sector, we use the import price of non-primary goods. It is constructed utilising the following quasi-identity:[7]

$$MTD = P_f^{\,1-m_t}\left(EEN * COMPR\right)^{m_t}$$

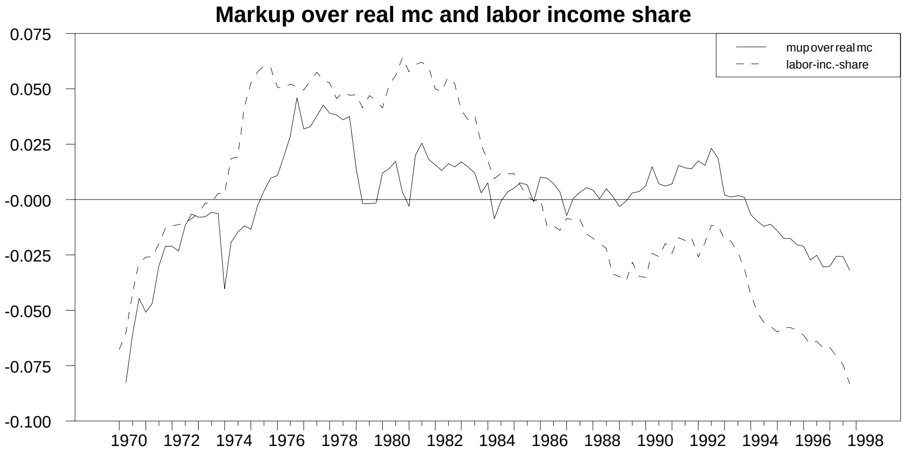
where MTD = deflator of the euro area imports, COMPR = commodity prices (HWWA index), in US dollars, EEN = nominal effective exchange rate, m_t = elasticity estimate (the share of the primary goods imports of total euro area imports).

[7] The area-wide model data contain the variables MTD, EEN and COMPR. The series for the import share of primary goods is calculated by the Directorate Statistics of the ECB on the basis of Eurostat data. This series covers the period from 1980/1981. In the 1970s, m_t is assumed to be constant, equalling to the value of 1980/1981.

Figure 1

Note: The ADF t-test , at -0.42, suggest failure of stationarity.

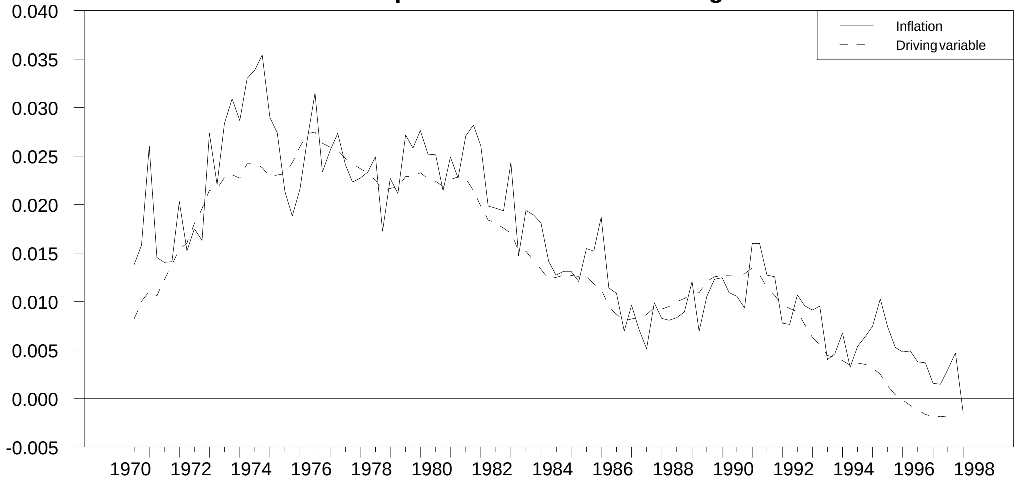
Figure 2



Markup over real mc and labor income share
mupoverrealmc
labor-inc.-share
0.075
0.050
0.025
-0.000
-0.025
-0.050
-0.075
-0.100
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998

Figure 3

Inflation and the present value of the driving variable



Inflation and the fitted values

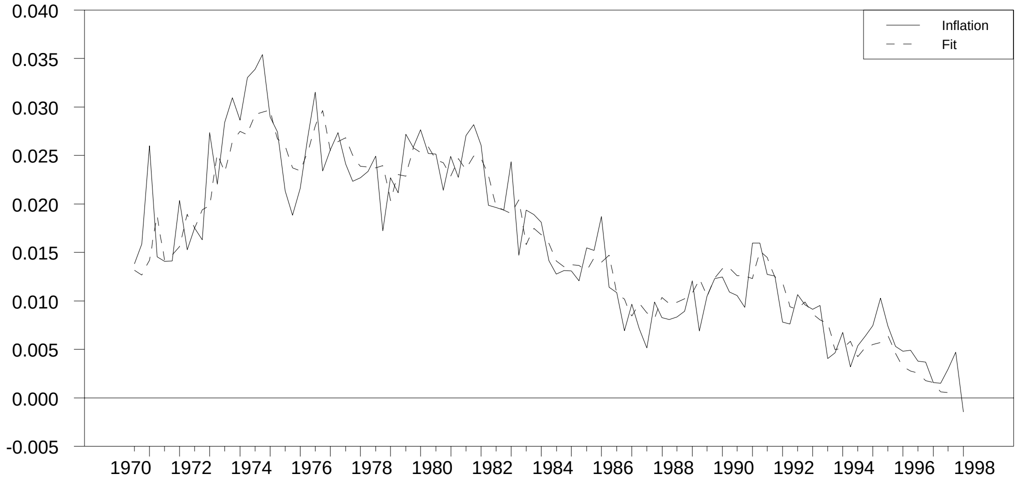


Table 1—Hybrid-version of the NKPC($\xi = 1$)

Parameter	Fundament					
	Labour Income Share (from sample average)					
	Equation (13)				Equation (12)	
	Un-Normalised		Normalised		Un-Normalised	Normalised
Columns	1	2	3	4	5	6
ω	0.0202 (0.1136)	0.0079 (0.0858)	0.3232 (0.1239)	0.3475 (0.1063)	0.0173 (0.0865)	0.3578 (1493.8552)
θ	0.9082 (0.0142)	0.9351 (0.0236)	0.9238 (0.0302)	0.9827 (0.0930)	0.9457 (0.0310)	0.9981 (4158.2923)
δ	0.8935 (0.0455)	0.99	0.9194 (0.0647)	0.99	1.0037 (0.0087)	1.00381 (8.8946)
Roots	0.0222 0.9080 1.2323	0.0084 0.9350 1.0803	0.3511 0.9206 1.1773	0.3537 0.9825 1.0279	0.0183 0.9457 1.0534	0.3585 $0.9981 \pm 1.6540*10^{-6}i$
J-test	8.5459 [0.4801]	8.7228 [0.5586]	7.4919 [0.5860]	7.3830 [0.5973]	8.5493 [0.4798]	7.3659 [0.5990]
γ_b	0.0218 (0.1200)	0.00835 (0.0902)	0.2643 (0.0707)	0.2619 (0.0531)	0.0180 (0.0882)	0.2636 (0.0521)
γ_f	0.8759 (0.0383)	0.9818 (0.0062)	0.6945 (0.0399)	0.7332 (0.0177)	0.98558 (0.00929)	0.7382 (814.0172)
λ	0.0183 (0.0108)	0.0051 (0.0039)	0.0064 (0.0075)	0.0002 (0.0021)	0.00281 (0.00374)	$-1.7103*10^{-6}$ $(1.4163*10^{-5})$
Duration	10.896 (1.688)	15.400 (5.5936)	13.129 (5.204)	57.838 (311.19)	18.43986 (10.56537)	526.7562 $(1.1538*10^{9})$

Table 2—Supply-Side Estimates.

Parameter	Coefficient
β	0.2926 (0.0029)
A	1.5086 (0.0236)
γ	0.0049 (0.0001)
$1+\mu$	1.0270 (0.0053)
η	0.0004 (0.0001)
χ	0.0792 (0.0117)
h	-0.0227 (0.0013)
SE_p	0.0231
ADF_p	-3.7911
$SE_{cK/wN}$	0.0537
$ADF_{cK/wN}$	-4.5490
$SE_{Y/N}$	0.0148
$ADF_{Y/N}$	-3.9400

Notes:
Standard errors in ()s.
SE_p refers to the standard error of the price equation etc.
ADF_p refers to the ADF t-test of the residual of the price equation etc.

Table 3—NKPC estimates: *Information Lag*

ω	θ	δ	Roots	J-test	γ_b	γ_f	λ	Duration
Un-normalised case								
	0.8370 (0.0365)	0.9982 (0.0148)	0.8369 1.1969	3.9196 [0.6876]	0.0000 (—)	0.9982 (0.0148)	0.0320 (0.0163)	6.1346 (1.3738)
0.3538 (0.2122)	0.8143 (0.0479)	1.0033 (0.0203)	0.4533 0.7804 1.2240	2.6758 [0.7498]	0.3027 (0.1306)	0.6988 (0.0360)	0.0188 (0.0123)	5.3841 (1.3889)
0.3901 (0.2047)	0.8078 (0.0459)	0.9900 (—)	0.5142 0.7586 1.2505	2.9681 [0.8128]	0.3265 (0.1205)	0.6694 (0.0337)	0.0197 (0.0115)	5.2016 (1.241)
Normalised with respect to lead Inflation								
	0.8472 (0.0397)	1.0003 (0.0147)	0.8472 1.1799	3.9954 [0.6772]	0.0000 (—)	1.0003 (0.01474)	0.0275 (0.0162)	6.5477 (1.70202)
0.3407 (0.2150)	0.8247 (0.0498)	1.0048 (0.0198)	0.4268 0.7983 1.2067	2.8140 [0.7286]	0.2921 (0.1336)	0.7102 (0.0343)	0.0170 (0.0123)	5.7049 (1.621)
0.3775 (0.20675)	0.81791 (0.04666)	0.9900 (—)	0.4837 0.7804 1.2349	3.1230 [0.7933]	0.31664 (0.12274)	0.67909 (0.03195)	0.01809 (0.0115)	5.4917 (1.407)
Normalised with respect to Inflation								
	0.8464 (0.0392)	0.9991 (0.0147)	0.8463 1.1826	3.9594 [0.6822]	0.0000 (—)	0.9991 (0.0147)	0.0280 (0.0162)	6.5093 (1.6589)
0.4804 (0.2305)	0.8100 (0.0584)	1.0067 (0.0250)	0.6908±0.0559i 1.22632	3.1385 [0.6786]	0.3715 (0.1180)	0.6306 (0.0365)	0.0141 (0.0108)	5.2644 (1.6190)
0.5318 (0.21805)	0.8014 (0.05808)	0.9900 (—)	0.7194±0.1192i 1.2603	3.458117 [0.74953]	0.40014 (0.10662)	0.59703 (.03485)	0.01444 (0.0101)	5.0378 (1.4742)
Normalised with respect to Fundament								
	0.7142 (0.0524)	0.9788 (0.0209)	0.7143 1.4303	8.9850 [0.1744]	0.0000 (—)	0.9788 (0.0209)	0.1203 (0.0523)	3.5002 (0.6418)
0.2108 (0.21687)	0.7290 (0.0513)	0.9877 (0.0222)	0.3044 0.6925 1.3887	7.1785 [0.2077]	0.2248 (0.1807)	0.7677 (0.0676)	0.0638 (0.0417)	3.6905 (0.6986)
0.2205 (0.2103)	0.7248 (0.0533)	0.9900 (—)	0.3227 0.6833 1.3935	7.8115 [0.2522]	0.23366 (0.1726)	0.76036 (0.0673)	0.06418 (0.0405)	3.6343 (0.7036)
Weighted Normalisation								
	0.7665 (0.0370)	0.9870 (0.0162)	0.7665 1.3217	6.5320 [0.3662]	0.0000 (—)	0.9870 (0.0162)	0.0741 (0.0270)	4.2836 (0.6791)
0.2922 (0.2003)	0.7538 (0.0477)	0.9946 (0.0213)	0.41668 0.7012 1.3338	5.0563 [0.4090]	0.2797 (0.1428)	0.7176 (0.0513)	0.0417 (0.0225)	4.0619 (0.7868)
0.2973 (0.1991)	0.7519 (0.0475)	0.9900 (—)	0.4275 0.6956 1.3433	5.4999 [0.4815]	0.2840 (0.1412)	0.7109 (0.0506)	0.04253 (0.0221)	4.03187 (0.7714)

Table 4—NKPC estimates: *No Information Lag*.

ω	θ	δ	Roots	J-test	γ_b	γ_f	λ	Duration
Un-normalised case								
0.4493 (0.2265)	0.8060 (0.0499)	1.0039 (0.0217)	0.5272 0.7524 1.2358	2.730 [0.7415]	0.3295 (0.1241)	0.6721 (0.1251)	0.01856 (0.01241)	5.1539 (1.3267)
0.4980 (0.2147)	0.7977 (0.04905)	0.9900 (—)	0.6645±0.0177i 1.2662	3.0089 [0.8077]	0.3575 (0.1136)	0.6389 (0.1117)	0.01920 (0.01272)	4.9446 (1.1992)
Normalised with respect to lead Inflation								
0.3853 (0.2304)	0.82471 (0.0498)	1.0048 (0.0198)	0.4266 0.8185 1.1889	2.8140 [0.7286]	0.2921 (0.1336)	0.7102 (0.1347)	0.01696 (0.01077)	5.7049 (1.6205)
0.42582 (0.2191)	0.81790 (0.0466)	0.9900 (—)	0.4837 0.7804 1.2349	3.1229 [0.7933]	0.3166 (0.1227)	0.6791 (0.1206)	0.01809 (0.01096)	5.4917 (1.4074)
Normalised with respect to Inflation								
0.53303 (0.2362)	0.8100 (0.05841)	1.0066 (0.02498)	0.6909±0.0559i 1.2263	3.1385 [0.6786]	0.3715 (0.1180)	0.6306 (0.1193)	0.0141 (0.0108)	5.2644 (1.6190)
0.5862 (0.2195)	0.8015 (0.0581)	0.9900 (—)	0.7194±0.1192i 1.2603	3.4581 [0.7495]	0.4001 (0.1066)	0.5971 (0.1048)	0.01444 (0.01204)	5.0378 (1.4742)
Normalised with respect to Fundament								
0.26817 (0.2570)	0.7290 (0.0513)	0.9877 (0.0222)	0.3044 0.6925 1.3887	7.1785 [0.2077]	0.2248 (0.1807)	0.7677 (0.1749)	0.0638 (0.0333)	3.6905 (0.6986)
0.28072 (0.2486)	0.72484 (0.0533)	0.9900 (—)	0.3227 0.6833 1.3935	7.8115 [0.2522]	0.2337 (0.1727)	0.7604 (0.1697)	0.06418 (0.0320)	3.6343 (0.7036)
Weighted Normalisation								
0.35203 (0.2268)	0.75322 (0.0477)	0.9944 (0.0214)	0.4142 0.7011 1.3351	5.1085 [0.4028]	0.2786 (0.1434)	0.7186 (0.1417)	0.0422 (0.0219)	4.0523 (0.7838)
0.35822 (0.2251)	0.751367 (0.0475)	0.9900 (—)	0.4249 0.6954 1.3443	5.5554 [0.4748]	0.2829 (0.1418)	0.7121 (0.1394)	0.0429 (0.0220)	4.0220 (0.7690)

Table 5—Present Value Estimates Based on Real Marginal Costs

	CONSTANT	γ	ω_1	ω_2	ω_3	$\sum \omega_i$
$\delta = 0.99$	0.0144 (0.0007)	0.0389 (0.0038)				
$\delta = 0.95$	0.0144 (0.0008)	0.0460 (0.0044)				
$\delta = 0.99$	0.0022 (0.0007)	0.0332 (0.0067)	0.8324 (0.0461)			0.8324
$\delta = 0.95$	0.0019 (0.0007)	0.0392 (0.0086)	0.8492 (0.0442)			0.8324
$\delta = 0.99$	0.0014 (0.0007)	0.0294 (0.0093)	0.6080 (0.0954)	0.2749 (0.1059)		0.8829
$\delta = 0.95$	0.0012 (0.0007)	0.0341 (0.0130)	0.6155 (0.0946)	0.2796 (0.1041)		0.8951
$\delta = 0.99$	0.0012 (0.0008)	0.0296 (0.0101)	0.5940 (0.1040)	0.3091 (0.1966)	-0.0113 (0.1394)	0.8818
$\delta = 0.95$	0.0011 (0.0007)	0.0330 (0.0151)	0.6018 (0.1042)	0.3094 (0.1966)	-0.0046 (0.1409)	0.9112
Auto-Regressive Case						
	0.0007 (0.0007)		0.6265 (0.0980)	0.2906 (0.1118)	0.0296 (0.0992)	0.9466

Table 6—Present Value estimates of Hybrid Model with Nominal Marginal Cost *(with* and *without constant)* ($\delta = 0.99$)

ω	θ	*Constant*	Roots	J-test	γ_b	γ_f	λ	Duration
0.62808 (0.0531)	0.7664 (0.0149)		0.7312±0.1719i 1.3180	12.5187 [0.4050]	0.4519 (0.0203)	0.5456 (0.0069)	0.0151 (0.0038)	4.2806 (0.2734)
0.4788 (0.0582)	0.8283 (0.0158)	0.0017 (0.0005)	0.6333 0.7560 1.2195	12.3024 [0.3413]	0.3674 (0.0289)	0.6293 (0.0075)	0.0124 (0.0030)	5.8250 (0.536)

Note: Full sample estimation, normalised with respect to current inflation.

Table 7—Present Value Estimates with Additional Lags ($\delta = 0.99$).

constant	ω_1	ω_2	ω_3	$\sum \omega$	θ
0.0017 (0.0005)	0.4787 (0.0582)			0.4787	0.8283 (0.0158)
0.0017 (0.0005)	0.5088 (0.0765)	-0.0507 (0.0710)		0.4581	0.8276 (0.0154)
0.0018 (0.0005)	0.4984 (0.0760)	-0.0185 (0.1325)	-0.0259 (0.1079)	0.4540	0.8288 (0.0151)

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