DEPARTMENT OF ECONOMICS

UNIVERSITY OF MILAN - BICOCCA

WORKING PAPER SERIES

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No. 186 – May 2010

Trend inflation, endogenous mark-ups and the non-vertical Phillips curve[*]

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May, 2010

Abstract

Recent developments in macroeconomics resurrect the view that welfare costs of inflation arise because the latter acts as a tax on money balances. Empirical contributions show that wage re-negotiations take place while expiring contracts are still in place. Bringing these seemingly unrelated aspects together in a stylized general equilibrium model, we find a disciplining effect of a positive inflation target on the wage markup and identify a long-term trade-off between inflation and output.

Jel codes: E52, E58, J51, E24.
Keywords: trend inflation, long-run Phillips curve, inflation targeting, real money balances.

1 Introduction.

Recent developments in macroeconomics contradict the widely held belief that permanently higher inflation cannot affect unemployment. A long-run relationship between inflation and real activity is obtained in New Keynesian models based on price staggering, where inflation has adverse effects due to relative price dispersion and to the effect of expectations on mark-ups (Goodfriend and King, 1997; Woodford, 2003; Schmitt-Grohè and Uribe, 2004). Benigno and

Ricci (2007) resurrect the "grease in the wheels" argument, showing that downward nominal wage rigidity generates a long-run inflation-unemployment trade-off at low inflation rates. Other contributions point in the opposite direction. For instance, Graham and Snower (2008) show that the interaction of staggered nominal contracts with hyperbolic discounting leads to a positive long-run effect of inflation on real variables.

We share the view that modern monetary models may underestimate the beneficial effects of inflation on wage markups, but we highlight a different disciplining channel. A positive inflation rate is typically associated with higher nominal interest rates, which increase the opportunity cost of holding money. Thus inflation is a tax on money balances. To model this effect, we introduce money in the utility function, as in Christiano *et al.* (2005).[1] The next step in our analysis is to identify a channel such that the inflation-tax effect on money balances might discipline wage markups. In our stylized model, we assume that in each period wages are predetermined to macroeconomic variables.[2] As a result wage setters internalize the effect of their wage choice on their own real money holdings. In the paper we show that such an effect is negative and becomes stronger with the expected inflation rate, inducing wage setters to limit their wage claims. We therefore obtain a new justification for the existence of a non-vertical Phillips curve. Model simulations show that a moderate inflation rate can generate substantial output gains relative to both the Friedman rule and the commitment to price stability, popularized in standard New Keynesian models. A central tenet of the New Keynesian literature is that nominal rigidities determine socially inefficient outcomes. Our paper reverses this view: properly designed monetary policies may take advantage of predetermined nominal wages to discipline wage setters. This, in turn, requires a positive inflation rate.

The crucial mechanism behind our result lies in the combination of an inflation-tax effect on money holdings with the assumption of pre-determined wages. This latter hypothesis is in contrast with New Keynesian models that typically model nominal wage rigidities as a mechanical transposition of the Calvo pricing formalism originally designed to characterize firms pricing behavior (Calvo, 1983). Relative to Calvo pricing, the pre-determined wage hypothesis neglects relative wage dispersion – the undesirable consequence of inflation under the Calvo formalism – but allows wage setters to internalize their consequences for household choices. In fact our approach is in line with recent empirical evidence on wage bargaining that *i)* downplays the importance of relative wage dispersion because firms concentrate nominal wage changes in a particular month of the year, following country-specific patterns (Duarte et al. 2009); *ii)* shows that wage renegotiations take place while expiring contracts are still in place, enabling wage setters to act as Stackelberg leaders (Du Caju *et al.* 2008).

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[1] Lagos and Wright (2005) point out that this is a reduced form monetary model, where assumptions about money holdings are meant to stand in for some role of money that is not made explicit, i.e. that it helps overcome spatial, temporal, or informational frictions.

[2] See Corsetti and Pesenti (2001) for a similar assumption.

The rest of the paper is organized as follows. The next section outlines our model. Section 3 discusses the benchmark case of flexible nominal wages. Section 4 introduces pre-determined wages and explains why a positive inflation target disciplines wage setters and outlines implications for the optimal inflation rate. Section 5 concludes.

2 The model.

We build on Neiss (1999), where a staggered timing structure in the acquisition of nominal money balances within a money-in-the-utility function framework generates a discretionary inflation equilibrium when the economy is plagued by monopolistic distortions. To simplify the analysis, we impose full price flexibility in the goods market, whereas wages are pre-determined.[3]

2.1 Households

The representative household (i) maximizes the following utility function

$$U = \sum_{t=0}^{\infty} \beta^t \left(\ln C_{t,i} - \frac{\eta}{1+\phi} l_{t,i}^{1+\phi} + \frac{\gamma}{1-\varepsilon} \left(\frac{M_{t,i}}{P_t} \right)^{1-\varepsilon} \right) \tag{1}$$

where $\beta \in (0,1)$ is the intertemporal discount rate, $C_{t,i}$ is a consumption bundle, $l_{t,i}$ is a differentiated labor type that is supplied to all firms, $\frac{M_{t,i}}{P_t}$ denotes real money holdings.

The flow budget constraint is:

$$C_{t,i} + \frac{M_{t+1,i}}{P_{t,i}} + \frac{B_{t+1,i}}{P_t} = \frac{(1-\tau_t) w_{t,i}}{P_t} l_{t,i} + \frac{M_{t,i}}{P_t} + \theta_t + R_t \frac{B_{t,i}}{P_t} \tag{2}$$

where $B_{t,i}$ denotes holdings of one-period bonds; $w_{t,i}$ is the nominal wage; τ_t is a labor-income tax;[4] θ_t denotes firms profits; R_t is the nominal interest rate. Note that $M_{t+1,i}$ is chosen at t.

Consumption basket and price index are defined as follows:

$$C_t = \left(\int_0^1 c_t(j)^\rho di \right)^{\frac{1}{\rho}} \tag{3}$$

$$P_t = \left(\int_0^1 p_t(i)^{\frac{\rho}{\rho-1}} di \right)^{\frac{\rho-1}{\rho}} \tag{4}$$

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[3]Right from the outset, it is worth emphasizing that this assumption completely removes inflation costs that plague sticky-price models when the Calvo (1983) or Rotemberg (1982) pricing formalisms are adopted. It should be noted, however, that such costs fall in the degree of inflation indexation adopted by non-optimizing firms. Following the celebrated Christiano *et al.* (2005) contribution, several estimated DSGE models assume full indexation to trend inflation (Christoffel *et al.* 2008, Jondeau and Sahuc, 2008). This is crucial to track down observed inflation persistence. Barnes et al. (2009) estimate a structural equation model exhibiting a very high degree of inflation indexation.

[4]We assume that firms profit are not taxed, as in Schmitt-Grohè and Uribe (2004).

The standard first order conditions for consumption are:

$$c_t(j) = C_t \left(\frac{p_t(j)}{P_t} \right)^{\frac{1}{\rho - 1}} \tag{5}$$

$$C_t = \frac{1}{\beta} \frac{1}{R_{t+1}} \frac{P_{t+1}}{P_t} C_{t+1} \tag{6}$$

The money demand equation is

$$\frac{M_{t+1}}{P_t} = \left(\frac{P_t}{P_{t+1}} \right)^{\frac{1-\varepsilon}{\varepsilon}} \left(\frac{\gamma \beta C_t}{1 - R_{t+1}^{-1}} \right)^{\frac{1}{\varepsilon}} \tag{7}$$

As in Neiss (1999) the agent faces a trade-off between period t consumption and period $t + 1$ holdings of nominal money balances.

Observe that (7) can also be interpreted as a demand function: when the central bank increases next period nominal money balances, *coeteris paribus* current consumption increases. Straightforward manipulations would show that $\frac{1}{\varepsilon}$ denotes the income elasticity of money demand.

The optimal labor supply condition will be introduced at a later stage, when we consider different wage-setting regimes.

2.2 Firms

There is a continuum of monopolistically competitive firms uniformly distributed over the interval $[0, 1]$. Each firm (j) produces a differentiated good using a Cobb-Douglas production function:[5]

$$y_t(j) = l_t(j)^\alpha \tag{8}$$

where

$$l_{t,j} = \left[\int_0^1 l_{t,j}(i)^{\frac{\sigma-1}{\sigma}} di \right]^{\frac{\sigma}{\sigma-1}} \tag{9}$$

denotes a labor bundle and σ is the intra-temporal elasticity of substitution across different labor inputs.

The price is set as a markup, $\mu^p = \frac{\sigma}{\sigma - 1} = \frac{1}{\rho}$, over real marginal costs. For any given level of its labor demand, $l_{t,j}$, the firm must decide the optimal allocation across labor inputs, subject to aggregation technology (9). Firm (j) demand for labor type (i) is

$$l_{t,j}(i) = \left(\frac{w_t(i)}{w_t} \right)^{-\sigma} l_{t,j} \tag{10}$$

where

$$w_t = \left[\int_0^1 w_t(i)^{1-\sigma} di \right]^{\frac{1}{1-\sigma}} \tag{11}$$

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[5] Capital is assumed fixed and normalized to unity.

is the wage index.

Aggregating across firms we obtain

$$Y_t = l_t^\alpha \tag{12}$$

$$l_t(i) = \left(\frac{w_t(i)}{w_t}\right)^{-\sigma} l_t \tag{13}$$

$$l_t = \left(\frac{1}{\alpha\rho}\frac{w_t}{p_t}\right)^{-\frac{1}{1-\alpha}} \tag{14}$$

Finally, the aggregate resource constraint is

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

where G_t is the public expenditure, defined below.

2.3 Monetary Policy

By assumption, the central bank directly controls the money growth rate m_t[6]

$$M_{t+1} = M_t(1 + m_t) \tag{16}$$

Using (7), (16) and (12), it is straightforward to show that

$$\frac{P_{t+1}}{P_t} = 1 + \pi_t = 1 + m_t \tag{17}$$

Central bank target determines the inflation rate.

2.4 Fiscal policy

The government supplies an exogenous amount of public good G_t and implements redistributive policies through transfers T_t.[7] Government financing is obtained through a labor-income tax and seigniorage, $\frac{M_t}{P_t}m_t$, which is obtained from (16). For sake of simplicity we impose a balanced-budget rule.

$$G_t + T_t = \tau_t \frac{w_t}{P_t} l_t + \frac{M_t}{P_t} m_t \tag{18}$$

We assume that $\frac{G_t}{Y_t} = g$ and $\frac{G_t}{Y_t} = T$ are exogenously given.

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[6] This is equivalent to assume that the central bank implements a constant nominal interest rate rule $R_t = \frac{1+m}{\beta}$, which implies that $\frac{M_{t+1}}{M_t} = 1 + m_t$.

[7] Business cycle models typically neglect transfer as they are completely smoothed by optimizing households. Transfers become relevant here because they raise the amount of distortionary taxation levied by the government.

3 Flexible wages.

The flexible wages solution provides the benchmark case for the evaluation of our results. Each household maximizes (1) subject to the (2), given (13) and (14). This amounts to

$$(1 - \tau_t) w_t = \eta \mu^w l_t^\phi C_t p_t \tag{19}$$

where $\mu^w = \sigma (\sigma - 1)^{-1}$ denotes the wage mark-up under flexible wages. As shown in Neiss (1999) the model has a time-independent solution. The nominal interest rate is

$$R_{t+1} = \frac{1}{\beta} \frac{P_{t+1}}{P_t} \tag{20}$$

By using (14), (12) and (19) equilibrium employment is:

$$l_t^\mu = \left(\frac{\alpha}{\eta} \frac{1}{\mu^p \mu^w} \frac{1 - \tau_t}{1 - g_t} \right)^{\frac{1}{1+\phi}} \tag{21}$$

Observe that $\mu^p \mu^w$ denotes the labor and goods market wedge, whereas τ_t creates a tax wedge due to the distortionary taxation. The competitive (Pareto optimal) level of employment obtains if $\frac{1-\tau_t}{\mu^p \mu^w} = 1$.

In this framework optimal inflation is determined considering the trade-off between increasing inflation or taxes to finance the public good. Only if non-distortionary taxation is available, or if $G_t = T_t = 0$, the optimal monetary policy coincides with the Friedman rule $m_t = \beta - 1$. However, it has to be noted that inflation does affect neither the labor nor the goods market wedge.

4 Predetermined wages.

Now consider a labor market regime where wages are preset with respect to monetary policy. The timing of the game is as follows.

1. At the beginning of the period, the central bank commits to a fixed money growth rate consistent with a certain exogenous inflation target, $\bar{m}$.

2. Given the central bank rule, households set the nominal wage rate, w_t, that maximizes expected utility (1), conditional to the expected values for labor demand, for the money growth rule and for their own choices concerning money demand and consumption, i.e. conditions (10), (14), (16), (7), (6), (20). To simplify exposition, we characterize the nominal wage rate as $w_t = \bar{w}_t P_t^e$, where P_t^e is the rational expectation of the price level and $\bar{w}_t$ is the desired real wage rate

3. Households choose consumption and next-period nominal money holdings. Simultaneously, full price flexibility ensures that markets clear.

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Relative to the flex-wage solution, the key difference is that now households anticipate the effects of their wage choice on real money holdings. Imposing rational expectations ($\pi_t^e = \pi_t^e = \bar{m}$), the money demand equation becomes[8]

$$\frac{M_{t,i}}{P_t^e} = \left(\frac{\gamma \beta C_{t,i}^e}{1 + \bar{m} - \beta} \right)^{\frac{1}{\varepsilon}} \tag{22}$$

Imposing also the symmetrical equilibrium we obtain the desired wage rate, which is lower than in the flex-wage case:

$$(1 - \tau_t) \bar{w}_t = (1 - \tau_t) \frac{w_t}{p_t^e} = \eta \frac{\mu^w}{1 + \delta_m} l_t^{e\phi} C_t^e \tag{23}$$

where

$$\delta_m = \frac{\gamma}{\varepsilon} \left(\frac{M_{t,i}}{P_t^e} \right)^{1-\varepsilon} = \frac{1}{\varepsilon} \left[\gamma \left(\frac{1 + \bar{m} - \beta}{\beta} \right)^{\varepsilon-1} C_t^{1-\varepsilon} \right]^{\frac{1}{\varepsilon}} \tag{24}$$

By comparing (23) to (19), it is clear that the combination of predetermined wages and positive inflation target has a disciplining effect on labor market distortions.

The rationale is as follows. Under flexible wages, the wage-setters' optimization problem is solved by choosing a real wage such that consumption falls below the perfectly competitive rate. This loss of utility is more than compensated for by the corresponding reduction in labor effort. When wages are predetermined and the central bank adopts an inflation targeting strategy, households also anticipate that real money balances fall due to the adverse effect of the wage choice on consumption. The term δ_m captures the impact of a real wage increase on expected real money holdings. The size of this adverse effect is unambiguously increasing in $\bar{m}$.[9] By substituting (24) (23) into (14) and imposing rational expectations we obtain an implicit solution for employment

$$l_t = \left\{ \frac{\alpha}{\eta \mu^p \mu^w} \frac{1 - \tau_t}{1 - g_t} \left[1 + \frac{1}{\varepsilon} \left[\gamma \left(\frac{1 + \bar{m} - \beta}{\beta} \right)^{\varepsilon-1} (1 - g_t) l_t^{\alpha(1-\varepsilon)} \right]^{\frac{1}{\varepsilon}} \right] \right\}^{\frac{1}{1+\phi}} \tag{25}$$

Straightforward manipulations would show that the inflation target effect on employment (and thus on consumption) is always positive, i.e. $\frac{\partial l_t}{\partial \bar{m}} > 0$ (see Appendix A for a formal proof).

To support intuition, it is worth emphasizing the key difference relative to standard New Keynesian models incorporating nominal rigidities. In our framework the wage choice is antecedent to consumption, employment and money demand realizations, whereas under Calvo's wage setting rule all these variables obtain simultaneously to the optimizing wage setters' decision.

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[8] Equation (22) has been obtained substituting (6), (16), (20) into (7) and imposing rational expectations.

[9] Recall that $\frac{1}{\varepsilon} < 1$.

5   The non-vertical Phillips curve.

5.1   Inflation and the employment gap

As shown above, the combination of preset wages and inflation targets implies wage moderation and thus a non-vertical Phillips curve. A quantitative flavor of our results is obtained by calibrating the model to the US economy, as in Schmitt-Grohé and Uribe (2004).[10] The time unit is meant to be a year. We set the subjective discount rate, β, at 0.97, consistent with a 3% real interest rate. Given the 4% average inflation rate observed over the period 1960-2000, this implies a 7% nominal interest rate. We assume constant returns to scale (i.e., $\alpha = 1$). To sharpen our analysis, at this stage we neglect fiscal policy issues by assuming that $G_t = T_t = 0$.[11] We assume an inverse Frisch elasticity, ϕ, equal to one and set the preference parameter η so that in the non-distorted equilibrium households allocate 20% of their time to work. The implied semi-elasticity of money demand with respect to the nominal interest rate is equal to -4.55. We calibrate the price and wage markups at 1.05 and 1.15, respectively.[12] These calibrations imply a 9% employment gap in the flexible wage regime. The values for γ and ε are calibrated to obtain the income elasticity of money demand and the income money velocity at 0.95[13] and 1.8, respectively.[14]

By using (25), we obtain a non-vertical Phillips curve plotting the employ-

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[10] We check the robustness of our results for alternative scenarios. See Appendix B.

[11] Following Neiss (1999) we assume here that seigniorage revenues are returned to households as lump-sum transfers.

[12] We calibrate the labor and goods market wedge, $\mu^p \mu^w$, Schmitt-Grohé and Uribe (2004) who restrict imperfect competition to the goods market. A similar markup structure is used Christiano *et al.* (2002). Larger markups (Gali *et al.* 2007) would unambiguously raise the optimal inflation target.

[13] It is worth noting that money demand studies report income elasticities which typically are below or close to one (see, e.g., Choi and Oh (2003), Dib (2004), Knell and Stix (2005) and references therein). Christiano *et al.* (2005) obtain an estimate of 0.1. We check the robustness of our results also for their calibration (see Appendix B).

[14] Income elasticity of money demand is $1/\varepsilon$; the value for γ is obtained by imposing $1.8 = \frac{Y}{M/P}$, where M/P is obtained from (22) under $C = l^\mu$.

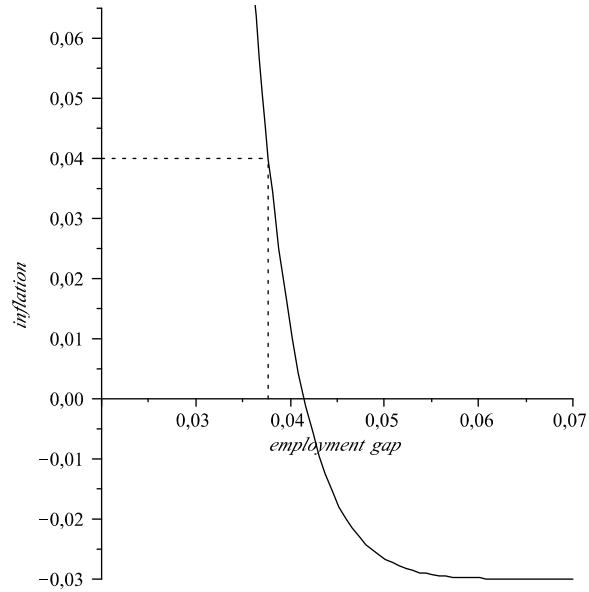ment gap and the inflation rate (see Figure 1).[15]

Figure 1 – The Phillips Curve

When $\bar{m} = \beta - 1$ the central bank implements the Friedman rule, the disciplining effect is nil and the employment gap is maximum, just like the flex wage case, when (21) obtains. Positive inflation targets cause non-negligible reductions in the employment gap.

This result is robust to changes in key parameters such as the income elasticity of money demand and the inverse Frisch elasticity, measured by ε and ϕ

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[15] The employment gap is $1 - l_t \left(\alpha/\eta \right)^{-\frac{1}{1+\phi}}$.

(see Figure 2 below).[16]

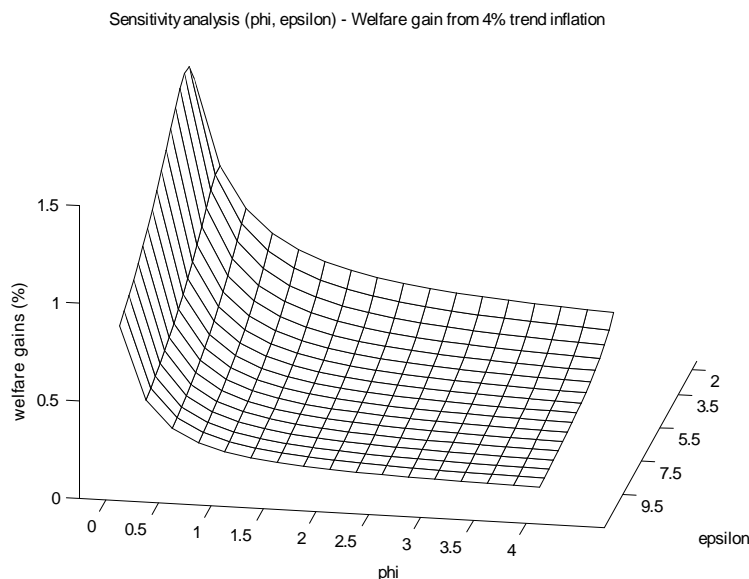Sensitivity analysis (phi, epsilon) - Welfare gain from 4% trend inflation

Figure 2 – Consumption/effort gain from 4% inflation

Even though the theoretical debate on the optimal inflation target is far from settled, empirical macro models have begun to incorporate an exogenous and positive long-run inflation rate. A growing literature has shown that New Keynesian models significantly improve their ability to replicate the business cycle facts if monetary policy rules are assumed to target time-varying, non-zero long-run inflation rates (see Cogley and Sbordone, 2008, and the references therein). Ireland (2007) estimates a New Keynesian model to draw inferences about the behavior of the Fed unobserved inflation target. His results indicate that the target soared from 1.25% in 1959 to over 8% percent in the mid-to-late 1970s before falling back to below 2.5% in 2004. He provides evidence which is consistent with the view that shifts in the secular trend in inflation, i.e. the expected long-term inflation rate, could be attributed to a systematic tendency for Federal Reserve policy either to limit the contractionary consequences of adverse shocks (Blinder, 1982; Hetzel, 1998; Mayer, 1998) or to exploit favorable economic conditions to eventually bring inflation down (Bomfim and Rudebusch, 2000; and Orphanides and Wilcox, 2002).

Our model is consistent with the view that persistent changes in real macro-economic factors induced the Fed to shift the inflation target. In Figure 3 the dashed line shows the inflation target adjustments necessary to stabilize the

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[16]The gains fall with the cost of inflating (ε) and with the effort disutility (ϕ).

employment gap following a persistent mark-up increase.[17] For instance, an inflation target surge from 4% to 6% is required to sterilize the real effects of a 1% mark-up increase.
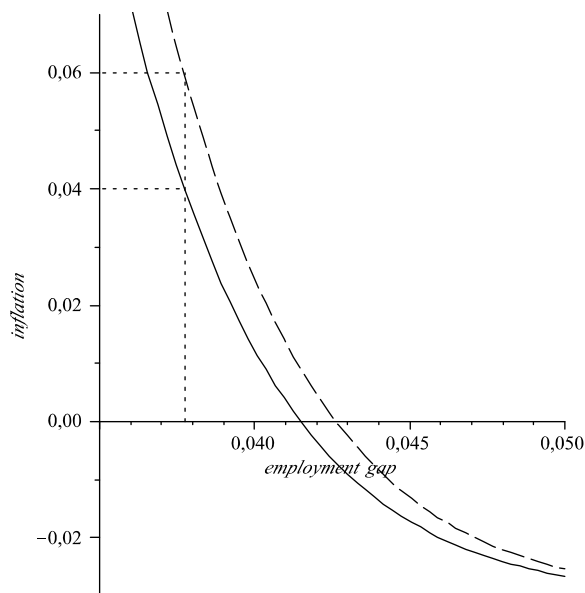

Figure 3 – The Phillips Curve shift

The obvious next step in our analysis is the identification of the optimal inflation rate. In this class of models the Friedman rule ($R_{t+1} = 1$, $\bar{m} = \beta - 1$) is optimal when goods and labor markets distortions are inflation invariant (Neiss, 1999). In our framework one would expect that the optimal inflation rate should strike a balance between the benefits in terms of markup reduction and the inflation-induced distortion on real money balances. Our calibrations show instead that the disciplining effect of inflation on wage markups never compensates for the inflation-induced distortion on real money balances. The Friedman rule remains therefore optimal. This result is surprisingly robust and holds for a wide range of parameter values. To support intuition, by using (24) to define l_t and C_t as functions of real money balances, we write the utility

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[17] We consider a shock to σ, the intra-temporal elasticity of substitution across different labor inputs, that typically determines cost-push (wage mark-up) shocks in New Keynesian models.

function (1) as

$$
U = \left\{ \frac{\alpha}{1+\phi} \ln \left[\frac{\alpha \left(1 + \frac{\gamma}{\varepsilon} \left(\frac{M}{P} \right)^{1-\varepsilon} \right)}{\eta(\mu^p \mu^w)} \right] - \eta \left[\frac{\alpha \left(1 + \frac{\gamma}{\varepsilon} \left(\frac{M}{P} \right)^{1-\varepsilon} \right)}{\eta(\mu^p \mu^w)} \right]^{\frac{1}{1+\phi}} \right\} +
$$
$$
+ \frac{\gamma}{1-\varepsilon} \left(\frac{M}{P} \right)^{1-\varepsilon} \tag{26}
$$

The term in curly brackets denotes the inflation-induced gain in the consumption/effort trade-off. In our simulations we always find that this gain is lower than the welfare loss deriving from the inflation-induced reduction in real money balances (Figure 4).
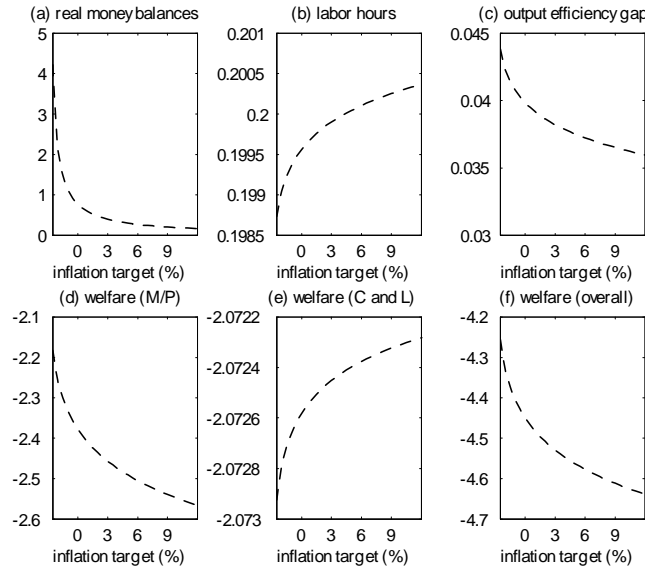

Figure 4 – Welfare analysis

An increase in the inflation target reduces real money balances (panel (a)), raises worked hours (panel (b)) and reduces the efficiency gap (panel (c)). The fall in real money balances reduces the welfare (panel (e)), whereas the increase in hours/consumption raises it (panel (f)). However, the overall effect is negative (panel (g)). This apparent setback suggests that our result should be qualified. So far we have shown that a non-vertical Phillips curve obtains to the extent that two conditions are satisfied:

1. wage contract renegotiations take place while expiring contracts are still

in place, enabling wage setters to internalize their consequences for subsequent households' choices;

2. inflation adversely affects households' welfare.

Within the relatively narrow framework of our model, this is not sufficient to support the optimality of a positive inflation rate. Intuition suggests, however, that the disciplining effect on wage markups outlined here would still apply in different models that justify deviations from the Friedman rule. In the next section we investigate the interaction between the seigniorage-induced inflation rate and the non-vertical Phillips curve mechanism outlined in this paper.

5.2 Seigniorage and optimal inflation targets

Now we assume that public consumption is equal to 20% of GDP – in line with postwar US data. The transfer T_t is set at 5.3%, in order to broadly match US data about total government expenditures net of production subsidies.[18] Optimal policy thus faces a dilemma between increasing inflation or taxes to finance public expenditures. In the flexible wage regime inflation does not affect wage-setters' choices, but seigniorage is a substitute for tax distortions (e.g., Damjanovic and Nolan, 2009). By contrast, in the preset-wage regime inflation also affects the labor market wedge.

In figure 5 below we plot the inflation rate needed to fulfill the fiscal solvency requirement for a given tax distortion chosen by the government.[19] Note that in the preset wages regime inflation unambiguously reduces the labor market wedge, thereby increasing employment and the wage bill. As a result, lower seigniorage revenues are necessary to finance public expenditures at a given tax rate. This, in turn, explains why government financing requires a lower inflation

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[18] Other parameters are calibrated as in the previous section. Notice that γ and η are adjusted to fit observed velocity and employment at the new values of public consumption and distortionary taxation.

[19] Note that in Figure 5 our definition of the employment gap includes both market and tax distortions. Thus the employment gap varies with tax distortion whereas the goods and labor market wedge is held constant.
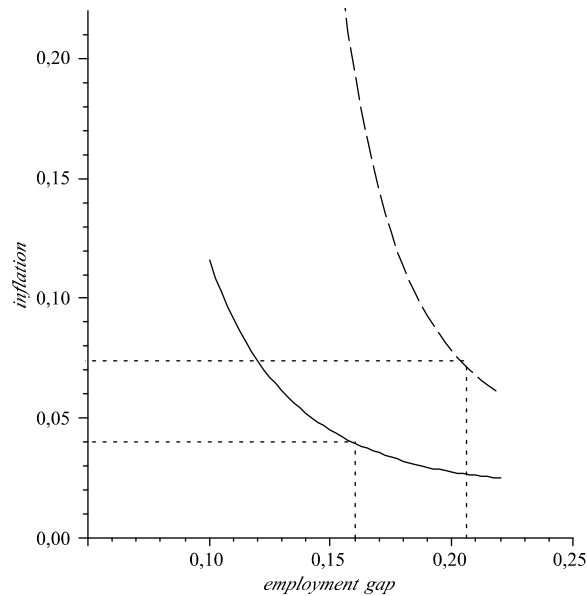
rate under preset wages.

Figure 5 – Seigniorage and inflation in the two
regimes. Solid line: preset wages

In table 1 we also show that, given our benchmark calibrations, the observed 4% inflation rate observed for the US might indeed be optimal.

Table 1 – Optimal targets, consumption
and employment

	π	τ	C	L
Flexible price	7.5	33.1	0.15	0.18
Pre-set wages	4.0	32.2	0.16	0.20

6 Conclusions.

Recent developments in macroeconomics resurrect the view that welfare costs of inflation arise because this acts as a tax on money balances. Empirical analyses of the labor market show that wage negotiations take place while expiring contracts are still in place.

Bringing these seemingly unrelated aspects together in a stylized general equilibrium model, we find a disciplining effect of a positive inflation target on the wage markup and identify a long-term trade-off between inflation and

output. Model simulations suggest that a moderate long-run inflation rate generates non-negligible output gains.

The key assumption for our result is that, differently from standard New Keynesian models usually based Calvo pricing, all nominal wages are predetermined to both the individual households' and the policymaker's decisions. As a consequence, wage setters internalize the effects of their choice on money holdings for the representative household's welfare because inflation is costly. This, in turn, paves the way for the disciplining effect of inflation targets and a non-vertical Phillips curve.

Appendix A

Abstracting from the government expenditure, under preset wage employment is determined by the following implicit expression (see (**??**)):

$$l_t(\bar{m}) = \left(\frac{\alpha}{\eta} \frac{1 + \delta_m\left(l_t(\bar{m})\right)}{\mu^p \mu^w}\right)^{\frac{1}{1+\phi}} = l_{flex}\left(1 + \delta_m\left(l_t(\bar{m})\right)\right)^{\frac{1}{1+\phi}} \qquad (27)$$

Recall that the endogenous markup is a function of the consumption level, which is non linearly related to the labor supply by the real wage.

Differentiating (27) we obtain

$$\frac{\partial l_t(\bar{m})}{\partial \bar{m}} = \frac{l_{flex}\left(1 + \delta_m\left(l_t(\bar{m})\right)\right)^{-\frac{\phi}{1+\phi}}}{1 + \phi} \frac{\partial \delta_m\left(l_t(\bar{m})\right)}{\partial \bar{m}} \qquad (28)$$

By differentiating (24) we get:

$$\frac{\partial \delta_m\left(l_t(\bar{m})\right)}{\partial \bar{m}} = \alpha \frac{\varepsilon - 1}{\varepsilon} \frac{\delta_m\left(l_t(\bar{m})\right)}{l_t} \frac{\partial l_t(\bar{m})}{\partial \bar{m}} + \frac{\varepsilon - 1}{\varepsilon} \frac{\delta_m\left(l_t(\bar{m})\right)}{1 + m - \beta} \qquad (29)$$

By combining (28)-(29) and using (27) we find

$$\frac{\partial l_t(\bar{m})}{\partial \bar{m}} = \left(1 - \alpha \frac{\varepsilon - 1}{\varepsilon} \frac{\delta_m\left(l_t(\bar{m})\right)}{1 + \delta_m\left(l_t(\bar{m})\right)} \frac{1}{1 + \phi}\right)^{-1} \frac{\varepsilon - 1}{\varepsilon} \frac{\delta_m\left(l_t(\bar{m})\right)}{1 + m - \beta} > 0 \qquad (30)$$

Note that the expression in parenthesis is one minus a product of terms all smaller than one. Thus it is positive.

Appendix B

In order to check the robustness of our results we also calibrate our model following Christiano *et al.* (2005: 15-17), under the assumption of flexible prices. We set $\alpha = 0.64$, $\phi = 1$, $\varepsilon = 8.5$, $\beta = 0.97$, $\mu^p = 1.2$ and $\mu^w = 1.05$. As Christiano *et al.* (2005) we calibrate η to normalize hours to one and γ at a level consistent with the (annual) observed money velocity (1.76 for $M2$) when inflation is 4%, i.e. the observed average post-war inflation in the US.

Figures below show that our results (large gains of preset wages with respect to the case of flexible wages and Friedman rule optimality) are confirmed.[20]
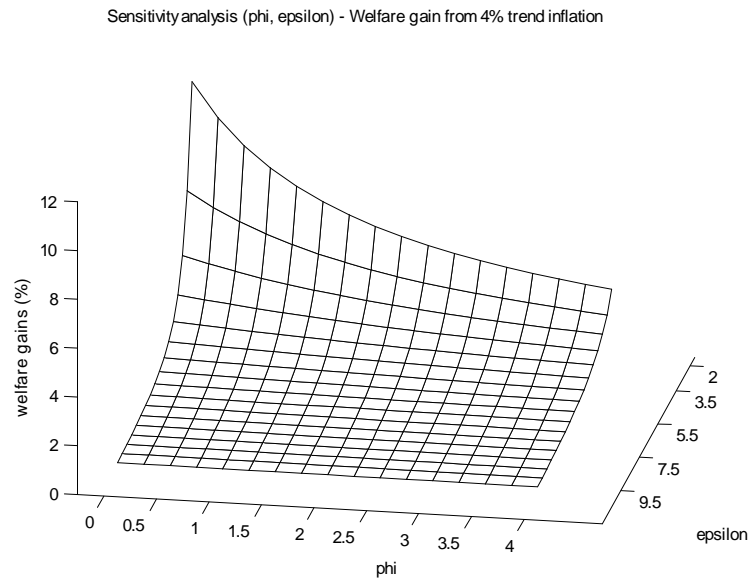
Sensitivity analysis (phi, epsilon) - Welfare gain from 4% trend inflation

Figure A1

[20] For the sake of brevity in Figure A2 we directly report the relationship between welfare and real money balances Recall that they are inversely related to the inflation targets.
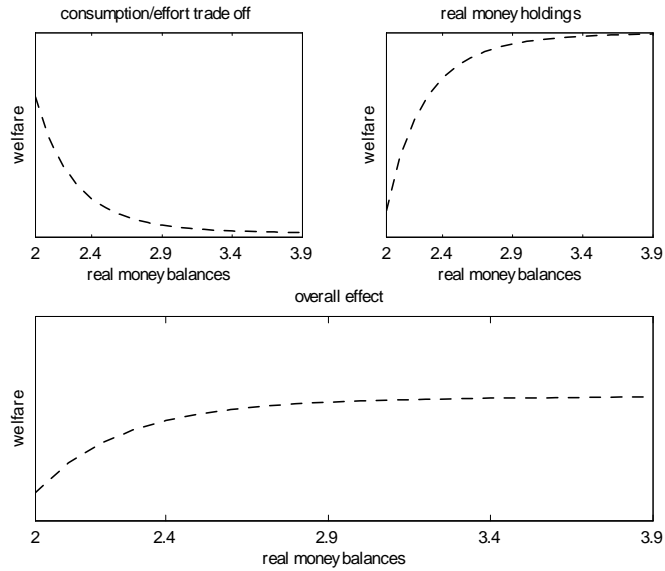
Figure A2

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