

# Wage Indexation and Monetary Policy\*

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October 2005

## Abstract

This paper analyzes the impact of indexed wage contracts on inflation and social welfare in a Barro–Gordon model with state contingent monetary policy. Wage indexation reduces the inflation bias but may raise the variance of inflation rates. In social optimum wages are fully indexed to the price level, but this requires optimal wage adjustments to productivity shocks. If wage adjustments to productivity are suboptimal, the second best solution calls for non-indexed wage contracts and a central banker with balanced aspiration levels of employment and real wages. In case of decentralized wage bargaining, a prohibition of wage indexation may improve welfare.

**Keywords:** monetary policy, Phillips curve, wage bargaining, wage indexation

**JEL classification:** E 24, E 52

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\*I want to thank Gerhard Illing, Helmut Hesse, seminar participants at CEMFI (Madrid) and two anonymous referees for helpful comments.

# 1 Introduction

It is an open question whether indexed contracts advance inflation. On one hand, wage indexation increases the slope of the Phillips curve and makes it more difficult to use monetary policy for stabilizing employment. Indexed bonds prevent that inflation depreciates the real value of government debt, and indexed tax schemes decouple real revenues of a progressive income tax from inflation. Thereby, indexation reduces the government's gains from inflation and its incentive for expansionary monetary policy. On the other hand, indexation reduces social costs of inflation and the central bank's resistance to inflationary policy. These two effects influence the inflation bias in opposite directions, and within the standard model of monetary policy by BARRO AND GORDON [1983]), it is not clear under which circumstances one or the other effect dominates (MOURMOURAS [1993]).

This paper extends the Barro–Gordon framework by modelling the impact of wage indexation on social costs of inflation. This allows a rigorous comparison of both effects and shows that wage indexation unambiguously reduces the inflation bias but may raise or lower the variance of inflation rates depending on the weight that the central bank attaches to the goal of price stability.

Wage indexation to the price level and wage adjustments to productivity are means to allocate risk stemming from real shocks and monetary policy. From GRAY [1976]) and FISCHER [1977] we know that indexation tends to stabilize output in the case of nominal shocks, but prevents the necessary adjustments to real shocks. In Gray's model, the optimal degree of indexation is an interior solution and corresponds to the relative importance of nominal shocks. This relies on her assumption that wage contracts cannot be conditioned on productivity measures. As KARNI [1983] laid out, indexation schemes are capable to duplicate the perfect information equilibrium if wages are indexed to a set of variables that are a sufficient statistic for exogenous shocks. In our model, wage contractors aim at minimizing a weighted average of the variances of employment and real wages. They can achieve an optimal allocation of supply side risk by indexing wages to some measure of productivity. Demand shocks can be neutralized by indexation to prices. Full indexation to the price level makes the real sector immune to monetary policy and eliminates any incentive, to pursue employment goals by inflation. This allows the central bank to stabilize inflation at the optimal level.

In real economies, however, asymmetric information impedes optimal wage adjustments to productivity shocks. Monetary policy can act as a partial substitute for insufficient wage adjustments by responding to temporary supply shocks and smoothing the adjustment process of the real economy to permanent shocks. Estimates of Taylor-rule coefficients indicate that leading central banks follow this policy of smoothing real fluctuations.<sup>1</sup>

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<sup>1</sup>CLARIDA, GALÍ AND GERTLER [1998] suggest that major central banks follow inflation targeting with some allowance for output gap stabilization.

In this paper, we combine these arguments and show that for suboptimal wage adjustments to productivity, monetary policy improves upon the allocation of supply side risk at the cost of fluctuating prices. The optimal monetary policy rule balances costs of price fluctuations with efficiency gains from stabilizing the real sector. A high degree of wage indexation hampers real effects of monetary policy on labor markets and raises the variance of inflation rates that is necessary to re-allocate risk in the real sector. Hence, wage indexation may reduce welfare, although it always lowers the inflation bias.

FISCHER [1983] argues that wage indexation may raise the variance of the price level, but has no effect on average inflation. In contrast, his empirical analysis shows that, in countries with a high degree of wage indexation, the oil price shocks had a lower impact on money growth rates. Our results are in line with this empirical observation.

The ambiguous effects of wage indexation on welfare have been subject to a number of previous studies: BARRO AND GORDON [1983] show that reduced social costs of inflation have a positive effect on the rate of inflation in a discretionary equilibrium. FISCHER AND SUMMERS [1989] build up on this argument and conclude that avoiding inflation mitigation measures is one way of committing to low future inflation rates. Governments whose ability to maintain low rates of inflation is uncertain should not reduce the costs of actual inflation. On the other side, GIERSCH [1973] argues that wage indexation helps to avoid reductions in employment during the transition from high to low inflation rates. CROSBY [1995] points out that indexation disables the government to pursue employment goals and thus, works as a credible commitment to low inflation, but it imposes costs in the form of suboptimal wage adjustments to real shocks.

While these studies assume that indexation is given exogenously, in most countries the degree of wage indexation is specified by wage contracts endogenously. BLANCHARD [1979] argues that wage indexation may be a partial substitute for contingent wage contracts that are costly to implement. DEVEREUX [1987], [1989] incorporates endogenous wage contracts into the Barro–Gordon model and analyzes the relation between average and variance of inflation. BALL [1988] follows this approach and argues that wage indexation is efficient, even in a decentralized economy. But, in his model monetary policy is assumed to be exogenous. ADOLPH AND WOLFSTETTER [1991] detect informational externalities of wage indexation and show that Ball’s result is not robust: if monetary policy responds to wage contracts, wage indexation creates a positive external effect by lowering the inflation bias. Decentralized unions do not account for this external effect, so that the overall degree of indexation may be too low (WALLER AND VANHOOSE [1992]). However, this approach does not consider welfare improvements of state contingent monetary policy. If monetary policy responds to supply shocks, indexation creates a negative externality on the ability of the central bank to stabilize output, which may reverse the result and lead to an inefficiently high degree of wage indexation, as we show in this paper.

We suggest to model the effect of indexation on social costs of inflation by including

real wage stability in the social cost function and also in the objective function of wage setters. One reason for this approach is that optimal contracts between risk averse workers and a risk neutral firms balance fluctuations in employment and real wages (AZARIADIS [1975]). Since wage fluctuations primarily concern workers, we assume that the weight of real wage stability in the objective function of wage setters exceeds its weight in the social welfare function. This difference implies a negative external effect of wage indexation on state contingent monetary policy. In the extreme case, where the central bank does not care about real wage stability at all, our results are most pronounced. However, this also means that social costs of inflation are not affected by wage indexation.

There are few other papers that explicitly consider wage stability as a macroeconomic policy objective: DUCA AND VANHOOSE [2001] assume that wage contracting results from minimizing a weighted average of fluctuations in real wages and employment. They show that greater sectoral output variance reduces the use of nominal wage contracts. CALMFORS AND JOHANSSON [2002] rely on a similar argument and show that entry in a monetary union implies stronger incentives to use indexed wage contracts.

The next section shows why the standard Barro–Gordon model cannot give a clear answer on whether wage indexation raises or lowers the inflation bias. Here, we also motivate why wage indexation may lower social costs of inflation. Section 3 presents an extended Barro–Gordon model that explicitly considers social costs of wage fluctuations and shows how discretionary monetary policy depends on the degree of wage indexation and on wage adjustments with respect to supply shocks. Optimal and equilibrium indexation are analyzed in Section 4. It is shown that wage adjustments to supply shocks are generally suboptimal and a second best solution requires a ban on wage indexation to the price level, provided that the inflation bias can be controlled by other means. Section 5 concludes this paper.

## 2 Wage Indexation in the Standard Barro–Gordon model

Wage indexation increases the slope of the Phillips curve and reduces social costs of inflation. First, we show that within the standard Barro–Gordon model, these changes have opposing effects on the rate of inflation in a discretionary equilibrium.

The standard Barro–Gordon model consists of a social cost function

$$L = (l - l^*)^2 + \beta (p - p^*)^2,$$

in which  $\beta$  measures the costs of inflation. As usual,  $l$  is employment,  $l^*$  is a target level of employment,  $p$  and  $p^*$  are actual and targeted price level. All terms are logarithms or

growth rates. The monetary authority chooses price level  $p$  in order to minimize  $L$  with respect to a short-run Phillips curve

$$l = x (p - p^e)$$

for given price expectations  $p^e$ .  $x$  is a positive parameter. This leads to the policy rule

$$p = p^e + \frac{x l^* - \beta (p^e - p^*)}{x^2 + \beta}.$$

Rational expectations imply

$$p^e = E(p) = p^* + \frac{x l^*}{\beta}.$$

Average inflation rises with falling costs of inflation  $\beta$ , because this increases the central bank's incentive to use monetary policy to pursue the employment goal. Average inflation is lowered by a reduction in  $x$ , because this makes monetary policy less effective, i.e. more inflation is needed to create a given number of jobs.

The more nominal wages are indexed to the actual price level, the lower is the impact that unexpected inflation has on real wages. On one hand, this prevents monetary policy from having employment effects. Wage indexation increases the steepness of the Phillips curve (reduces  $x$ ) and, ceteris paribus, lowers inflation in a rational expectations equilibrium. On the other hand, wage indexation reduces social costs of inflation  $\beta$ , which increases the inflation bias. The net effect is ambiguous, because both impacts are exogenous to the model and there is no way to judge which one prevails (MOURMOURAS [1993]).

The model that we lay out in the subsequent parts of this paper endogenizes social costs of indexation and shows under which conditions indexation raises or lowers welfare. The rationale behind the idea that wage indexation reduces social costs of inflation is not obvious. Several arguments may be brought forward: (i) AZARIADIS [1975] shows that an ex ante optimal contract between risk neutral firms and risk averse workers balances two sources of variability in wage income: fluctuating wages and uncertainty over employment status. Wage indexation affects both variances. The variance of employment is captured by the first argument in the social cost function, costs of real wage fluctuations are not considered. They may be thought of being hidden in  $\beta$ . (ii) In the standard Barro-Gordon model, an allocation is characterized by output, inflation, and real wages. Wage indexation affects all three. Since output and inflation are contained in the social cost function already, the argument that wage indexation reduces social costs of inflation leaves real wage fluctuations as the only remaining source of such costs. (iii) Workers are subject to capital market imperfections, so that real wage fluctuations lead to a welfare loss. (iv) After analyzing survey data from US firms, BEWLEY [1995], [1998] argues that employers are also interested in wage stability as motivation for their workers' allegiance and to avoid bad morale. FEHR AND GÄCHTER [1998] attribute firms' reluctance to cut wages

in a recession to reciprocity as a basic component of human behavior. (v) In an economy with staggered wage setting as described by BALL AND CECCHETTI [1991], real wage fluctuations lead to a welfare reducing wage dispersion.<sup>2</sup>

These arguments suggest that wage indexation reduces social costs of inflation, because real wage fluctuations are costly to society, and in particular to workers and employers. We account for this argument by including real wage fluctuations as an explicit argument in the social cost function and in the objective function of wage setters. We show that this resolves the ambiguity and allows a rigorous analysis of the optimal indexation regime.

### 3 Discretionary Monetary Policy in the Presence of Wage Indexation

To analyze the interaction between wage setters and a central bank we use a four stage game that we solve backwards starting with the last stage. We assume that wage contracts allow for indexation of nominal wages to the actual price level and for flexible adjustments to supply shocks. The central bank controls the price level in order to minimize a weighted average of fluctuations in employment, prices and real wages around socially desired levels that may deviate from equilibrium levels. The time structure of our model is as follows:

1. Wage setters agree upon a contingent wage contract that specifies the nominal wage as a function of unexpected changes in the aggregate price level and of supply conditions.
2. A supply shock  $\theta$  realizes.
3. Monetary authority sets money supply.
4. Firms decide on employment and production. Equilibrium prices are formed simultaneously. Wages are adjusted according to the agreed-upon contract.

The basic variables of our model are firm-specific and aggregate nominal wages  $w_i$  and  $w$ , employment  $l_i$  and  $l$ , output  $y_i$  and  $y$ , and the aggregate price level  $p$ . Firms are assumed to be small and indexed by  $i \in [0, 1]$ . Aggregate variables are defined by integrating their sectoral components, e.g.  $(w, l, y) = \int_0^1 (w_i, l_i, y_i) di$ . Small letters always denote logarithmic terms and may be interpreted as growth rates.

The production function of firm  $i$  is given by

$$y_i = a l_i + \theta_i, \quad 0 < a < 1, \tag{1}$$

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<sup>2</sup>In their model, indexation unambiguously raises welfare. Reasons are the absence of supply shocks and the assumption that wage setters and central bank have the same objectives.

where  $\theta_i = \theta + \delta_i$  is the productivity shock faced by firm  $i$ .  $\theta$  is an aggregate shock, distributed with variance  $\sigma_\theta^2 > 0$  around a mean of zero.  $\delta_i$  is the deviation of firm  $i$ 's productivity from the aggregate, distributed with mean zero and variance  $\sigma_i^2 > 0$ . We assume that random terms  $\theta$ ,  $\delta_i$ , and  $\delta_j$ , ( $j \neq i$ ), are pairwise independent of each other.

Firms decide on labor demand and output by maximizing their profits. Hence, labor demand is given by

$$l_i = \ln \arg \max_{L_i} \{P Y_i - W_i L_i \mid Y_i = \Theta_i L_i^a\}, \quad (2)$$

where capital letters denote the according non-logarithmic terms. Firms produce a homogeneous good and stand in perfect competition. Maximizing profits yields the labor demand function

$$l_i = \bar{l} + \frac{1}{1-a} [p - w_i + \theta_i], \quad (3)$$

where  $\bar{l} = \ln a / (1-a)$ . We normalize  $E(l_i) = \bar{l}$ , which is equivalent to normalizing  $E(w_i - p) = E(\theta_i) = 0$ .

Short-run labor supply is assumed to be high enough to meet whatever is demanded, so there is no rationing of firms even in the case of positive shocks. We shall calculate the expected values under this hypothesis. Consistency requires that the support of our random term is limited above, because otherwise short-run labor supply would have to be infinite.

Wage setters fix a contingent contract previous to the realization of supply shocks and monetary policy. Contingencies are reactions to the realized price level and to realized productivity. Both contingencies are specified in the contract. A wage contract in firm  $i$  is a function

$$w_i = p^e + (1 - \lambda_i) (p - p^e) + \phi_i \theta_i. \quad (4)$$

$p^e$  is the expected price level,  $1 - \lambda_i$  is the degree of wage indexation to aggregate prices, and  $\phi_i$  is an index for wage adjustments to productivity. To ease the exposition, we assume that  $\sigma_i = \sigma_j$  for all  $i, j$ . If all firms have the same objective function, in equilibrium, they will all choose the same contract parameters  $\lambda_i = \lambda$  and  $\phi_i = \phi$ .

Combining this with equations (3) and (4), we get the short-run Phillips curve

$$l - \bar{l} = \frac{1}{1-a} [\lambda (p - p^e) + (1 - \phi) \theta]. \quad (5)$$

A high degree of wage indexation ( $\lambda$  close to 0) leads to a steep Phillips curve and a high sacrifice ratio. With a low index of wage adjustments to productivity, the Phillips curve is shifted by supply shocks, i.e. supply shocks have a large impact on employment.

A similar relation obtains for real wages,

$$w - p = \lambda (p^e - p) + \phi \theta. \quad (6)$$

Equation (6) shows that  $\lambda$  is the elasticity of real wages with respect to unexpected inflation. It can be interpreted as the degree to which wages stay behind the price level if that exceeds its expected value.  $\phi$  is the real wage elasticity w.r.t. productivity. It may be viewed at as the speed of wage adjustments to supply shocks. It may also be interpreted as a productivity bonus.<sup>3</sup>

Aggregate demand is generated by the quantity equation, and prices are assumed to clear the goods market. This defines the price level as

$$p = m - y, \quad (7)$$

Using (5), production function (1) and quantity equation (7) imply

$$p - p^e = \frac{1}{1 + c\lambda} [m - \bar{y} - p^e - (1 + c(1 - \phi)) \theta], \quad (8)$$

where  $\bar{y} = a\bar{l}$  and  $c = a/(1 - a)$ .

The social cost function is extended by including real wage stability as an explicit policy goal. It is defined by

$$C = \frac{1}{1 + \beta + \gamma} \left[ (l - l^*)^2 + \beta (p - p^*)^2 + \gamma (w - p - w^*)^2 \right], \quad (9)$$

where  $l^*$ ,  $p^*$  and  $w^*$  are desired levels of employment, prices and real wages,  $\beta \in [0, \infty]$  is the relative weight on the goal of price stability, and  $\gamma \in [0, \infty]$  is the relative weight on the real wage goal in comparison to the employment goal that has a normalized weight. The explicit consideration of real wages in the cost function endogenizes the impact of indexation on social costs. Wage indexation reduces real wage fluctuations and associated social costs via this term. Henceforth,  $\beta$  may be assumed to be independent from real

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<sup>3</sup>A wage contract that restricts wage adjustments to prices and supply shocks is an analytical simplification. Replacing or combining wage adjustments to productivity by adjustments to firm revenues, unemployment or any other variable that is a sufficient statistic for productivity gives the same results. KARNI [1983] demonstrates that optimal wage indexation to aggregate prices and output can duplicate the equilibrium that is obtained if wages are conditioned on productivity.

wage fluctuations and, thereby, from wage indexation, whereas in the standard Barro–Gordon model of Section 2 real wage fluctuations entered the social cost function via an unspecified impact on  $\beta$ . Our results are most pronounced, when  $\gamma = 0$ , i.e. real wages do not enter the social cost function, which also means that social costs of inflation are not affected by wage indexation.

The division by the sum of weights normalizes the cost function. For optimal responses of wages and employment to shocks, costs are still positive. This reflects (1) inefficiencies responsible for deviations of target levels from expected employment and wages, and (2) inevitable adjustment costs associated with fluctuations of employment and real wages if  $0 < \gamma < \infty$ . The latter will be discussed in Chapter 4.

Target levels  $l^*$  and  $w^*$  may be defined by maximizing the sum of profits and consumer surplus as in BLANCHARD [1979]. With risk averse workers, however, a measure of ex ante efficiency cannot define optimal levels for employment and wages independently from induced fluctuations. More generally, target levels in the social cost function may also account for distribution objectives. Since our model aims at analyzing optimal fluctuations instead of optimal levels, we avoid specific assumptions about target levels.

Many papers in the literature assume that the central bank minimizes deviations of output growth from the natural growth rate (output gap). In our model, the natural rate is given by  $y^n = a\bar{l} + \theta$ . Minimizing fluctuations around this rate is equivalent to targeting  $l^* = \bar{l}$ .

We assume that monetary authorities set money supply  $m$  in order to minimize social costs as defined by (9). Discretionary monetary policy determines the inflation bias and state contingent price levels.

**Proposition 1** *Discretionary monetary policy in a rational expectations equilibrium is described by the price rule  $p = p^e - q\theta$  with*

$$p^e = p^* + \frac{\lambda}{b}(ck - gw^*) \tag{10}$$

and

$$q = \lambda \frac{c^2 - \phi(c^2 + g)}{\lambda^2(c^2 + g) + b}, \tag{11}$$

where  $k = a(l^* - \bar{l})$ ,  $b = a^2\beta$ , and  $g = a^2\gamma$ .

**Proof** Minimizing (9) with respect to (5), (6) and (8) yields the first order condition

$$\frac{\partial C}{\partial(p - p^e)} \frac{\partial(p - p^e)}{\partial m} = 0 \quad \text{with} \quad \frac{\partial(p - p^e)}{\partial m} = \frac{1}{1 + c\lambda} > 0. \quad (12)$$

Hence, monetary policy is characterized by  $\partial C/\partial(p - p^e) = 0$ , which is equivalent to

$$[\lambda^2(c^2 + g) + b] (p - p^e) + \lambda [c^2 - \phi(c^2 + g)] \theta = \lambda ck - b(p^e - p^*) - \lambda gw^*. \quad (13)$$

With rational expectations,  $p^e$  equals the unconditional expectation of  $p$  at stage 1 one of the game,  $E(p)$ . Applying this to (13) yields the price rule in Proposition 1. QED

The expected price level  $p^e$  (or rather the rate of inflation, since we have logarithmic terms) deviates from the socially desired one if and only if  $ck \neq gw^*$ . As we know from standard versions of the Barro–Gordon model, it is higher, the larger the gap  $k$  between desired and equilibrium output and the flatter the Phillips curve (larger  $c$ ). The real wage goal has an opposite effect. The higher desired real wages  $w^*$ , the lower is inflation.<sup>4</sup>

In an economy with a less than perfectly elastic labor supply function, employment stays below supply if and only if real wages are above their market clearing level. Under-employment equilibria may be motivated by unionized wage setting or by efficiency wages. In these cases  $k > 0 > w^*$ , and aiming at these target levels inevitably leads to a positive inflation bias. On the other hand, central bankers usually claim to minimize the output gap, which relates to target levels  $k = w^* = 0$ . Whenever central bankers have balanced targets of employment and real wages, such that  $ck = gw^*$ , the inflation bias is zero for any degree of wage indexation. We will use this property later when analyzing second best monetary policy.

Equation (10) shows that the deviation between expected and desired price level is zero for full indexation ( $\lambda = 0$ ) and rises with falling degree of wage indexation (rising  $\lambda$ ). A high degree of indexation reduces the capability of monetary policy to influence employment and real wages. It makes the real sector immune to monetary policy. Hence, there is a low incentive to use monetary policy for achieving real effects. The public correctly expects the central bank to concentrate on stabilizing prices and the inflation bias is close to zero in this case.

$q$  is a monetary stabilization term that may have either sign, depending on whether social costs are dominated by employment or real wage fluctuations. (5) and (6) show that wage adjustments to productivity  $\phi$  shift uncertainty from employment to real wages. If flexibility is low, employment fluctuations are a more serious threat to welfare than fluctuating wages. In this case the goal of employment stability dominates real wage

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<sup>4</sup>In non-stochastic models, the difference between the two targets is all that matters. Therefore, non-stochastic models do not gain from including an explicit real wage goal.

stability,  $q$  is positive, and prices move in opposite direction to aggregate supply shocks. A drop in productivity will be accompanied by a rise in prices. This dampens the shock's impact on employment and leads to stronger volatility in real wages. On the other hand, if the central bank thinks that wages overreact to supply shocks, it could reverse the process by creating a positive correlation between productivity and prices.

For  $\phi = c^2/(c^2 + g)$ , the central bank views wage flexibility as being optimal and  $q = 0$ . Otherwise, monetary policy can substitute wage adjustments to productivity in its task to allocate uncertainty between employment and real wages. However, if monetary policy is used for an active re-allocation of uncertainty between real variables, this leads to undesirable price fluctuations. Proposition 1 implies  $\text{Var}(p) = q^2 \sigma_\theta^2$ . As (11) shows, this variance is smaller, the bigger social costs of price fluctuations  $b$  are. If  $b$  is very high, or if real effects of prices are low (e.g. for  $\lambda$  close to zero), the central bank will hardly use monetary policy to achieve real effects.

It has been suspected that indexation raises the inflationary impact of negative supply shocks (FISCHER [1983]). Obviously, this cannot be true in general. In the case of full wage indexation ( $\lambda = 0$ ) real variables are immune to monetary policy, and the central bank will concentrate on stabilizing prices, i.e.  $q$  equals zero. Using (11), we find that for  $q \neq 0$ ,  $\partial q^2/\partial \lambda < 0$  is equivalent to  $\lambda^2 > b/(c^2 + g)$ . This shows that the variance of  $p$  rises in the degree of wage indexation ( $1 - \lambda$ ) if and only if  $\lambda^2 > b/(c^2 + g)$ .

$b/(c^2 + g)$  is the relation between social costs of price fluctuations and the costs of real fluctuations. If  $b < c^2 + g$  and the degree of indexation is sufficiently low, so that  $(1 - \lambda) < 1 - \sqrt{b/(c^2 + g)}$ , then an increase in the degree of indexation raises the variance of the price level until a level is reached where rising marginal costs of price instability outweigh decreasing marginal benefits from stability of real variables. A further increase in indexation is a disincentive for the central bank to use monetary policy to achieve real effects and, therefore, lowers price volatility until its elimination with full indexation. If  $b > c^2 + g$ , an increase in wage indexation always lowers the variance of the price level.

In his empirical section, FISCHER [1983] shows that, in countries with a high degree of wage indexation, the oil price shock of 1973 had a lower impact on money growth rates. Our analysis explains this observation: wage indexation reduces the ability of the central bank to influence the impact of supply shocks on the real economy. Thereby, the central bank has lower incentives to react to these shocks.

## 4 Optimal and Equilibrium Indexation

The impact of supply shocks must be borne by real variables. This can best be seen from

$$(1 - a)(l - \bar{l}) + (w - p) \equiv \theta, \tag{14}$$

which is implied by Equations (5) and (6). Contingent wage contracts and monetary policy govern the allocation of uncertainty among employment and real wages, but it is impossible to keep both constant, when  $\theta$  varies. The distribution of a shock's impact on employment and real wages is optimal if it accords with the weights in the social cost function. This distribution can be perfectly controlled by wage adjustments to productivity, summarized by the index  $\phi$ . If wages adjust in an optimal way, there is no need for monetary policy to re-shift fluctuations between real variables. Instead, monetary policy can concentrate on stabilizing prices. Full indexation eliminates the inflation bias, because it works like a credible commitment of the central bank, not to pursue an output or a real wage goal.

**Proposition 2** *The elasticities of real wages w.r.t. prices and productivity that minimize expected social costs are given by  $\lambda^* = 0$  and  $\phi^* = c^2/(c^2 + g)$ , leading to  $p^e = 0$  and  $q = 0$ .*

**Proof** see Appendix.

It accords with basic intuition that optimal wage adjustments to productivity are higher, for a lower relative weight on real wage stability in the social cost function.  $g = 0$  describes the special case that has been well analyzed by much of the previous literature. In this case the optimal degree of wage adjustments is one, preventing any employment fluctuations, as in KARNI [1983] or ERCEG, HENDERSON AND LEVIN [2000].<sup>5</sup> But, even for a positive weight on real wage stability, with optimal wage adjustments to productivity, full indexation minimizes social costs.

The level of social costs associated with first best adjustments of employment and wages to shocks is

$$EC^{min} = \frac{1}{(1 + \beta + \gamma)} \left[ l^{*2} + \gamma w^{*2} + \frac{\gamma}{1 + (1 - a)^2 \gamma} \sigma_\theta^2 \right]. \quad (15)$$

This level serves as a reference point for higher costs associated with suboptimal adjustments. The difference may be interpreted as welfare loss due to suboptimal wage flexibility. For  $\gamma$  tending to either zero or infinity, expected social costs are independent from the variance of supply shocks  $\sigma_\theta^2$ . In these cases only one of the two variables, employment or real wages, enters the cost function. Optimal wage adjustments may keep one variable constant (employment by  $\phi = 1$  and real wages by  $\phi = 0$ ). However, it is not possible to avoid fluctuations of employment *and* wages. Hence, if both goals matter ( $0 < \gamma < \infty$ ), any supply shock is inevitably associated with social costs from fluctuations of one or

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<sup>5</sup>ERCEG, HENDERSON AND LEVIN [2000] derive the welfare function from a representative consumer's utility. However, they do not consider capital market imperfections nor explicit labor contracts by which firms can insure workers against wage fluctuations. In their model, full wage flexibility leads to the social optimum, because wage fluctuations per se do not reduce expected utility. Wage fluctuations affect social costs only via their impact on the output gap and, thereby, on employment.

both of these variables.  $\phi^*$  balances these effects and minimizes the social costs induced by supply shocks.

In real economies, however, asymmetric information and moral hazard impede an optimal and immediate adjustment of wages to measures of productivity. In addition, legal and procedural confinements may restrict flexibility of labor markets, as is often claimed especially with respect to European labor markets. Most theoretical papers neglect contingent contracts and implicitly set  $\phi = 0$ , which is an extreme limitation to wage flexibility as it does not allow for any direct wage adjustments to productivity shocks. In this paper, we allow for contingent contracts and assume that wage setters place a higher weight on real wage stability than monetary authorities.

If wage adjustments are not optimal, there are two opposing welfare effects: a high degree of indexation lowers the inflation bias and reduces social costs of inflation, but it also disables monetary policy to stabilize real variables in substitution for insufficient wage adjustments, and thus increases social costs from employment fluctuations. A ban on wage indexation may, as we shall see, also influence the chosen index of wage adjustments to productivity.

To analyze welfare implications of a ban on wage indexation, we turn now to the first stage of the game and derive equilibrium wage contracts: first for the case, where wage setters are free to index wages, and afterwards for the case, where wage indexation to prices is restricted.

The optimal wage contract between risk averse workers and a risk neutral employer balances expected fluctuations in employment and real wages (AZARIADIS [1975]). Therefore, we assume that contract parameters  $\lambda_i$  and  $\phi_i$  are determined by

$$\min_{\lambda_i, \phi_i} \text{Var}(l_i) + \zeta \text{Var}(w_i - p). \quad (16)$$

$\zeta \in [0, \infty]$  represents the relative weight given to the goal of stabilizing real wages<sup>6</sup>. Wage setters are likely to attribute a higher weight to real wage stability than the rest of society, whose income is not directly affected by wage contracts. The next proposition shows that for  $\zeta > \gamma$  the equilibrium degree of wage adjustments to productivity is suboptimal.<sup>7</sup> The solution to this optimization problem depends on price fluctuations which are controlled by the central bank. When deciding on contract parameters, wage setters take the central bank's response to supply shocks as described by Proposition (1) into account.

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<sup>6</sup>CUKIERMAN AND LIPPI [1999] and LAWLER [2001] argue that price stability should also be included in the unions objective function. We assume instead that firms are too small to influence aggregate prices.

<sup>7</sup>An alternative way to justify suboptimal wage flexibility is to introduce costs associated with timely adjustment of wages to productivity shocks. Replacing costs of real wage fluctuations by a linear cost function  $C(\phi)$  or combining both in equation 16 leads to the same conclusions that we obtain for  $\zeta > \gamma$ .

**Proposition 3** *In an unconstrained equilibrium, wage adjustments to productivity are given by  $\hat{\phi} = 1/z$ , with  $z = 1 + (1 - a)^2 \zeta$ . If  $\zeta \neq \gamma$ , wage contractors choose full wage indexation to prices,  $\lambda = 0$ .*

**Proof** see Appendix.

$\hat{\phi}$  is the unique equilibrium degree of wage adjustments if wage indexation is not constrained. It is an interior optimum for the wage reaction to supply shocks. Higher reactions to supply shocks would hurt desired real wage stability, lower reactions would lead to too strong fluctuations in employment. With direct reactions of wages to supply shocks, the remaining purpose of indexation is to eliminate shocks from unanticipated price movements that may be due to spillover effects from other sectors or from monetary policy. Given monetary policy as specified above, in equilibrium, such price movements occur whenever  $\phi \neq \phi^*$ .

Let us first have a look on the special case where  $\zeta = \gamma$ . This condition says that private and social weight on real wage stability are the same. Here, contracted wage adjustments  $\hat{\phi}$  equal  $\phi^*$ . They are regarded as appropriate by the central bank and implement the ex ante optimal allocation of risk. The distribution of a shock's impact between fluctuations of employment and real wages is optimal and the central bank has no reason to use monetary policy to redistribute uncertainty. Monetary policy concentrates on stabilizing prices and eliminates all fluctuations here. Hence, indexation serves no purpose and the degree of indexation is irrelevant.

Although monetary policy could achieve the same fluctuations of aggregate employment and real wages as optimal wage adjustments, private contracts achieve this goal better, because they account for sectoral productivity changes while monetary policy can only respond to aggregates. Besides, if monetary policy is used to re-allocate uncertainty between employment and real wages, it also leads to fluctuating prices. This creates a welfare loss that can be avoided if the shock's impact is properly allocated by wage contracts.

If the private weight for real wage stability exceeds the social weight ( $\zeta > \gamma$ ), then the central bank views wage adjustments to productivity as too low and is interested in shifting a part of the shock's impact on employment to real wages by creating a negative correlation between supply shocks and price level, i.e.  $q > 0$ . For  $\zeta < \gamma$  these effects are reversed.<sup>8</sup> However, this policy requires imperfect indexation, since otherwise monetary policy is ineffective. In order to reach a given allocation of uncertainty between real variables, price deviations can be smaller, the lower the degree of indexation is. So, with suboptimal wage adjustments, a low degree of indexation to prices may be advantageous, because it allows to stabilize employment at low costs of price uncertainty.

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<sup>8</sup>This case seems less relevant to real economies.

If indexation is prohibited, the individually optimal degree of wage adjustments to productivity solves (16) with respect to  $\lambda = 1$ . The solution to this problem deviates from the unconstrained optimum, if wage contractors and monetary authority assign different weights to the goal of real wage stability.

**Lemma 1** *If wage contracts cannot be indexed to the price level, equilibrium wage adjustments are given by*

$$\phi = \hat{\phi} \left[ 1 - \frac{a^2(\zeta - \gamma)}{b + (c^2 + b + g) \sigma_i^2 / \sigma_\theta^2} \right]. \quad (17)$$

**Proof** see Appendix.

If  $\zeta > \gamma$ , wage setters stipulate suboptimal wage adjustments to productivity and the central bank has an incentive to shift uncertainty from labor to real wages by creating a negative correlation between supply shocks and prices. Wage setters would want to offset the effects of monetary policy by indexing to the price level. But, if wage indexation is restricted, wage negotiators will arrange even lower wage adjustments and, thus, steer against monetary policy. Thus, limits to wage indexation reduce wage adjustments to productivity. This might describe the situation in some European and Latin American countries, where wage indexation is forbidden or socially banned.

If  $\zeta < \gamma$ , wage negotiators pay too little attention to real wage stability.<sup>9</sup> If indexation is prohibited,  $\phi$  exceeds  $\hat{\phi}$ . Here, the interdiction of indexed contracts increases wage adjustments to productivity, but again, this is not in the interest of social welfare, because the degree of adjustments exceeds the social optimum already ( $\hat{\phi} > \phi^*$ ).

In both cases, indexation to the price level has opposing welfare effects: a high degree of indexation lowers the inflation bias, reduces social costs of inflation, and induces more efficient adjustments of wages in response to supply shocks. On the other hand, wage indexation hinders monetary policy to stabilize real variables in substitution for non-optimal wage adjustments and thereby increases social costs of real fluctuations. The next proposition states that for  $ck = gw^*$  the net effect is unique and social costs are always lower, when indexation to the price level is restricted.

**Proposition 4** *Assume that  $\zeta \neq \gamma$  and  $ck = gw^*$ . If the degree of wage indexation can be limited above by  $(1 - \bar{\lambda})$ , expected social costs  $E(C)$  rise in  $1 - \bar{\lambda}$ .*

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<sup>9</sup>This seems a rather odd assumption, because the social welfare function should also regard the interest of the unemployed who have no advantage from real wage stability. But, note that in some countries social benefits to unemployed or retired people are coupled to wages. So, retired people may be interested in real wage stability while being indifferent to employment figures. Since retired people are an important fraction of all voters, their aims might be over-represented in the government's objective function and spill over to central bank objectives.

**Proof** see Appendix.

If the desired levels of employment and real wages are such that  $ck = gw^*$ , the inflation bias is zero independent of the degree of wage indexation. If, in addition, wage adjustments to productivity are suboptimal, expected social costs unambiguously rise with rising degree of indexation.<sup>10</sup> Reason is the hampering effect of indexation on the effectiveness of monetary policy in its effort to compensate the lack of wage adjustments. Here, a prohibition of indexation ( $\bar{\lambda} = 1$ ) is the second best solution even though this leads to a further reduction in wage adjustments to productivity.

Proposition 4 shows that there may be good reasons to interdict wage indexation although it may be desired by wage negotiators. Reason is a conflict in interests between contracting parties (insiders) on one hand and those who are excluded from negotiations (unemployed, outsiders) on the other hand. Without wage indexation, the central bank can correct the distribution of uncertainty that insiders impose on outsiders. The strength of this result comes from the fact that avoiding wage indexation is optimal whenever private and social weights for real wage stability do not coincide. There is no need to argue which one is larger. It is sufficient that two distinct groups of society have different preferences.

Following ROGOFF [1985] and WALSH [1995] it should be possible to design central bank contracts in such a way that monetary policy aims at minimizing costs of fluctuations without caring for the absolute levels of employment and real wages or to appoint a central banker whose preferences fulfill  $ck = gw^*$ . Central bankers usually claim to minimize the output gap which relates to target levels  $k = w^* = 0$ . In these cases there is no inflation bias to fear, indexation is irrelevant if wage adjustments to productivity are optimal, and if they are suboptimal we should abstain from wage indexation to prices. This describes a second best solution, and it is remarkable that the second best degree of indexation is zero instead of one in the optimum.

Proposition 4 is in sharp contrast to WALLER AND VANHOOSE [1992], who emphasized the positive external effect of wage indexation on the inflation bias. Our result demonstrates that wage indexation has a negative external effect on stabilizing the economy by state contingent monetary policy. In countries that are able to keep the inflation bias low without wage indexation, the negative external effect dominates. However, if a country is not able to control the inflation bias, the positive external effect may dominate and indexed wage contracts should be applied.

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<sup>10</sup>Note that this result is robust, as it does not depend on the specific objective of wage setters. It holds, whenever the chosen degree of wage adjustments to flexibility deviates from the social optimum.

## 5 Conclusion

Within the Barro–Gordon model the literature recognized two opposing effects of indexed wage contracts on inflation: a steeper Phillips curve reduces incentives to use inflationary policy, but lower costs of inflation reduce the resistance to inflation. The net effect appeared to be ambiguous. This paper provides a unified framework for studying both effects. Endogenizing social costs of real wage fluctuations, the paper has shown that indexed wage contracts do always reduce the inflation bias.

Welfare effects of indexation are ambiguous, though. While lowering the inflation bias improves welfare, indexed wage contracts reduce the ability of state contingent monetary policy to stabilize the real sector. This reduces welfare. Therefore, policy recommendations must consider the specific situation of a country. If wages respond with sufficient flexibility to changes in productivity, full indexation is socially optimal, because it reduces the inflation bias and insulates the real economy from demand shocks. In this case, there is no need to stabilize the real sector by monetary policy, which voids the negative welfare effect of indexed wage contracts.

Sufficient wage adjustments to productivity plus full wage indexation are always a first best solution. However, conflicting interests between wage setters and other parts of society and costs of implementing state contingent wage contracts are two important reasons, why wage adjustments to productivity may fall short of the social optimum. If wage adjustments to productivity are suboptimal, while the average rate of inflation can be kept low without indexed wage contracts and money demand is highly predictable, then the negative welfare effects of indexation dominate and wage indexation should be avoided.

Decentralized wage bargaining creates external effects of indexation: a positive effect on the inflation bias had been recognized by WALLER AND VANHOOSE [1992] before. In this paper, we have shown that wage indexation generates a negative externality on the ability to stabilize the real economy with monetary policy. Policy recommendations are case sensitive: If the inflation bias can be kept at low levels without indexation and money demand is predictable, a ban on wage indexation improves welfare.

The strongest opposition against the Barro–Gordon model comes from central bankers, who deny that central banks aim at achieving employment above expected levels. If central banks are only concerned with stabilizing prices and real fluctuations, the inflation bias is zero independent of wage indexation. The denial of employment goals has never been entirely convincing, but including real wages in the objective function, as we did in this paper, adds to the plausibility of a low bias: the majority of voters is interested in high employment *and* high wages. Both goals may spill over to monetary policy. However, desires to raise employment and real wages above their expected levels affect the inflation

bias in opposing directions and may offset each other, leaving us with a low bias despite (or more precisely *because of*) these targets.

We cannot and did not intend to answer the question whether central banks should care about real variables at all. But, to the extent that monetary policy has implications for employment and real wages, it can be used as a means for macroeconomic stability. With balanced aspiration levels of employment and real wages, there is no inflation bias to fear, and hence, no case against such macroeconomic stabilization within the logic of a Barro–Gordon model. Resulting price fluctuations are weighted against the beneficial stability of other variables. In order to minimize price fluctuations that are associated with an active monetary policy, wage contracts should not be indexed.

## Appendix

Using (9), (5), (6) and (10), we can express expected social costs as a function of  $\lambda$ ,  $\phi$  and  $q$ :

$$EC = \frac{1}{a^2 + b + g} \left[ \left[ ((c^2 + g)\lambda^2 + b) q^2 - 2\lambda (c^2 - \phi(c^2 + g)) q + (c^2(1 - \phi)^2 + g\phi^2) \right] \sigma_\theta^2 + k^2 + g(w^*)^2 + \frac{\lambda^2}{b} (ck - gw^*)^2 \right].$$

As  $q$  is the optimal stabilization term chosen by the central bank to optimize the welfare function, we have  $\partial EC / \partial q = 0$  (envelope theorem). For the other derivatives, we find

$$\frac{\partial EC}{\partial \lambda} = \frac{2}{a^2 + b + g} \left[ q \left[ \lambda(c^2 + g) q - c^2 + \phi(c^2 + g) \right] \sigma_\theta^2 + \frac{\lambda}{b} (ck - gw^*)^2 \right],$$

$$\frac{\partial EC}{\partial \phi} = \frac{2}{a^2 + b + g} \left[ \lambda(c^2 + g) q - c^2 + \phi(c^2 + g) \right] \sigma_\theta^2.$$

**Proof of Proposition 2** Using (11),  $\partial EC / \partial \phi = 0$  is equivalent to  $\phi = c^2 / (c^2 + g)$ . Then  $q = 0$ , and  $\partial EC / \partial \lambda = 0$  is equivalent to  $\lambda = 0$ . QED

**Proof of Proposition 3** Using (3), (4) and (16), the individually optimal real wage elasticities solve  $\min_{\lambda_i, \phi_i} f(\lambda_i, \phi_i)$ , where

$$f(\lambda_i, \phi_i) = \lambda_i^2 z \text{Var}(p) + 2 \lambda_i (1 - z \phi_i) \text{Cov}(p, \theta_i) + (z \phi_i - 2) \phi_i \text{Var}(\theta_i) \quad (18)$$

and  $z = 1 + \zeta(1 - a)^2$ . The first order conditions are

$$\begin{aligned} \frac{\partial f}{\partial \lambda} = 0 &\Leftrightarrow \phi_i = \frac{1}{z} + \frac{\text{Var}(p)}{\text{Cov}(p, \theta_i)} \lambda_i = \frac{1}{z} - q \lambda_i, \\ \frac{\partial f}{\partial \phi} = 0 &\Leftrightarrow \phi_i = \frac{1}{z} + \frac{\text{Cov}(p, \theta_i)}{\text{Var}(\theta_i)} \lambda_i = \frac{1}{z} - \frac{\sigma_\theta^2}{\sigma_\theta^2 + \sigma_i^2} q \lambda_i. \end{aligned} \quad (19)$$

As  $\sigma_i^2 > 0$ , they imply  $\phi_i = 1/z$  for all  $i$ . Note that  $q = 0 \Leftrightarrow \phi = \phi^*$  and  $\phi^* = 1/z \Leftrightarrow \gamma = \zeta$ . Hence, for  $\gamma = \zeta$  the degree of indexation is indetermined. If  $\gamma \neq \zeta$ , the only solution to the FOC's implies  $\lambda_i = 0$  for all  $i$ . QED

**Proof of Lemma 1** If  $\lambda = 1$ ,  $\phi$  is determined by equation (19). Using (11) and solving for  $\phi$  yields equation (17). QED

**Proof of Proposition 4** From (18) we get

$$\frac{\partial f}{\partial \lambda} = [\lambda_i z q^2 - (1 - z \phi_i) q] 2 \sigma_\theta^2.$$

If  $\zeta \neq \gamma$  and wage indexation is limited by  $(1 - \bar{\lambda}) < 1$ , wage contractors will nevertheless choose  $\phi_i$  according to (19). Using this,  $\partial f / \partial \lambda > 0$ , and wage contractors choose  $\lambda_i = \bar{\lambda}$ . As  $\phi$  is determined by (19), we get

$$\frac{\partial \phi}{\partial \bar{\lambda}} = \frac{-q \sigma_\theta^2}{\sigma_\theta^2 + \sigma_i^2}.$$

Using this, the total effect of  $\bar{\lambda}$  on welfare is given by

$$\frac{dEC}{d\lambda} = \frac{\partial EC}{\partial \lambda} + \frac{\partial EC}{\partial \phi} \frac{\partial \phi}{\partial \bar{\lambda}} = \frac{2}{a^2 + b + g} \left[ \lambda(c^2 + g)q - c^2 + \phi(c^2 + g) \right] q \frac{\sigma_\theta^2 \sigma_i^2}{\sigma_\theta^2 + \sigma_i^2}.$$

For  $\phi < \phi^*$  [ $\phi > \phi^*$ ],  $q$  is positive [negative] and

$$\begin{aligned} \frac{dEC}{d\lambda} < 0 &\Leftrightarrow \lambda(c^2 + g)q < [>] c^2 - \phi(c^2 + g) \\ &\Leftrightarrow \lambda^2(c^2 + g) \frac{c^2 - \phi(c^2 + g)}{\lambda^2(c^2 + g) + b} < [>] c^2 - \phi(c^2 + g) \\ &\Leftrightarrow 0 < [>] (c^2 - \phi(c^2 + g)) b \Leftrightarrow 0 < b. \end{aligned}$$

QED

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