MONETARY POLICY IN THE PRESENCE OF ASYMMETRIC WAGE INDEXATION

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Abstract: This paper studies monetary policy in the presence of asymmetric wage indexation. It is found that monetary authorities do not react to small output shocks and that their reaction to large shocks is asymmetric, insofar as they absorb positive shocks more than negative ones. As a consequence, asymmetric wage indexation skews the distribution of output to the left, and can therefore be contractionary. It has ambiguous effects on expected inflation, on the volatility of output and inflation, and on expected welfare, relative to an equivalent symmetric indexation. Optimal symmetric inflation however always outperforms optimal asymmetric indexation.

Key words: monetary policy, wage indexation.

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Abstract: This paper studies monetary policy in the presence of asymmetric wage indexation. It is found that monetary authorities do not react to small output shocks and that their reaction to large shocks is asymmetric, insofar as they absorb positive shocks more than negative ones. As a consequence, asymmetric wage indexation skews the distribution of output to the left, and can therefore be contractionary. It has ambiguous effects on expected inflation, on the volatility of output and inflation, and on expected welfare, relative to an equivalent symmetric indexation. Optimal symmetric inflation however always outperforms optimal asymmetric indexation.

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1. Introduction

The study of the reaction functions of central banks has attracted a lot of attention from both academics and practitioners over the recent years, leading to a flourishing literature that has accumulated fresh evidence. Among the fresher results stands the fact that monetary policy tends to be asymmetric. Namely, it is not adjusted in the same way in the presence of positive or adverse shocks. This observation initially made by Mishkin and Posen (1997) and Clarida and Gertler (1997) was later confirmed by Dolado et al. (2000). It thus appears that major central banks tend to react more aggressively when inflation exceeds its target level than when it is below it.

This finding is clearly at odds with most of the theoretical work on monetary policy, which, in the spirit of Barro and Gordon (1983), usually assumes that central banks with symmetric preferences face symmetric economies. To depart from the perfect symmetric world that is usually depicted in theoretical contributions, and provide a rationale for observed stylised facts, some authors explicitly introduced an asymmetry in the preferences of
monetary authorities. Thus, the recent papers by Dolado et al. (2000), Cukierman (2000), Jordan (2001), Cukierman and Gerlach (2003), Nobay and Peel (2003), or Gerlach (2003) all assume that the monetary authorities’ loss function is asymmetric. Namely, they assume that positive and negative deviations of economic variables from their target levels impact differently on the central banker’s utility.

Asymmetric preferences is however not the only asymmetry that may interfere with the conduct of monetary policy. In fact monetary authorities are confronted with many asymmetries, the most obvious of which being the economy itself. Thus, Cover (1992) observes that negative monetary growth shocks in the United States induce large contractions in real output growth whereas positive monetary shocks have only limited expansionary consequences. Kandil (1995, 1998, 2002) also repeatedly observed similar asymmetries in various samples of countries both developed and developing. This kind of asymmetry was subsequently incorporated in theoretical models by Bean (1997), Nobay and Peel (2000), and Dolado et al. (2005), thanks to the assumption of a non-linear Phillips curve. However, those contributions left the asymmetry in the Phillips curve unexplained.

A likely culprit for those non-linearities is wage indexation, since wages are typically indexed upward but not downward. Such an observation was for instance made by Card (1986) for North American wages. Moreover, Kandil (1995, 1998) observed asymmetric reactions of nominal wages to monetary shocks at the aggregate level. In a more recent paper Kandil (2002) studies the evolution of the United States’ performance in the light of the variations in the downward rigidity and upward flexibility of nominal wages. Those empirical observations were recently complemented by Cover and VanHoose (2002)’s contribution. These authors show that asymmetric wage indexation can be the result of a rational behaviour of the private sector. Namely, they show that the private sector can choose to index nominal wages upward but not downward.

In this paper, we concentrate on the consequences of asymmetric wage indexation for monetary policy. Our paper therefore bridges the gap between tow strands of the literature. The first one, mentioned above, studies the consequences of an asymmetric economy on monetary policy. The second one is devoted to the impact of wage indexation on monetary policy, and was pioneered by Ball and Cecchetti (1991), Vanhoose and Waller (1991, 1992), or Milesi-Ferretti (1994). That literature shows that wage indexation can be welfare enhancing because it cuts down the inflationary bias of monetary policy. Surprisingly it has only focused on symmetric wage indexation. Due to the policy implications of that strand of
research, it is important to check the robustness of its results in the light of a more realistic framework. This is the aim of the present paper.

We find that the assumption of asymmetric wage indexation, although it leads to greater analytical complexity, significantly modifies the results of the literature. More precisely, we observe that the monetary authorities do not react to all output shocks, and most of all that they adopt an asymmetric monetary policy rule. Accordingly, they tend to absorb expansionary shocks more than contractionary ones, which is in line with the stylised fact underlined above. That behaviour can moreover cause the expected level of income to fall short of its natural level.

We also find that asymmetric wage indexation lowers expected inflation with respect to a situation with no indexation, which is a standard result of the literature. However, we observe that its impact on average inflation relative to an equivalent symmetric indexation is ambiguous. Similarly, asymmetric wage indexation increases the volatility of output and decreases the volatility of inflation with respect to a situation without inflation, but the comparison of output and inflation volatility with an equivalent symmetric indexation leads to mixed results. Furthermore, we find that it has an ambiguous effect on expected welfare relative to both an equivalent symmetric wage indexation and a situation without indexation. However, when the optimal degree of indexation is used, asymmetric indexation is always outperformed by symmetric indexation.

To reach those conclusions, the paper is organized as follows: the next section presents the simple set-up on which our reasoning rests. The following section describes the monetary authorities’ behaviour. Section 4 closes the model and compares the outcome of monetary policy in the presence of asymmetric wage indexation with the outcomes of monetary policy in the presence of symmetric wage indexation or no indexation. Section 5 concludes.

2. The set-up

To describe the supply side of our model, we suppose that output is a downward-sloping schedule of the real wage. When all variables are expressed in logs, the supply function reads:

\[ y_t = -\left(\tilde{w}_t - \tilde{p}_t\right) + u_t \]  

Where \( y_t \) is output, \( \tilde{w}_t \) the nominal wage, \( \tilde{p}_t \) the price level. \( u_t \) is a real shock, the magnitude of which is unknown to workers when they sign their wage contracts. \( u_t \) is i.i.d.
and has a zero mean and a well defined variance $\sigma^2$. Expression (1) implicitly assumes that the natural level of output is zero.

The nominal wage is supposed to follow a modified Gray (1976) indexation rule. Namely, and following Cover and VanHoose (2002), we assume that wages are indexed upward but not downward. Therefore, the indexation rule reads:

$$w_i = p_i^e + \delta(p_i - p_i^e)$$

where $0 < \delta \leq 1$ if $p_i > p_i^e$, and $\delta = 0$ if $p_i \leq p_i^e$.

$\delta$ is the indexation parameter and $p_i^e$ the rationally expected price level. When the observed price level exceeds the expected price level, the nominal wage is therefore a weighted average of current and expected price levels. It is fully indexed when $\delta = 1$. On the other hand, when the expected price level overshoots the observed price level, the nominal wage remains fixed. In other words, we assume that the nominal wage is automatically adjusted upward but is sticky downward.\(^1\)

When (2) is plugged into (1), the supply function is transformed into an expectations-augmented short-run aggregate supply curve:

$$y_i = (1 - \delta)(\pi_i - \pi_i^e) + u_i$$

where $\pi_i = p_i - p_{i-1}$ and $\pi_i^e = p_i^e - p_{i-1}$ are period $i$'s current and rationally expected inflation. Expression (3) shows that the slope of the trade-off between income and unexpected inflation is a decreasing function of the indexation parameter $\delta$ whenever current inflation exceeds expected inflation. However, the slope of the supply curve is strictly greater when current inflation does not exceed or is equal to its expected level, as wages are not indexed downward. This means that the supply curve is kinked, which will have dramatic consequences on the behaviour of the monetary authority, as we will see below.\(^2\)

To model the demand side, we simply assume that the inflation rate is set directly by a monetary authority whose loss function is similar to Barro and Gordon (1983)'s:

$$l_t = \frac{\theta}{2} \pi_t^2 + \frac{1}{2}(y_t - \bar{y})^2$$

\(\bar{y}\) is the target level of output, which can be greater than its natural level due, for instance, to distortions on the labour market. $\theta$ measures the relative weight the authorities place on inflation stabilization versus output stabilization.

\(^1\) This is clearly a simplification. Our results would nevertheless remain qualitatively unchanged if we assumed instead that wages are less indexed downward than upward.

\(^2\) One may note that this specification nests the usual symmetric specification, which is obtained when $\delta = 0$. 
To complete the description of our model, we must specify the timing of events. It is depicted in figure 1 below.

***Insert figure 1 here***

We accordingly assume that workers sign their wage contracts at the beginning of period $t$. The value of the real shock $u_t$ is then revealed. The authorities subsequently set the inflation rate accordingly. Finally, production takes place.

3. The authorities’ reaction function

When monetary policy is discretionary and players move sequentially, the only time consistent policy can be determined by backward induction. As the private sector plays first, we must therefore determine the authorities' reaction function for a given nominal wage.

When the authorities set the inflation rate, they have already observed the nominal wage, and the supply shock. Accordingly, they minimize the value of their loss function (4) subject to supply function (3) for a given level of $\pi^e$ and $u_t$. Taking the first order condition, we can determine an expression of the authorities' reaction function when the inflation rate exceeds its expected value:

$$\pi_t = \frac{(1-\delta)^2 \pi^e + (1-\delta)\bar{y} - (1-\delta)u_t}{\theta + (1-\delta)^2} \quad \text{if } \pi_t > \pi^e$$ \hfill (5a)

One can immediately get an expression of the reaction function of the authorities when the price level is smaller than or equal to the expected inflation rate by setting $\delta = 0$ in (5a). One consequently gets:

$$\pi_t = \frac{\pi^e + \bar{y} - u_t}{\theta + 1} \quad \text{if } \pi_t \leq \pi^e$$ \hfill (5b)

Of course, expressions (5a) and (5b) do not provide a complete description of the behaviour of the authorities. We must indeed determine under which circumstances they will implement an inflation rate that is higher or lower than expected. In other words, we must determine the magnitude of the shock that will lead the authorities to set $\pi_t > \pi^e$ or $\pi_t < \pi^e$. To

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3 As all periods are ex ante identical and expected inflation is therefore equal across periods, $\pi^e$ is not indexed anymore for notational convenience.
do so, we substitute $\pi_t$ by its value in (5a) and solve the resulting inequality for $u_t$. It then appears that the authorities will choose $\pi_t > \pi^e$ if (and only if) $u_t$ is strictly smaller than a trigger value $u$ such that:

$$u = \bar{y} - \frac{\theta}{1-\delta} \pi^e$$  \hspace{1cm} (6a)

By the same token, and using expression (5b), we find that the authorities set $\pi_t < \pi^e$ if and only if $u_t$ is strictly larger than a trigger value $\bar{u}$ such that:

$$\bar{u} = \bar{y} - \theta \pi^e$$  \hspace{1cm} (6b)

We assume that the parameters of the model are such that they result in a positive expected inflation. Since we assume that $\delta$ is smaller than one, it is clear that $\bar{u} \geq u$. Therefore, if the reaction of the authorities is well defined for shocks smaller than $u$ or greater than $\bar{u}$, we do not know yet what it may be in between. However, we demonstrate in appendix A1 that their best response whenever $u_t \in [u; \bar{u}]$ is to set an inflation rate that is equal to the expected inflation rate.

We can now give a precise definition of the reaction function of the authorities. It reads:

$$\pi_t = \begin{cases} 
\left(1-\delta\right)^2 \pi^e + \left(1-\delta\right)\bar{y} - \left(1-\delta\right)u_t & \text{if } u_t < u \\
\pi^e & \text{if } u \leq u_t \leq \bar{u} \\
\pi^e + \bar{y} - u_t & \text{if } u_t > \bar{u} 
\end{cases}$$  \hspace{1cm} (7)

From this expression of the reaction function, we can reach our first two propositions:

Proposition 1: The authorities do not accommodate shocks belonging to interval $[u; \bar{u}]$.

Proof: From (7) it is clear that whenever $u_t \in [u; \bar{u}]$, there is no unexpected inflation and the authorities therefore do not absorb the supply shock, which proves proposition 1.

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4 Note that $\pi_t > \pi^e$ is equivalent to $p_t > p^e$.
5 It is in fact possible that expected inflation turns out negative as, as we will see below, the authorities tend to react more to positive output shocks that to negative ones. For realism’s sake, we rule out that configuration.
6 This reaction function may be reminiscent of the discrete reaction functions assumed in escape clause models, such as Flood and Isard (1989) or Lohmann (1990). However, unlike in those models, the authorities’ discrete response is fully endogenous in our analysis.
Proposition 2: The authorities accommodate large expansionary supply shocks more than large contractionary supply shocks.

Proof: By plugging the relevant part of (7) in (3), one obtains the actual value of output for a given expected inflation rate when the authorities behave according to their reaction function. It amounts to

\[ y_t = \frac{-\theta(1-\delta)\pi^e + (1-\delta)^2 \bar{y}}{\theta + (1-\delta)^2} + \frac{\theta}{\theta + (1-\delta)^2} u_t \text{ whenever } u_t < \bar{u} \]

and to

\[ y_t = \frac{-\theta \pi^e + \bar{y}}{\theta + 1} + \frac{\theta}{\theta + 1} u_t \text{ whenever } u_t > \bar{u} \]

The coefficient on \( u_t \) indicates the elasticity of output to the initial shock. As \( \delta \) is positive and smaller than one, it appears that the absolute elasticity of output to shock \( u_t \) is greater when the shock is smaller than \( \bar{u} \) than when it is greater than \( \bar{u} \), which proves proposition (2).


The intuitive explanations of proposition 1 and 2 are easily grasped by looking at figure 2 below.

***insert figure 2 here***

Figure 2 features five different kinked supply functions for a given level of expected inflation \( \pi^e \) and five different values of the supply shock \( u_t \), such that \( u_t > \bar{u} \), \( u_t = \bar{u} \), \( u_t = 0 \), \( u_t = \bar{u} \) and \( u_t < \bar{u} \).\(^7\) The indifference curves corresponding to each equilibrium are also represented. They are turned towards the authorities’ bliss point \( B \) whose abscissa is zero and ordinate \( \bar{y} \), which are respectively their target levels of inflation and output.

Whenever the shock is positive and large, i.e. whenever \( u_t > \bar{u} \), the authorities’ optimal response is to accommodate the shock by implementing an inflation rate that lies below the expected one. That situation corresponds to point \( E_1 \) in figure 2. By the same token, if the output shock is very contractionary, i.e. \( u_t < \bar{u} \), the authorities will create unexpected inflation to boost output, as one can see at point \( E_5 \).

\(^7\) For the sake of clarity, we assume in figure 2 that \( \bar{u} < \theta < \bar{\bar{u}} \), which not necessarily the case.
If the shock is of limited magnitude, i.e. \( u \leq u_t \leq \bar{u} \), we obtain corner solutions, since the supply curve is kinked. Therefore the authorities do not find it optimal to react to the shock, which means that they set \( \pi_t = \pi^e \) and thereby validate the private sector’s expectations. In other words they choose the monetary policy that corresponds to the kink in the supply function. This is for instance the case at point \( E_3 \). As a consequence, the observed level of output is simply equal to the value of the shock, since the natural level of output is normalized to zero.

The trigger values of the output shock can easily be observed graphically. They correspond to the values of the supply shock for which the slope of the authorities’ indifference curve is equal to the slope of the lower (respectively upper) part of the corresponding supply function exactly on its kink, as shown at points \( E_2 \) and \( E_4 \). It takes a larger shock to move the supply function beyond those trigger points and drive the optimal inflation rate above or below its expected level, as at point \( E_1 \) and \( E_5 \), which is the substance of proposition 1. The results of the simulations run in the next section show that interval \([u; \bar{u}]\) can be quite large, which implies that asymmetric wage inflation could be an important source of passivity of the monetary policy.

Figure 2 also helps capturing the intuition of our second proposition. The abscissa of point \( Q_5 \) shows the level of output that would have been obtained if the central bank had refrained from accommodating a shock that would have driven the supply curve to \( S_5 \). The difference between the abscissas of point \( Q_5 \) and \( E_5 \) (\( \Delta y_5 \)) therefore represents the stabilization achieved by monetary policy. By the same token, the difference between the abscissas of point \( E_1 \) and point \( Q_1 \) (\( \Delta y_1 \)) measures the stabilization achieved by monetary policy in the presence of a positive shock of similar magnitude that would have driven the supply curve to \( S_1 \). It is readily observed that stabilization is greater for the positive shock than for the negative one (\( \Delta y_1 > \Delta y_5 \)), which corresponds to our second proposition.

This result stems from the fact that the authorities determine the inflation rate by comparing the marginal loss incurred by increased inflation to the marginal benefit from bringing output closer to its target level. As wages are indexed upward but not downward, the marginal benefit of manipulating inflation is smaller for negative output shocks, that require to inflate more than expected and face wage indexation, than for positive output shocks that require to inflate less than expected. Therefore the incentive to manipulate inflation is smaller for negative shocks than for positive shocks. The former are consequently less accommodated than the latter.
The results we have obtained so far do not necessitate determining expected inflation. However, determining expected inflation is a necessary step to complete the description of the outcome of monetary policy in our model. We turn to that step in the next section.

4. Expectations, volatility, and welfare

When private agents form their expectations about the inflation rate, they do not know the magnitude of the inflation rate. They therefore ignore whether the authorities will manipulate inflation and how. They must consequently base their wages on the expected value of the inflation rate, which depends in turn on the inflation rate they have expected. Accordingly, the private sector rationally expects the inflation rate that solves the following equation:

\[ \pi^e = E(\pi_t) \] (8)

Solving equation (8) requires specifying the distribution of \( u_t \). In the rest of the paper, we assume therefore that it is normally distributed around zero. Equation (8) can therefore be rewritten as:

\[
\pi^e = \int_{-\infty}^{\infty} f(\pi_t | u_t) du \\
= \int_{-\infty}^{0} f(\pi_t | u_t < u) du + \int_{0}^{\infty} f(\pi_t | u_t < u) du + \int_{-\infty}^{\infty} f(\pi_t | u_t > u) du
\] (9)

where \( f = \frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{u^2}{2\sigma^2}} \) is the normal density function.

Unfortunately, that equation is quite messy and has no simple solution. In the rest of this paper, we therefore resort to simulations to solve it. Once it is solved, its solution can be plugged in the expressions of the chosen inflation rate, the trigger shocks, output, and losses. It can also be used to compute expected output and losses, as well as the probability that shock \( u_t \) be in interval \([u;\bar{u}]\). For conciseness sake, the expressions of those variables are reported in appendix (A2).

***Insert table 1a and 1b here***
Table 1a and 1b report the results of our simulations for a realistic range of the parameters. Table 1a exhibits the expected values of the inflation rate and of output, the values of the trigger shocks, and the probabilities that the shock belongs to each of the three intervals that those trigger shocks define. It also displays the inflation rates that would be expected if wage indexation was symmetric, that is denoted $\pi^e_{\text{sym}}$, and with no indexation, that is designated by $\pi^e_{\text{noindex}}$. It is noteworthy that expected output in the presence of symmetric indexation, or in the absence of indexation, is always equal to the natural level of output, which is zero in our set-up. It is therefore not reported in table 1a.

Although the results displayed in table 1a rest on a simulation and cannot therefore be generalized, an important finding that is summarized in our next result is worth underlining.

Simulation result 1: Asymmetric wage indexation can cause the mean output level to lie below the natural level.

That striking feature of our simulations is obtained by reading the sixth column of table 1a. The intuition of this result rests on proposition 2. As the authorities absorb positive shocks more than negative ones, output lies on average below its natural level. Such a result was already obtained by Bean (1997), Nobay and Peel (2000), and Dolado et al. (2005). It has strong empirical implications as it underlines the necessity to distinguish the natural and the average levels of output.

The rationale for that result may be grasped more easily by looking at figure 3 that sketches the authorities’ reaction function and the relationship between output and the output shock, the former being drawn in the upper quadrant. The relationships obtained for an asymmetric indexation are complemented by those obtained under an equivalent symmetric indexation, and without indexation. In the case of the symmetric indexation and the zero indexation, both the inflation rate and the output level are linear functions of the output shock. In both cases inflation decreases while output increases with the output shock. The difference between the two situations is that inflation is less responsive to the output shock when wages are indexed than when they are not, while the reverse is true for output. One may therefore say that wage indexation transfers volatility from inflation to output. This transfer of volatility is the result of the lower responsiveness of monetary policy to output shocks in the presence

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8 The inflation rates are given by $\pi^e_{\text{sym}} = \frac{1-\delta}{\theta} \bar{\pi}$ and $\pi^e_{\text{noindex}} = \frac{1}{\theta} \bar{\pi}$ respectively.
of wage indexation.

***insert figure 3 here***

The striking feature of figure 3 is that asymmetric indexation results in a non-linear relationship between output shocks and both inflation and output. One may thus observe that over interval \([\underline{\mu};\bar{u}]\), the inflation rate is constant and equal to the expected rate. The output shock is therefore directly transferred to output, which is why the relationship between \(y_t\) and \(u_t\) follows the forty-five degree line over that interval. When the output shock exceeds \(\bar{\pi}\), inflation is lower than expected and wages are not indexed. This is why the asymmetric reaction function is then parallel to the one that would prevail without indexation, and so does output.

When the output gap is smaller than \(\underline{\mu}\), inflation exceeds its expected level, and wages are indexed. The authorities’ reaction therefore parallels the one they would have had in the presence of a symmetric indexation schedule and is thus less aggressive than without indexation. Output is therefore more adversely affected.

What figure 3 makes clear is that in the presence of asymmetric indexation, a negative shock has a greater absolute impact on output than a positive shock of the same magnitude. If shocks are distributed symmetrically around zero, then expected output is bound to be negative.

A slightly more careful inspection of table 1a reveals a second set of noteworthy findings that are summarized in results 2a and 2b.

Simulation result 2a: Asymmetric wage indexation can reduce the inflationary bias relative to a situation without indexation.

Simulation result 2b: Asymmetric wage indexation has an ambiguous effect on the inflationary bias relative to an equivalent symmetric indexation.
Estimation result 2a is obtained by comparing columns (5) and (14) of table 1a. It appears that the inflationary bias, alternatively expected inflation, is systematically lower in the presence of asymmetric wage indexation than in the presence of no indexation at all. This finding is in line with the common view of the consequences of wage indexation on monetary policy, which can for instance be traced back to Devereux (1987). It results from the fact that wage indexation lowers the perceived benefits from unexpected inflation because it reduces its impact on the real wage and output. The temptation to inflate is therefore cut down accordingly.

Estimation result 2b is more innovative. It is obtained by comparing columns (5) and (13) of table 1. One thus observes that expected inflation is greater under asymmetric indexation than under symmetric indexation in most lines, but the inequality is reversed in lines (7) and (12), where the output gap is small relative to the variance of shocks. It underlines that there is more to asymmetric indexation than a simple combination of symmetric indexation and no indexation. To grasp the rationale behind that proposition, one must bear in mind that we are dealing with a stochastic model and that wage indexation interacts with both the deterministic component of the inflation rate and its stochastic component. Namely it reduces the inflationary bias but also modifies the way in which the authorities adjust the inflation rate so as to absorb output shocks, and does so in an asymmetric way.

By contrast, when indexation is symmetric, it cuts down the inflationary bias but has a symmetric impact on the reaction of the authorities to output shocks. In other words, it not only reduces the incentives to engineer unexpected inflation but also unexpected disinflation, when shocks are very expansionary. On average, both effects cancel out.

When indexation is asymmetric however, it also cuts down the inflationary bias but only reduces the incentive to create unexpected inflation, and leaves intact the incentive to create unexpected disinflation. That asymmetry in the reaction of the authorities to output shocks may further reduce the average inflation rate, which explains why expected inflation may be smaller than in the presence of symmetric wage inflation, as in lines (7) and (12).

An additional effect must nonetheless also be taken into account. Asymmetric wage indexation creates an interval where the authorities do not absorb shocks. Table 1a moreover shows that this interval can be quite large and tends to be centred on a positive value of output shocks. Therefore asymmetric wage indexation causes the monetary authority to validate wage setters’ expectations where it would otherwise have engineered unexpected disinflation.
For some of the shocks belonging to interval $[\mu;\pi]$, which happens with probability of up to 81.1% in our simulations, inflation is therefore higher than what it would have been in the presence of symmetric wage indexation. For some values of the parameters, this effect can compensate the authorities’ asymmetric reaction to shocks, which results in a greater average inflation rate, as in all lines but 7 and 12. This line of reasoning explains why asymmetric indexation may raise the inflationary bias, as simulation result 2b underlines.

The impact of asymmetric indexation on the levels of inflation and output should however be weighed in light of its impact on their volatilities, which is the focus of our next two propositions, which are derived from columns 18 to 23 of table 1b.

Simulation result 3a: Asymmetric wage indexation can raise the volatility of output and decrease the volatility of inflation relative to a situation without indexation.

Simulation result 3b: Asymmetric wage indexation can increase or decrease the volatilities of output and inflation relative to an equivalent symmetric indexation.

The intuition of result 3a is standard and has already been underlined in the literature on symmetric indexation. Indeed, as indexation cuts down the marginal benefit of unexpected inflation, it results in a less aggressive monetary policy. The authorities accordingly tend to absorb a lower portion of output shocks, which results in lower inflation volatility but greater output volatility.

The rationale result 3b stems from the fact that asymmetric wage indexation only reduces the incentive to absorb large negative output shocks but leaves unchanged the incentive to absorb large positive output shocks, as proposition 2 underlines. Monetary policy over interval $[\mu;+\infty]$ is therefore more aggressive when wage indexation is asymmetric than when it is symmetric. However, monetary policy is at the same time fully passive over interval $[\mu;\mu]$ when wage indexation is asymmetric, as proposition 1 stresses, while it would have remained active with an equivalent symmetric indexation. Depending on the value of parameters and therefore of both trigger shocks, the volatilities of inflation and output may consequently be greater or lower in the presence of asymmetric indexation than in the presence of symmetric inflation.
One may now wonder what the previous results imply for the welfare effects of wage indexation. Table 1b provides some insights on that issue, which are described in the following simulation results:

Simulation result 4a: Asymmetric wage indexation can increase or decrease expected welfare relative to a situation without indexation.

Simulation result 4b: Asymmetric wage indexation can increase or decrease expected welfare relative to an equivalent symmetric indexation.

The finding described by result 4a is obtained by comparing column 15 and column 17 of table 1b. It is in line with the standard results of the literature. The positive impact of wage indexing stems from its capacity to cut down the inflationary bias. This effect is for instance at the core of Devereux (1987)’s analysis. On the negative side, wage indexing increases the volatility of output, as shown in columns 21, 22, and 23. This results in the traditional trade-off between the inflationary bias and the volatility of output that is investigated by Milesi-Ferretti (1994) among others. Depending on the volatility of output shocks and the inflationary bias, indexation may increase or decrease welfare, be it symmetric or not. It thus appears that no indexation dominates asymmetric indexation when the variance of output shocks is large relative to the output gap, namely in lines (7) and (12).

Result 4b, which pertains to the comparison between asymmetric wage indexation and an equivalent symmetric wage indexation, is somewhat subtler than result 3a. It is obtained by comparing column 15 and column 16 of table 1b. Its rationale rests on three differences between the effects of symmetric and asymmetric wage indexation. First, their impacts on expected inflation differ, as result 2b underlines. Second, their effects on the variance of output differ although their ranking is ambiguous, as result 3b shows. Third, unlike symmetric indexation, asymmetric indexation results in an expected output that is lower than the natural level of output. Depending on the magnitude of those three effects, either type of indexation may dominate the other. In our simulations, we observe that asymmetric inflation dominates when the volatility of output is large relative to the output gap, like on lines (7) and (12). However, asymmetric wage indexation is also found to outperform symmetric wage indexation on line (6) of table 1b.
In a symmetric model, our comments would be limited to considerations on the value of expected inflation and output and on their variances, but asymmetric wage indexation also affects the third moment of the distribution of those variables, as columns (24) and (25) of table 1b show. This remark takes us to our fifth simulation result.

Simulation result 5: Asymmetric wage indexation skews the distribution of inflation and output to the left.

The intuition for that result has to be found in the asymmetry of the authorities’ reaction function. They accordingly tend to absorb positive shocks more than negative ones. This implies that they are keener on creating surprise disinflation than surprise inflation. Output and inflation are therefore more likely to assume values that are lower rather than greater than their means, hence the skewness of their distributions.

This result is new in the literature. With symmetric models, equilibrium levels of output and inflation are linear functions of a shock that is normally distributed. Their distribution is therefore also normal, which implies that it is symmetric, i.e. with a skewness of zero. What is striking here, is that the shock is normally distributed but results in distributions of output and inflation that are not normal but skewed. This result may influence the empirical investigation of the reaction function of central banks. Besides, it hinges on the impact of wage indexation on welfare. In the next section, we investigate the way in which the optimal value of the degree of wage indexation is affected.

5. Optimal wage indexation

In this section we use our model to determine the value of the indexation parameter that minimizes the authorities’ expected losses. As before, we have to resort to simulations to do so. For all the sets of parameter values displayed in table 1, we simply compute expected losses for increasing values of \( \delta \) ranging from zero to one. We subsequently isolate the value of \( \delta \) that leads to the smallest expected losses and accordingly approximate optimal wage indexation. The results of our computations are displayed in table 2 below.10

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9 As the skewness of the distributions of output and inflation with either a symmetric indexation or no indexation is necessarily zero, it is not reported in table 1b.
10 The expression of the optimal symmetric degree of wage indexation is reported in appendix A3. It is for instance derived in Milesi-Ferretti (1994).
Table 2 allows a description of the relationship between the optimal level of indexation and the parameters. The main findings are consistent with those pertaining to the optimal degree of symmetric wage indexation. Thus, lines (1), and (4) to (6) show that optimal asymmetric indexation drops as the authorities’ relative aversion for inflation rises. This result stems from the fact that, as the authority becomes more concerned about inflation, its inflationary bias diminishes. The marginal benefit of reducing that bias by raising indexation therefore decreases.

By the same token, one can see that optimal asymmetric inflation increases when the output gap increases. This result appears by comparing lines (1) and (7) to (9). It is again a consequence of the positive impact of the output gap on the inflationary bias. As the output gap increases, the inflationary bias increases, which raises the marginal benefit of raising wage indexation.

Finally, lines (1) and (10) to (12) reveal that optimal asymmetric indexation decreases as the variance of the output shock increases. This result must be understood through the impact of wage indexation on the marginal benefit of stabilizing output. As output becomes more volatile, the marginal benefit of an active monetary policy increases. However, wage indexation makes monetary policy less aggressive. The marginal cost of raising wage indexation therefore increases with the variance of the output shock, which leads to a lower indexation. This finding, together with the two previous ones are summarized in simulation result 6 below:

Simulation result 6: The optimal degree of asymmetric wage indexation is an increasing function of the output gap, and a decreasing function of the variance of the output shock and of the authorities’ relative aversion for inflation.

Table 2 moreover allows comparisons between optimal asymmetric indexation and optimal symmetric indexation. It appears that for most values of the parameters, the optimal degree of symmetric wage indexation takes on corner solution values. Namely, it is equal to one when the output gap is large with respect to the variance of the output shock and equal to
zero when it is small with respect to the variance of the output shock. On the contrary, it
appears that the optimal degree of asymmetric indexation never hits its upper bound for the
parameter values that we use, although it may get very close to those bounds.

Most of all, table 2 allows to compare the level of welfare achieved under an optimal
asymmetric indexation with that obtained under an optimal symmetric indexation. This takes
us to our final result.

Simulation result 7: Optimal asymmetric wage indexation is outperformed by or equivalent to
optimal symmetric wage indexation in terms of welfare.

This observation can be made by comparing columns (9) and (17) of table 2 that
exhibit the minimal level of losses that can be achieved by choosing the adequate degree of
wage indexation for the different sets of wage indexation under consideration. The result is
unambiguous, as expected losses reported in column (9) are always greater than those
reported in column (17). The authority is therefore systematically better off with an optimal
symmetric indexation than with an optimal asymmetric indexation for the same set of
parameters.

An intuitive rationale for that result rests on the fact that the design of the optimal
degree of asymmetric wage indexation has to take into account one more variable than the
design of optimal symmetric wage indexation. Namely, whereas symmetric indexation
determines the volatility of output, the volatility of inflation, and the average level of
inflation, it always leaves average output equal to its natural level. On the contrary,
asymmetric wage indexation not only impacts the first three variables but also the expected
level of income, which is always smaller than its natural level when asymmetric wage
inflation is different from zero.

One may thus notice that optimal asymmetric wage indexation results in a greater
variance and expected level of inflation and a lower variance of output than optimal
symmetric wage indexation when full symmetric indexation is optimal. This can be seen by
comparing columns (7) and (15) and (8) and (16) in lines (1) to (6) and (8) to (10) of table 2,
where the output gap is high relative to the variance of output shocks. However, further
inspection of those lines shows that the expected log of output is negative. True, under those
circumstances, the marginal cost of increasing output volatility might be outweighed by the
marginal benefit of reducing the expected level and the volatility of inflation, but one must also take into account the resulting increase in the marginal cost of widening the gap between the average and natural levels of output. It is therefore not surprising that optimal asymmetric wage indexation remains incomplete when full asymmetric wage indexation is optimal.

On the other hand, when no indexation is optimal, the same result can be achieved with both a symmetric and an asymmetric indexation scheme by setting either $\delta$ or $\delta_{sym}$ equal to zero. Under those circumstances, (no) asymmetric indexation achieves the same level of expected losses as (no) symmetric indexation.

6. Concluding remarks

In this paper, we studied the consequences of asymmetric wage indexation for monetary policy in a framework à la Barro and Gordon (1983). We observed that marginal modification of their framework provides unexpected modifications of the usual findings of the literature. Namely, we found that the reaction of monetary authorities to output shocks becomes asymmetric and non-linear, leading to an expected level of output that is below its natural level. We also found that if asymmetric wage indexation clearly cuts down inflation with respect to a situation without indexation, it has an ambiguous impact on inflation when it is compared with an equivalent symmetric wage indexation. A similar finding was obtained for the volatilities of output and inflation. Namely, whereas asymmetric wage indexation clearly raises the volatility of output and reduces the volatility of inflation with respect to a situation without indexation, the ranking of its impact relative to an equivalent symmetric indexation is ambiguous. Another interesting feature of asymmetric indexation is that it skews the distribution of output and inflation, whereas neither symmetric indexation nor no indexation at all do.

In terms of welfare, we observed that asymmetric wage indexation could be superior or inferior to an equivalent symmetric wage indexation or the absence thereof. However, when the optimal degree of asymmetric indexation is compared with the optimal degree of symmetric indexation that would result from the same parameter values, asymmetric indexation is unambiguously dominated.

A synthetic theoretical implication of our findings is that making our models slightly more realistic can significantly alter the results that are usually considered standard in the

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11 In fact, when symmetric indexation is total, both the expected level and the variance of inflation amount to
literature. Our results’ main policy implication is that wage indexation is subtler a policy instrument and that its effects are more pervasive than what is usually contended in the literature. Owing to the complexity of our calculations, we had to resort to numerical simulations and cannot unfortunately be more specific as to the critical values of the parameters. Our results accordingly deserve closer examination. They should also be extended to related issues, like inflation targeting, which paves the way for future research. They. However, in the mean time, they remain, to say the least, intriguing.

Appendix

A1 Monetary policy when \( u_i \in [u; \bar{u}] \)

In this appendix, we show that the optimal monetary policy when \( u_i \in [u; \bar{u}] \) consists in validating the private sector’s expectations. Our line of reasoning is organized in two steps. We firstly show that it is not optimal for the authorities to implement an inflation rate that exceeds expected inflation. We then show that it is not optimal to implement an inflation rate that is lower than expected inflation.

Let us assume that the authorities implement an inflation rate that exceeds expected inflation. Under those circumstances, wages are indexed and the supply function is given by (3). To determine the optimal inflation rate, we plug (3) in (4) and differentiate. We thus get the following expression:

\[
\frac{\partial I}{\partial \pi_i} \bigg|_{\delta \in [\delta, 1]} = (1 - \delta)(\pi_i - \pi^*) + (1 - \delta)(\bar{y} - u_i) + \theta \pi_i
\]  

(A1)

As we assume that the inflation rate that the authorities implement is greater than the expected inflation rate, it is clear that the first member of expression (A1) is positive. It can easily be shown that the remaining part of that expression is also positive. Thus, as we assume that \( u_i \in [u; \bar{u}] \), we know from (6a) that \( u_i > \bar{y} - \frac{\theta}{1 - \delta} \pi^* \). This is equivalent to:

\[
(1 - \delta)(u_i - \bar{y}) > -\theta \pi^*
\]  

(A2)

By adding \( \theta \pi^* \) to both sides of the above inequality and factorising, one finds:

\[
(1 - \delta)(u_i - \bar{y}) + \theta \pi_i > \theta(\pi_i - \pi^*) > 0
\]  

(A3)

zero.
As we assume that $\pi_t > \pi^e$, expression (A3), that is equal to the second part of expression (A1), is clearly positive, meaning that the authorities’ losses are increasing in $\pi_t$. The authorities’ optimal solution is consequently a corner solution and they set $\pi_t = \pi^e$.

By the same token, we can show that the authorities will not set an inflation rate that is lower than expected. Under those circumstances, wages are not indexed and the supply function is given by (3) with $\delta = 0$. To determine the optimal inflation rate, we plug (3) in (4) and differentiate. We thus get the following expression:

$$\frac{\partial I}{\partial \pi_t} = \pi_t - \pi^e_t - \bar{y} + u_t + \theta \pi_t, \quad (A4)$$

As we assume that the inflation rate that the authorities implement is smaller than the expected inflation rate, it is clear that the first member of expression (A4) is negative. It can easily be shown that the second member of that expression is also negative. Thus, as we assume that $u_t \in [\underline{u}; \bar{u}]$, we know from (6a) that $u_t < \bar{y} - \theta \pi^e$, which is equivalent to:

$$u_t - \bar{y} < -\theta \pi^e_t \quad (A5)$$

By adding $\theta \pi_t$ to both sides of the above inequality and factorising, one finds:

$$u_t - \bar{y} + \theta \pi_t < \theta (\pi_t - \pi^e_t) < 0 \quad (A6)$$

As we assume that $\pi_t < \pi^e$, expression (A6) shows that the second member of expression (A4) is clearly negative, meaning that the authorities’ losses are decreasing in $\pi_t$. The authorities’ optimal solution is consequently a corner solution and they set $\pi_t = \pi^e$.

Consequently, whenever $u_t \in [\underline{u}; \bar{u}]$, the authorities’ optimal policy is to implement the inflation rate that was expected by the private sector. They consequently do not accommodate the supply shock.

**A2 Probabilities and expectations**

As $u_t$ follows a normal distribution, the conditional probabilities on $u_t$ can be written as:

$$\text{prob}(u_t < \underline{u}) = \int_{-\infty}^{\underline{u}} fdu \quad \quad \text{prob}(\underline{u} < u_t < \bar{u}) = \int_{\underline{u}}^{\bar{u}} fdu \quad \quad \text{prob}(u_t > \bar{u}) = \int_{\bar{u}}^{\infty} fdu$$

(A7a) (A7b) (A7c)

where $f = \frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{u^2}{2\sigma^2}}$ is the normal density function.
By the same token, the expected value of any variable is obtained by the following formula:

\[
E(x) = \int_{-\infty}^{\infty} f(x, |u, < u|)du + \int_{u}^{\infty} f(x, |u < u, < \bar{u}|)du + \int_{\bar{u}}^{\infty} f(x, |u, > \bar{u}|)du
\]

(A8)

**A3 Optimal symmetric indexation**

The optimal level of symmetric wage indexation is given by the following formula:

\[
\delta = 0 \quad \text{iff} \quad Q \geq 1
\]

\[
\delta = 1 - Q^{\frac{1}{2}} \quad \text{iff} \quad 0 < Q < 1
\]

\[
\delta = 1 \quad \text{iff} \quad Q \leq 0
\]

(A9)

where \( Q = \theta \left( \frac{\sigma}{y} - 1 \right) \).
References


Cukierman, A., 2000. ‘The inflation bias result revisited’, *Manuscript, Tel-Aviv University*.


Figure 1
Time sequence of events

Contracts $w_t$
Shock $u_t$
Monetary Policy $\pi_t$
Production $y_t$

Period $t$

Time
Figure 2
The authorities’ response to shocks
Figure 3

The authorities’ reaction function and the relationship between output and the output shock

\[ \pi_t = \pi(u_t, 0) \]

\[ \pi^e \]

\[ \pi(u_t, \delta) \]

\[ u \]

\[ y_t \]

\[ y_t = u_t \]

\[ y(u_t, \delta) \]

\[ y(u_t, 0) \]
Table 1a
Simulation results: expected income and inflation

<table>
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<tr>
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<th>Symmetry</th>
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Table 1b
Simulation results: expected losses and higher moments of inflation and output

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*: Simulations (2) and (3) are not reported because they are the same as simulation (1).


N°10.RS Michele Cincera « The link between firms’ R&D by type of activity and source of funding and the decision to patent », April 2005.


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<td>Inter-industry Wage Differentials and the Gender Wage Gap: Evidence from European Countries</td>
<td>Brenda Gannon, Robert Plasman, Ilan Tojerow, and François Rycx</td>
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</table>
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