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Abstract: Wage indexation practices have changed. Evidence on the U.S. for instance suggests that wages were heavily indexed to past inflation during the Great Inflation but not during the Great Moderation. However, most DSGE models assume fixed indexation parameters in wage setting, which might not be structural in the sense of Lucas (1976). This paper presents a New-Keynesian model in which workers, by maximizing their welfare, set their wage indexation rule in response to aggregate shocks and monetary policy. We find that workers index their wages to past inflation when technology and permanent inflation-target shocks drive output fluctuations; when aggregate demand shocks do, workers index to trend-inflation. In addition, workers' choices do not coincide with the social planner's choice, which may explain the observed changes in wage indexation in the post-WWII U.S. data.
Keywords: Wage indexation, Welfare costs, Nominal rigidities.
JEL Classification: E24, E32, E58.

Resumen: La indexación salarial ha cambiado. Por ejemplo, los datos sugieren que en los Estados Unidos los salarios estaban fuertemente indexados a la inflación rezagada durante la Gran Inflación pero no durante la Gran Moderación. Sin embargo, la mayoría de los modelos DSGE suponen parámetros de indexación salarial constantes, los cuales pueden ser no estructurales en el sentido de Lucas (1976). El presente artículo presenta un modelo Nuevo-Keynesiano en donde los trabajadores escogen, maximizando su bienestar, su regla de indexación salarial en respuesta a choques agregados y a la política monetaria. Encontramos que los trabajadores indexan su salario a la inflación rezagada cuando choques permanentes en tecnología y en la inflación objetivo explican las fluctuaciones en el producto; cuando son los choques de demanda agregada quienes explican estas fluctuaciones, los trabajadores indexan a la inflación de largo plazo (tendencia). Además, notamos que las decisiones de los trabajadores no coinciden con la decisión de un planeador social benévolo, lo cual puede explicar los cambios observados en la indexación salarial de los Estados Unidos desde la segunda guerra mundial.
Palabras Clave: Indexación salarial, Costos de bienestar, Rigideces nominales.

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1 Introduction

There are strong indications that price and wage inflation persistence have changed over time. Concerning prices, Cogley, Primiceri and Sargent (2010) show that inflation gap inertia has decreased in the U.S. since the post-Volcker era, which they attribute to an improved stability of the Fed's long-run inflation target.[1] For wages, Hofmann, Peersman and Straub (2012) find that wage inflation was more persistent in the U.S. during the 1970s' *Great Inflation* - a period known for important supply-side shocks and loose monetary policy - than the *Great Moderation* (mid-1980s to 2007). Using a New-Keynesian model, these authors link the strong wage inertia with a high degree of past-inflation indexation in nominal wages. Interestingly, their findings echo the path of the COLA index, which measured the proportion of union labor contracts that included cost-of-living adjustment clauses (COLAs).[2] This index was considered as a proxy for the degree of wage indexation to past inflation in the U.S. economy. As shown in Figure (1), the index peaks in the mid-70s and it monotonically falls in the 90s.

Despite the aforementioned evidence, most New-Keynesian models assume constant and exogenous indexation coefficients in price and wage setting. We question this assumption as the presumed intrinsic persistence might not be structural in the sense of Lucas (1976).[3] In this paper we focus on wages and we ask which macroeconomic factors influence the indexation choices of workers. To answer this question, we build a stylized dynamic, stochastic general equilibrium (DSGE) model with wage rigidities in which workers select their preferred indexation rule in response to the specific *economic regime* they face. We define an economic regime as an environment with particular market structures, stochastic shock distributions, and Central Bank policy rules.[4] Given a regime, a worker chooses her welfare-maximizing indexation rule. It follows that in our framework workers decisions are micro-founded.

Our setup contains key ingredients of state-of-the-art New-Keynesian models.[5] The new

[1]Similarly, Benati (2008) analyzes inflation persistence across different monetary regimes and finds that inflation is less persistent in economies with a clear and stable nominal anchor.

[2]Note that the COLA index measured wage indexation in major union agreements involving 1000 or more workers, representing less than 20% of the U.S. labor force (Devine, 1996). However, Holland (1988) finds that nonunion and economy wide wage inflation react similarly to price level shocks as the COLA index does. The index was discontinued in 1995.

[3]See Benati (2008).

[4]Although we include government spending, we omit any active role for public debt or any fiscal rule.

[5]We include nominal rigidities in price and wage setting, optimizing households and firms, a public sector with a balanced budget, and a Central Bank that sets the nominal interest rate and the inflation target.

feature is that, in periods in which wages are re-optimised, workers select an indexation rule among two different types: one based on past inflation, and the other one based on the inflation target of the Central Bank (i.e. trend inflation, which may vary). Workers then choose the rule associated with the highest expected utility, given the average length of the labor contract and the regime's economic characteristics. Similar to Schmitt-Grohé and Uribe (2007), we solve the non-linear model to compute the welfare criterion of workers. The sum of all workers' decisions determines the degree at which nominal wages are indexed to past inflation on average. We name this level the degree of **aggregate indexation** in the economy. We implement an algorithm that computes the equilibrium level for aggregate indexation, given the economic regime.

We have three main results. First, we find that workers prefer to index their wages to past inflation when permanent shocks to technology and the inflation target explain an important proportion of output fluctuations. In contrast, when aggregate spending shocks dominate, workers prefer to index to target-inflation. Thus, aggregate indexation is high in regimes with large technology and/or permanent inflation-target shocks, and it is low in regimes driven by aggregate-demand shocks and/or temporal inflation-target shocks. The intuition behind these results is straightforward. Nominal wage rigidities cause welfare losses because the labor supply of each worker is sticky and it cannot adapt optimally to current economic events. Wage indexation rules may moderate welfare costs by closing the gap between the desired and actual labor supply. Thus, an indexation rule is preferred if it closes the labor-supply gap faster. As it turns out, the optimal individual rule is the one associated with a more stable expected labor supply. This is the case because workers are risk averse in leisure, and thus prefer a labor contract that guarantees smaller variations in their expected hours worked.

Second, we show that, in general, a social planner would prefer a different aggregate indexation level than the one reached by the decentralized equilibrium. In particular, the social planner would choose target-inflation indexation in regimes driven by technology and permanent inflation-target shocks, while she would choose past-inflation indexation in regimes driven by aggregate-demand shocks. The social planner's solutions, which are in line with the seminal contributions of Gray (1976) and Fischer (1977), thus oppose the ones picked by workers alone. The two solutions differ because the social planner pools all workers and focus on average welfare losses given aggregate indexation. In contrast, workers care about marginal changes in their utility implied by labor contracts with different indexation rules. In addition, we assume that a worker does not internalize the effect that her own indexation choice imposes on the aggregate, as her size is negligible in comparison with the whole. In consequence, workers choices lead to an inefficient decentralized equilibrium.

Finally, we perform a set of counterfactual exercises in which we calibrate the model to represent two recent regimes of the U.S. economy. The first calibration portrays the *Great Inflation*, with volatile shocks - especially in productivity - and drifting trend inflation (as argued by Cogley and Sargent, 2005; Cogley and Sbordone, 2008; Coibion and Gorodnichenko, 2011, among others). The other calibration mimics the *Great Moderation*, with low shock volatility and a stable inflation target. We find that the decentralized equilibrium can predict the degree of aggregate indexation well for both economic regimes, as suggested by the COLA index: a high level for the *Great Inflation* and a low level for the *Great Moderation*. In addition, our sensitivity analysis indicates that the high levels predicted for the 70s were mainly due to *bad luck*, i.e. due to very volatile supply-side shocks, and not *bad policy*, i.e. not due to a loose inflation policy. Our analysis suggests that changes in the monetary policy rule or the stability of the inflation target played a minor role in the determination of aggregate indexation for the two periods.

The seminal contributions of Gray (1976) and Fischer (1977) set the benchmark in the wage indexation literature. Using an aggregate loss function criterion, they find that the optimal aggregate indexation increases when supply-side shocks become more important in explaining output fluctuations (relative to nominal or demand-side shocks). More recent papers find similar conclusions.[6] In contrast, our results rely on the analysis of the welfare of individual workers, and thus on their individual decisions, rather than on an average welfare measure. Our findings do not conflict with Gray and Fischer results as long as we focus on the social planner's problem. However, we show that, at the margin, a worker has incentives to deviate from the social planner's solution, and since all workers act similarly, the decentralized equilibrium ends up in a coordination failure. We argue that the decentralised equilibrium better explains the presumed changes in aggregate indexation and wage dynamics in U.S. data. A paper closely related to ours is Minford, Nowell and Webb (2003), who also focus on

[6] Cho and Phaneuf (1993), Cho (2003), and Amano *et al.* (2007) find similar results using DSGE models and a social welfare criterion. Several other extensions in this tradition have been considered, although most of them do not use a model with fully optimising agents (see Cover and van Hoose, 2002; Calmfors and Johansson, 2006, for a brief revisions of the literature).

the individual decisions of workers. However, they emphasize the effects of the persistence of shocks on aggregate indexation and they do not compare their results with the social welfare outcome. Our results are thus complementary.[7]

The remainder of the paper is organized as follows. Section 2 presents the model. Section 3 characterizes the equilibrium aggregate indexation of the economy given different economic regimes. Section 4 performs counterfactual exercises with the *Great Inflation vs. Great Moderation* comparison and a sensitivity analysis. The final section concludes.

2 The model

We build our analysis on a standard New Keynesian model with nominal rigidities in both prices and wages, and no capital. The model economy is populated by a continuum of households and firms, with differentiated labor and goods supply, respectively. A competitive labor intermediary and a final good producer then aggregate these differentiated inputs and place them on their respective markets. The following presents the main ingredients of the model.[8]

2.1 Households

Households are indexed by $i \in [0, 1]$. Each one is endowed with a unique labor type, $\ell_{i,t}$, which allows them to set their own nominal wage, $W_{i,t}$ by using their monopolistic power. A household chooses consumption, $c_{i,t}$, one-period-maturity bond holdings, $b_{i,t}$, and $W_{i,t}$ to maximize their discounted lifetime utility, i.e.

$$\max_{c_{i,T}, b_{i,T}, W_{i,T}} \mathrm{E}_t \left(\sum_{T=t}^{\infty} \beta^{T-t}\, \mathcal{U}\left(c_{i,T}, \ell_{i,T}\right) \right), \tag{1}$$

subject to a sequence of budget constraints of the form

$$c_{i,T} + \frac{b_{i,T}}{R_T} \leq \frac{W_{i,T}}{P_T}\ell_{i,T} + \frac{b_{i,T-1}}{1+\pi_T} + \frac{\Upsilon_{i,T}}{P_T} \qquad \forall T = t, t+1, t+2, ... \tag{2}$$

a labor-specific demand, and *no Ponzi* schemes. The term E_t denotes the expectation operator conditional on information available in period t; in turn, R_t denotes the risk free

[7] Wieland (2009) analyses the indexation decisions of firms in a model with learning, and proposes similar indexation rules as us. However, Wieland does not use an objective-maximizing criterion for choosing the indexation rule, but rather a forecasting rule for the true process of inflation.

[8] The full description of the model is laid out in the technical appendix, available upon request.

gross nominal interest rate, P_t is the aggregate price level, $\pi_t \equiv P_t/P_{t-1} - 1$ is the inflation rate, and $\Upsilon_{i,t}$ is a lump sum including net transfers, profits from monopolistic firms, and Arrow-Debreu state-contingent securities that ensures that households start each period with an equal wealth. The instantaneous utility function is given by

$$\mathcal{U}\left(c_{i,t}, \ell_{i,t}\right) = \log\left(c_{i,t} - \gamma^h c_{i,t-1}\right) - \psi \frac{\ell_{i,t}^{1+\omega}}{1+\omega}.$$

The parameters γ^h and ω denote the degree of consumption habits and the inverse Frisch elasticity of labor supply, respectively. In turn, ψ is a normalizing constant that ensures that labor equals $\frac{1}{3}$ at the deterministic steady-state. A household is composed of two decision-making units: a consumer, who chooses consumption and savings, and a worker, who decides on a labor contract consisting of a nominal wage and an indexation rule. The decision rules for the consumer are standard and we omit them for brevity (see the technical appendix for details).

Labor contracts. We follow Calvo (1983) and assume that in each period a worker re-optimizes his labor contract with probability $1 - \alpha_w$. The optimization happens in two stages. In the first, a worker chooses the indexation scheme that dictates how his nominal wage must be updated in periods where no optimization takes place. In the second, a worker sets his optimal wage conditional on the chosen indexation rule. In both stages, workers maximize their expected utility. For simplicity, we allow for only two indexation rules for wage updating: one uses the target inflation of the central bank (i.e., *trend*), and the other uses lagged inflation (i.e., *past*). Suppose that the last wage re-optimization of worker i happened in period t, where he selected the wage $W_{i,t}^{k,\star}$ for either contract $k = trend$, or contract $k = past$. Thus, in period $T > t$, worker i's wage is updated either to $W_{i,T}^{trend} = \delta_{t,T}^{trend} W_{i,t}^{trend,\star}$ or $W_{i,T}^{past} = \delta_{t,T}^{past} W_{i,t}^{past,\star}$, where

$$\delta_{t,T}^{trend} = \left(1 + \pi_T^\star\right) \delta_{t,T-1}^{trend} \text{ and } \delta_{t,T}^{past} = \left(1 + \pi_{T-1}\right) \delta_{t,T-1}^{past} \text{ with } \delta_{t,t}^{k} = 1 \; \forall k.$$

The term $\pi_T^\star$ represents the time T inflation target of the central bank, which determines trend inflation. For simplicity, we assume that this target is directly observed by the population. Each of the indexation rules allows the worker to smooth adjustments in his labor supply, which otherwise will be fixed due to nominal wage rigidities.

Wage setting. For the sake of exposition, we first describe the choice of the optimal wage conditional on $\delta_{t,T}^k$. We start with this problem because it takes the familiar setting of a sticky-wage model *à la* Erceg *et al.* (2000). Thus, given a δ^k, a worker selects his wage by solving

$$W_{i,t}^{k,\star} \in \arg\max_{W_{i,t}^k} \quad \mathrm{E}_t \left(\sum_{T=t}^{\infty} (\beta\alpha_w)^{T-t} \left[\lambda_T \frac{\delta_{t,T}^k W_{i,t}^k}{P_T} \ell_{i,t,T}^k - \frac{\psi}{1+\omega} \left(\ell_{i,t,T}^k \right)^{1+\omega} \right] \right), \tag{3}$$

subject to the labor-specific demand

$$\ell_{i,t,T}^k = \left(\frac{\delta_{t,T}^k W_{i,t}^k}{W_T} \right)^{-\theta_w} \ell_T. \tag{4}$$

The term λ_t is the marginal utility of wealth associated to the household budget constraint, ℓ_t is aggregate labor, and the coefficient θ_w denotes the elasticity of substitution between any two labor types, as implied by a Dixit-Stiglitz aggregator used by the labor intermediary. Notice that, since we have assumed no inequalities in wealth (due to the Arrow-Debreu securities), λ_t is common to all households. In contrast, a worker's labor mapping, $\ell_{i,t,T}^k$, may differ from one worker to another due to nominal wage rigidities. Let $rw_t^{k,\star} \equiv \frac{W_t^{k,\star}}{W_t}$ denote the relative optimal wage with respect to the aggregate wage level. Thus, according to the F.O.C. of the worker's problem, $rw_t^{k,\star}$ is given by

$$\left[rw_t^{k,\star} \right]^{1+\omega\theta_w} = \psi\mu_w \frac{\mathrm{num}_{k,t}^{\mathrm{w}}}{\mathrm{den}_{k,t}^{\mathrm{w}}}, \tag{5}$$

where $\mu_w \equiv \frac{\theta_w}{\theta_w - 1}$ is the gross wage markup and

$$\begin{aligned}
\mathrm{num}_{k,t}^{\mathrm{w}} &\equiv (\ell_t)^{1+\omega} + \beta\alpha_w \mathrm{E}_t \left(\left(\frac{1+\pi_{t+1}^w}{\delta_{t,t+1}^k} \right)^{\theta_w(1+\omega)} \mathrm{num}_{k,t+1}^{\mathrm{w}} \right), \\
\mathrm{den}_{k,t}^{\mathrm{w}} &\equiv \lambda_t w_t \ell_t + \beta\alpha_w \mathrm{E}_t \left(\left(\frac{1+\pi_{t+1}^w}{\delta_{t,t+1}^k} \right)^{\theta_w - 1} \mathrm{den}_{k,t+1}^{\mathrm{w}} \right),
\end{aligned}$$

and $\pi_{t+1}^w \equiv \frac{W_{t+1}}{W_t} - 1$ is the wage inflation rate. We drop the subindex i since workers with indexation rule k who can re-optimize in period t will choose the same wage. Notice that in the case of fully flexible wages, wage dispersion vanishes along with the differences in individual labor supplies (so $rw_t^{k,\star} = 1$). In that case, equation (5) collapses to the familiar welfare-maximizing condition in which the marginal rate of substitution between consumption and leisure equals the real wage (re-scaled by a wage markup), i.e.

$$\psi \frac{(\ell_t)^\omega}{\lambda_t} = w_t \times \frac{1}{\mu_w}. \tag{6}$$

Nominal wage rigidities impose welfare losses to workers because they cannot adapt their labor supply quickly or optimally when shocks hit the economy. Thus, after a shock, there is a wedge between a worker's desired labor supply, given by equation (6), and her actual labor supply, given by equation (5). An indexation rule may aid in closing this wedge and moderate welfare losses. Workers thus prefer the rule associated with the lowest welfare loss. But the optimal rule is conditional on the economic regime, as we show next.

Indexation-rule selection. Let ξ_t denote the time t total proportion of workers who have selected past-inflation indexation, independently of their last contract optimization. In short, ξ_t represents the degree of **aggregate indexation** to past inflation in time t. Furthermore, let Σ_t be an information set describing the economy's markets structure, the distribution of stochastic shocks, and the economic policy rules, i.e. the *economic regime* in period t. Finally, let the vector Ξ collect present and future levels for aggregate indexation and economic regimes, so $\Xi_t = \mathrm{E}_t\left(\left\{\left[\xi_{t+h},\ \Sigma_{t+h}\right]'\right\}_{h=0}^{\infty}\right)$. We can now formalize workers indexation-rule decision as follows: When worker i re-optimizes her labor contract in time t, she selects the rule that maximizes her conditional expected utility, i.e.

$$\delta_{i,t}^{\star}\left(\Xi_t\right) \in \underset{\delta_i \in \left\{\delta^{trend}, \delta^{past}\right\}}{\arg\max}\ \mathbb{W}_{i,t}\left(\delta_i, \Xi_t\right) \text{ subject to } \wp\left(\Xi_t\right), \tag{7}$$

where

$$\mathbb{W}_{i,t}\left(\delta_i, \Xi_t\right) = \mathrm{E}_t\left(\sum_{T=t}^{\infty}\left(\beta\alpha_w\right)^{T-t}\ \mathcal{U}\left(c_T\left(\xi_T, \Sigma_T\right),\ \ell_{i,T}\left(\delta_i, \xi_T, \Sigma_T\right)\right)\right). \tag{8}$$

The term $\wp\left(\Xi_t\right)$ is a system of equations that summarizes all relevant general-equilibrium constraints that determine the allocation of the economy. Notice that $\mathbb{W}_{i,t}$ is constrained by the expected duration of the labor contract (as the effective discount factor is $\beta\alpha_w$). Further, because of the state-contingent securities, individual consumption equals the aggregate level, and it does not depend on the individual indexation choice δ_i; it does, however, depend on aggregate indexation ξ_t and the current economic regime Σ_t. Finally, notice that, given worker i's atomistic size with respect to the aggregate, her choice of indexation-rule has a negligible effect on aggregate indexation. Worker i thus takes ξ_t, Σ_t, and c_t as given and she selects the indexation rule δ_i that minimizes her individual expected labor disutility, given by $\Omega\left(\delta_i, \Xi_t\right)$. In formal terms, $\delta_{i,t}^{\star}\left(\Xi_t\right)$ also satisfies the problem

$$\delta_{i,t}^{\star}\left(\Xi_t\right) \in \underset{\delta_i \in \left\{\delta^{trend}, \delta^{past}\right\}}{\arg\min}\ \Omega\left(\delta_i, \Xi_t\right),\ \text{subject to } \wp\left(\Xi_t\right),$$

where

$$\Omega\left(\delta_i, \Xi_t\right) = \frac{\psi}{1+\omega} \mathrm{E}_t \left(\sum_{T=t}^{\infty} \left(\beta \alpha_w\right)^{T-t} \left[\ell_{i,T}\left(\delta_i, \xi_T, \Sigma_T\right)\right]^{1+\omega} \right). \tag{9}$$

Labor market aggregation. The degree of aggregate indexation ξ_t is determined as follows: each period, only a fraction $1-\alpha_w$ of workers re-optimize their wages. Let χ_t denote the time t proportion of workers from subset $(1-\alpha_w)$ that selects δ^{past}. Accordingly, ξ_t is given by

$$\xi_t = (1-\alpha_w) \sum_{h=0}^{\infty} \chi_{t-h} \left(\alpha_w\right)^h, \tag{10}$$

which recursively can be written as $\xi_t = (1-\alpha_w)\chi_t + \alpha_w \xi_{t-1}$. In section 3 we characterize the equilibrium solution for aggregate wage indexation $\xi^\star$, which is a function of the economic regime Σ. But first we describe useful measures of wage dispersion and discuss aggregation details of the labor market.

Without loss of generality, assume that workers are sorted according to the indexation rule they have chosen, so workers in the interval $i \in I_t^{past} = [0, \xi_t]$ use δ^{past}, while those in the interval $i \in I_t^{trend} = [\xi_t, 1]$ use δ^{trend}. Measures of wage dispersion for each of the two sectors can be computed by adding up total hours worked as given by the set of labor-specific demands. So, we have that $\int_{i \in I_t^k} \ell_{i,t} \mathrm{d}i = \ell_t \mathrm{disp}_{k,t}^{\mathrm{w}}$, where $\mathrm{disp}_{k,t}^{\mathrm{w}} = \int_{i \in I_t^k} \left(\frac{W_{i,t}}{W_t}\right)^{-\theta_w} \mathrm{d}i$. Recursive expressions for the wage dispersion measures are given by

$$\mathrm{disp}_{k,t}^{\mathrm{w}} = (1-\alpha_w)\tilde{\chi}_t^k \left(rw_t^{k,\star}\right)^{-\theta_w} + \alpha_w \left(\frac{1+\pi_t^w}{\delta_{t-1,t}^k}\right)^{\theta_w} \mathrm{disp}_{k,t-1}^{\mathrm{w}}, \tag{11}$$

$$\text{where } \tilde{\chi}_t^k = \begin{cases} \chi_t & \text{if } k = past \\ 1-\chi_t & \text{if } k = trend \end{cases}. \tag{12}$$

Finally, given the Dixit-Stiglitz technology of the labor intermediary, the aggregate wage level is given by $W_t^{1-\theta_w} = \int_0^1 W_{i,t}^{1-\theta_w} \mathrm{d}i$. This expression can be rewritten in terms of the sum of relative wages within each indexation-rule sector, which are given by $\tilde{w}_t^k \equiv \int_{i \in I_t^k} \left(\frac{W_{i,t}}{W_t}\right)^{1-\theta_w} \mathrm{d}i$. Thus, it follows that

$$\tilde{w}_t^{past} + \tilde{w}_t^{trend} = 1.$$

Notice that these weights may change over time due to variations in rw_t^k and χ_t. The recursive law of motion of $\tilde{w}_t^k$ is given by

$$\tilde{w}_t^k = (1-\alpha_w)\tilde{\chi}_t^k \left[rw_t^{k,\star}\right]^{1-\theta_{w,t}} + \alpha_w \left(\frac{1+\pi_t^w}{\delta_{t-1,t}^k}\right)^{\theta_w - 1} \tilde{w}_{t-1}^k. \tag{13}$$

The rest of the model is quite standard, so we describe it briefly.

2.2 Firms and price-setting

A perfectly competitive firm produces a homogeneous good, y_t, by combining a continuum of intermediate goods, $y_{j,t}$ for $j \in [0,1]$, using a typical Dixit-Stiglitz aggregator. Each intermediate good is produced by a single monopolistic firm using the linear technology

$$y_{j,t} = A \exp(z_t) n_{j,t},$$

where $n_{j,t}$ is the composite labor input, A is a normalizing constant that ensures that detrended output at the deterministic steady state equals one, and z_t is a permanent technology shock which obeys

$$z_t = z_{t-1} + \varepsilon_{z,t}, \tag{14}$$

where $\varepsilon_{z,t}$ is a zero-mean white noise. Each period an intermediate firm re-optimizes its price with a fixed probability $1-\alpha_p$. If the firm is unable to re-optimize in period T, then its price is updated according to a rule-of-thumb of the form $P_{j,T} = \delta^p_{t,T} P_{j,t}$, where $t < T$ denotes the period of last reoptimization, and $\delta^p_{t,T} = (1+\pi^*_T)^{1-\gamma_p} (1+\pi_{t-1})^{\gamma_p} \delta_{t,T-1}$ for $T > t$ and $\delta^p_{t,t} = 1$.[9] The firm sets $P_{j,t}$ by maximizing its profits, so

$$P^\star_{j,t} \in \arg\max_{P_{j,t}} \hat{\mathrm{E}}_t \sum_{T=t}^{\infty} (\beta\alpha_p)^{T-t} \varphi_{t,T} \left[\frac{\delta^p_{t,T} P_{j,t}}{P_T} y_{j,t,T} - S(y_{j,t,T}) \right],$$

$$\text{subject to } y_{j,t,T} = \left(\frac{\delta^p_{t,T} P_{j,t}}{P_T} \right)^{-\theta_p} y_T,$$

where the real cost function is given by $S(y_{j,t}) = w_t [y_{j,t}/ (A \exp(z_t))]$, and $\theta_p > 1$ is the price elasticity of demand for intermediate good j.

2.3 Policymakers

The government budget constraint is balanced at all times (i.e. lump-sum taxes finance government expenditures). Public spending is given by

$$g_t = g \exp(\varepsilon_{g,t}) y_t \tag{15}$$

where $0 < g \exp(\varepsilon_{g,t}) < 1$ is the public-spending-to-GDP ratio and $\varepsilon_{g,t}$ is a stochastic disturbance with mean zero, and follows an AR(1) process:

$$\varepsilon_{g,t} = \rho_g \varepsilon_{g,t} + \eta_{g,t}.$$

[9] We could have assumed that firms also endogenously select their price indexation rule. However, we decided to keep the model as simple and tractable as possible to analyze the determination and implications of wage indexation alone. Endogenous price indexation is a subject left for future research.

Similar to Smets and Wouters (2007) and Hofmann *et al.* (2012), we assume that the central bank chooses the gross nominal interest rate according to the rule

$$R_t = [R_{t-1}]^{\rho_R} [R_t^\star]^{1-\rho_R} \left[\frac{1+\pi_t}{1+\pi_t^\star}\right]^{a_\pi(1-\rho_R)} [y_t]^{a_y(1-\rho_R)} \left[\frac{y_t}{y_{t-1}}\right]^{a_{\Delta y}} \tag{16}$$

where $R_t^\star = \beta^{-1}\left(1+\pi_{t+1}^\star\right)$ denotes the long-term level of the nominal interest rate. This rule has shown good empirical properties and we use it in our counterfactual exercises of section 4. The inflation target follows a rule of the form

$$\pi_{t+1}^\star = \rho_\pi \pi_t^\star + \varepsilon_{\pi,t+1}.$$

Unless explicitly mentioned, we assume $\rho_\pi = 1$, making the inflation-target shocks permanent.

2.4 Equilibrium, model solution, and calibration

Equilibrium in the goods market satisfies the resource constraint, so $y_t = c_t + g_t$, where $c_t \equiv \int_0^1 c_{i,t} di$. In the labor market, the supplied composite labor-input equals the aggregate intermediate-firms labor demand, or $\ell_t = \int_0^1 n_{j,t} \mathrm{d}j$. Using the input-specific demand, it follows that $\ell_t = y_t A^{-1} \exp(-z_t) \operatorname{disp}_t^{\mathrm{p}}$ where $\operatorname{disp}_t^{\mathrm{p}} = \int_0^1 \left(\frac{P_{j,t}}{P_t}\right)^{-\theta_p} \mathrm{d}j$ is a measure of price dispersion. In equilibrium, there exists a set of prices $\{\lambda_t, P_t, P_{j,t}, W_t, W_{i,t}, R_t\}$ and a set of quantities $\{y_t, g_t, c_{i,t}, b_{i,t}, n_{j,t}, \ell_t, \ell_{i,t}, \chi_t\}$, for all i and j, such that all markets clear at all times, and agents maximize their utility and profits. It is worth mentioning that, when ξ_t is given and equals an exogenous constant in the interval $[0,1]$, the model is observationally equivalent to a standard New Keynesian model with fixed indexation coefficients.[10]

Given an economic regime Σ, we use a second-order perturbation method to solve the model and find the stochastic steady state, as proposed by Schmitt-Grohé and Uribe (2007). We use this method because we are interested on the welfare effects of different indexation schemes.[11] Then, given an economic regime we implement an algorithm to find the equilibrium level for aggregate indexation.

For the analysis that follows, we calibrate the model to fit the estimation of Hofmann *et al.* (2012) for the *Great Moderation* period.[12] Before estimation, the authors fix the discount rate β to 0.99; the Frisch elasticity ω equals 2; θ_p and θ_w are both set to 10. Further,

[10]See the technical appendix for the demonstration.

[11]Such effects vanish in the linear version of the model (see Kim and Kim, 2003; Schmitt-Grohé and Uribe, 2007).

[12]See their estimation for the first quarter of the year 2000.

we assume that the level of initial trend inflation is $\pi_0^\star = 0$, the public-spending ratio g is .2., and the parameters A and ψ are set at levels which put output and labor equal to 1 and $\frac{1}{3}$, respectively, in the deterministic steady state. Using a minimum distance estimation to fit the impulses responses of a permanent technology shock and a government spending shock, Hofmann *et al.* (2012) estimate the degree of external habits ($\gamma^h = .37$), inflation inertia ($\gamma^p = .17$), the degree of rigidities in prices and wages ($\alpha_p = .76$ and $\alpha_w = .54$), the monetary rule parameters ($\rho_R = .78,\ a_\pi = 1.35,\ a_y = .10$ and $a_{\Delta y} = .39$), and the size of the technology and the government spending shock ($\sigma_z = .31$ and $\sigma_g = 3.25$). Finally, the authors find a degree of wage indexation equal to $\xi = .17$. In section 4, we show that the endogenous indexation criterion we have hereby described predicts an indexation value in accordance to the estimated value. All of the parameter estimates lie within the ballpark of empirical findings (see Smets and Wouters, 2007; Cogley, Primiceri and Sargent, 2010). Finally, for completeness, we set the variance of the trend-inflation shock equal to the estimated value of Cogley *et al.* (2010) for the period 1982-2006 ($\sigma_{\pi^\star} = .049$).

3 Equilibrium aggregate indexation

This section characterizes the aggregate indexation level that prevails in the long-run equilibrium given an economic regime. We show that workers choose to index their wages to past inflation when technology and (permanent) trend-inflation shocks explain a large proportion of output fluctuations. When demand-side shocks (such as exogenous government spending) drive the aggregate dynamics, workers prefer to index to trend inflation. We show how the relationship between wage dispersion and the volatility in expected hours explains our results. In addition, we argue that the equilibrium indexation need not coincide with the socially desired level.

3.1 Welfare costs at the stochastic steady state

At the steady state, worker i's expected welfare equals its unconditional expected value, given by $\mathbb{W}_{ss}\left(\delta^k, \xi, \Sigma\right) \equiv \mathrm{E}\left\{\mathbb{W}_{i,t}\left(\delta^k, \xi,\ \Sigma\right)\right\}$ (see equation 8). Notice that, in general, $\mathbb{W}_{ss}$ varies with the chosen indexation rule δ^k, aggregate indexation ξ, and the economic regime Σ. However, if the economic regime contains no stochastic shocks, then consumption and labor (and thus welfare) will be invariant to ξ and δ^k. Denote this scenario as the deterministic regime Σ_d, and its associated steady-state welfare as $\mathbb{W}_d$, defined as:

$$\mathbb{W}_d = \frac{1}{1-\beta\alpha_w}\mathcal{U}\left(c_d, \ell_d\right).$$

Our calibration implies that $c_d = 0.8$ and $\ell_d = \frac{1}{3}$. It is common in the literature to measure the welfare costs from stochastic regimes in terms of proportional losses in deterministic steady-state consumption (see Schmitt-Grohé and Uribe, 2007). But one could also measure these costs using leisure, as we do next. Let λ^k for $k \in \{past, trend\}$ denote the required percentage change in ℓ_d that makes a household with indexation rule δ^k indifferent between the deterministic regime and the stochastic one. Formally, given a δ^k, ξ and Σ, the term λ^k is implicitly defined by

$$\mathbb{W}_{ss}\left(\delta^k, \xi, \Sigma\right) = \frac{1}{1-\beta\alpha_w}\mathcal{U}\left(c_d, \ell_d\left(1+\lambda^k\right)\right).$$

In words, λ^k measures the increase in *deterministic* labor that leaves a worker indifferent between the *deterministic* scenario and the *stochastic* one. For the utility function we have assumed, it is straightforward to show that

$$\lambda^k = \left[\frac{\mathbb{W}_{ss} \times (1-\beta\alpha_w) - \log\left(c_d\left(1-\gamma^h\right)\right)}{\mathbb{W}_d \times (1-\beta\alpha_w) - \log\left(c_d\left(1-\gamma^h\right)\right)}\right]^{\frac{1}{1+\omega}} - 1.$$

3.2 Aggregate indexation in the decentralized equilibrium

Assume that at time t the economy is at its stochastic steady state and that worker i is drawn to re-optimize. According to the indexation-rule selection criterion of page 7, worker i prefers the indexation rule associated with the lowest λ^k. The equilibrium degree of aggregate indexation, denoted by $\xi^\star$, is then obtained according to equation (10). Notice that at the stochastic steady state, it should be the case that $\xi_t = \chi_t = \xi^\star$.

There are two types of solutions for the aggregate equilibrium level $\xi^\star$. The corner solution $\xi^\star = 0$ is achieved when, for any $\xi \in [0, 1]$, the trend-inflation indexation rule yields the lowest welfare costs (i.e., $\lambda^{trend} < \lambda^{past}$). Similarly, $\xi^\star = 1$ when $\lambda^{trend} > \lambda^{past}$ for any $\xi \in [0, 1]$. An interior solution exists if there is at least one $\xi \in [0, 1]$ for which $\lambda^{trend} = \lambda^{past}$; in such a case, workers are indifferent between indexation rules. Next, we use an array of examples to show that $\xi^\star$ is an *equilibrium state* and is *globally stable*.

For the sake of exposition, consider four different regimes, each one including *only* one type of shock. The first one contains permanent productivity shocks (Σ^{prod}); the second one is driven by government spending shocks (Σ^{dem}); the third and fourth ones display trend-inflation shocks, but in the former these are permanent shocks ($\Sigma^{\pi^\star,\text{P}}$, where $\rho_\pi = 1$, so trend inflation is a random walk), while in the latter these are temporary shocks ($\Sigma^{\pi^\star,\text{T}}$, where $\rho_\pi = 0.7$, so trend inflation is mildly persistent and stationary). The first row of Figure 2 shows the long-run welfare costs associated with labor contracts with a trend-inflation indexation rule λ^{trend} is the plain line) and those with a past-inflation rule (λ^{past} is the line with circles).

[Insert Figure 2 here]

In the first three cases (Σ^{prod}, Σ^{dem}, and $\Sigma^{\pi^\star,\text{P}}$) there is a corner solution, as for any level of ξ, worker i has a clear preference: she chooses the past-inflation indexation rule when the economy is driven by either productivity shocks or permanent trend-inflation shocks; and she chooses the trend-inflation rule when the aggregate-demand shock drives the economy.[13] It follows that aggregate indexation is high for regimes Σ^{prod} and $\Sigma^{\pi^\star,\text{P}}$ (in equilibrium $\xi^\star = 1$), and it is low for regime Σ^{dem} (in equilibrium $\xi^\star = 0$).[14] The temporary trend-inflation shock regime has an interior solution, since for $\xi^\star = .5$ we have that $\lambda^{trend} = \lambda^{past}$.

Notice that $\xi^\star$ denotes an equilibrium for all regimes, since at such level of aggregate indexation workers have no incentives to change their rule. Also, $\xi^\star$ is globally stable since for any initial $\xi_0 \neq \xi^\star$, workers choose the contract with the lowest expected losses and aggregate indexation ξ_t converges towards $c^\star$.[15]

In order to understand what drives differences between the welfare costs across contracts, recall from the wage-setting problem that nominal rigidities bring about welfare losses because they create a wedge between the desired labor supply and the actual one. The dynamics of the wedge depend on the indexation rule chosen. Since we have two types of labor contracts, it follows that we also have two types of dispersion in nominal wages. As we show next, the indexation rule that creates lower welfare losses, given a level of ξ, is the one with the lowest wage dispersion. Thus, workers will prefer such rule over the alternative. To see this, it proves useful to disentangle the main determinants of the expected labor disutility at the stochastic steady state. Let $x_{ss} = \text{E}\{x_t\}$ define the unconditional expectation of variable x_t, which coincides with its steady state and is time invariant. In the technical appendix we show that the expected labor disutility associated with labor contract k, Ω^k_{ss}, can be

[13]The aggregate-demand shocks we have analysed, apart from government spending, are a preference shock, a risk-premium shock *à la* Smets and Wouters (2007), or a high frequency monetary-policy shock (i.e., a temporary deviation from the policy rule). In all cases, we have similar results.

[14]A similar picture emerges if we measure welfare costs in terms of the deterministic steady-state consumption instead of leisure.

[15]It is worth mentioning that in every single exercise we have performed, either with an interior or corner solution, $\xi^\star$ is globally stable. Our exercises array a wide combination of shocks, including productivity, preferences, monetary policy, government spending, price-markup, etc. Global stability is achieved because, when welfare costs increase with ξ, λ^{past} tends to be lower than λ^{trend}; in contrast, when welfare costs decrease with ξ, the opposite holds. It follows that, when the $\lambda^{k\prime}s$ have an inverse U-shape form, they cross only once.

approximated as:[16]

$$\Omega_{ss}^{k} \approx \frac{\psi}{(1-\beta\alpha_w)(1+\omega)}\left[\text{Rdisp}_{ss}^{k}\times \ell_{ss}\right]^{1+\omega}, \text{ where}$$

$$\text{Rdisp}_{ss}^{k} = \begin{cases} \frac{\text{disp}_{past,ss}^{\text{w}}}{\xi} & \text{if } k = past \\ \frac{\text{disp}_{trend,ss}^{\text{w}}}{1-\xi} & \text{if } k = trend \end{cases},$$

The terms Rdisp_{ss}^{k} are *relative* measures of wage dispersion, while ℓ_{ss} is the aggregate level of hours worked. Similar to Erceg *et al.* (2000) or Galí and Monacelli (2004), it can be shown that relative wage dispersion increases with a measure of variance of hours worked (in logarithms) in each specific contract, i.e.

$$\frac{\text{disp}_{k,ss}^{\text{w}}}{\tilde{\xi}} \simeq 1+\frac{1}{2\theta_w}\text{var}_{k,ss}\left\{\ln \ell_{i,t}\right\} - \mu_w\left(\frac{\tilde{\xi}-\text{E}\left\{\tilde{w}_t^k\right\}}{\tilde{\xi}}\right), \tag{17}$$

$$\text{where } \tilde{\xi} = \begin{cases} \xi & \text{if } k = past \\ 1-\xi & \text{if } k = trend \end{cases},$$

and $\text{var}_{k,ss}\left\{\ln \ell_{i,t}\right\} = \text{E}\left\{\tilde{\xi}^{-1}\int_{i\in IR_k}\left(\ln \ell_{i,t} - \ln \ell_T\right)^2 \text{d}i\right\}$.[17] The weight $\tilde{\xi}^{-1}$ is used to ensure that sector moments are properly re-scaled by the proportion of workers in each sector. The third term of equation (17) is a correcting term associated with the weight of relative wages, $\tilde{w}_{ss}^{k}$, from its deterministic steady state level, $\tilde{\xi}$. However, one expects these terms to be relatively small.[18]

Labor disutility increases with the variance of hours worked because worker i is risk averse to surprises in his leisure time ($\omega > 0$ in the utility function). She thus prefers a labor contract with a low variability in her expected labor supply. The second row of Figure 2 shows the relative wage dispersion measures for each regime considered. Notice that disp_k^{w} may be either above or below $\tilde{\xi}$, while the population average lies fairly close to one (light dashed line). For a given level of ξ, the preferred contract is the one that has the lowest relative wage dispersion. The implied equilibrium $\xi^{\star}$ derived from the comparison between the dispersion measures is thus consistent with the welfare costs analysis of the row above.

[16] The complete expression is more complex, as it involves correcting terms that include the variance and co-variance of future control variables. These terms are however small so we omit them here. For further details, consult the technical appendix.

[17] See the technical appendix.

[18] Notice that the sum of all relative wages, $\tilde{w}_{ss}^{1} + \tilde{w}_{ss}^{2}$, must be equal to 1 due to the zero-profit condition of the labor intermediary (i.e., $W_t = \left[\int_0^1 W_{i,t}^{1-\theta_w}\text{d}i\right]^{\frac{1}{1-\theta_w}}$). However, within each labor sector, some deviations may occur at the stochastic steady state.

3.3 Social *vs.* Private Welfare

The equilibrium aggregate indexation $\xi^\star$ just described corresponds to a set of uncoordinated decisions among workers; it is thus a decentralized equilibrium and it might not reflect the socially desired indexation level. In fact, in most cases, $\xi^\star$ differs from the socially optimal level, as we show next.

Social welfare is obtained by adding up all households' welfare, i.e.[19]

$$\mathbb{SW}_t = \mathrm{E}_t \left\{ \sum_{T=t}^{\infty} \beta^{T-t} \int_0^1 \mathcal{U}\left(c_T, \ell_{i,T}\right) \mathrm{d}i \right\},$$

which differs from private welfare in two main respects. First, social welfare is the weighted sum of every single household in the economy, regardless of their last wage re-optimization. In contrast, the individual measure $\mathbb{W}_t$ refers only to the welfare of those workers drawn to reset their wage in period t. And second, social welfare is not conditional on the average duration of a labor contract, so the discount factor is closer to 1 than for private welfare.

At the stochastic steady state, social welfare converges to its unconditional expected level, defined as $\mathbb{SW}_{ss}\left(\xi, \Sigma\right) \equiv \mathrm{E}\left(\mathbb{SW}_t\right)$. Notice that $\mathbb{SW}_{ss}$ varies with aggregate indexation and the economic regime. The upper bound in social welfare is achieved when there are no shocks in the economy, and there is no chance they may ever happen, i.e. the deterministic scenario. In all other stochastic regimes, there will be welfare losses, which can be measured in the same way as private welfare. Let λ^S denote the increase in deterministic hours worked that leave the *representative* household indifferent between the deterministic regime and the stochastic one, i.e.,

$$\lambda^S = \left[\frac{\mathbb{SW}_{ss} \times (1-\beta) - \log\left(c_d\left(1-\gamma^h\right)\right)}{\mathbb{SW}_d \times (1-\beta) - \log\left(c_d\left(1-\gamma^h\right)\right)} \right]^{\frac{1}{1+\omega}} - 1,$$

where $\mathbb{SW}_d = \frac{1}{1-\beta}\mathcal{U}\left(c_d, \ell_d\right)$. Gray (1976) and Fischer (1977) show in their seminal contributions that the socially optimal degree of aggregate indexation depends on the structure of shocks prevailing in the economy, i.e. on the economic regime Σ. These authors argue that full indexation ($\xi = 1$) is optimal when only monetary shocks prevail, and that no indexation ($\xi = 0$) is optimal when only real shocks are present. Gray and Fischer's results hold in a New Keynesian model like ours, as we show on the third row of figure 2 (see also Amano *et al.* (2007)). Let ξ^S denote the socially most preferred level of aggregate indexation that minimizes social welfare losses. It follows that no indexation is socially optimal when the

[19] Since there are no differences on wealth or consumption, each household has a similar weight.

economy is driven by permanent productivity shocks and temporal inflation-target shocks (regimes Σ^{prod} and $\Sigma^{\pi^\star,\text{T}}$). In contrast, full indexation is optimal in response to aggregate spending shocks and permanent inflation shocks (regimes Σ^{dem} and $\Sigma^{\pi^\star,\text{P}}$).

Interestingly, $\xi^\star$ and ξ^S differ substantially for regimes Σ^{prod} and Σ^{dem}. They indeed oppose each other from corner to corner. The reason is that the socially optimal indexation level aims to stabilize the real wage, thus avoiding excessive fluctuations in both aggregate labor and consumption (see Gray, 1976). However, even if the economy would start at ξ^S, workers have the incentive to change their indexation rules because, at the margin, they can obtain gains in terms of leisure. Indeed, in the decentralized equilibrium workers neglect the effect that their own indexation-rule decision imposes on the rest, given their atomistic size with respect to the whole population. The decentralized equilibrium is therefore inefficient as the externalities caused by workers' uncoordinated decisions create unnecessary fluctuations and higher welfare costs.

4 Counterfactuals

In this section we show that the model predictions for aggregate indexation are in line with the empirical evidence discussed in the introduction. Specifically, the model predicts high indexation for the *Great Inflation* and low indexation for the *Great Moderation*. We also conclude that high indexation during the *Great Inflation* was likely due to volatile productivity shocks, rather than loose monetary policy. Finally, we discuss the sensitivity of our results to variations in the parameter values.

4.1 Great Moderation and Great Inflation

We build our analysis on the results of Hofmann *et al.* (2012) (hereafter HPS), who consider a New-Keynesian model akin to ours.[20] They estimate the model for three points in time (1960:Q1, 1974:Q1, and 2000:Q1) by minimizing the distance between the DSGE implied impulse responses and those arising from an estimated Bayesian structural VAR with time-varying parameters in the spirit of Cogley and Sargent (2005) and Primiceri (2005). HPS identified two shocks in their VAR through sign restrictions: a supply-side shock and a demand-side shock. The first one was mapped into the model by means of a permanent productivity shock, while the second one was represented by a government-spending shock. Since we want to compare the model predictions for the *Great Inflation* vs. the *Great Moder-*

[20]The only difference is that in the framework of HPS, indexation coefficients are fixed.

ation, we take the calibration and estimated parameters for the points 1974:Q1 and 2000:Q1 for each of the two economic regimes, respectively. Table (1) shows the model parameters for the two scenarios. A set of calibrated parameters common to both models are shown in the upper half of the table. For the specific parameters of each regime, we chose the median values of the posterior distributions computed by HPS. Notice that these authors do not consider shocks in trend inflation, and so, they do not have an estimation of its variance. To amend this issue, we consider two exercises for our counterfactuals. In the first, trend inflation remains constant ($\sigma_{\pi^\star} = 0$); in the second, trend inflation volatility is higher during the *Great Inflation* than in the *Great Moderation*. For this particular case, we chose the values for $\sigma_{\pi^\star}$ from the posterior median estimations of trend inflation volatility as computed by Cogley *et al.* (2010) for the two economic regimes considered.[21] The specific parameters for each regime exhibit typical patterns found in the literature,[22] as shown in table (1). For instance, persistence parameters, such as habits (γ^h) and inflation inertia (γ^p), are higher for the *Great Inflation*, while the reaction of the central bank to inflation deviations in the Taylor rule (a_π) is bigger for the *Great Moderation*. Also, we report the estimated wage indexation coefficient ($\hat{\xi}$), which is equivalent to our aggregate indexation, as computed by HPS for the two regimes. In line with the COLA index, the estimated aggregate indexation is higher in the 70s and lower in the 2000s.

Now, we turn to the model predictions conditional on each regime. For case 1, where target inflation is constant, the model predicts an aggregate indexation $\xi^\star$ equal to zero for the *Great Moderation* and equal to .89 for the *Great Inflation*. The similarities between the model's endogenous predictions and the HPS estimates are remarkable. For case 2, when the model includes a time-varying trend inflation, we find that $\xi^\star$ increases from zero to 5% in the *Great Moderation* and it remains at .89 in the *Great Inflation*. The results are again in line with the COLA index and HPS estimations. However, it is surprising that a volatile trend inflation has a minor impact on the results. The reason is that the trend-inflation shocks are relatively small in comparison to the other shocks present in the economy, even if for the Great Inflation the volatility of trend-inflation is twice that of the 2000s. In fact, for the 1974 regime, trend inflation explained about 0.79 percent of the total output fluctuations in the long-run, according to the model. For the 2000 regime, the same figure is

[21] Cogley *et al.* (2010) estimate a New Keynesian model with sticky prices and flexible wages through Bayesian methods over two sample periods: 1960:Q1-1979:Q3 and 1982:Q4-2006:Q4. We take the estimated $\sigma_{\pi^\star}$ for the first subperiod for our *Great Inflation* calibration, while the value for the second subperiod appears in the *Great Moderation* calibration.

[22] See Boivin and Giannoni (2006), Smets and Wouters (2007), or Carrillo (2012).

1.25 percent. Notably, Ireland (2007) reports a similar explanatory power for trend-inflation shocks at impact in a New Keynesian estimated with Bayesian methods and including several shocks.[23]

The bottom of table (1) also reports the model-based socially optimal rate of aggregate indexation ξ^S. Importantly, the social optimum diametrically differs from the decentralized equilibrium presented above. Indeed, the social planner would have liked to implement high indexation during the *Great Moderation* and low indexation for the *Great Inflation*. As pointed out, these are the recommendations elicited from the seminal contributions of Gray (1976) and Fischer (1977), which appear to have little influence in the actual indexation scheme of workers.

4.2 Sensitivity analysis

Figure (3) shows how the equilibrium aggregate indexation reacts to changes in different parameter values; in each panel, only the indicated coefficient varies while the others are kept constant. The star sign marks a reference point for aggregate indexation, which equals $\xi^\star = .55$. This reference point is obtained by increasing the volatility of the technology shock by 15% in the 2000:Q1 calibration, which we take as benchmark. We prefer a reference point away from zero because it covers a broader variation interval for aggregate indexation. To facilitate the discussion, we classify the varying parameters into three hypotheses that have been proposed to explain the high level of inflation and its volatility during the 70s: *Good Policy*, *Good Luck* and *Structural Change*.

Good Policy. The good policy hypothesis asserts that monetary policy has become hawkish towards inflation in the post-*Great Inflation* period, thereby stabilizing it. The first row of figure (3) displays how $\xi^\star$ changes with the Taylor rule parameters and with trend inflation volatility. We find that increases in the Taylor rule coefficients for inflation and the output gap induce higher aggregate indexation. The opposite holds for the Taylor rule coefficient on the growth of the output gap. Although the results for the inflation coefficient seem counterintuitive, one should not interpret them in terms of the benefits associated with inflation stability, but rather on their effect on the allocation of hours worked within each indexation rule sector. Accordingly, aggregate indexation increases with a stricter monetary policy because, conditional on the specific economic regime assumed, labor contracts indexed to past-inflation eliminate quicker the distortions created by nominal wage rigidities than

[23] In Ireland's estimation, the long-run contribution of trend-inflation shocks in explaining output fluctuations is even more modest, approaching zero as the horizon grows.

those indexed to target inflation. Further, as anticipated before, a higher volatility of trend inflation leads to a higher $\xi^\star$. Although, as noticed in the previous section, trend inflation volatility must be relatively large to affect $\xi^\star$ when other shocks are present.

In the light of the counterfactual exercises of the previous section, these sensitivity results imply that neither a hawkish monetary policy on the inflation gap, nor a more stable inflation target, seem to be determining factors in reducing aggregate indexation during the *Great Moderation*.

Good Luck. A competing explanation for the transition from the *Great Inflation* to the *Great Moderation* is that a lower volatility of aggregate shocks naturally resulted in a more stable economic climate. The second row of figure (3) confirms the analysis of section 3, as $\xi^\star$ increases in the volatility of the permanent productivity shock and decreases with the volatility of the aggregate demand shock. According to our analysis, an overall lower shock volatility does not necessarily imply lower aggregate indexation. What really matters is the relative importance of shocks. As such, the stronger reduction in the size of productivity shocks with respect to aggregate-demand shocks seems to be a crucial driver in explaining the reduction of $\xi^\star$ during the *Great Moderation*.

Structural Change. Finally, the third row of figure (3) shows how ξ^* varies with some structural parameters pertaining to nominal rigidities and the labor market. In this case, we find that the nonlinearities of the model become apparent, as aggregate indexation varies in a non-monotonic way with the degree of nominal rigidities. It is thus not possible to elicit a general conclusion about the effect of such rigidities on $\xi^\star$, since it depends on the initial values.

For the labor market parameters, $\xi^\star$ increase monotonically with the elasticity of labor demand and the Frisch elasticity of labor supply. Accordingly, more aggregate indexation results from more elastic labor supply curves or a lower wage markup (μ_w falls with θ_w). Since the markup can be interpreted as an indirect measure for the monopolistic power of wage-setters, it might appear counterintuitive, from anecdotal experience,[24] that higher indexation goes with a lower monopolistic power. However, as in the case of the *Good Policy* parameters, these result should interpreted in terms of its effect on the allocation of hours worked within each indexation sector. Besides, it must not be forgotten that the relative

[24] The decrease of the COLA index in the U.S. was accompanied by a decrease in the power of labor unions.

importance of shocks is crucial to explain the results.

In sum, it appears that the Good Luck hypothesis, i.e. lower shock volatility, is the crucial determinant in explaining the changes of aggregate indexation from the *Great Inflation* to the *Great Moderation*.

5 Conclusion

In this paper we explore an endogenous channel for wage indexation in which workers decide on the indexing scheme that applies to their nominal salaries. We depart from the literature as we highlight the decentralised equilibrium that results from workers decisions (which minimize *individual* welfare losses), rather than the socially optimal level of indexation (which minimizes *average* welfare losses across workers; this is the solution of papers on the long-standing tradition of Gray, 1976, and Fischer, 1977). We show that the decentralised equilibrium better explains the transition from high to low indexation in the U.S. for the period spanning the *Great Inflation* to the *Great Moderation*. This is the case because workers prefer past-inflation indexation in regimes dominated by strong productivity shocks (like the 70s), while they prefer target-inflation indexation in regimes driven by aggregate-demand shocks (presumably, the 2000s). We argue that the relative importance of aggregate shocks in explaining output fluctuations, and not changes in monetary policy, was a crucial determinant for the presumed variations of wage indexation in the U.S.

This paper partially responds to recent concerns about the lack of endogenous channels explaining price and wage inflation persistence (see Benati, 2008). Models with such devices are indispensable tools for the conduct of monetary policy. It is thus desirable to extend our framework to price setting, but this is a subject we leave for future research.

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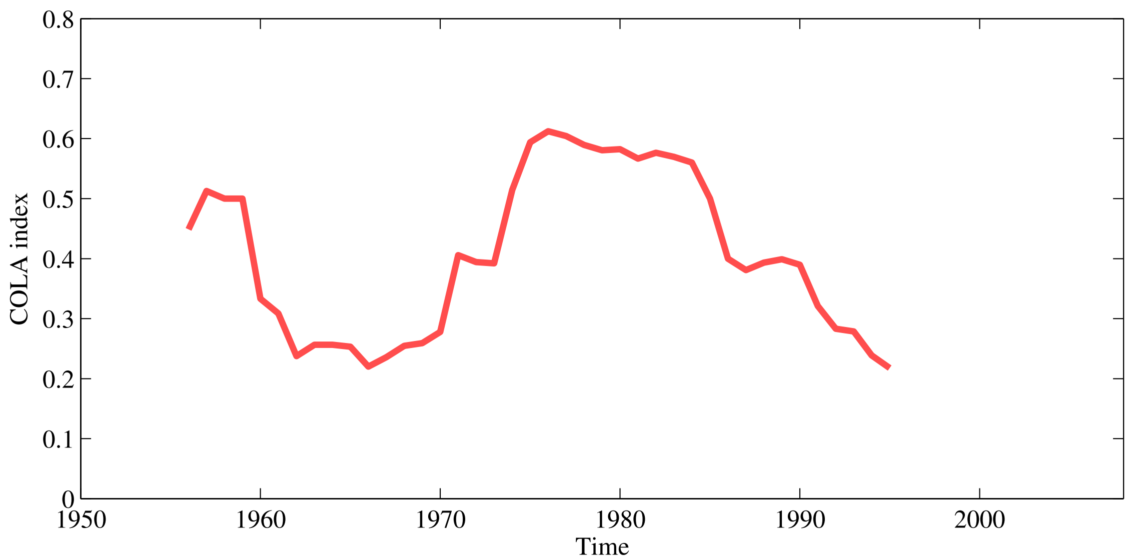
Table and figures

Table 1. Calibration for counterfactuals

		Great Moderation 2000 (benchmark)	Great Inflation 1974
	Common parameters		
β	Subj. discount factor	.99	.99
σ	Intertemp. elasticity of subst.	1	1
ϕ^{-1}	Labor share	1	1
ω^{-1}	Frisch elast. of labor supply	2	2
θ_w	Elast. labor demand	10	10
θ_p	Elast. input demand	10	10
	Specific parameters		
γ^h	Habit formation	.37	.71
γ^p	Inflation inertia	.17	.8
α_p	Calvo-price rigidity	.78	.84
α_w	Calvo-wage rigidity	.54	.64
a_π	Taylor Rule: inflation	1.35	1.11
a_y	Taylor Rule: output gap	.1	.11
$a_{\Delta y}$	Taylor Rule: output gap growth	.39	.5
ρ_R	Taylor Rule: smoothing	.78	.69
σ_z	Std. dev. Tech. shock	.31	1.02
σ_g	Std. dev. Dem. shock	3.25	4.73
ρ^g	Autocorr. Dem. shock	.91	.89
$\hat{\xi}$	Estimated indexation by HPS	.17	.91
	Case 1: $\sigma_{\pi^\star} = 0$		
$\xi^\star$	Implied equilibrium indexation	0	.89
ξ^S	Implied social optimum	1	0
	Case 2: $\sigma_{\pi^\star} > 0$		
σ_{π^*}	Std. dev. inflation target	.049	.081
$\xi^\star$	Implied equilibrium indexation	.05	.89
ξ^S	Implied social optimum	1	0

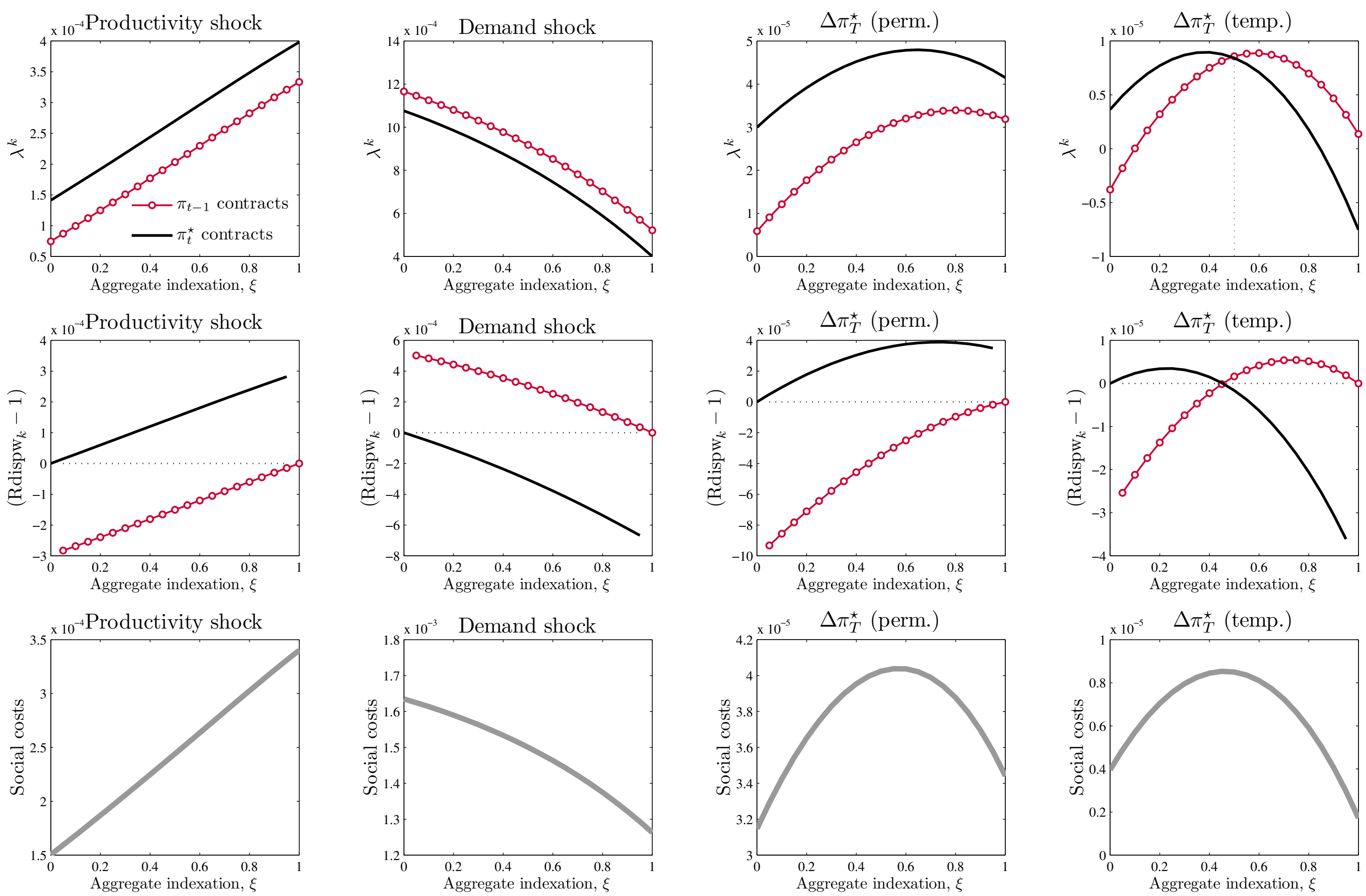
Note : All *common* and *specific* parameters values are extracted from Hofmann *et al.* (2012). The standard deviations for trend-inflation are taken from Cogley *et al.* (2010). We were careful in properly homologating the size of $\sigma_{\pi^\star}$ to do not decrease the importance of trend inflation. The *implied* parameter values are computed using the tools provided in section 3.

Figure 1: Presumed wage indexation in the U.S.



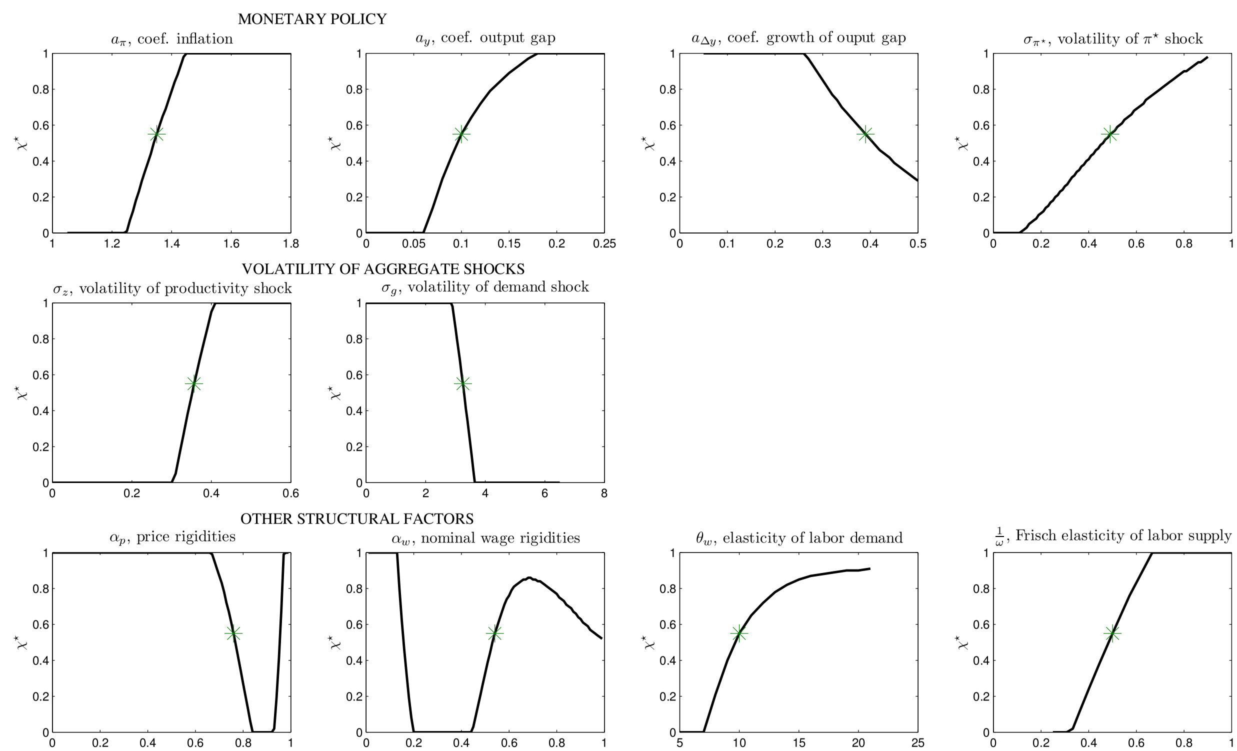
Note: The COLA index gives the proportion of union workers in large collective bargaining agreements with explicit contractual wage indexation clauses. The series is annual from 1956-1995. Source: Ragan and Bratsberg (2000)

Figure 2: Welfare costs and wage dispersion for different economic regimes.



Note: Labor-based welfare costs conditional on specific shocks. The model is solved using a Taylor expansion of order two.

Figure 3: Sensitivity analysis



Note: The responses for selected variables are shown after shocks in productivity, government spending (demand shock), and the inflation target. For productivity, it is assumed that output rises 1 percent in the long-run. For demand shock, government spending rise at impact by 1 percent. Finally, the inflation-target shock rises by 2 percent at impact; in the first case, the rise is temporary while in the second one, the change is permanent.