A Theory of Downward Wage Rigidity*

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(Most Recent Version Here)

Abstract

I develop a model where workers are averse to losses as in the cognitive psychology literature, and need to search in order to find a job. In a frictional market in which both workers and firms determine the terms of labor contracts, nominal downward wage rigidity emerges endogenously as a result of the privately optimal division of gains from trade. The model implies that the response of wages to shocks is asymmetric. In response to a temporary negative productivity shock that is not too large, nominal wages are initially rigid and take some time to catch up. In response to a symmetric positive shock, firms increase nominal wages immediately but let real wages erode over time. Inflation "greases the wheels of the labor market", in the sense that the inaction region is smaller in a high-inflation environment. The model rationalizes a number of additional empirical regularities: (1) wages of job-switchers are more flexible than wages of job-stayers, but not conditional on employment history, (2) the Phillips curve is nonlinear, and (3) the probability of wage changes is state-dependent. Moreover, a calibration to US microdata yields a good fit to the distribution of nominal wage changes with parameters that are consistent with common estimates. The model prescribes an optimal positive inflation target, and a countercyclical response to shocks.

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1 Introduction

Nominal wages rarely change, and when they do, they are much more likely to increase than to decrease. This empirical pattern is so well-documented that economists have long recognized the importance of incorporating it in macroeconomic models. However, the phenomenon remains puzzling. On the one hand, empirical studies have suggested that inefficient separations often occur because nominal wages do not go down (Davis and Krolikowski (2023)). On the other hand, standard models with rationality have made little progress in explaining why downward nominal wage rigidity occurs in the first place.

Bewley (1999) suggests a possible explanation. In the hundreds of interviews he conducted with managers, words such as "anger" or "rage" are prevalent. Moreover, nominal wages cuts seem to trigger a reaction in workers that real wage cuts do not:

> *"The pay freeze is psychologically easier. People don't factor in inflation so easily."* (p. 209)

> *"Real pay cuts [through inflation] are easier than nominal ones (...). A significant event (...) may wake people up and make them angry. Nominal pay cuts are an insult, even if everybody is cut."* (p. 209)

These answers suggest that the utility loss from a nominal pay cut is not consumption-related, consistent with the literature on "prospect theory." In their seminal paper, Kahneman and Tversky (1979) recognized that standard consumer theory is not consistent with many properties of decision-making. Based on experimental evidence, the authors argue that people rank outcomes according to their distance to a "status quo", and that the marginal utility of a gain is smaller than the marginal disutility of a loss. Furthermore, aversion to losses is a cognitive bias: the asymmetric ranking is tied to emotional issues such as regret or anger, rather than related to pure utility gains from consumption (see Barberis (2013)).

In this spirit, I develop a general-equilibrium model where workers have loss aversions: they are more sensitive to nominal pay cuts than to pay hikes. When the individual nominal wage decreases, utility possibilities contract for a given price level, and workers are inclined to work less. At the individual level, workers have a labor supply curve that has a kink at the past nominal wage, which they take as the "status quo", and is more elastic in the region of pay cuts.

I first show that without any frictions in the labor market, loss aversion fails to generate downward wage rigidity. Under perfect competition, firms take wages as given, so that there is a labor demand curve that shifts with productivity. If productivity decreases, labor demand shifts to the left, and the new equilibrium lies in the loss region of the labor supply curve. Even though the wage change is smaller for a productivity decrease than for a productivity increase of the same amount, the equilibrium wage still decreases. The kink in the labor supply curve is of no special importance.

I then move to a search version of the model in which firms make take-it-or-leave-it wage offers to workers. Even though firms have full bargaining power, workers still affect the terms of their labor contracts through the number of hours they work. Each firm faces a labor supply curve as a whole, and finds it optimal to be at the kink as long as productivity shocks are not substantially large. Downward nominal wage rigidity then arises as an optimal decision by the firm on how to split gains from trade. The equilibrium is well-defined, and there is no need to resort to assumptions on how market clearing is attained, as in Schmitt-Grohé and Uribe (2016) or Erceg et al. (2000).

The model implies that wages respond asymmetrically to productivity shocks. In response to a temporary negative productivity shock that is not too large, nominal wages are initially rigid, but quickly catch up with their previous trend. In response to a positive productivity shock of the same size and persistence, nominal wages initially go up, but remain stable until inflation has sufficiently eroded real wages. Moreover, the initial discrete increase in the nominal wage is lower than in a version of the model without loss aversion due to a precautionary motive: firms do not want to increase wages too much to avoid having to decrease them in the future.

Using common parameter estimates from the literature, the distribution of nominal wage changes in the model does a good job at fitting the analogous distribution for the US. However, the model still predicts a high degree of wage flexibility when either inflation is high, or productivity shocks are large. First, when inflation is high, the current real value of past nominal wages is low, and so loss aversion has little effect on firm decisions. Wages adjust more easily, as documented in the empirical literature (Elsby (2009); Dickens et al. (2007)). Second, unlike in many models with exogenous downward wage rigidity, wages still go down when shocks are large enough because productivity is outside of the inaction region. This property is consistent with the downward flexibility that is observed during particularly adverse events, such as the Great Recession (Kurmann and McEntarfer (2019)) or the COVID-19 Pandemic (Cajner et al. (2020)).

The model has a number of important additional properties. First, consistent with Grigsby et al. (2021) and Hazell and Taska (2024), wages of job-switchers are more flexible, but this flexibility is not present once we condition on employment history. When a worker arrives to a new firm, she has a reference wage that was determined in the past. If the worker was previously employed, the new firm faces the same supply curve as the continuing firm would face if the worker had not been laid off. If the worker is coming out of unemployment, however, the reference point is very low, and therefore loss aversion is irrelevant to the new firm.

Second, in the tightness-inflation space, the model generates a slanted-L Phillips curve of the sort proposed by Benigno and Eggertsson (2023). As inflation goes up, reference wages are more and more devalued in real terms, and labor market tightness asymptotes vertically to the benchmark without loss aversion. This property implies that recessions caused by supply shocks are more severe than expansions. When costs increase, labor market tightness decreases along the flat region of the Phillips curve, while when costs decrease, labor market tightness increases along the steep region. Therefore, unemployment has a larger response to a negative aggregate shock than to a positive shock of the same size. This phenomenon has been documented in the literature on asymmetric business cycles, such as Abbritti and Fahr (2013) and McKay and Reis (2008).

Third, wage changes are state-dependent. Under the assumption of *i.i.d.* shocks, firms with past wages that are different from the mean have a higher probability of a wage change. However, that probability increases more slowly when past wages are above, rather than below the mean. This feature is consistent with the state-dependence in wage setting found in Grigsby et al. (2021).

I also study optimal monetary policy in this economy. The model prescribes a target for positive inflation. In the literature, optimal positive steady state inflation arises in the presence of downward wage rigidity in order to give policymakers enough leeway to respond to negative shocks (see Adam and Weber (2024) for a review). In my model, instead, positive inflation ameliorates the congestion externality that is present in a search model. By inflating, the monetary authority decreases utility of employed workers via real wage erosion, and increases average profits. In expectation of high profits, firms have high incentives to post vacancies, which makes it easier to find a job. Therefore optimal policy uses inflation to transfer resources from the employed to the unemployed.

This paper is related to two main strands of models with downward wage rigidity.

Theories with rationality The most popular explanation of downward wage rigidity in models with full rationality is based on the insurance-providing role of the firm. In the tradition of Azariadis (1975), Harris and Holmstrom (1982) develop a model where, due to incomplete information on worker ability by both parties, risk-neutral firms optimally provide insurance to risk-averse workers. Workers are insulated from pay cuts, and only receive pay bumps in response to outside bids from the market. In a directed search model, Menzio and Moen (2010) follow along the same lines, except that the authors focus on a layoff margin whereby firms replace senior by junior workers. Bewley (1999) argues that theories based on the risk-providing motive are implausible, since they would imply much higher severance packages that the ones observed in the data. Moreover, this theory is best suited to explain real, rather than nominal downward wage rigidity.

Behavioral theories This paper is related to Eliaz and Spiegler (2014) and, most closely, to Fongoni (2024), which build on the reciprocity-based theories advocated by Akerlof (1982) and Akerlof and Yellen (1990). Eliaz and Spiegler (2014) develop a labor search model in which firm productivity exogenously drops if wages go below a reference wage, but, as in Kőszegi and Rabin (2006), the reference is endogenously determined as the rational expectation on compensation before shocks are realized. Wages are rigid in the sense that they do not respond to shocks within a given period, but they still move over time. Moreover, the theory is framed in terms of real wages. Fongoni (2024) develops a partial equilibrium model which features an exogenous reference-dependent effort function by workers. He uses this model to study the cyclicality of job creation. While the wage policy functions are similar, his model features macro downward wage rigidity, while my model features macro downward wage stickiness. Moreover, Fongoni (2024) does not study the effects of inflation on the economy. In fact, the workers in his model suffer strongly from nominal illusion, in the sense that regardless of real wages, effort increases as long as nominal wages go up. Alternative theories are based on internal equity concerns, as in Card et al. (2012), or renegotiation costs, as in Guerreiro et al. (2024). My paper provides a model that captures the spirit of many of these explanations, but it is sufficiently tractable to study the macro, general-equilibrium implications of theories based on loss aversion.

This paper is organized as follows. In Section 2, I describe the fundamentals of the baseline static model and I show that under perfect competition, wages are not rigid downward. Section 3 characterizes the model with labor search and describes its implications. In Section 4 I describe the infinite-period extension of the model, and in Section 5 I conclude.

2 The Static Model

I start with a static model, in which a pre-period indexed by $t = -1$ determines initial conditions. There is a single consumption good produced with labor only. The economy consists of a continuum of measure one of workers indexed by $i \in [0,1]$, and a shareholder indexed by s. Workers supply labor and have no other sources of income, while the shareholder does not work but owns all profits. The consumption good is produced by a continuum of firms indexed by $j \in [0,1]$ with idiosyncratic productivity. There is a monetary authority with direct control over inflation.

Whenever it is convenient, I drop the multiple dependence of functions on the same variable, *i.e.*, I write $G(H(x), x) = G(x)$.

2.1 Workers

Let c_i and n_i denote consumption and labor of worker $i \in [0,1]$. Utility from consumption is[1]

$$u(c_i) = \frac{c_i^{1-\nu}}{1-\nu}, \;\; \nu < 1,$$

and disutility from labor is

$$g(n_i) = \frac{n_i^{1+\psi}}{1+\psi}, \;\; \psi > 0.$$

The budget constraint of each worker is

$$Pc_i = W_i n_i,$$

where P is the price level, and W_i is the nominal wage earned by worker i.

A worker without cognitive biases would solve

$$\max_{n_i \geq 0} u\left(\frac{W_i}{P} n_i\right) - g(n_i).$$

In this economy, however, each worker also has preferences over her opportunity sets. The utility function is instead

$$U = v\left[u\left(\frac{W_i}{P} n_i\right); W_i, \overline{W}_i\right] - g(n_i),$$

where $\overline{W}_i$ is a reference nominal wage, and

$$v = \begin{cases} u\left(\frac{W_i}{P} n_i\right), & \text{if } u\left(\frac{W_i}{P} n_i\right) \geq u\left(\frac{\overline{W}_i}{P} n_i\right) \\ \left[\frac{u\left(\frac{W_i}{P} n_i\right)}{u\left(\frac{\overline{W}_i}{P} n_i\right)}\right]^{\lambda} u\left(\frac{\overline{W}_i}{P} n_i\right), & \text{if } u\left(\frac{W_i}{P} n_i\right) < u\left(\frac{\overline{W}_i}{P} n_i\right) \end{cases},$$

[1] The case of $\nu \geq 1$ is not interesting even at the benchmark without loss aversion, labor supply would be either fully inelastic or downward-sloping due to income effects.

with $\lambda \geq 1$. Given labor n_i and the price level P, the worker compares consumption utility at the current nominal wage W_i with the utility she would obtain had the wage offer been equal to a reference $\overline{W}_i$. If utility at W_i is smaller than at $\overline{W}_i$, there is a penalty term $\left[u\left(\frac{W_i}{P}n_i\right)/u\left(\frac{\overline{W}_i}{P}n_i\right)\right]^{\lambda}$ that decreases utility.

The interpretation is that each worker solves a two-step problem. Given the state variables of the consumer problem, there is a standard consumption-labor decision. However, drawing from the literature on preferences over freedom of choice (Arrow (1995); Sen (1991); Pattanaik and Xu (1990)), workers also rank the environments under which they are called upon to act according to the utility possibilities they offer. I assume that this ranking has two properties. First, in the spirit of Kahneman and Tversky (1979), contractions in utility possibility sets are more painful than expansion are enjoyable. Second, to formalize the idea of "insult", the ranking of the environment depends on variables that are specific to the employer-employee relationship – the nominal wage –, and not on variables than no single decision-maker controls – the price level.[2]

The first-order condition for n_i implies that labor supply is

$$n\left(\frac{W_i}{P} \mid \frac{\overline{W}_i}{P}\right) = \begin{cases} \left(\frac{W_i}{P}\right)^{\frac{1}{\eta}}, & \text{if } \frac{W_i}{P} \geq \frac{\overline{W}_i}{P} \\ \left(\frac{W_i/P}{\overline{W}_i/P}\right)^{\frac{1}{\eta_L}-\frac{1}{\eta}} \left(\frac{W_i}{P}\right)^{\frac{1}{\eta}} & \text{if } \frac{W_i}{P} < \frac{\overline{W}_i}{P} \end{cases},$$

where

$$\eta \equiv \frac{\psi+\nu}{1-\nu}, \;\; \eta_L \equiv \frac{\eta}{\lambda}.$$

When $\lambda = 1$, so that there is no loss aversion, supply is the same in both regions. When $\lambda > 1$, the worker demands a higher wage to supply the same amount of labor relative to the benchmark without loss aversion.

Note that as in a standard model, supply still moves with the real wage. This property implies that workers cannot be manipulated to supply any amount of labor due to sufficiently high inflation.

[2]An alternative formulation, more in line with Kahneman and Tversky (1979), would display loss aversion in total utility. In Appendix A, I show that solution to the worker's problem would be qualitatively similar. However, the model would be less tractable.

2.2 Firms and the Shareholder

There is a continuum of firms of measure 1 indexed by j, each with production function

$$y_j = Az_j n_j^{\alpha}, \;\; 0 < \alpha \leq 1.$$

where $z_j \sim \text{Lognormal}\left(0, \sigma_z^2\right)$, and A is an aggregate component.

The shareholder has preferences over consumption characterized by

$$u_s\left(c\right) = \frac{c^{1-\nu_s} - 1}{1 - \nu_s}, \;\; \nu_s \geq 0,$$

and no loss aversion. The budget constraint of the shareholder is

$$c_s = \int \Xi_j d_j,$$

where c_s is the consumption of the capitalist, and Ξ_j are the profits of firm j. I postpone the discussion of the monetary authority to Section 3.

2.3 No Downward Rigidity Under Perfect Competition

This section shows that if the labor market is integrated and perfectly competitive, loss aversion of the form I specified is unable to generate aggregate downward wage rigidity, and provides at most a theory of aggregate wage markdowns. In this section, I assume that $\pi = 1$. Let $w_i \equiv W_i/P$ and $w_{i,-1} \equiv W_{i,-1}/P$.

Under perfect competition, firms set their demands so that the marginal productivity of labor is equal to the real wage, *i.e.*,

$$w = \frac{\alpha A z_j}{n_j^{1-\alpha}} \iff n_j = \left[\frac{\alpha A z_j}{w}\right]^{\frac{1}{1-\alpha}}.$$

Aggregate demand is

$$N^d\left(w\right) \equiv \int_0^1 n_j d_j = \left[\frac{\alpha A e^{\frac{1}{2}\left(\frac{\alpha}{1-\alpha}\right)\sigma_z^2}}{w}\right]^{\frac{1}{1-\alpha}}.$$

For simplicity, suppose that $w_{i,-1} = w_{-1}$. In that case, aggregate supply is

$$N^s\left(w \mid w_{-1}\right) = \begin{cases} w^{\frac{1}{\eta}}, & \text{if } w \geq w_{-1} \\ w_{-1}^{\frac{1}{\eta}}\left(\frac{w}{w_{-1}}\right)^{\frac{1}{\eta_L}} & \text{if } w < w_{-1} \end{cases}.$$

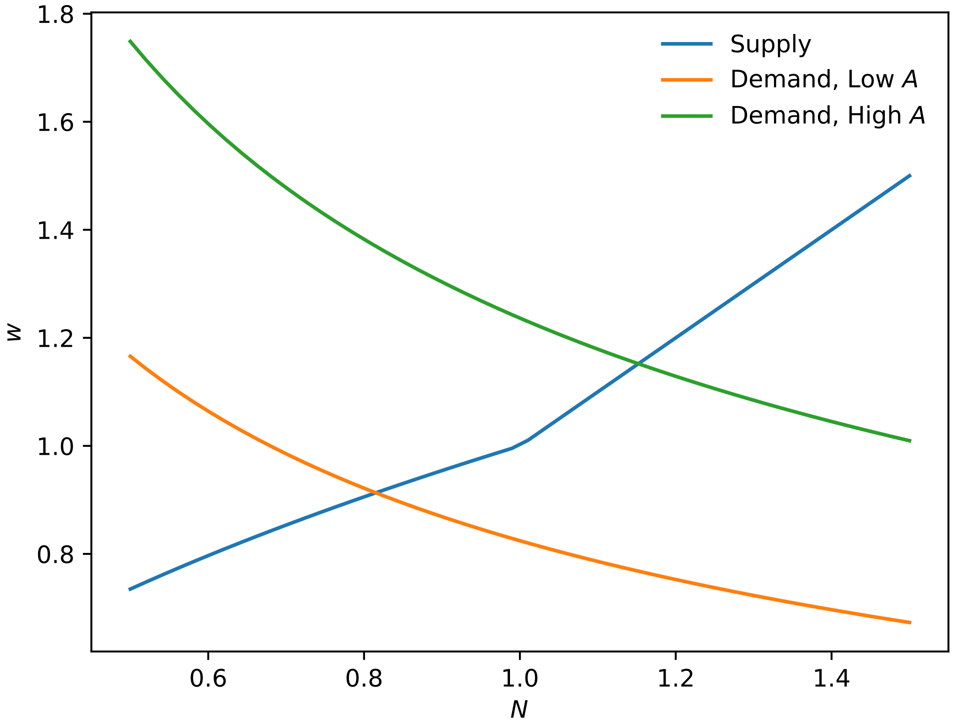

Figure 1: Equilibrium Under Perfect Competition.

The following proposition shows that under perfect competition, wages are not rigid.

Proposition 1 (No DWR Under Perfect Competition)**.** *Under perfect competition, the equilibrium wage is*

$$w^* = \begin{cases} \left[\alpha A e^{\frac{1}{2}\left(\frac{\alpha}{1-\alpha}\right)\sigma_z^2}\right]^{\frac{\frac{1}{1-\alpha}}{\frac{1}{\eta}+\frac{1}{1-\alpha}}}, & \text{if } A \geq \frac{e^{-\frac{1}{2}\left(\frac{\alpha}{1-\alpha}\right)\sigma_z^2}}{\alpha} w_{-1}^{\frac{\frac{1}{\eta}+\frac{1}{1-\alpha}}{\frac{1}{1-\alpha}}} \\ \left\{ w_{-1}^{\alpha\left(\frac{1}{\eta_L}-\frac{1}{\eta}\right)} \left[\alpha A e^{\frac{1}{2}\left(\frac{\alpha}{1-\alpha}\right)\sigma_z^2}\right] \right\}^{\frac{\frac{1}{1-\alpha}}{\frac{1}{\eta_L}+\frac{1}{1-\alpha}}}, & \text{if } A < \frac{e^{-\frac{1}{2}\left(\frac{\alpha}{1-\alpha}\right)\sigma_z^2}}{\alpha} w_{-1}^{\frac{\frac{1}{\eta}+\frac{1}{1-\alpha}}{\frac{1}{1-\alpha}}} \end{cases}$$

Proof. In Appendix B.1. □

Figure (1) plot the equilibrium in this economy for different levels of productivity. As productivity changes, labor demand shifts. In the loss region, the equilibrium wage moves less than in the gain region. However, it always responds to productivity.

In order for loss aversion to generate downward wage rigidity, it is necessary that one party has some market power relative to the other at the individual level. Suppose now that a worker

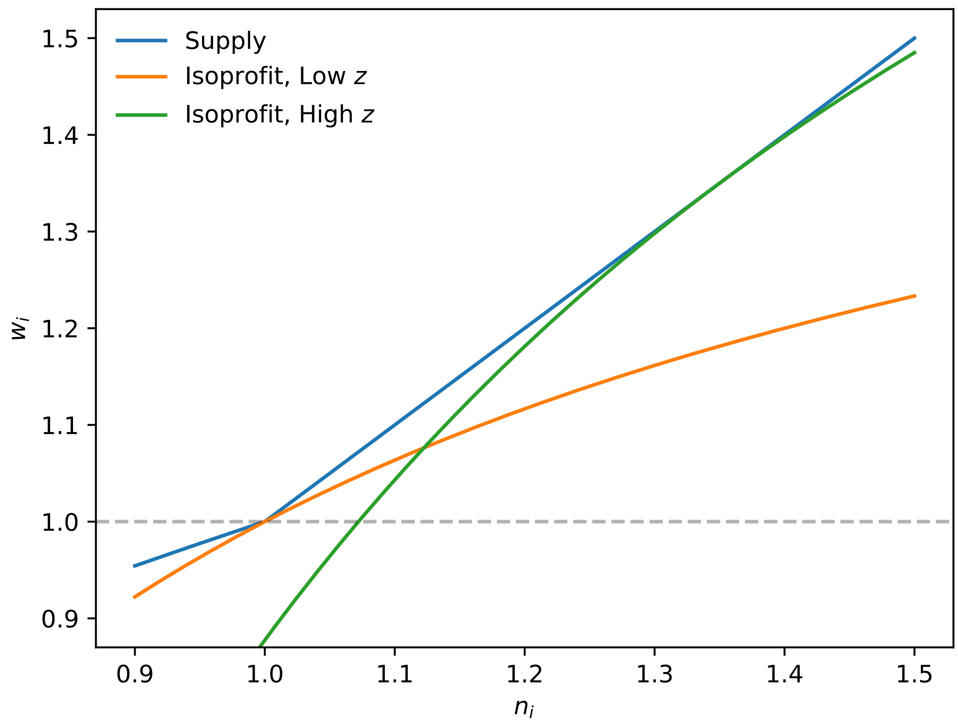

Figure 2: Profit maximization problem of the individual monopsonist.

i is attached to a firm j, and the firm acts as a monopsonist. For simplicity, assume that production is linear. Then firm j faces a kinked supply curve, and chooses w_j to maximize

$$\Xi_j \equiv n\left(w_i \mid w_{i,-1}\right)\left(Az_j - w_i\right)$$

For simplicity, assume a linear production function. On the (w_i, n_i)-axis, the isoprofit lines are

$$w_i = Az_j - \frac{\overline{\Xi}_j}{n_i}.$$

The monopsonistic firm wishes to achieve the lowest possible isoprofit curve. Due to the convex, but kinked supply, it might be optimal for the firm to set the wage equal to the past wage.

Figure 2 shows that whether it does so depends on productivity. If productivity is high, the lowest possible isoprofit line is tangent in the region of losses. If productivity goes down, the lowest possible isoprofit line is attained at the past wage.

This discussion suggests that in order for loss aversion to have substantial implications on downward wage rigidity, there must be a micro-level labor relationship that forces one party to react to the other. In the following sections I develop a labor search model where that is the case.

3 Labor Search

In this section, I consider a disaggregated labor market structure characterized by a search friction. There are three subperiods. In the morning, workers search and new firms open vacancies. In the afternoon, workers and firms match, wages are determined, and production occurs. In the evening, workers and firms separate with an exogenous probability. I assume that in the pre-period, that exogenous probability was equal to δ, but in this period, that probability is equal to 0.

Let $\vartheta_{u,-1}$ be the fraction of unemployed workers at the beginning of the period, and ϑ_v the fraction of firms posting vacancies. I assume $\vartheta_{u,-1} < 1$, so that at the beginning of the period there is a fraction $1 - \vartheta_{u,-1}$ of matches. The number of meetings in the economy, m, is determined as

$$m = \mathcal{M}\left(\vartheta_{u,-1}, \vartheta_v\right),$$

where $\mathcal{M}$ is a matching function satisfying the following standard properties:

- $\mathcal{M}\left(\vartheta_{u,-1}, \vartheta_v\right) \in [0, \min\left\{\vartheta_u, \vartheta_v\right\}]$;
- $\mathcal{M}$ is increasing in both arguments;
- $\lim_{\vartheta_{u,-1}\to\infty} \mathcal{M}\left(\vartheta_{u,-1}, \vartheta_v\right) = \vartheta_v$, $\lim_{\vartheta_v\to\infty} \mathcal{M}\left(\vartheta_{u,-1}, \vartheta_v\right) = \vartheta_{u,-1}$;
- $\mathcal{M}$ exhibits constant returns to scale.

Let $\theta \equiv \vartheta_v/\vartheta_{u,-1}$ be labor market tightness. The constant returns to scale assumption implies that the probability that an entrant finds a job-seeker, m/ϑ_v, and the probability that a job-seeker finds an entrant, $m/\vartheta_{u,-1}$, can be written as functions of θ only, *i.e.*,

$$\alpha_f(\theta) \equiv \frac{m}{\vartheta_v} = \mathcal{M}\left(\theta^{-1}, 1\right),$$

$$\alpha_w(\theta) \equiv \frac{m}{\vartheta_{u,-1}} = \mathcal{M}(1, \theta).$$

It follows that $\alpha_f'(\theta) \leq 0$ and $\alpha_w'(\theta) \geq 0$.

Within each period, the timing is as follows:

1. In the morning, workers search and firms post vacancies,

2. In the afternoon, workers and firms meet, productivity is realized, wages are determined, and production and consumption occur;

3. In the evening, workers are laid off with probability δ.

To keep the problem of the firm simple, I assume that firms make take-it-or-leave-it offers as in Postel-Vinay and Robin (2002). Moreover, the fact that wages are determined after search decisions are made implies that wages do not depend on labor market tightness.

I make the following additional assumptions:

1. $\alpha = 0$, *i.e.*, the production function of each firm is linear;

2. In the pre-period, all firms had productivity A_0;

3. $\vartheta_{u,-1} = \delta$, so that in the pre-period, all workers who wished to find a firm could get a job;

4. The value of home production is zero;

5. Workers have a utility quitting cost that is large enough so that at the beginning of the period, employed workers never wish to quit and look for a new job.

While assumptions 1-4 are for algebraic simplicity only, the other two assumptions are consequential. Assumption 3 implies that new jobs are filled by workers with the same reference point as workers who did not lose their job. Therefore the wage distributions of continuing and new firms are the same. Assumption 5 implies that there are no endogenous separations.

There is a real cost $\xi A^{1+\frac{1}{\eta}}$ per vacancy. I scale the cost by a power of aggregate productivity so that at the benchmark without loss aversion, labor market tightness does not depend on aggregate productivity. The value of a vacancy is

$$-\xi A^{1+\frac{1}{\eta}} + \alpha_f(\theta)\,\mathbb{E}\left[\Xi_j\right].$$

The monetary authority is able to determine inflation, and follows a rule that responds to labor market conditions:

$$\frac{\pi}{\overline{\pi}} = \left(\frac{\theta}{\overline{\theta}}\right)^{-\phi}, \tag{1}$$

where $\phi > 0$, and $\overline{\pi}$ and $\overline{\theta}$ are targets. The interpretation of this rule is that if the labor market is tight, the monetary authority responds by contracting the money supply and decreasing inflation.[3]

I define an equilibrium as follows.

[3] In Section 4, I show that an equilibrium relation like equation (1) is also implied by a Taylor rule in which the nominal interest rate responds to both inflation and labor market tightness.

Definition 1 (Equilibrium)**.** An equilibrium is a vector of prices $\left(w_j, \pi\right)$, allocations $\left(c_i, n_i, y_j, \Xi_j, C, \theta\right)$, and vacancies and unemployment $(\vartheta_v, \vartheta_u)$, such that, given w_{-1}, $\vartheta_{u,-1}$, C_{-1}, μ, and A:

1. Given w_j and π, n_i maximizes the utility of worker i;
2. Given the supply function of worker i, and π, $n\left(w \mid \frac{w_{-1}}{\pi}\right)$, w_j maximizes profits $\Xi_j \equiv n\left(w \mid \frac{w_{-1}}{\pi}\right)\left(Az_j - w\right)$;
3. θ satisfies the free-entry condition $\xi A^{1+\frac{1}{\eta}} = \alpha_f\left(\theta\right)\mathbb{E}\left[\Xi_j\right]$;
4. Vacancies satisfy $\vartheta_v = \theta\vartheta_{u,-1}$, and end-of-period unemployment satisfies $\vartheta_u = \left[1 - \alpha_w\left(\theta\right)\right]\vartheta_{u,-1}$,
5. The goods market clears: $C = \int y_j dj - \xi A^{1+\frac{1}{\eta}}\vartheta_v$, where $y_j = Az_j n\left(w_j \mid \frac{w_{-1}}{\pi}\right)$;
6. Inflation satisfies the monetary rule.

3.1 Labor Supply and the Distribution of Wages

The problem of the worker has already been described in section 2. Utility maximization results in the individual labor supply function

$$n\left(w \mid \frac{w_{-1}}{\pi}\right) = \begin{cases} w^{\frac{1}{\eta}}, & \text{if } w \geq \frac{w_{-1}}{\pi} \\ \left(\frac{\pi}{w_{-1}}\right)^{\frac{1}{\eta_L}-\frac{1}{\eta}} w^{\frac{1}{\eta_L}} & \text{if } w < \frac{w_{-1}}{\pi} \end{cases}. \tag{2}$$

Note how inflation affects hours worked. Suppose first that it is optimal for a firm to keep the nominal wage constant. Then hours worked are w_{-1}/π. Due to real wage erosion, those workers work less when inflation is high. Now suppose that a firm decreases the nominal wage. Workers who suffer a pay cut increase the number of hours when inflation is high (keeping w constant). The reason is that in the loss region, high inflation implies that the distance between the current and past nominal wages is small in real terms. Therefore the utility penalty is small, and workers are inclined to work more. This discussion suggests that in this economy, inflation influences output in two ways: directly by increasing the labor of workers with pay cuts and by decreasing labor for workers with pay freezes, and indirectly by increasing tightness due to high profits.

Once a worker i is attached to a firm j, w_j solves

$$\max_w n\left(w \mid \frac{w_{-1}}{\pi}\right)\left(Az_j - w\right).$$

Taking the first-order conditions, an interior solution in the gain region involves

$$w_j = \frac{Az_j}{1+\eta},$$

valid as long as $Az_j \geq (1+\eta)\frac{w_{-1}}{\pi}$. An interior solution in the loss region involves

$$w_j = \frac{Az_j}{1+\eta_L},$$

valid as long as $Az_j < (1+\eta_L)\frac{w_{-1}}{\pi}$. Since $\eta_L < \eta$, the optimal wage solves

$$w_j = \begin{cases} \frac{Az_j}{1+\eta_L}, & \text{if } Az_j < (1+\eta_L)\left(\frac{w_{-1}}{\pi}\right) \\ \frac{w_{-1}}{\pi}, & \text{if } (1+\eta_L)\left(\frac{w_{-1}}{\pi}\right) \leq Az_j < (1+\eta)\left(\frac{w_{-1}}{\pi}\right) \\ \frac{Az_j}{1+\eta}, & \text{if } Az_j \geq (1+\eta)\left(\frac{w_{-1}}{\pi}\right) \end{cases}.$$

I set w_{-1} at

$$w_{-1} = \frac{A_0}{1+\eta}.$$

This initial condition corresponds to the deterministic steady state of this economy in which loss aversion is irrelevant. Let $A = A_0 e^{\epsilon_A}$, where ϵ_A is the log growth rate of aggregate productivity, $\omega \equiv e^{\epsilon_A}\pi$, and

$$z_\ell \equiv \left(\frac{1+\eta_L}{1+\eta}\right)\frac{1}{\omega}, \quad z_h \equiv \frac{1}{\omega}.$$

The following Proposition shows that wages are downward rigid.

Proposition 2 (Downward Micro Wage Rigidity In Response to Aggregate Shocks)**.** *Suppose that* $z_j = \mathbb{E}\left[z_j\right] = 1$. *Then:*

$$\Gamma_j = \begin{cases} \frac{z_j}{z_\ell}, & \textit{if } z_j < z_\ell \\ 1, & \textit{if } z_\ell \leq z_j < z_h \\ \frac{z_j}{z_h}, & \textit{if } z_j \geq z_h \end{cases}.$$

Figure 3 plots log nominal and real wage growth for a firm with $z_j = 1$ and assuming $\ln \pi = 2\%$. When aggregate productivity goes up, the real wage grows at the growth rate of aggregate productivity. If aggregate productivity goes down, but by less than log inflation, the firm increases the nominal wage while eroding the real wage. For medium negative productivity shocks, the nominal wage is fully rigid. Finally, for large productivity shocks, the real and nominal wage goes down, but by less than at the benchmark without loss aversion. The reason

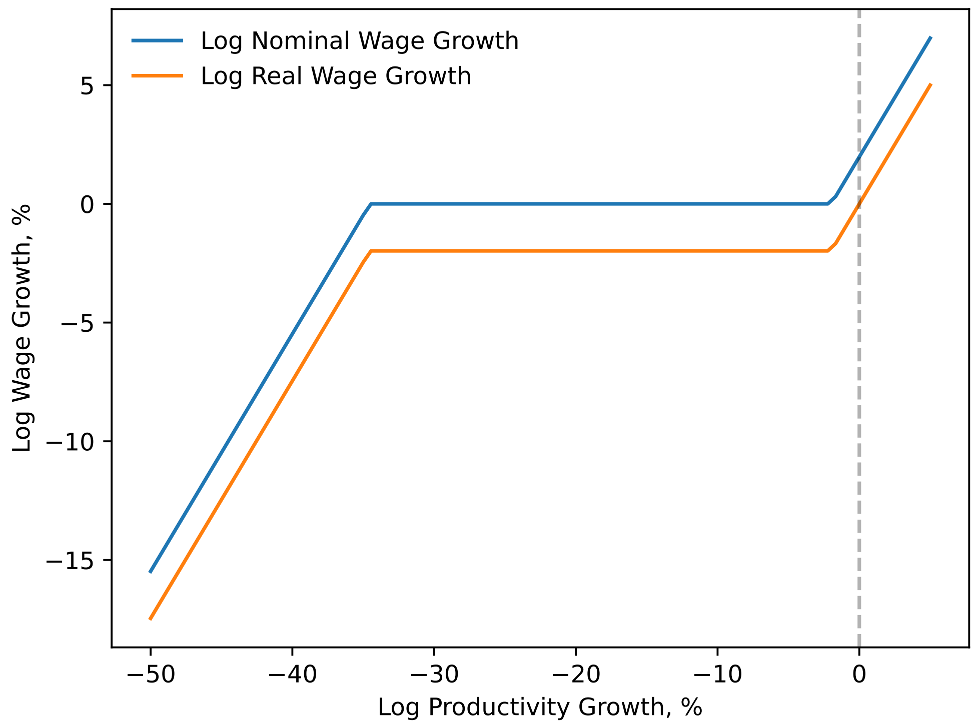

Figure 3: Wage growth in response to an aggregate productivity shock, 2% inflation.

is that in the loss region, supply is more elastic and the monopsonist sets a lower markdown.[4]

For the economy as a whole, firms with very low idiosyncratic productivity relative to the past ($z_j < 1$) decrease wages even if aggregate productivity grows. The next proposition shows that nevertheless, the average wage is sticky downwards.

Proposition 3 (Downward Macro Wage Stickiness in Response to Aggregate Shocks)**.** *Let* $\hat{\Gamma}(\epsilon_A) \equiv \int \ln \Gamma_j dj$, *and let* $\hat{\Gamma}^*(\epsilon_A)$ *be the corresponding growth rate in the economy without loss aversion. Then:*

1. $\hat{\Gamma}^*(\epsilon_A) = \epsilon_A + \ln \pi$;
2. $\hat{\Gamma}(\epsilon_A) > \hat{\Gamma}^*(\epsilon_A)$ *for all* ϵ_A;
3. $\hat{\Gamma}(\epsilon_A) - \hat{\Gamma}^*(\epsilon_A) \to 0$ *as* $\epsilon_A \to \infty$;
4. $\hat{\Gamma}(\epsilon_A) - \hat{\Gamma}^*(\epsilon_A) \to \ln\left(\frac{1+\eta}{1+\eta_L}\right) > 0$ *as* $\epsilon_A \to -\infty$.

Proof. In Appendix B.2. □

[4] I define the markdown, v, as $v = \frac{Az_j}{w}$.

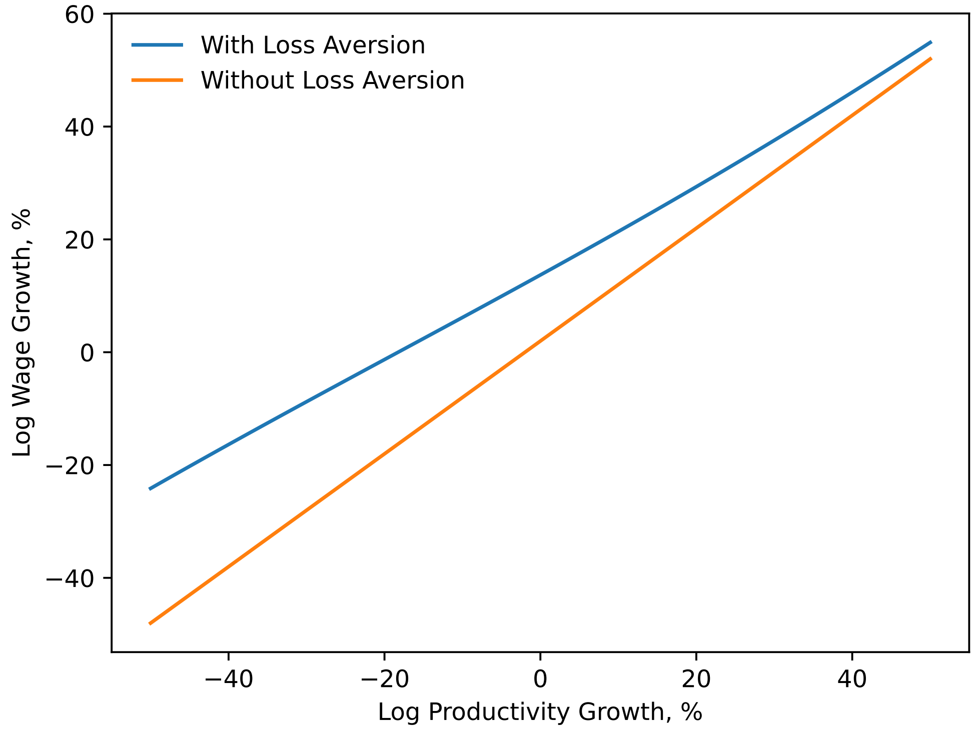

Figure 4: Average wage growth in response to an aggregate productivity shock, 2% inflation.

Figure 4 compares the average nominal wage growth as a function of productivity growth in the economies with and without loss aversion. The growth rate of wages is always higher than at the benchmark without loss aversion. The reason is that some firms keep their wages constant, and conditional on a decrease, the wage markdown is higher than at the benchmark. For positive shocks, as the productivity shock becomes larger, more and more firms increase wages, and so eventually wages grow one-to-one with productivity as in the baseline scenario. For negative shocks, as the productivity shock becomes larger, more and more firms decrease wages, but to a higher level than without loss aversion. So wages decrease by less. Micro wage rigidity translates to macro wage stickiness.

As I pointed out before, the assumption that all the unemployed at the beginning of the period were employed in the pre-period implies that the wage distribution of entrant and incumbent firms is the same. Therefore wages of new hires are as rigid as wages of continuing workers. If some of the initially unemployed were also unemployed in the pre-period, the wage distribution of entrants would exhibit more flexibility because some of the newly hired would have the lowest possible reference point.

Grigsby et al. (2021) show that for new hires, wages are more flexible than for continuing workers. However, this flexibility is not present once we condition on employment history. Therefore the model is in line with the empirical literature.

3.2 Output, Unemployment, Labor Market Tightness, and Equilibrium

I now characterize the behavior of macro variables in this economy. Let Ξ_j be the profits of firm j. Substituting w_j and n_j in the expression for profits,

$$\Xi_j = \left(\frac{A}{1+\eta}\right)^{1+\frac{1}{\eta}} \begin{cases} \eta_L \left[\left(\frac{1+\eta}{1+\eta_L}\right) z_j\right]^{1+\frac{1}{\eta_L}} \omega^{\frac{1}{\eta_L}-\frac{1}{\eta}} & \text{if } z_j < z_\ell \\ \left(\frac{1}{\omega}\right)^{\frac{1}{\eta}} \left[(1+\eta) z_j - \left(\frac{1}{\omega}\right)\right] & \text{if } z_\ell \leq z_j < z_h \\ \eta z_j^{1+\frac{1}{\eta}}, & \text{if } z_j \geq z_h \end{cases}.$$

Let now

$$\Psi(\omega) \equiv \int \frac{\Xi_j}{A^{1+\frac{1}{\eta}}} dj. \tag{3}$$

From the free entry condition,

$$\min\left\{\frac{\xi}{\Psi(\omega)}, 1\right\} = \alpha_f(\theta). \tag{4}$$

Let θ^* be labor market tightness in the economy without loss aversion. Then θ^* satisfies

$$\xi = \alpha_f(\theta^*) \eta \frac{\mathbb{E}\left[z_j^{1+\frac{1}{\eta}}\right]}{(1+\eta)^{1+\frac{1}{\eta}}}.$$

Therefore, at the benchmark without loss aversion, labor market tightness does not depend on productivity. The following Proposition characterizes labor market tightness in this economy.

Proposition 4 (Slanted-L Phillips Curve)**.** *Let $\theta(\omega)$ denote the equilibrium relation between labor market tightness and ω. Then*

1. $\theta'(\omega) \geq 0$;
2. Let $\underline{\omega}$ be defined as $\Psi(\underline{\omega}) = \xi$. For $\omega < \underline{\omega}$, an equilibrium with search does not exist;
3. For all $\omega \geq \underline{\omega}$, $\theta(\omega) < \theta^*$;
4. As $\omega \to \infty$, $\theta \to \theta^*$.

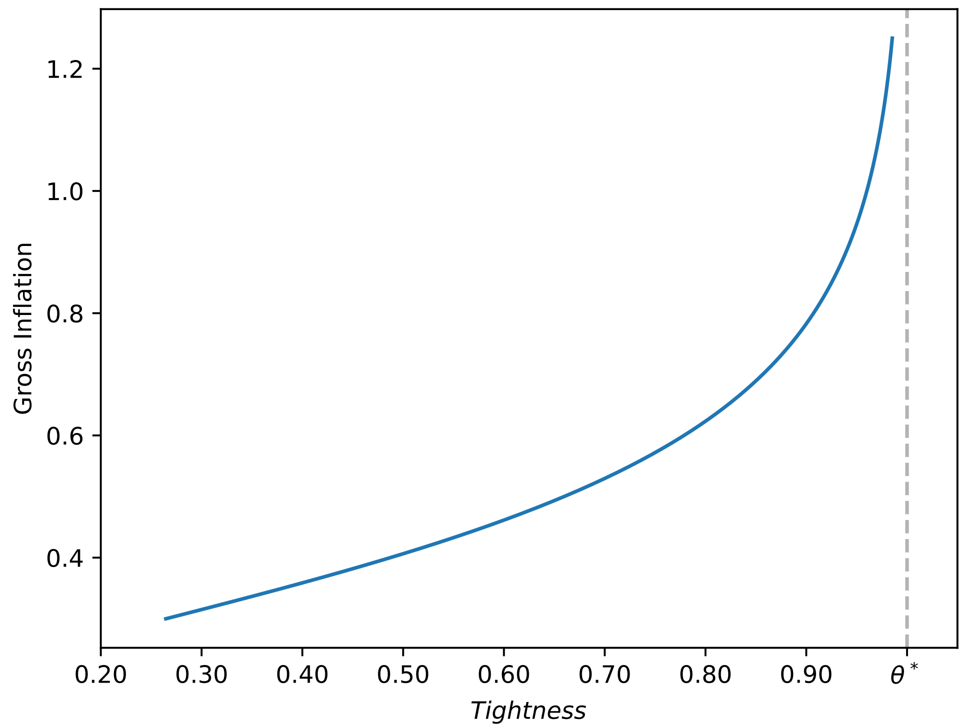

Figure 5: Equilibrium relation between inflation and labor market tightness.

Proof. In Appendix B.3. □

Figure 5 illustrates this Proposition.

Property 1 is due to the fact that expected profits are increasing in inflation. As inflation increases, the status quo wage decreases in real terms, and therefore firms are more likely to face the less elastic part of labor supply. Since profits increase, for the same labor market tightness firms have a strictly positive surplus from posting a vacancy. Firms enter the market until the probability of finding a worker decreases to the point that erases that surplus.

Property 2 immediately follows. As inflation becomes too low, firms are more likely to face the more elastic part of supply. Moreover, because in the loss region labor supplied depends on the distance between the current and past nominal wages, workers are less and less inclined to work. As a consequence profits go to zero, implying that there is a minimum inflation level such that it pays off to post vacancies. Below that point, the economy is populated solely by incumbents.

Properties 3 and 4 follows from the fact that without loss aversion, expected profits are strictly higher.

It follows that the model implies a nonlinear Phillips curve in the tightness-inflation space of the sort that has been documented by Benigno and Eggertsson (2024). The mechanism in my model, however, is very different. When inflation is low, it is as if firms face a negative productivity shock. A bigger fraction of firms is more inclined to keep wages constant, (optimally) eroding production profits. Labor market tightness has to go down. On the other hand, when inflation is high, firms are more likely to increase wages, so tightness asymptotes towards the no-loss-aversion equilibrium. For Benigno and Eggertsson (2024) causality is reversed. When tightness is high, it is hard to find a worker. Firms pass the high hiring costs to prices, increasing inflation.

The previous proposition can be restated in terms of unemployment. In this economy,

$$\vartheta_u\left(\pi e^A\right) = \left\{1 - \alpha_w\left[\theta\left(\pi e^A\right)\right]\right\}\vartheta_{u,-1}.$$

Therefore unemployment is negatively related to inflation, which suggests a classic, negatively sloped Phillips curve.

3.3 Equilibrium

Equilibrium inflation and labor market tightness are obtained from equations (1) and (4).

Lemma 1. *The equilibrium exists and is unique.*

Proof. Equation (1) defines a negative relation between tightness and inflation, with $\pi \to \infty$ as $\theta \to 0$ and $\pi \to 0$ as $\theta \to \infty$. By Proposition (4), equation (4) defines a positive relation between tightness and inflation, with $\pi \to 0$ as $\theta \to 0$ and $\pi \to \infty$ as $\theta \to \theta^*$. Therefore the equilibrium exists and, moreover, it is unique. □

To compute equilibrium inflation, I first assume that in the absence of an aggregate productivity shock there is no inflation. Picture 6 suggests that in this economy prices rise faster than they decrease.

The intuition is as follows. When productivity goes up, real wages grow one-to-one with productivity, but when productivity goes down, real wages decline by less than one-to-one. The increase in marginal costs puts additional pressure in the goods market, and prices go up faster.

Analogously, labor market tightness and unemployment also react more strongly to a cost increase than to a cost decrease.

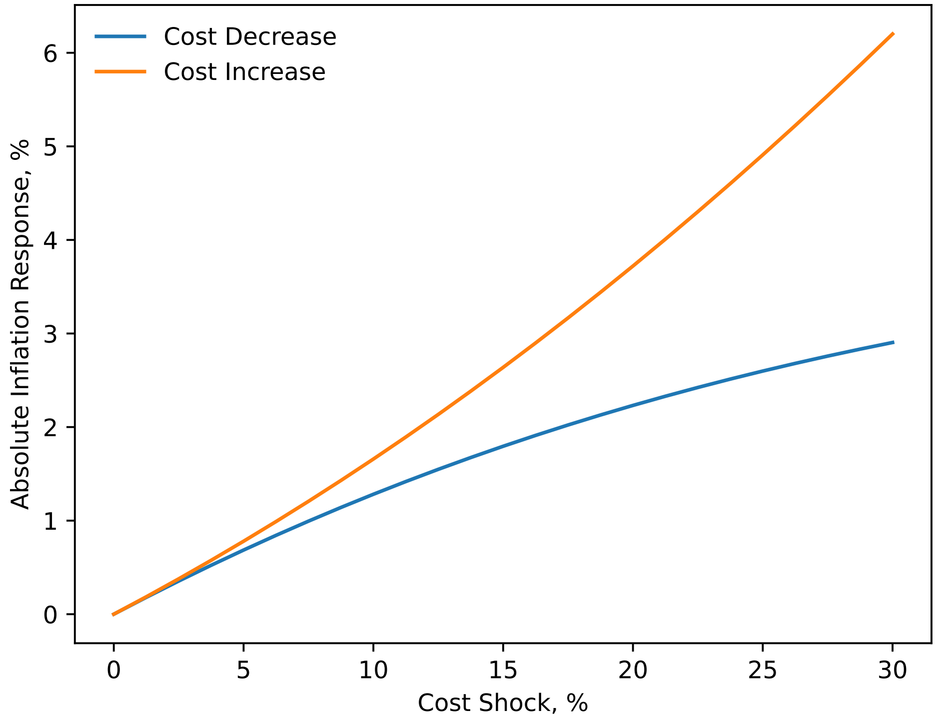

Figure 6: Response of log inflation to aggregate productivity, in absolute terms.

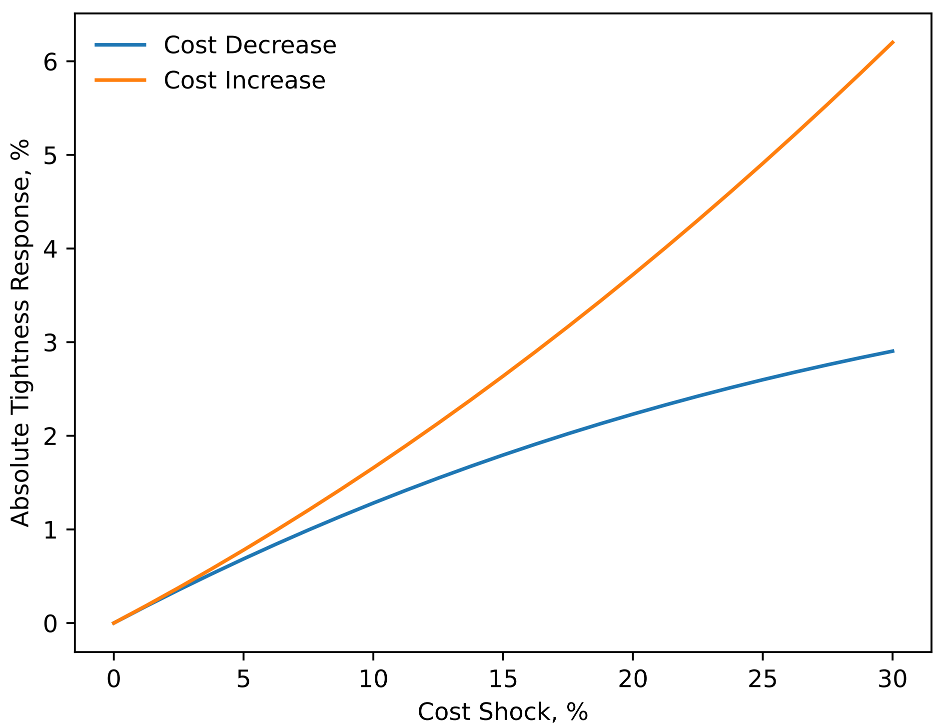

Figure 7: Response of labor market tightness to aggregate productivity, in absolute terms.

3.4 Optimal Policy

How should monetary policy be conducted? For simplicity, assume that $\vartheta_{u,-1} = 1$, so that everyone starts the current period in unemployment. Then welfare in this economy can be written as

$$\mathcal{W}(\omega) = \alpha_w(\omega)\,\overline{\mathcal{U}}(\omega),$$

where $\overline{\mathcal{U}}(\omega)$ is proportional to average utility per employed worker. The next Proposition shows that there are potential gains from inflation.

Proposition 5. *At an interior optimum, the optimal ω is characterized by*

$$\frac{\alpha_w'[\theta(\omega)]}{\alpha_w[\theta(\omega)]}\theta'(\omega) = -\frac{\overline{\mathcal{U}}'(\omega)}{\mathcal{U}(\omega)} \tag{5}$$

Therefore $\overline{\mathcal{U}}'(\omega) < 0$ at the optimum. Moreover, under parameter conditions, the optimum involves $\omega > 1$.

At the optimum, there is a utility transfer from continuing to new workers. With inflation, worker welfare per employed worker goes down due to real wage erosion. However, it increases expected profits for new firms because loss aversion becomes less important. Equilibrium tightness increases, which increases the number of workers who are able to find a job.

Equation (5) is intimately related to the standard efficiency condition in labor search models first described by Hosios (1990). To see why, it is useful to consider the function

$$\mathcal{B}(\omega) \equiv \left[\overline{\Psi}(\omega)\right]^{1-\phi}\left[\overline{\mathcal{U}}(\omega)\right]^{\phi}.$$

$\mathcal{B}(\omega)$ corresponds to the generalized Nash product that would arise at an equilibrium $\omega = \pi e^{\epsilon_A}$. $\mathcal{B}(\omega)$ is not in general maximized at the competitive equilibrium because wages are determined as take-it-or-leave-it offers. In any case, consider an infinitesimal change in ω that leaves the Nash product from a firm-worker meeting unchanged. Along $\mathcal{B}(\omega) = \overline{\mathcal{B}}$,

$$\frac{\overline{\mathcal{U}}'(\omega)}{\overline{\mathcal{U}}(\omega)} = -\left(\frac{1-\phi}{\phi}\right)\frac{\overline{\Psi}'(\omega)}{\overline{\Psi}(\omega)}.$$

Substituting in equation (5), and recognizing that the elasticity of the job-finding probability is equal to 1 plus the elasticity of the vacancy-filling probability,

$$\begin{aligned} & \frac{\alpha_w' \left[\theta\left(\omega\right)\right]}{\alpha_w \left[\theta\left(\omega\right)\right]} \frac{\overline{\Psi}'\left(\omega\right)}{\overline{\Psi}\left(\omega\right)} = -\left(\frac{1-\phi}{\phi}\right) \frac{\overline{\Psi}'\left(\omega\right)}{\overline{\Psi}\left(\omega\right)} \frac{\alpha_f' \left[\theta\left(\omega\right)\right]}{\alpha_f \left[\theta\left(\omega\right)\right]} \\ \iff & -\hat{\alpha}_f \left[\theta\left(\omega\right)\right] = \phi. \end{aligned}$$

This equality is exactly the Hosios (1990) condition. Therefore inflation might be able to ameliorate the congestion externality.[5] [6]

Finally, note that only ω is optimally determined. Therefore optimal inflation policy involves

$$\ln \pi^* = \ln \omega^* - \epsilon_A,$$

While steady state inflation is positive, monetary policy should still be countercyclical.

4 The Infinite-Period Model

In this section, I develop an infinite-period version of the model without aggregate shocks. Time is indexed by $t = 0, 1, \ldots$.

I assume that the search process takes one period. This assumption does not influence the problem of optimal wage setting, but simplifies the computation of the ergodic wage distribution. However, the assumption does imply that the wages of new hires are fully flexible, since any vacancy is filled by a worker who was previously unemployed. The timing within each period is as follows:

1. In the morning, workers and firms meet, firms make their wage offers, and production and consumption occur.

2. In the afternoon, workers and firms separate with probability δ.

3. In the evening, firms post vacancies, and workers search.

I assume that in period t, output produced by firm j is

$$y_{j,t} = z_{j,t} n_{j,t}^{\alpha},$$

[5]Note that 4 raises the possibility that implementing the social optimum might not be possible, since in this economy the maximum attainable labor market tightness is θ^*.

[6]Abo-Zaid (2013) studies optimal monetary policy in a setting that is similar to mine, except that nominal downward wage rigidity is exogenously imposed as an adjustment cost on firms. In his model, strictly positive inflation is optimal, but nominal price rigidities and the money demand motive are necessary to bring optimal inflation to a level that is more aligned with data.

where $\ln z_{j,t}$ follows a normal distribution with mean zero and variance σ_z^2, and is i.i.d. across firms and time. I impose the i.i.d. assumption to ensure that all persistence in wages is due to loss aversion.

I assume that workers are myopic. This assumption implies that they accept any wage offer made by the firm, and, most importantly, that they do not take into consideration the reference effect of the current wage on future utility. The latter implication is related to the concept of myopic loss aversion (Thaler et al. (1997)), which has been found to substantially mitigate the equity premium puzzle. It follows that at each point in time, workers solve a static problem and post the supply function

$$n\left(w' \mid w\right) = \begin{cases} \left[\pi\left(\frac{w'}{w}\right)\right]^{\frac{\lambda-1}{\eta}} \left(w'\right)^{\frac{1}{\eta}}, & \text{if } w' < \frac{w}{\pi} \\ \left(w'\right)^{\frac{1}{\eta}}, & \text{if } w' \geq \frac{w}{\pi} \end{cases},$$

where w' is the current real wage offer, and w the real wage offer in the previous period.

Capitalists discount the future at rate $\frac{1}{\beta} > 1$, and invest in government debt at nominal interest rate R_t. R_t is set by the government according to a Taylor rule that responds to inflation and output.

I characterize the stochastic stationary equilibrium of this economy with constant inflation, labor market tightness, and unemployment. At the steady state, consumption of capitalists is also constant, so that their Euler equation is

$$\frac{1}{\beta} = \frac{R}{\pi}.$$

The Taylor rule is

$$\frac{R}{\overline{R}} = \left(\frac{\pi}{\overline{\pi}}\right)^{\phi_\pi} \left(\frac{\theta}{\overline{\theta}}\right)^{\phi_\theta},$$

where ϕ_π, $\phi_\theta > 0$, and $\overline{\pi}$, $\overline{\theta}$, and $\overline{R}$ are the targets for inflation, tightness, and nominal interest rate, respectively. Combining these two equations yields an equilibrium relation between inflation and labor market tightness:

$$\frac{\pi}{\overline{\pi}} = \left[\frac{\overline{\pi}}{\beta\overline{R}} \left(\frac{\theta}{\overline{\theta}}\right)^{-\phi_\theta}\right]^{\frac{1}{\phi_\pi - 1}}.$$

Assuming that $\beta\overline{R} = \overline{\pi}$ and that the Taylor rule is active ($\phi_\pi > 1$),

$$\frac{\pi}{\overline{\pi}} = \left(\frac{\theta}{\overline{\theta}}\right)^{-\phi},$$

where $\phi > 0$.[7] I assume that the equilibrium involves $\pi = \overline{\pi}$ and $\theta = \overline{\theta}$, where $\overline{\pi}$ and $\overline{\theta}$ satisfy the free entry condition

$$\xi = \beta\alpha_f(\theta)\,\mathcal{J}(0;\pi),$$

where $\mathcal{J}(0;\pi)$ denote the expected profits from vacancy posting at reference point 0 and inflation π, and ξ is the unit cost of vacancy posting. I assume that ξ is sufficiently small so that the equilibrium exists.

4.1 The Problem of the Firm and the Individual Response to Shocks

I now turn to the recursive formulation of the firm's problem. At each point in time, the firm solves the Bellman equation

$$J(w,z) = \max_{w' \geq 0}\left\{r(w',w,z) + \beta(1-\delta)\,\mathcal{J}(w')\right\}, \tag{6}$$

where

$$\mathcal{J}(w) \equiv \int J(w,z)\,F_z(dz)$$

is the expected value function at reference w, and

$$r(w',w,z) \equiv z\left[n(w' \mid w)\right]^\alpha - w'n(w',w)$$

is the contemporaneous profit. The solution for the value function is unique because Blackwell's sufficient conditions are satisfied.

Let

$$\sigma(w,z) \equiv \underset{w' \geq 0}{\text{argmax}}\left\{r(w',w,z) + \beta(1-\delta)\,\mathcal{J}(w')\right\}.$$

The following Lemma establishes some properties of the solution to the firm's problem.

Lemma 2. *Let $\sigma_\ell(w,z)$ and $\sigma_h(w,z)$ denote the interior solutions for the current real wage in the loss and gain regions, respectively. Let also $\sigma_{static}(w,z)$ denote the policy function if $\beta = 0$. The value function $J(w,z)$ and policy function $\sigma(w,z)$ satisfy the following properties.*

1. *$J(w,z)$ is non-increasing in w and strictly increasing in z;*

[7] This equation rationalizes the monetary rule I assumed in Section 2.

2. *For all w and z, $\sigma(w,z) \leq \sigma(w,z)$;*

3. *For each state w and z, $r[\sigma(w,z), w, z] \geq 0$;*

4. *For all w, there productivity bounds $z_\ell(w)$ and $z_h(w)$, satisfying $z_\ell(w) \leq z_h(w)$, such that*

$$\sigma(w,z) = \begin{cases} \sigma_\ell(w,z), & \textit{if } z < z_\ell(w) \\ \frac{w}{\pi'}, & z_\ell(w) \leq z \leq z_h(w) \\ \sigma_h(w,z), & \textit{if } z > z_\ell(w) \end{cases}.$$

5. $\mathcal{J}'(0) = \lim_{w\to\infty} \mathcal{J}(w) = 0.$

Proof. Property 1 is due to the fact that the Bellman operator in (6) maps a function $\tilde{J}(w,z)$ that is non-increasing in w and non-decreasing in z to a function satisfying that property. Property 2 follows as a corollary. Because J is non-increasing in w, $\mathcal{J}'(w) \leq 0$, which implies that at any interior solution to the static problem, where $r_1(w', w, z) = 0$, the first derivative with respect to w' is non-positive. Property 3 follows immediately, since optimal profits are non-negative in the static problem. Properties 4 and 5 are derived from the first-order necessary conditions for $\sigma(w,z)$, and from the envelope condition that characterizes $\mathcal{J}'(w)$. □

As in the static model, there is an inaction region for productivity in which the nominal wage is constant. Differently from the static model, however, there is a precautionary motive for not increasing wages in response to a positive shock.

The derivative of the expected value function, plotted in Figure 11, is useful to characterize this dynamic effect. For low initial real wages, changes in the reference have little impact on the continuation value: in the future, the firm is likely to have a productivity level such that it is optimal to set a higher wage. For high initial real wages, the intuition is analogue, except that the marginal effect of a reference increase is zero because in the future the firm is likely to be in the loss region.

Figure 9 illustrates this result in terms of the policy functions. It shows the optimal nominal wage growth set by a firm that was born with productivity z, and experiences an idiosyncratic productivity shock the following period. The orange dotted line is optimal nominal wage growth in an economy without loss aversion.

If the firm initially had moderate productivity, the passthrough of a positive shock to the nominal wage is small. If the firm initially had low productivity, the passthrough is nearly complete, and the dynamic effect of loss aversion is irrelevant.

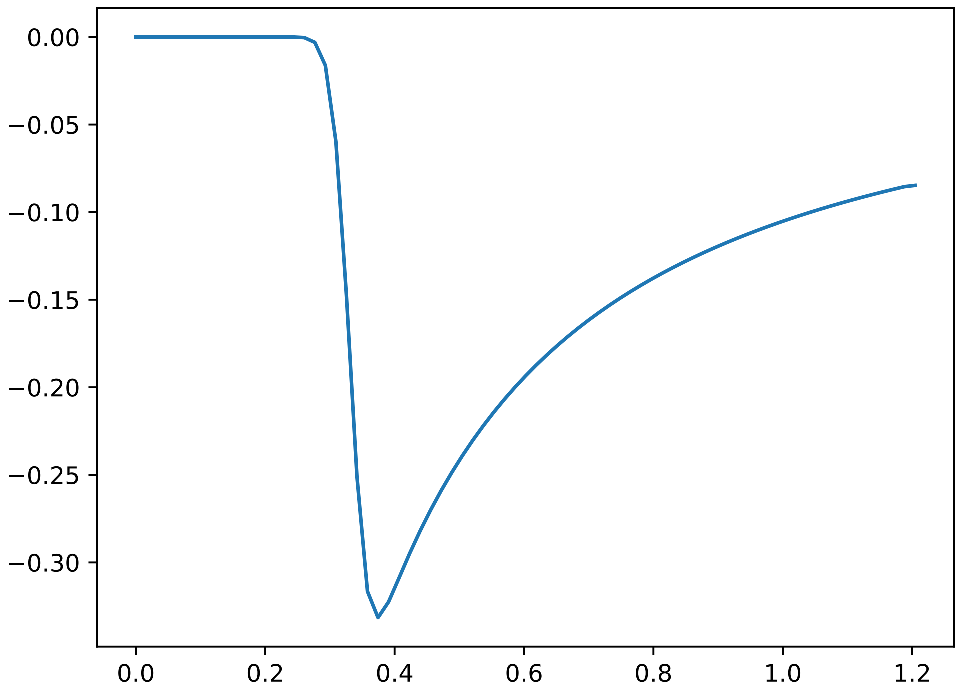

Figure 8: $\mathcal{J}'(w)$.

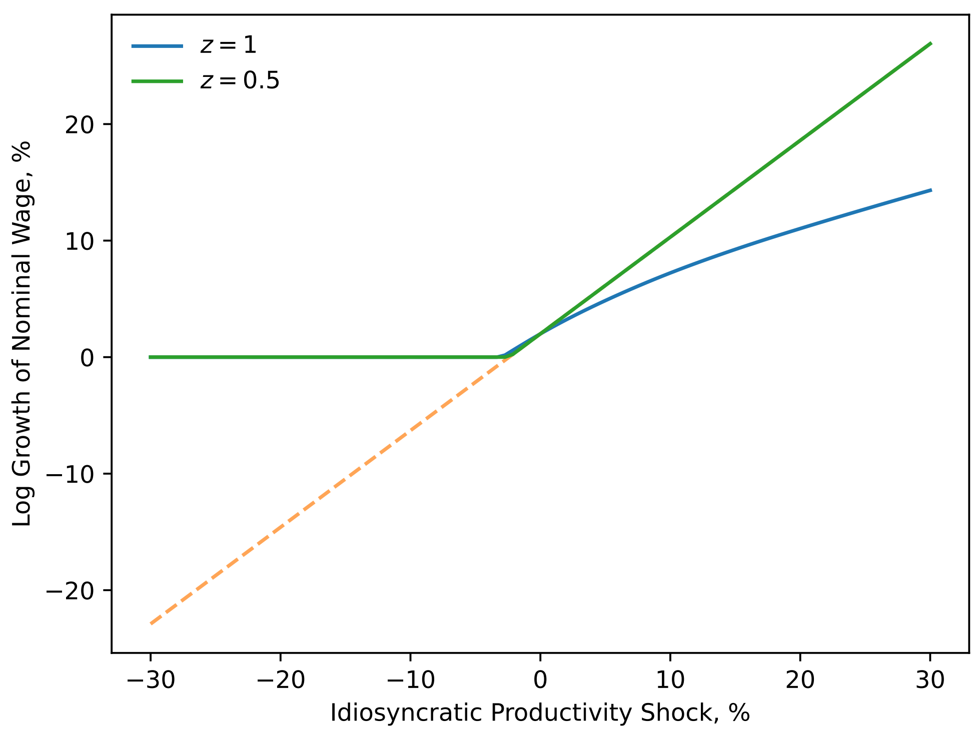

Figure 9: Optimal nominal wage growth.

The model implies state-dependence in wage setting. Figure 10 plots the probability of a nominal wage change as a function of the initial real wage. For firms with both low and high initial wages, the probability is nearly one. This property is due to the fact that firms with low wages almost certainly want to increase them because productivity is high, and firms with high wages almost certainly want to decrease them because productivity is low. Firms in the middle have the highest probability of keeping the wage fixed because productivity most likely aligns with their past wage.

The figure therefore has a menu-cost interpretation. In a random menu cost model, each firm has an optimal reset price, and draws an adjustment cost in each period. The firm chooses to reset its price if the current price gap, the difference between the previous and the optimal reset prices, is not too large relative to the menu cost. The model generates, for each price gap, a reset probability based on the distribution of menu costs.

In my model, consider the initial wage for which the probability of a wage change is minimized. That wage is close to the average wage in the economy, and therefore in expectation firms always revert to that wage. For each firm, there is always a region of productivity shocks such that it is optimal for them to change wages. On average, they change their wage to the mean wage. The distribution of productivity shocks therefore implies a reset probability for each wage gap, where the gap is now defined as the difference between the previous period's and the current wages. In this model, the probability is asymmetric: when the initial wage increases above average, the probability of wage change increases more slowly than when the initial wage decreases below average. This discussion suggests that this model produces wage dynamics that are similar to an asymmetric menu-cost model, a class of models that is suggested by Grigsby et al. (2021) to capture the observed state-dependence in data. However, while typically in a menu cost model price changes are large, in this model there are many small wage changes. The observed distribution of wage changes in the data exhibits this feature as well (even though more so in the region of positive wage changes).

Figure 11 shows how the nominal wage set by a firm with initial productivity $z = 1$ responds to a temporary shock in its second period of operations. The blue line represents the log change the nominal wage relative to the initial period. The orange dotted line is the analogous at the benchmark without loss aversion. The left panel plots the response to a positive shock, while the right panel plots the response to a negative shock.

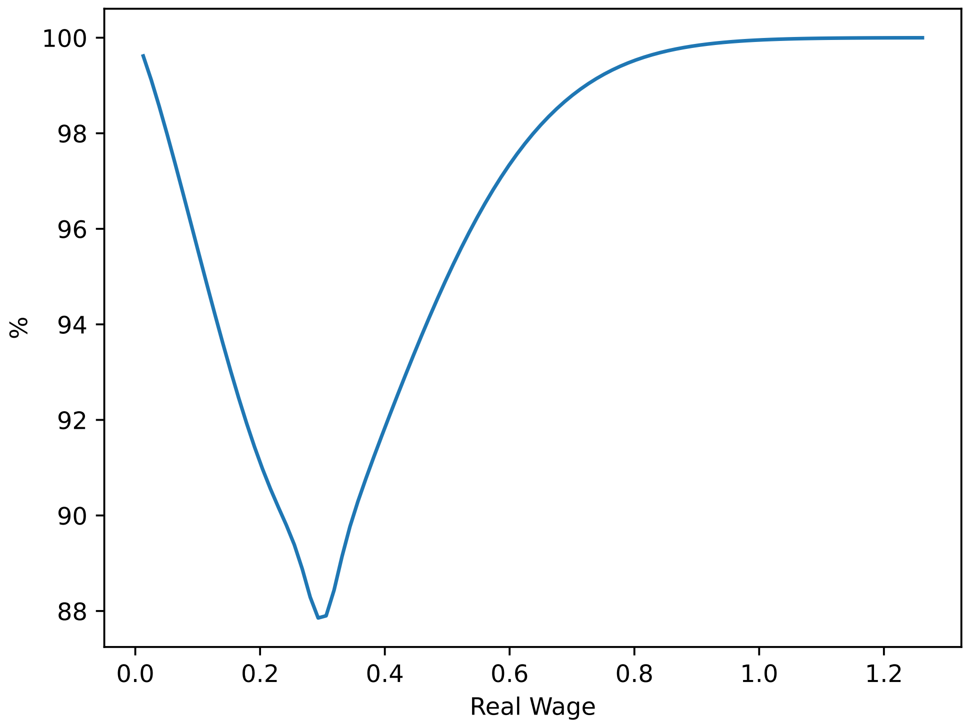

Figure 10: Probability of nominal wage change as a function of the initial real wage.

In both panels, the nominal wage change eventually coincides with the benchmark without loss aversion. The reason is that in the absence of shocks, nominal wages have the same cumulative growth in both scenarios, equal to the cumulative sum of log inflation. Therefore, after period 2, the orange line also represents the steady state path of nominal wages.

In the right panel, the nominal wage does not decrease in response to a negative shock, and goes back to trend one period after. In the right panel, the nominal wage increases, but by less than in the benchmark without loss aversion. It stays constant for many periods, until inflation brings the real wage close to (marked down) marginal productivity.

The asymmetry in the initial response was already captured by the static model of Section 3, except for the small upward movement in the case of a positive shock. The asymmetry in the speed of adjustment is new. In the case of a negative shock, the fact that the nominal wage stays constant means that it also stays close to the steady state. Therefore it catches up quickly. In the case of a positive shock, the nominal wage moves away from, and above its steady state trend. In order to avoid future wage decreases, the firm pays a constant nominal wage until inflation has sufficiently eroded the real wage, after which it reverts back to its steady state trend.

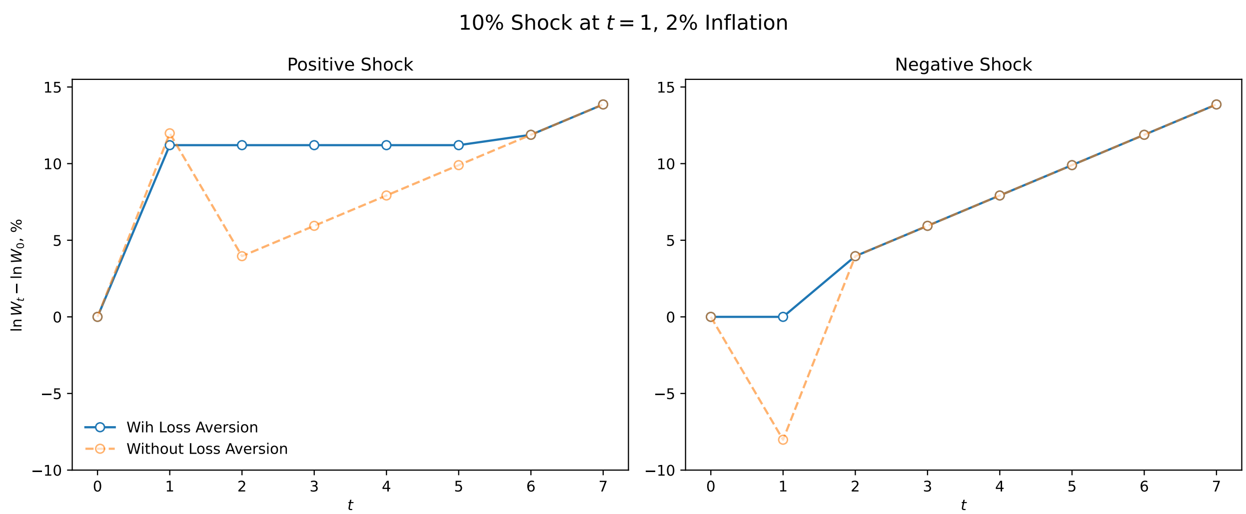

Figure 11: Equilibrium path of wages.

4.2 Ergodic Distribution of Nominal Wage Changes

To study whether the model is able to account of the distribution of nominal wage changes observed in the data, I calibrate the model with parameter estimates from the literature. Table 1 describes the calibration. The only exception is σ_z, which I calibrate to match the variance of the yearly nominal wage change distribution for job-stayers in Grigsby et al. (2021). As is common in the literature on firm monopsony power (Berger et al. (2022)), I assume that $\nu = 0$ for workers.

Parameter	Description	Value	Source
ψ	Inverse of the Frisch elasticity	2.0	Chetty et al. (2011)
λ	Coefficient of loss aversion	3.0	Crawford and Meng (2011)
β	Discount factor	0.9968	Christiano et al. (2016)
α	Labor share of income	0.59	Karabarbounis and Neiman (2014)
δ	Separation probability (Weekly)	0.005	Fujita and Ramey (2012)

Table 1: Parameter Values

At the stationary equilibrium, the unemployment rate satisfies the standard equation:

$$\vartheta_u = \frac{\delta}{\alpha_w(\theta) + \delta}.$$

Moreover, the fraction of jobs that are destroyed, δ, must be equal to the fraction of jobs that are created. It follows that the ergodic distribution of wages, $p(w)$, satisfies

$$p(w) = (1-\delta)\int \mathcal{P}(w \mid \tilde{w})\, p(\tilde{w})\, d\tilde{w} + \delta p_v(w),$$

where $\mathcal{P}$ is the endogenous Markov matrix and $p_v(w)$ is the density of entrants with wage w.

The implied distribution is plotted in Figure 12.

The model also implies, consistent with Card and Hyslop (1997) and Dickens et al. (2007), that an economy with high inflation will have a higher degree of real wage flexibility. Figure 13 illustrates this property. As inflation grows, optimal real wage setting is less and less constrained by the nominal reference point. Therefore the distribution of real wage changes approaches a symmetric distribution, with the probability of a pay freeze converging to zero.

5 Conclusion

In this paper, I developed a model that rationalizes the phenomenon of downward wage rigidity with two main ingredients: the cognitive bias of loss aversion, and a frictional labor market.

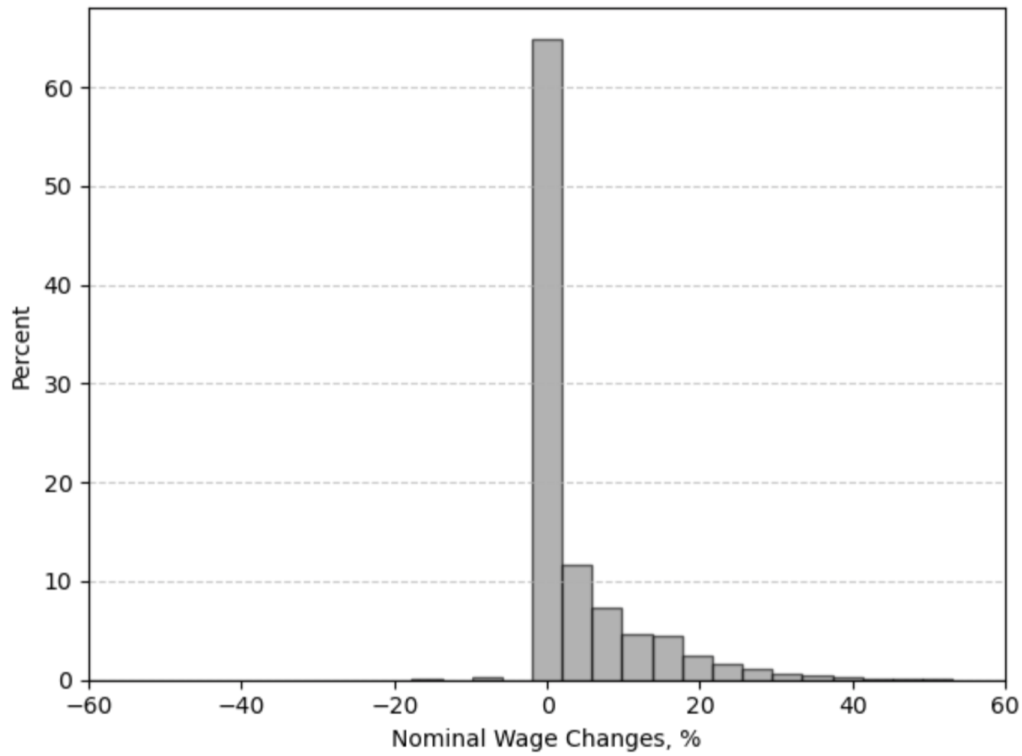

Figure 12: Stationary distribution of nominal wage changes.

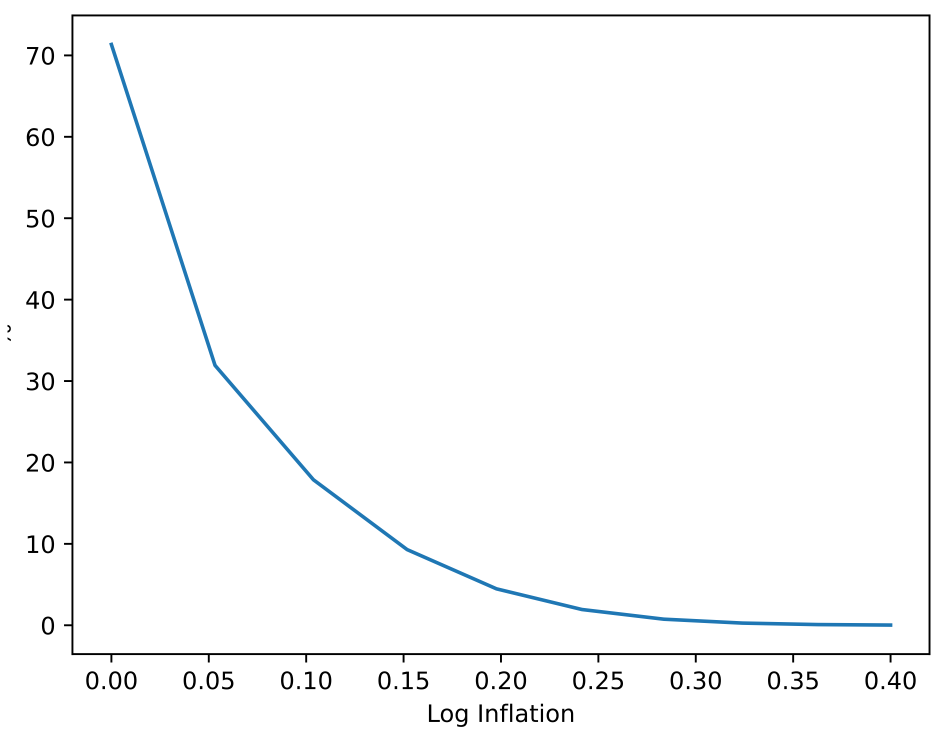

Figure 13: Fraction of real pay freezes.

Not only is the model well-aligned with micro-data, but it also has macro and policy implications.

There are potentially three extensions that could provide useful insights.

First, the dynamic model should be extended to include aggregate shocks. Studying how this economy reacts to large shocks can provide insights that other models of downward wage rigidity cannot.

Second, unemployment benefits may have a different impact in this economy than in other standard models. Christiano et al. (2016) show that an increase in unemployment benefits outside of the zero lower bound cause a decrease in employment. With loss aversion, however, there is an added incentive not to decrease wages in recessions. Therefore workers might be less inclined to quit their jobs, which suggests that an increase in unemployment benefits may have smaller effects in this economy.

Finally, the fact that workers' utility depends on the nominal wage set by the firm suggests that statutory incidence may be relevant. Appendix C shows that this is the case. This property suggests that policies that are equivalent in standard models may not be so with loss aversion. An example is the common equivalence between nominal and fiscal devaluations.

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A Loss Aversion Over Total Utility

Consider now the following formulation for loss aversion:

$$U = v\left[u\left(n; \frac{W_i}{P}\right) - g(n)\right],$$

where

$$v\left(u\left(n; \frac{W_i}{P}\right) - g(n)\right) = \begin{cases} u\left(n; \frac{W_i}{P}\right) - g(n), & \text{if } u\left(n; \frac{W_i}{P}\right) \geq u\left(n; \frac{\overline{W}_i}{P}\right) \\ \begin{array}{l} u\left(n; \frac{\overline{W}_i}{P}\right) - g(n) + \\ +\lambda\left\{u\left(n; \frac{W_i}{P}\right) - u\left(n; \frac{\overline{W}_i}{P}\right)\right\} \end{array} & \text{if } u\left(n; \frac{W_i}{P}\right) < u\left(n; \frac{\overline{W}_i}{P}\right) \end{cases}.$$

Substituting the functional forms and simplifying, I obtain

$$\mathcal{U}\left(n; \frac{W_i}{P}\right) = \begin{cases} \frac{\left(\frac{W_i}{P}\right)^{1-\sigma} n^{1-\sigma}}{1-\sigma} - \frac{n^{1+\psi}}{1+\psi}, & \text{if } \frac{W_i}{P} \geq \frac{\overline{W}_i}{P} \\ \left(\frac{\overline{W}_i}{P}\right)^{1-\sigma} \frac{n^{1-\sigma}}{1-\sigma} - \frac{n^{1+\psi}}{1+\psi} + \lambda\left[\left(\frac{W_i}{P}\right)^{1-\sigma} - \left(\frac{\overline{W}_i}{P}\right)^{1-\sigma}\right] \frac{n^{1-\sigma}}{1-\sigma} & \text{if } \frac{W_i}{P} < \frac{\overline{W}_i}{P} \end{cases}.$$

In the loss region, the first-order condition for labor yields

$$n\left(\frac{W_i}{P} \mid \frac{\overline{W}_i}{P}\right) = \left\{\left(\frac{\overline{W}_i}{P}\right)^{1-\sigma} + \lambda\left[\left(\frac{W_i}{P}\right)^{1-\sigma} - \left(\frac{\overline{W}_i}{P}\right)^{1-\sigma}\right]\right\}^{\frac{1}{\sigma+\psi}}.$$

This solution is only valid if

$$\begin{aligned} &\left(\frac{\overline{W}_i}{P}\right)^{1-\sigma} + \lambda\left[\left(\frac{W_i}{P}\right)^{1-\sigma} - \left(\frac{\overline{W}_i}{P}\right)^{1-\sigma}\right] \geq 0 \\ \iff &\lambda\left(\frac{W_i}{P}\right)^{1-\sigma} \geq (\lambda - 1)\left(\frac{\overline{W}_i}{P}\right)^{1-\sigma} \\ \iff &\frac{W_i}{P} \geq \left(\frac{\lambda - 1}{\lambda}\right)^{\frac{1}{1-\sigma}} \frac{\overline{W}_i}{P}. \end{aligned}$$

The fact that there is a minimum acceptable wage leads to difficulties in the profit maximization problem.

B Proofs

B.1 Proof of Proposition 1

Aggregate supply is

$$N^s\left(w \mid w_{-1}\right) = \begin{cases} w^{\frac{1}{\eta}}, & \text{if } w \geq w_{-1} \\ w_{-1}^{\frac{1}{\eta}} \left(\frac{w}{w_{-1}}\right)^{\frac{1}{\eta_L}} & \text{if } w < w_{-1} \end{cases}.$$

Aggregate demand is

$$N^d\left(w\right) = \left[\frac{\alpha A e^{\frac{1}{2}\left(\frac{\alpha}{1-\alpha}\right)\sigma_z^2}}{w}\right]^{\frac{1}{1-\alpha}}.$$

For an equilibrium to involve $w \geq w_{-}$, it must be that

$$w^{\frac{1}{\eta}} = \left[\frac{\alpha A e^{\frac{1}{2}\left(\frac{\alpha}{1-\alpha}\right)\sigma_z^2}}{w}\right]^{\frac{1}{1-\alpha}}$$

$$\iff w = \left[\alpha A e^{\frac{1}{2}\left(\frac{\alpha}{1-\alpha}\right)\sigma_z^2}\right]^{\frac{\frac{1}{1-\alpha}}{\frac{1}{\eta}+\frac{1}{1-\alpha}}}.$$

This equilibrium is valid if

$$A \geq \frac{e^{-\frac{1}{2}\left(\frac{\alpha}{1-\alpha}\right)\sigma_z^2}}{\alpha} w_{-1}^{\frac{\frac{1}{\eta}+\frac{1}{1-\alpha}}{\frac{1}{1-\alpha}}}.$$

Otherwise, the equilibrium is

$$w_{-1}^{\frac{1}{\eta}} \left(\frac{w}{w_{-1}}\right)^{\frac{1}{\eta_L}} = \left[\frac{\alpha A e^{\frac{1}{2}\left(\frac{\alpha}{1-\alpha}\right)\sigma_z^2}}{w}\right]^{\frac{1}{1-\alpha}}$$

$$\iff w = \left\{ w_{-1}^{\alpha\left(\frac{1}{\eta_L}-\frac{1}{\eta}\right)} \left[\alpha A e^{\frac{1}{2}\left(\frac{\alpha}{1-\alpha}\right)\sigma_z^2}\right] \right\}^{\frac{\frac{1}{1-\alpha}}{\frac{1}{\eta_L}+\frac{1}{1-\alpha}}}$$

B.2 Proof of Proposition 3

Without loss aversion,

$$w_j = \frac{A z_j}{1+\eta}.$$

Therefore

$$\Gamma_j^* = \frac{W_j}{W_{-1}} = \pi \frac{w_j}{w_{-1}} = \pi e^{\epsilon_A} z_j.$$

Part 1 follows from taking logs, expectation, and using the fact that $\mathbb{E}\left[\ln z_j\right] = 0$.

Next consider the remaining parts. Log nominal wage growth for firm j is

$$\ln \Gamma_j = \begin{cases} \ln z_j - \ln z_\ell, & \text{if } \ln z_j < \ln z_\ell \\ 0, & \text{if } \ln z_\ell \leq \ln z_j \leq \ln z_h \\ \ln z_j - \ln z_h, & \text{if } \ln z_j > \ln z_h \end{cases}.$$

Now note that

$$\ln z_h = -\epsilon_A - \ln \pi$$

and

$$\ln z_\ell = \ln\left(\frac{1+\eta_L}{1+\eta}\right) - \epsilon_A - \ln \pi.$$

Therefore

$$\ln \Gamma_j - \ln \Gamma_j^* = \begin{cases} \ln\left(\frac{1+\eta}{1+\eta_L}\right), & \text{if } \ln z_j < \ln z_\ell \\ -\left(\ln z_j + \epsilon_A + \ln \pi\right), & \text{if } \ln z_\ell \leq \ln z_j \leq \ln z_h \\ 0, & \text{if } \ln z_j > \ln z_h \end{cases}.$$

Clearly this random variable is non-negative. Moreover, since z_ℓ and z_h are of the same order with respect to $\ln \omega$, it follows that as $\ln \omega \to \pm\infty$, the region $\ln z_\ell \leq \ln z_j \leq \ln z_h$ vanishes from the expectation (see Abramowitz and Stegun (1968), Sec. 26.2.). As $\omega \to \infty$, $\lim_{\omega \to \infty} z_\ell = \lim_{\omega \to \infty} z_h = -\infty$, and the expectation goes to zero. As $\omega \to -\infty$, $\lim_{\omega \to \infty} z_\ell = \lim_{\omega \to \infty} z_h = \infty$, and the expectation goes to $\ln\left(\frac{1+\eta}{1+\eta_L}\right) > 0$.

B.3 Proof of Proposition 4

For part 1, applying Leibniz's integral rule to (3) shows that $\Psi'(\omega) > 0$. From the implicit function theorem,

$$\theta'(\omega) = -\frac{\hat{\Psi}(\omega)}{\hat{\alpha}_f(\theta)} > 0,$$

where $\hat{\Psi}(\omega) \equiv d \ln \Psi(\omega) / d \ln \omega$ and $\hat{\alpha}_f(\theta) \equiv d \ln \alpha_f(\theta) / d \ln \theta$. The derivative is positive because $\hat{\alpha}_f(\theta) < 0$. Part 2 is due to the fact that $\Psi \to 0$ as $\omega \to 0$. It follows that there is a $\underline{\omega}$ such that for all $\omega < \underline{\omega}$, equation (3) implies that $\alpha_f(\theta) = 1 \iff \theta = 0$. Parts 3 and 4 come from the fact that for all z_j, profits are lower than at the benchmark without loss aversion, but they are asymptotically equal as $\omega \to \infty$.

C Relevance of Statutory Incidence

In this section, I revisit the classic doctrine of the irrelevance of statutory incidence of taxes. To analyze this issue, I go back to the environment of Section 2 and assume perfect competition. For simplicity, I also consider one representative firm with production function

$$Y \leq AN^{1-\alpha}.$$

Let $\left(1+\tau_p\right)$ be the ad-valorem gross payroll tax. The inverse labor demand is

$$w = \left(\frac{1-\alpha}{N^{\alpha}}\right)\left(\frac{A}{1+\tau_p}\right). \tag{7}$$

Let $(1-\tau_n)$ be the ad-valorem gross labor income tax. I now consider two alternatives for the status quo real wage: net-of-tax or gross-of-tax.

Net-of-tax status quo Assume that $\overline{w} = w_-$. This assumption means that workers have the same dislike for a world in which taxes go up as for a world in which wages go down by the same amount. In that case, labor supply is

$$N = \begin{cases} \left[(1-\tau_n)\, w\right]^{\frac{1}{\eta}}, & \text{if } (1-\tau_n)\, w \geq w_- \\ \left[(1-\tau_n)\, \frac{w}{w_-}\right]^{\frac{1}{\eta\lambda}} w_-^{\frac{1}{\eta}} & \text{if } (1-\tau_n)\, w < w_- \end{cases}.$$

Using (7) to substitute w,

$$N = \begin{cases} \left[\left(\frac{1-\tau_n}{1+\tau_p}\right)\left(\frac{1-\alpha}{N^{\alpha}}\right) A\right]^{\frac{1}{\eta}}, & \text{if } \left(\frac{1-\tau_n}{1+\tau_p}\right)\left(\frac{1-\alpha}{N^{\alpha}}\right) A \geq w_- \\ \left[(1-\tau_n)\left(\frac{1-\alpha}{N^{\alpha}}\right)\frac{A}{w_-}\right]^{\frac{1}{\eta\lambda}} w_-^{\frac{1}{\eta}} & \text{if } \left(\frac{1-\tau_n}{1+\tau_p}\right)\left(\frac{1-\alpha}{N^{\alpha}}\right) A < \overline{w} \end{cases}. \tag{8}$$

This equation defines equilibrium labor as a function of $(1-\tau_n)\,/\,\left(1+\tau_p\right)$ only. Therefore the irrelevance of statutory incidence still holds.

Gross-of-tax status quo Now assume that $\overline{w} = (1-\tau_n)\, w_-$. According to this assumption, workers penalize wage cuts only, irrespective of taxes. In that case, labor supply is

$$N = \begin{cases} \left[(1-\tau_n)\, w\right]^{\frac{1}{\eta}}, & \text{if } w \geq \overline{w} \\ \left[\frac{w}{w_-}\right]^{\frac{1}{\eta\lambda}} \left[(1-\tau_n)\, w_-\right]^{\frac{1}{\eta}} & \text{if } w < \overline{w} \end{cases}.$$

Substituting labor demand,

$$N = \begin{cases} \left[\left(\frac{1-\tau_n}{1+\tau_p}\right)\left(\frac{1-\alpha}{N^\alpha}\right)A\right]^{\frac{1}{\eta}}, & \text{if } \left(\frac{1-\alpha}{N^\alpha}\right)\left(\frac{A}{1+\tau_p}\right) \geq \overline{w} \\ \left[\frac{\left(\frac{1-\alpha}{N^\alpha}\right)\left(\frac{A}{1+\tau_p}\right)}{w_-}\right]^{\frac{1}{\eta\lambda}} \left[(1-\tau_n)\, w_-\right]^{\frac{1}{\eta}} & \text{if } \left(\frac{1-\alpha}{N^\alpha}\right)\left(\frac{A}{1+\tau_p}\right) < \overline{w} \end{cases}.$$

An equilibrium in the gain region can only depend on taxes through the wedge

$$\left(\frac{1-\tau_n}{1+\tau_p}\right),$$

whereas an equilibrium in the loss region can only depend on taxes through the wedge

$$\frac{(1-\tau_n)^{\frac{1}{\eta}}}{(1+\tau_p)^{\frac{1}{\eta\lambda}}}.$$

It follows that statutory incidence is no longer irrelevant.

The failure of irrelevance of statutory relevance may have important consequences for policy such as whether a fiscal devaluation is a good substitute for a nominal devaluation.