

# Working Papers



## Path-Dependent Wage Responsiveness

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Abstract:

We present a theory of nominal wage adjustment based on worker loss aversion, along the lines of prospect theory. Wage changes are evaluated relative to an endogenous reference wage, which depends on the workers' rational wage expectations from the recent past. By implication, firms face an upward-sloping labor supply curve that is convexly kinked at the workers' reference wage. Firms adjust wages flexibly in response to variations in labor demand, incorporating the endogenous response of the reference wage. The resulting theory of wage adjustment is starkly at variance with past theories. In line with the empirical evidence, we find that (1) wages are completely rigid in response to small labor demand shocks, (2) wages are downward rigid but upward flexible for medium-sized labor demand shocks, and (3) wages are relatively downward sluggish for large shocks.

Keywords: downward wage sluggishness, loss aversion

JEL classification: D03, D21, E24

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# 1 Introduction

This paper presents a theory of nominal wage adjustment based on worker loss aversion, along the lines of prospect theory (Kahnemann and Tversky, 1979). Workers evaluate nominal wage changes relative to an endogenous reference wage, which depends on their rational wage expectations from the recent past. Firms anticipate adjustments of the reference wage when they make their wage setting decisions. The theory has distinctive implications which are starkly at variance with major existing theories of nominal wage adjustment but consonant with the empirical evidence. In particular, the theory implies that (1) for small labor demand shocks, nominal wages are fully rigid, (2) for medium-sized shocks there is upward nominal wage adjustment for positive shocks, but complete downward nominal wage rigidity for negative shocks and (3) for large shocks, nominal wages decline less strongly to negative shocks than they increase to equiproportionate positive shocks. In short, our theory can explain the empirically well documented occurrence of nominal wage rigidity in the presence of small labor demand variations, downward nominal wage rigidity but upward nominal wage adjustment to intermediate labor demand variations, and relative downward nominal wage sluggishness in the presence of large shocks. While current theories of nominal wage adjustment fail to account for all three of these pieces of empirical evidence, this paper offers a theoretical rationale.

The basic idea underlying our theory is simple. In the spirit of prospect theory, the workers' utility losses from nominal wage decreases are weighted more heavily than the utility gains from nominal wage increases of equal magnitude. Consequently, employment responses are more elastic to nominal wage decreases than to nominal wage increases. The result is a kinked labor supply curve, for which the kink depends on the workers' nominal reference wage. The kink of the labor supply curve implies that nominal wages are rigid in response to sufficiently small labor demand shocks, but nominal wages adjust asymmetrically to larger shocks. While it is well-known that wage loss aversion leads to kinked labor supply curves (e.g., Bhaskar, 1990), our contribution lies in combining nominal wage loss aversion with endogenous reference wage dynamics and in investigating the implications of these dynamics for the firm's wage and employment decisions. In the spirit of Kőszegi and Rabin (2006), we model the reference wage as the workers' rational wage expectations from the recent past, which are adjusted through time. The reference wage implicitly determines workers' endogenous income tar-

get. An increase in the reference wage raises their implicit income target, whereas a decrease in the expected nominal wage lowers it. Workers adjust their labor supply accordingly. Consequently, there is a positive relationship between the workers' reference wage and their labor supply. Therefore, a labor demand shock not only produces a change in employment following the firm's immediate wage setting decision, but also an adjustment in the workers' future reference wage. Firms foresee that their wage setting decision has an effect on the workers' future reference wage and thereby their future labor supply. A rise in the reference wage raises the firms' long-run profits (since the reference wage is located at the kink of the labor supply curve), whereas a fall in the reference wage lowers long-run profits. On this account, medium-sized to large positive labor demand shocks lead to nominal wage increases, while medium-sized to large negative labor demand shocks may lead to relatively little if any downward nominal wage adjustment.<sup>1</sup>

From a methodological point of view, this paper is closely related to Ahrens, Pirschel and Snower (2014) which considers how consumer loss aversion with endogenous reference price dynamics affects firms' price setting decision.

The remainder of the paper is structured as follows. Section 2 reviews the relevant literature. Section 3 presents our general model setup. In section 4 we analyze the effects of various demand shocks on nominal wages, both numerically and analytically, and check our results for robustness. Section 5 concludes.

## 2 Relation to the Literature

In this section, we review the empirical evidence suggesting that nominal wages are (imperfectly) downward rigid, while they are upward flexible. In particular, ample

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<sup>1</sup>Our theory may help shed light on asymmetric effects of monetary policy, though such implications lie beyond the scope of this paper. First it is relevant to the literature on short-run monetary policy, which has asymmetric effects under downward nominal wage rigidity (e.g. McDonald and Sibly, 2001; Carlsson and Westermark, 2008; Fahr and Smets, 2010). Second, while symmetric nominal rigidities give rise to a long-run Phillips curve which is virtually vertical (e.g. Goodfriend and King, 1997; Khan et al., 2003), downward nominal wage rigidity leads to a significantly non-vertical long-run Phillips curve, thereby generating substantial long-run real effects of monetary policy on output and employment for negative shocks, as shown by Kim and Ruge-Murcia (2009, 2011), Fagan and Messina (2009), Fahr and Smets (2010), Benigno and Ricci (2011) and Abo-Zaid (2013). In all of these latter contributions, downward nominal wage rigidity is introduced in an ad-hoc way, using a linex function as proposed by Varian (1974). The only exception to this is Benigno and Ricci (2011), who use a case sensitive approach. Consequently, these models exhibit permanent downward nominal wage rigidity, independent of the size and the sign of the shock. However, since the degree of downward nominal wage rigidity varies with the size of the shock, the short- and long-run Phillips curves are state-dependent, a feature not considered in the studies above.

microeconomic evidence points towards three important stylized facts, namely that (i) nominal wage rigidity is common in the presence of minor labor market shocks, (ii) under mid-range shocks (such as those in standard business cycle fluctuations), downward-wage rigidity and upward wage adjustment are common, (iii) nominal wage cuts do take place in severe downturns.

This evidence implies that the distribution of nominal wage changes spikes at zero and contains much fewer observations below zero than above. Such a distribution of nominal wage changes is documented for a wide variety of industrialized countries. For the United States, McLaughlin (1994), Card and Hyslop (1996), Kahn (1997), and Altonji and Devereux (1999) derive such evidence from the Panel Study of Income Dynamics, while Akerlof et al. (1996), Lebow et al. (1999), Gottschalk (2005), and Dickens et al. (2007) find this distribution based on employer reports, social security files, and several different household surveys. Based on national wage and income surveys as well as on employer reports, Smith (2000), Agell and Lundborg (2003), Nickell and Quadrini (2003), Fehr and Goette (2005), Bauer et al. (2007), Dickens et al. (2007), Babecký et al. (2010), Böckerman et al. (2010), and Sigurdsson and Sigurdardottier (2012) provide this evidence for a large sample of European economies, while Kimura and Ueda (2001), Cobb and Opazo (2008), and Iregui et al. (2009) find this for Japan, Chile, and Colombia, respectively.

While all these studies find that nominal wage cuts are rare, they do happen and commonly take place in times of severe financial distress, such as long lasting and deep recessions or any other sort of immanent risk of bankruptcy for a firm (Kahneman et al., 1986; Bewley, 1995, 1999; Akerlof et al., 1996; Campbell and Kamlani, 1997; Kimura and Ueda, 2001; Fehr and Goette, 2005; Böckerman et al., 2010). Moreover, there is empirical evidence that extremely large demand shocks induce responses of hours and hourly wages, both for positive and negative shocks.

Furthermore, there is much macroeconomic empirical evidence pointing towards relative downward nominal wage rigidity. Kandil (1995) shows for a sample of 19 industrialized countries that in response to permanent monetary policy shocks nominal wages generally respond stronger to positive shocks than to negative shocks of equal magnitude. Similar evidence in response to permanent aggregate demand shocks is provided by Kandil (2006) for United States industries and Kandil (2010) for a large variety of industrialized countries.<sup>2</sup>

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<sup>2</sup>In addition to the asymmetric wage reaction in response to the permanent demand shock, Kandil (1995, 2006, 2010) finds an asymmetric reaction of output. Output responds much stronger to per-

There is a variety of wage adjustment theories accounting for downward nominal wage rigidity, the most prominent being contract theory (Fisher, 1977; Taylor, 1979), implicit contract theory (Baily, 1974; Azariadis, 1975; Gordon, 1976; Stiglitz, 1986), efficiency wage theory (Weiss, 1980; Akerlof, 1982; Shapiro and Stiglitz, 1984; Weiss, 1990), the fair wage hypothesis (Akerlof and Yellen, 1990), and the insider-outsider theory (Lindbeck and Snower, 1988). These theories aim at explaining, why firms avoid nominal wage cuts or, in the case of the (implicit) contract theory, why nominal wages are sluggish in general. However, none of these theories explain all three of the empirical regularities on nominal wage adjustment as outlined above.

In this paper we offer a new theory of downward nominal wage rigidity resting on worker loss aversion in the wage dimension, endogenous reference wage dynamics, and the implications of these dynamics for the firm's decision making. The resulting theory provides an account of asymmetric nominal wage rigidity in line with the empirical evidence cited above. Although, there is no hard evidence for a direct link of worker loss aversion and downward nominal wage rigidity, there is ample indicative evidence for the existence of such a link. Dunn (1996) presents survey evidence from US labor markets and finds that the behavior of labor supply is consistent with the notion of loss averse workers. Similar evidence is also presented by Goette et al. (2004) and Fehr and Goette (2007).

Furthermore, there is a large literature that documents that relative pay matters for subjective well-being (Clark and Oswald, 1996). Workers evaluate their wages relative to a reference point, e.g. in the form of an implicit wage norm (Jaques, 1956, 1961), past earnings (Clark, 1999; Grund and Sliwka, 2007; Kawaguchi and Ohtake, 2007), or the earnings of others (Clark and Oswald, 1996; Clark et al, 2008). Falling behind reference points lowers life satisfaction and gives rise to negative morale effects. Supportive evidence for such morale effects is provided by, e.g. Kube et al. (2013) who document in a field experiment that there is a highly asymmetric reaction of work morale to positive and negative deviations from a reference wage. Similar evidence is provided by a field experiment by Chemin and Kurmann (2014). Survey evidence for the United States and various European

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manent negative demand shocks than to positive ones, a feature which is implied by standard theories of downward nominal rigidities and, given standard production technologies, also predicted by our model. This asymmetry in output is further documented by a large empirical literature. While DeLong and Summers (1988), Cover (1992), Kandil (2001), and Ravn and Sola (2004) provide evidence for the United States, Karras (1996), Lenz (1997), Kandil (1999), and Karras and Stokes (1999) provide evidence for a wide variety of industrialized countries. Finally, evidence for developing countries is given by Kandil (1998), Tan et al. (2010), and Mehrara and Karsalari (2011).

economies suggests that amongst the most important factors for why firms do not adjust wages downward is the risk of negative effect to workers' morale (Campbell and Kamlani, 1997; Du Caju et al., 2015). However, Chen and Horton (2015) show that the effect on work morale vanishes if the wage cut is justified by reasonable arguments such as severe financial stress of the firm. Furthermore, Koch (2015) shows in an laboratory experiment that wage cuts in recessions are stronger in the absence of reference wages. If reference wages exist, wage cuts are smaller by approximately half the amount.

In our model, loss-averse workers evaluate wages relative to a reference wage. Kőszegi and Rabin (2006, 2007, 2009) and Heidhues and Kőszegi (2005, 2008, 2014) argue that reference points are determined by agents' rational expectations about outcomes from the recent past. There is much empirical evidence suggesting that reference points are determined by expectations, in concrete situations such as in police performance after final offer arbitration (Mas, 2006), in the United States TV show "Deal or no Deal" (Post et al., 2008), with respect to domestic violence (Card and Dahl, 2011), in cab drivers' labor supply decisions (Crawford and Meng, 2011), in the effort choices of professional golf players (Pope and Schweitzer, 2011), or in the aggressiveness of professional soccer players (Bartling et al., forthcoming). In the context of laboratory experiments, Knetsch and Wong (2009) and Marzilli Ericson and Fuster (2011) find supporting evidence from exchange experiments, Abeler et al. (2011) and Gill and Prowse (2012) from effort provision experiments, Banerji and Gupta (2014) from an auction experiment, and Karle et al. (2015) from a consumption choice experiment. Endogenizing workers' reference wages in this way allows our model to capture that current nominal wage changes influence the workers' future reference wage and thereby affect labor supply. That reference wages influence reservation wages via this effect is supported by experimental evidence of Falk et al. (2006) who introduce a minimum wage as reference point and show that this introduction leads to an increase in the subjects' reservation wage, whereas the removal of that minimum wage, only leads to a marginal reduction in reservation wage. These pieces of evidence are consonant with the assumptions underlying our analysis. Our analysis works out the implications of these assumptions for state-dependent nominal wage sluggishness in the form of asymmetric nominal wage adjustment for positive and negative labor demand shocks.

While we are not of course the first to explain downward nominal wage rigidity through workers' loss aversion with respect to wages, our innovation lies in

accounting for all three of the empirical regularities above through loss aversion. McDonald and Sibly (2001) set up an insider-outsider model with wage bargaining, where workers are loss averse with respect to real wages and where the reference wage equals last period's wage, i.e. the status quo, as suggested by Kahnemann et al. (1991). They find that wages are rigid with respect to the reference wage, giving rise to real effects of monetary policy for expansionary monetary shocks. An analogous result is derived by Bhaskar (1990) in a model of union bargaining, where workers are loss averse with respect to their own wages relative to wages paid to members of other unions. Finally, Eliaz and Spiegler (2014) analyze loss averse workers in a restricted search and matching model. They follow Kőszegi and Rabin (2006) and assume that reference points are determined by rational expectations from the recent past. Eliaz and Spiegler (2014) find that in response to productivity shocks, wages of newly hired workers are (imperfectly) flexible, whereas they are downward rigid for existing workers. As noted, none of these papers can explain all three pieces of evidence outlined above.

### **3 Model**

We incorporate reference-dependent preferences and loss aversion into an otherwise standard model of monopsony on the labor market. Workers are loss averse with respect to nominal wages. They evaluate nominal wages relative to their reference wage, which depends on their lagged rational wage expectations from the recent past, i.e. workers are backward-looking. For simplicity, we abstract from saving, implying that workers become single-period optimizers. Firms are monopsonists and can set their wages freely in each period to maximize their total expected discounted profits. Firms' wage setting decision is forward-looking, taking into account their influence on the workers' future reference wage. Thus, reference dependence in our model is obviously an intertemporal phenomenon, linking the decisions in one period to the decisions in the next. To analyse the firms' wage setting decision in response to permanent labor demand shocks in such an intertemporal context we consider a dynamic two-period analysis, for algebraic simplicity. (A multi-period analysis with longer time horizons would not affect our qualitative conclusions.)

### 3.1 Labor Supply Curve of the Loss Averse Worker

We assume that workers are loss averse with respect to nominal wage changes, i.e. the perceived utility losses from nominal wage decreases relative to the reference wage are weighted more heavily than the perceived utility gains from nominal wage increases of equal magnitude. This gives rise to a labor supply curve which is convexly kinked at the reference wage. In what follows, we assume that this labor supply curve is upward sloping, since the substitution effect of a nominal wage change dominates the income effect.<sup>3</sup> Consequently the employment increase associated with a nominal wage increase is small relative to the employment decrease associated with a wage decrease of equal magnitude.

The worker's preferences in period  $t$  are represented by the following utility function<sup>4</sup>

$$U_t(c_t, n_t) = U_t^c(c_t) - \theta_i \frac{n_t^{\vartheta_i}}{\vartheta_i}, \quad (1)$$

where  $c_t$  is consumption in period  $t$ ,  $\theta_i$  is a shifting parameter that ensures continuity of the worker's preferences at the nominal reference wage<sup>5</sup>  $W_t^r$  and  $n_t$  is hours worked in period  $t$ .<sup>6</sup> The parameter  $\vartheta_i$  is an indicator function of the form

$$\vartheta_i = \begin{cases} \vartheta_g & \text{for } W_t > W_t^r, \text{ i.e. gain domain} \\ \vartheta_l & \text{for } W_t < W_t^r, \text{ i.e. loss domain} \end{cases}, \quad (2)$$

which describes the degree of the worker's loss aversion and where  $W_t$  and  $W_t^r$  are the workers current nominal wage and reference wage, respectively.

For loss averse workers  $\vartheta_g > \vartheta_l$ , which implies that the worker's disutility of labor  $U_t^n(n_t) = \frac{n_t^{\vartheta_i}}{\vartheta_i}$  is steeper, i.e. the marginal disutility of labor is higher in the gain domain than in the loss domain. Therefore, the workers willingness to adjust hours is lower when the nominal wage is above the worker's reference wage than when it is below. Since labor income is assumed to be the only means to finance nominal consumption, the household's budget constraint is  $P_t c_t = W_t n_t$ . Without loss of generality, we normalize the price  $P_t$  to unity so that real and nominal wages

<sup>3</sup>As long as labor is less responsive to nominal wage increases (relative to the reference wage) than to nominal wage decreases, it can be shown that our model can explain the above outlined three empirical regularities on nominal wage adjustment, irrespective of the sign of the slope of the labor supply curve.

<sup>4</sup>In what follows, we normalize the worker's marginal utility of consumption  $\frac{\delta U_t^c}{\delta c_t}$  equal to 1.

<sup>5</sup>Therefore, it must hold that  $\theta_g = (W^r)^{1 - \frac{\lambda_l}{\lambda_g}} \theta_l^{\frac{\lambda_l}{\lambda_g}}$ .

<sup>6</sup>Throughout the model, capital letters denote nominal variables, while small letters denote real variables.

are the same. Maximization of the utility function (1) subject to the budget constraint yields the following kinked labor supply function

$$n_t = \begin{cases} \left(\frac{W_t}{\theta_g}\right)^{\lambda_g} & \text{for } W_t > W_t^r, \text{ i.e. gain domain} \\ \left(\frac{W_t}{\theta_l}\right)^{\lambda_l} & \text{for } W_t < W_t^r, \text{ i.e. loss domain} \end{cases}, \quad (3)$$

where  $\lambda_i = \frac{1}{\vartheta_i - 1}$  denotes the Frisch elasticity of labor supply. Loss aversion with respect to nominal wage changes implies that  $\lambda_g < \lambda_l$ , i.e. the worker reacts stronger to wage decreases relative to the reference wage (by reducing employment) than to wage increases relative to the reference wage (by increasing employment).<sup>7</sup>

The worker's nominal reference wage  $W_t^r$  is formed at the beginning of each period. In the spirit of Kőszegi and Rabin (2006), we assume that the worker's nominal reference wage depends on her rational nominal wage expectation from the recent past. Shocks materialize unexpectedly in the course of the period and therefore do not enter  $I_t$ , the information set available to the worker at the beginning of the period. In short, the worker observes the shock with a one-period lag. Thus, the worker's nominal reference wage is defined as  $W_t^r = E_{t-1}[W_t | I_{t-1}]$ . Changes in the reference wage  $W_t^r$  change the position of the kink of the worker's labor supply curve and also shift the labor supply curve as a whole. We follow Kőszegi and Rabin (2006) and assume that the worker's expected nominal wage implicitly determines the worker's endogenous income target.<sup>8</sup> Thus, an increase in the expected nominal wage raises her implicit income target, whereas a decrease in the expected nominal wage lowers it. If, at the beginning of the period, the worker anticipates a higher (lower) nominal wage for the following period, i.e. her reference wage increases (decreases), she will supply relatively more (less) labor in order to reach her new higher (lower) implicit income target. From this, it follows that the worker's labor supply curve shifts outwards (inwards) in response to an upward (downward) adjustment of the worker's reference wage.

<sup>7</sup>While this point is crucial for the predictions of our theory, it is worth pointing out that these results hold irrespective of the sign of the slope of the labor supply curve above the kink as long as the ratio of the absolute slopes above and below the kink remains unchanged (i.e. the labor supply curve is steeper above than below the kink). Thus, our theory does cover the evidence that the substitution effect always outweighs the income effect (upward sloping labor supply curve) as well as the evidence of, e.g., Kőszegi and Rabin (2006) and others according to which we have a backward bending labor supply curve above the reference wage.

<sup>8</sup>If the labor demand curve is inelastic and the firm faces costs of labor adjustment (a realistic scenario, certainly for the short run), so that the profit-maximizing employment can take place in the inelastic portion of the labor demand curve, then increases in the reference wage translate one-to-one into increases in the reference income.

The kink, lying at the intersection of the two labor supply curves  $n_t(W_t, \lambda_g, \theta_g)$  and  $n_t(W_t, \lambda_l, \theta_l)$ , is given by the wage-labor combination

$$(\widehat{W}_t, \widehat{n}_t) = \left( W_t^r, \left( \frac{\theta_g}{\theta_l} \right)^{\frac{1}{\lambda_l - \lambda_g}} \right), \quad (4)$$

where “ $\widehat{\phantom{x}}$ ” denotes the value of a variable at the kink.

### 3.2 The Firm’s optimization problem

The firm maximizes its expected discounted profits

$$\Pi_t^{Total} = \Pi_t + \beta \Pi_{t+1} \quad (5)$$

where  $\Pi_t = y_t - W_t n_t$  are period  $t$  profits and  $\beta$  is the discount factor. The firm takes into account its production function  $y_t(n_t)$ , the workers’ kinked labor supply function  $n_t = \left( \frac{W_t}{\theta_l} \right)^{\lambda_l}$ , and the influence of its wage decision on the workers’ future labor supply via changes in the workers’ reference wage. The resulting first order condition of the firm’s optimization problem reads as

$$\frac{\partial \Pi_t^{Total}}{\partial W_t} = \left[ \frac{\partial y_t(n_t)}{\partial n_t} \frac{\partial n_t(W_t)}{\partial W_t} - n_t(W_t) - W_t \frac{\partial n_t(W_t)}{\partial W_t} \right] + \beta \left[ \frac{\partial \Pi_{t+1}}{\partial W_{t+1}^r} \frac{\partial W_{t+1}^r}{\partial W_t} \right] = 0, \quad (6)$$

which is equivalent to

$$\underbrace{\frac{\partial y_t(n_t)}{\partial n_t}}_{mpl_t} - \underbrace{\left( W_t(n_t) + \frac{\partial W_t}{\partial n_t} n_t \right)}_{mcl_t} = -\beta \frac{\partial \Pi_{t+1}}{\partial W_{t+1}^r} \frac{\partial W_{t+1}^r}{\partial W_t} \frac{\partial W_t}{\partial n_t}. \quad (7)$$

The term on the left hand side is the current period marginal product of labor  $mpl_t$  minus the current period marginal cost of labor  $mcl_t$ . The term on the right hand side measures the influence of the wage setting decision in period  $t$  on the workers’ next period reference wage and thereby the firm’s future profits. For the partial derivatives, it holds that  $\frac{\partial W_{t+1}^r}{\partial W_t} \geq 0$  and  $\frac{\partial W_t}{\partial n_t} > 0$ . Thus, for  $\frac{\partial \Pi_{t+1}}{\partial W_{t+1}^r} > 0$ , the reference-wage-updating effect drives a negative wedge between the marginal product of labor and the marginal cost of labor, i.e.  $mpl_t \leq mcl_t$ . Note that in the absence of reference-wage-updating the standard optimality condition of a firm holds, i.e.  $mpl_t = mcl_t$ . Only if the firm’s wage setting decision has an influence on the future reference wage the firm faces a tradeoff between current period optimality (deter-

mined by the left hand side of equation (7)) and future ramifications of the current decision (determined by the right hand side of equation (7)).

In what follows we assume that the firm's production function is given by  $y_t(n_t) = \mu n_t^\alpha$  where  $\mu > 0$  and  $0 < \alpha < 1$ . The firm's current period labor demand function, given by its marginal product of labor ( $mpl$ ), is downward sloping:  $l_t^D = mpl_t = \mu \alpha n_t^{(\alpha-1)}$ . Since the labor supply function of the loss averse worker is kinked at the reference wage  $W^r$ , the firm's real marginal cost of labor is discontinuous at the kink:

$$mcl_t^i(\widehat{n}_t, \lambda_i, \theta_i) = \left(1 + \frac{1}{\lambda_i}\right) \theta_i \widehat{n}_t^{\frac{1}{\lambda_i}} \quad \text{for } i = g, l. \quad (8)$$

The interval  $[mcl_t^l, mcl_t^g]$  we call "marginal cost discontinuity".<sup>9</sup>

We assume that in the initial steady state, the exogenously given reference wage is  $W_{ss}^r$ . Furthermore, in the steady state the firm's labor demand curve ( $mpl$ ) intersects the marginal cost discontinuity. To fix ideas, we assume that initially the labor supply curve crosses the midpoint of the discontinuity in the marginal cost curve<sup>10</sup>, as depicted in Figure 1. This assumption permits us to derive the symmetry characteristics of wage and employment responses to positive and negative labor demand shocks. It follows that the firm's optimal wage in the initial steady state  $W_{ss}^*$  is equal to  $W_{ss}^r$ .<sup>11</sup>

### 3.3 Demand Shocks

For simplicity, we analyse the firm's wage setting reaction in response to permanent labor demand shocks in a two-period context. These labor demand shocks, represented by  $\varepsilon_t$ , are unexpected and enter the labor demand function multiplicatively:

$$l_t^D = \mu \alpha n_t^{(\alpha-1)} \varepsilon_t. \quad (9)$$

<sup>9</sup>Note that  $mcl_t^g(\widehat{n}_t, \lambda_g, \theta_g) > mcl_t^l(\widehat{n}_t, \lambda_l, \theta_l)$ . See also Figure 1.

<sup>10</sup>This implies that the slope parameter of the firm's labor demand function has to fulfill  $\mu = \frac{mcl_{ss}(\widehat{n}_{ss}, \lambda_g, \theta_g) + mcl_{ss}(\widehat{n}_{ss}, \lambda_l, \theta_l)}{2\alpha \widehat{n}_{ss}^{(\alpha-1)}}$ , evaluated at the initial steady state.

<sup>11</sup>The proof is straightforward: Let  $v$  be an arbitrarily small number. Then for wages equal to  $W_{ss}^r + v$  the firm faces a situation in which marginal cost is higher than marginal revenue product and decreasing the wage would raise the firm's profit, while for wages equal to  $W_{ss}^r - v$  the firm faces a situation in which marginal cost is lower than marginal revenue product and increasing the wage would raise the firm's profit. Thus  $W_{ss}^* = W_{ss}^r$  has to be the profit maximizing wage in the initial steady state.

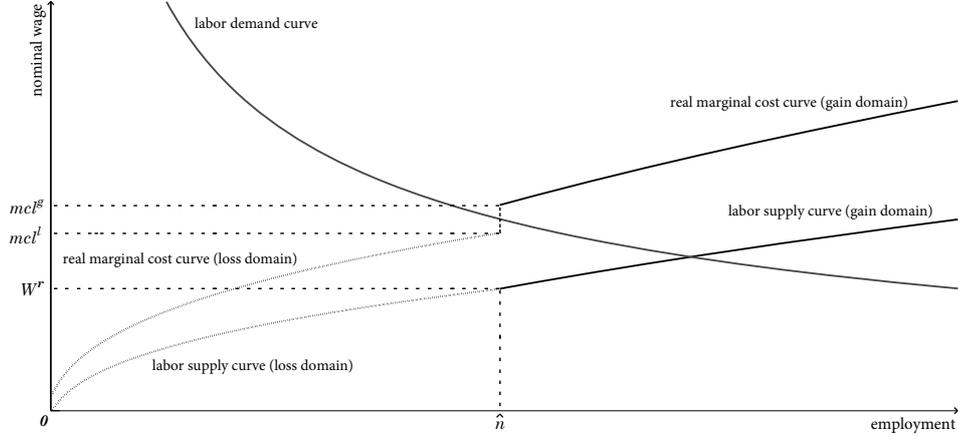


Figure 1: Initial problem of the monopsonistic firm

We consider the effects of a shock that hits the economy in period  $t$ . We define a “small” shock as one that leaves the labor demand curve passing through the marginal cost discontinuity, and a “large” shock as one that shifts the labor demand curve sufficiently so that it no longer passes through the marginal cost discontinuity.

The maximum size of a small shock for the labor demand function (9) is

$$\bar{\varepsilon}_t(\lambda_i, \theta_i) = \frac{\left(1 + \frac{1}{\lambda_i}\right) \theta_i}{\mu \alpha} \widehat{n}_{ss}^{\frac{1}{\lambda_i} - (\alpha - 1)}, \quad (10)$$

i.e.  $\bar{\varepsilon}_t(\lambda_i, \theta_i)$  is the shock size for which the shifted labor demand curve lies exactly on the upper (for  $\bar{\varepsilon}_t(\lambda_g, \theta_g)$ ) or lower (for  $\bar{\varepsilon}_t(\lambda_l, \theta_l)$ ) boundaries of the marginal cost discontinuity. In the analysis that follows, we will distinguish between small and large permanent labor demand shocks. We simulate our model numerically in order to quantitatively assess the wage setting reaction of the firm to small and large labor demand shocks.

### 3.4 Calibration

We calibrate the model for a quarterly frequency in accordance with standard values in the literature. We assume an annual interest rate of 4 percent, which yields a discount factor  $\beta = 0.99$ . Loss aversion is measured by the relative slopes of the demand curves in the gain and loss domain, i.e.  $\kappa = \frac{\lambda_l}{\lambda_g}$ . The empirical literature finds that the loss aversion ratio is commonly around 2 (e.g., Bleichrodt et al.,

Table 1: Base calibration

Parameter	Symbol	Value
Discount rate	$\beta$	0.99
Frisch elasticity of labor supply (gain domain)	$\lambda_g$	1.5
Frisch elasticity of labor supply (loss domain)	$\lambda_l$	3
Loss aversion	$\kappa$	2
Output elasticity of labor	$\alpha$	2/3
Shifting parameter	$\theta_l$	1/2

2001; Tversky and Kahnemann, 1992; Pennings and Smidts, 2003; Booij and van de Kuilen, 2009). Therefore, we set  $\kappa = 2$ . Following Galí (2008), we set  $\alpha = 2/3$ . The Frisch elasticity of labor supply is set to  $\lambda_g = 1.5$ , which ensures that  $\lambda_g$  and  $\lambda_l$  are well between the estimates of Prescott (2004), Chetty et al. (2011), and Fiorito and Zanella (2012), which range from 1.1 to 3.<sup>12</sup> The base calibration is summarized in Table 1.

## 4 Results

Figure 2 presents the shock-arc elasticities of the wage ( $\tilde{\eta}_{\varepsilon, W} = \frac{\% \Delta W}{\% \Delta \varepsilon}$ ) in the period of the shock  $t$  for negative and positive labor demand shocks of the two-period model, given the base calibration given in Table 1. On the vertical axis we show the shock-arc elasticities of wage, which measure the relative strength of the wage reaction in response to negative and positive labor demand shocks. The horizontal axis measures the shock, where the shock size increases from the left to the right. The vertical, dotted lines denote the thresholds between the small and the large labor demand shocks as defined in section 3.3.

According to our numerical analysis the firm's wage reaction in response to permanent labor demand shocks depends crucially on the size and the sign of the shock. Figure 2 indicates that wages are completely rigid for small positive and small negative labor demand shocks (region left of the dotted lines in both panels of figure 2), while they are relatively downward sluggish for larger shocks. Moreover, for a certain range of large shocks, wages are completely downward rigid but upwards flexible.

<sup>12</sup>This calibration takes a macro point of view, as micro estimates of the Frisch labor supply elasticity are usually much lower, i.e. between 0 and 1 with a strong tendency towards zero rather than one (for a survey see Fiorito and Zanella (2012)). In section 4.2, we show that the results hold true also for a micro approach to our calibration.

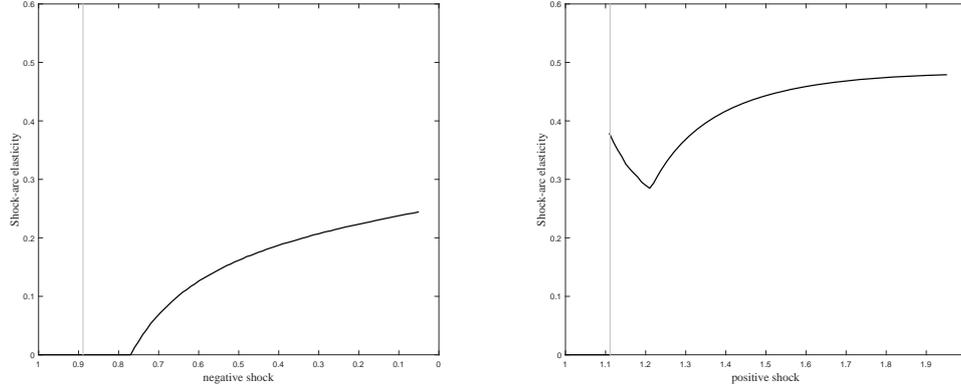


Figure 2: Shock-arc elasticities to positive and negative demand shocks

## 4.1 Intuition

### *Small labor demand shocks*

As noted, for a sufficiently small demand shock  $\bar{\varepsilon}_t(\lambda_t, \theta_t) \leq \varepsilon_t^s \leq \bar{\varepsilon}_t(\lambda_g, \theta_g)$  the labor demand curve still intersects the marginal cost discontinuity, i.e.  $l_t^D(\hat{n}_t) \in [mcl_t^l, mcl_t^g]$ .

Therefore, the prevailing nominal steady state wage, which is equal to the worker's current reference wage, remains the firm's profit-maximizing wage,<sup>13</sup> i.e.  $W_t^* = W_{ss}^* = W_{ss}^r$ , and we have *complete wage rigidity*. With rigid wages, labor supply is unaffected by the small labor demand shock. Accordingly, the profit-maximizing amount of labor employed remains unchanged as well:  $\Delta n_t^* = 0$ . This holds true *irrespective of the sign of the small labor demand shock*.

### *Large labor demand shocks*

In contrast to the small labor demand shock, for a large shock, i.e.  $\varepsilon_t^l > \bar{\varepsilon}_t(\lambda_g, \theta_g)$  or  $\varepsilon_t^l < \bar{\varepsilon}_t(\lambda_t, \theta_t)$ , generally both, a nominal wage and a labor reaction are induced.

In our analysis, there are two channels whereby a large permanent labor demand shock affects nominal wages and employment; a direct demand and supply effect and an indirect reference-wage-updating effect.

The direct demand and supply effect: For the analysis of nominal wage adjustment in response to large variations in labor demand it proves useful to suppose,

<sup>13</sup>Compare the proof from footnote 11.

for the moment, that the worker's reference wage is exogenously fixed and does not change. This implies that  $\frac{\partial W_{t+1}^r}{\partial W_t} = 0$  and therefore the firm's profit maximization problem becomes a one-period problem. According to the optimality condition (7), the new profit-maximizing wage of the firm is determined by the standard condition according to which  $mpl_t = mcl_t$ . The new profit maximizing wage of the firm is

$$W_t^* = \theta_i \left[ \frac{\mu \alpha \varepsilon_t^l}{\left(1 + \frac{1}{\lambda_i}\right) \theta_i} \right]^{\frac{1}{\lambda_i(1-\alpha)+1}}, \quad (11)$$

while its corresponding profit-maximizing amount of labor is

$$n_t^* = \left[ \frac{\mu \alpha \varepsilon_t^l}{\left(1 + \frac{1}{\lambda_i}\right) \theta_i} \right]^{\frac{1}{(1-\alpha)+\frac{1}{\lambda_i}}}, \quad (12)$$

where  $\lambda_i = \lambda_g$ ,  $\theta_i = \theta_g$  for positive and  $\lambda_i = \lambda_l$ ,  $\theta_i = \theta_l$  for negative shocks, respectively.

Whether the new profit maximizing wage and employment reactions are larger for positive or negative shocks depends on the relative slopes of the demand and supply functions, which differ for negative and positive shocks due to loss aversion. For the base calibration and reasonable shock sizes<sup>14</sup>, equations (11) and (12) imply that abstracting from any adjustment in the workers' reference wage, nominal wages are *relatively downward sluggish* (i.e. less responsive to large negative than to large positive shocks). Intuitively, the change of quantity in response to a large labor demand shock depends positively on  $\lambda_i$ , the Frisch elasticity of labor supply, whereas the change of the wage in response to a large labor demand shock depends negatively on  $\lambda_i$ . Since for the loss averse worker  $\lambda_g < \lambda_l$ , the labor reaction of the firm facing loss-averse workers is relatively smaller in response to large positive labor demand shocks than to large negative ones of equal magnitude. This however implies that wages are relatively less responsive to negative than to positive large labor demand shocks, since the former move the firm along the relatively flat portion of the labor supply curve, whereas the latter move it along the relatively steep portion of the labor supply curve.

The reference-wage-updating effect: Accounting for the adjustment of the worker's reference wage in response to large labor demand shocks changes the

<sup>14</sup>Refer to Section 4.2 for a sensitivity analysis concerning this condition.

wage setting decision of the firm dramatically. Now  $\frac{\partial W_{t+1}^r}{\partial W_t} \neq 0$ . The new profit-maximizing wage of the firm is not only determined by the relation between  $mpl_t$  and  $mcl_t$ , but also by the effect of the wage decision on the reference wage.

As discussed above, a large labor demand shock induces a nominal wage and a labor reaction in the shock period  $t$ . Accordingly the worker's reference wage adjusts at the beginning of the following period  $t + 1$ , i.e.  $W_{t+1}^r = E_t [W_{t+1} | I_t] = W_t^*$ , which triggers an outward shift of the worker's labor supply curve for positive labor demand shocks and an inward shift for negative labor demand shocks. This phenomenon is the *reference-wage-updating effect*. This effect implies that in period  $t + 1$  the firm's profit is higher than in the shock period  $t$  for positive permanent shocks, while it is lower for negative permanent shocks due to the worker's labor supply reaction in response to the change of her implicit income target<sup>15</sup>.

Since the firm anticipates this, the following incentives arise: In response to a large positive labor demand shock, the firm could raise the nominal wage above the optimal current period nominal wage  $W_t^*$  in order to induce a stronger outward shift of the worker's labor supply curve in the following period. By contrast, in response to a large negative labor demand shock, the firm could try to dampen or even completely avoid the inward shift of the worker's labor supply curve in the next period by lowering the nominal wage less than otherwise optimal or by not lowering the nominal wage at all<sup>16</sup>.

Whether or not this occurs, generally depends on whether the firm's gain from an upward deviation from the optimal nominal wage  $W_t^*$  in terms of future profits (due to the relative rise in the reference wage) exceeds the firm's loss in terms of present profits (due to not setting the profit maximizing wage), i.e. whether  $\Pi_t(W_t') + \beta\Pi_{t+1}(W_{t+1}^r = W_t') > \Pi_t(W_t^*) + \beta\Pi_{t+1}(W_{t+1}^r = W_t^*)$  where  $W_t' > W_t^*$ . While period  $t$  marginal losses (the left hand side of equation (7)) strictly increase in an upward deviations from  $W_t^*$ , the discounted period  $t + 1$  gains due to the reference-wage-updating effect (the right hand side of equation (7)) feature an inverse u-shaped function in an upward deviations from  $W_t^*$ . Therefore, the firm exploits the reference-wage-updating effect as long as the discounted marginal gain is larger than its period  $t$  marginal loss. Hence, the optimal wage  $W_t'$  is set, where

<sup>15</sup>Intuitively, the firm can employ more labor for the same optimal nominal wage  $W_{t+1}^* = W_t^*$  in the case of a large positive labor demand shock, whereas it must employ less labor in the case of a large negative labor demand shock.

<sup>16</sup>Note that setting a nominal wage below  $W_t^*$  is never an option for the firm since it negatively affects future profits.

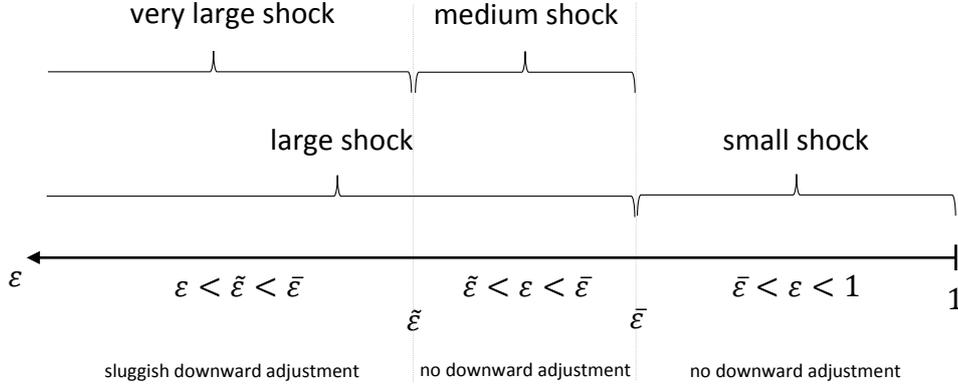


Figure 3: Classification of negative labor demand shocks.  
The threshold shocks in this figure are  $\tilde{\varepsilon} = \tilde{\varepsilon}_t(\lambda_l, \theta_l)$  and  $\bar{\varepsilon} = \bar{\varepsilon}_t(\lambda_l, \theta_l)$ .

marginal gains are equal to marginal losses.<sup>17</sup>

Figure 2 shows that for large negative labor demand shocks there is some threshold value  $\tilde{\varepsilon}_t(\lambda_l, \theta_l)$  up to which there is still complete downward nominal wage rigidity. For shocks larger than  $\tilde{\varepsilon}_t(\lambda_l, \theta_l)$  there is some downward nominal wage adjustment. More precisely, we find that for  $\varepsilon_t^l < \tilde{\varepsilon}_t(\lambda_l, \theta_l)$ , the firm sets the wage  $W_t^l$  such that  $W_{ss}^* > W_t^l > W_t^*$ , while for  $\tilde{\varepsilon}_t(\lambda_l, \theta_l) < \varepsilon_t^l < \bar{\varepsilon}_t(\lambda_l, \theta_l)$  the firm does not adjust the wage, i.e.  $W_t^l = W_{ss}^*$ . Due to these qualitative differences in the response of wages to large negative demand shocks, we divide the class of large shocks into two categories: The range of large shocks which do not induce any downward wage reaction we classify as “medium-sized” shocks, whereas all other large shocks are considered “very large” shocks. Figure 3 summarizes the full classification of negative permanent labor demand shocks. These results suggest that the firm’s incentive to dampen the inward shift of the worker’s labor supply curve due to an adjustment in the worker’s reference wage in the following period is very strong. The firm apparently always deviates upwards from  $W_t^*$ , the optimal wage given by equation (11), and sets  $W_t^l$  instead.

By contrast, for large positive labor demand shocks  $\varepsilon_t^l > \bar{\varepsilon}_t(\lambda_g, \theta_g)$ , the firm always adjusts the nominal wage upwards (see Figure 2). However, our results also indicate that the firm’s incentive to induce a stronger outward shift of the worker’s labor supply curve declines as the positive shock increases. In particular, our numerical results suggest that the firm does not always set a wage  $W_t^l$  that is

<sup>17</sup>Note that the marginal gain from an upward deviation from  $W_t^*$  depends negatively on the absolute value of the shock, i.e. the effect declines the larger the positive shock, while it increases the larger the negative shock (the smaller the shock in absolute value).

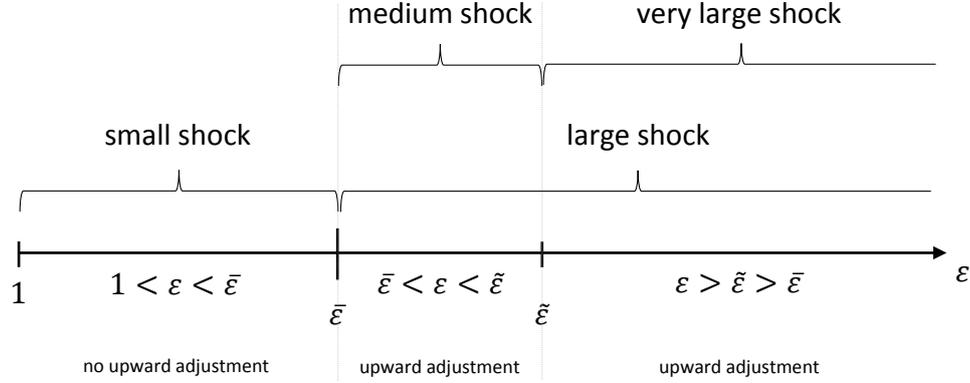


Figure 4: Classification of positive labor demand shocks.  
The threshold shocks in this figure are  $\tilde{\varepsilon} = \tilde{\varepsilon}_t(\lambda_g, \theta_g)$  and  $\bar{\varepsilon} = \bar{\varepsilon}_t(\lambda_g, \theta_g)$ .

higher than  $W_t^*$  for large positive labor demand shocks. If the shock exceeds a certain threshold, i.e.  $\varepsilon_t^l > \tilde{\varepsilon}_t(\lambda_g, \theta_g)$ , the firm's loss in terms of present profits from not setting  $W_t^*$  is not compensated by the gain in terms of future profits. This is due to the effect that the marginal gain from an upward deviation declines in the absolute size of the shock. Thus only for medium-sized positive shocks  $\tilde{\varepsilon}_t(\lambda_g, \theta_g) > \varepsilon_t^l > \bar{\varepsilon}_t(\lambda_g, \theta_g)$  the firm set the wage  $W_t'$  such that  $W_t' > W_t^*$ . Otherwise, for very large shocks, it just sets  $W_t^*$ . Figure 4 summarizes the full classification of positive permanent labor demand shocks.

Finally, comparing the left hand panel and the right hand panel from Figure 2, our numerical results also confirm that for large labor demand shocks nominal wages always adjust stronger upwards than downwards for equiproportionate shocks as predicted by our theory.

## 4.2 Sensitivities

Figure 5 shows the shock-arc elasticities of the wage for the following values of the loss aversion parameters:  $\kappa \in (1.43; 2; 4.8)$ , where our base case is  $\kappa = 2$ . The lower value was estimated by Schmidt and Traub (2002). The higher value was estimated by Fishburn and Kochenberger (1979). Intermediate values are supported by Bleichrodt et al. (2001), Tversky and Kahnemann (1992), Pennings and Smidts (2003), and Booij and van de Kuilen (2009).

Figure 5 shows that the higher the loss aversion parameter, ceteris paribus, the more sluggish is wage adjustment in response to labor demand shocks, both upwards and downwards. The shock-arc elasticity curves stemming from higher pa-

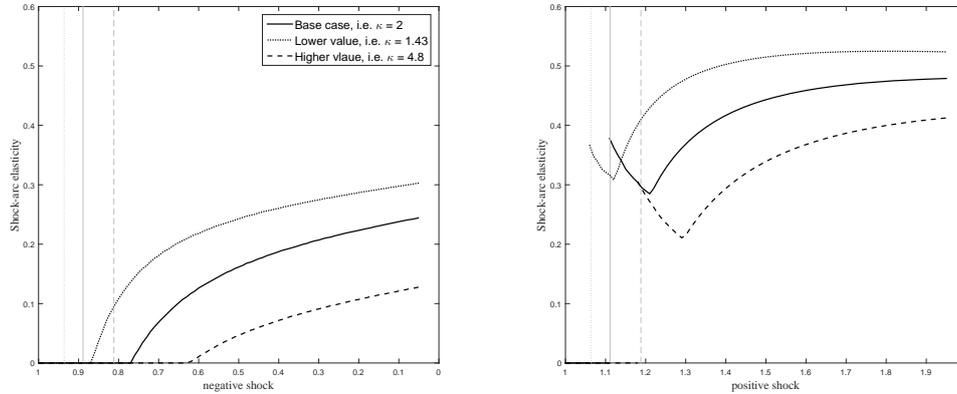


Figure 5: Sensitivity with respect to the loss aversion parameter.

parameter values always lie below the curves stemming from lower parameter values. Both critical shocks, positive and negative, increase. This implies that the marginal cost discontinuity widens as the loss aversion parameter increases, extending the range of full wage rigidity. The range of medium-sized shocks (i.e. large shocks for which there is upward flexibility but full downward rigidity) is shifted towards larger shocks, as the loss aversion parameter increases. Finally, overall wage sluggishness increases, as the positive and negative shock-arc elasticities are generally lower the higher the loss aversion parameter. It is apparent from the left panel of Figure 5 that the firms' incentive to avoid wage cuts increases substantially as the shock-arc elasticities are generally lower for higher loss aversion parameters compared to lower ones. Intuitively, the higher the Frisch elasticity of labor supply for the loss domain, the stronger is the permanent loss in profit due to a decrease in the reference wage. This stems from the fact that, according to the labor supply function (3), the reference-wage-updating effect increases in loss aversion. For the positive shock it holds that the higher the loss aversion parameter, the lower is the firm's incentive to deviate upwards. Since the reference-wage-updating effect is stronger, the firm does not necessitate to deviate by as much in order to produce the profit maximizing amount of labor in period  $t + 1$ .

Figure 5 shows another interesting fact. Due to the negative reference-wage-updating effect, the firms' wage responses are always downward sluggish. This implies that the reference-wage-updating effect always dominates the direct demand and supply effect. Even though for the base calibration the direct demand and supply effect produces downward sluggishness, the direction of the direct demand and supply effect depends strongly on the calibration of the model. Figure 6

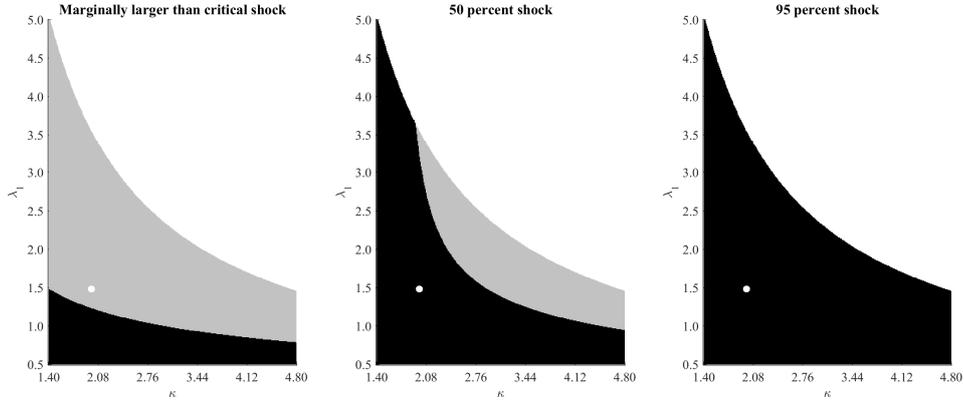


Figure 6: Sluggishness from the direct *demand and supply effect*.

shows a comparison of the relative shock arc elasticities for positive and negative demand shocks for different combinations of the Frisch elasticity of labor supply for the gain domain (i.e.  $\lambda_g$ ) and the loss aversion coefficient (i.e.  $\kappa$ ) and for three different shock sizes. Black shaded areas denote relative upward sluggishness (i.e. shock-arc elasticities of the wage is larger for permanent negative labor demand shocks relative to positive ones of equal magnitude), while gray shaded areas show relative downward sluggishness. Areas in white are not considered, as the resulting parameter value for  $\lambda_l$  exceeds reasonable values.<sup>18</sup> The white dot indicates our base calibration. As is apparent from Figure 6, for larger shocks (middle and right panel) the direct demand and supply effect generates upward sluggishness.

From this it follows that in the absence of the reference-wage-updating effect the shock-arc elasticities of wage in response to a permanent labor demand shock should be higher than their positive shock counterparts over a large range of the shocks. From the overall reaction (including both, the direct demand and supply effect and the reference-wage-updating effect) it is apparent that the negative reference-wage-updating effect dominates the demand and supply effect over the full range of shocks considered.

Figure 7 shows the sensitivity with respect to the following reasonable values for the Frisch labor supply elasticity:  $\lambda_g \in (0.5; 2; 4)$ , where  $\lambda_g = 1.5$  is our base case. We contrast our base with a much lower value  $\lambda_g = 0.5$  as often estimated in micro studies (for a survey refer to Chetty et al. (2011)) and a much higher value  $\lambda_g = 4$ , as estimated by Imai and Keane (2004).

<sup>18</sup>As indicated above,  $\lambda$  takes values between 0.5 and rarely above 4. The cutoff value for consideration is set to  $\bar{\lambda} = 7.2$ , which is the highest value considered in Figure 5.

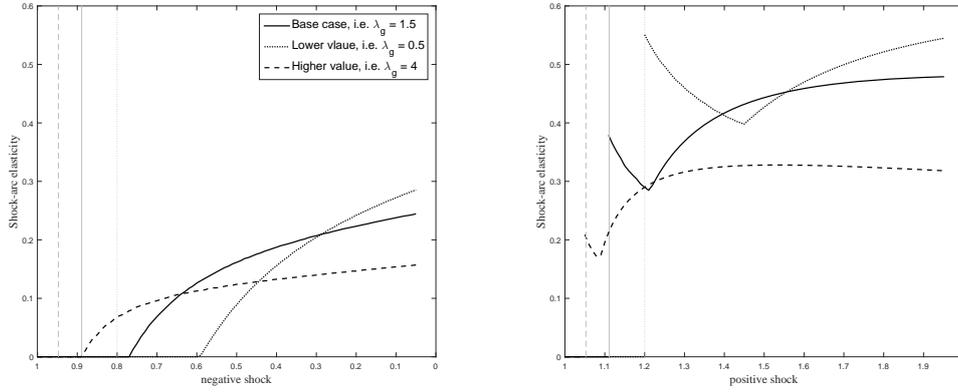


Figure 7: Sensitivity with respect to the Frisch elasticity of labor supply.

From Figure 7 it is apparent that the larger the Frisch elasticity of labor supply, the more sluggish are the responses of wages to positive and negative demand shocks. The intuition for this result is the same as for the loss aversion parameter: According to the labor supply equation (3), the larger Frisch elasticity of labor supply, the stronger is the reference-wage-updating effect. Therefore, the firm's incentive to avoid the negative reference-wage-updating effect increases with  $\lambda_g$ , while the necessity to deviate from  $W_0^*$  decreases with  $\lambda_g$ . Additionally, the qualitative result that wages are relatively downward sluggish carries over over the full range of elasticities considered. In contrast to the loss aversion parameter, however, the marginal cost gap closes, *ceteris paribus*, the larger the the Frisch labor supply elasticities. Both, positive and negative critical shocks decrease and therewith the range of full wage rigidity decreases.

Our sensitivity analysis confirms that over the wide range of reasonable parameter values for the Frisch labor supply elasticity and the loss aversion parameter, our theory implies that (1) for small labor demand shocks, nominal wages are fully rigid, (2) for medium-sized shocks there is upward nominal wage adjustment for positive shocks, but complete downward nominal wage rigidity for negative shocks and (3) for large shocks, nominal wages decline less strongly to negative shocks than they increase to equiproportionate positive shocks.

## 5 Conclusion

With our theory of wage adjustment under loss aversion we are able to provide an integrated account of the three important empirical regularities concerning wage

adjustments to labor market shocks. In particular, we can explain wage rigidity in the face of minor labor market shocks, downward nominal wage rigidity combined with upward wage adjustment in “normal” times, and wage cuts in deep recessions.

In contrast to the New Keynesian literature, our explanation of wage adjustment is thoroughly microfounded, without recourse to ad hoc assumptions. As future work, our model needs to be incorporated into a general equilibrium setting to validate the predictions of our theory.

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