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# Evaluating the Economic Significance of Downward Nominal Wage Rigidity

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## Abstract

The existence of downward nominal wage rigidity has been abundantly documented, but what are its economic implications? This paper demonstrates that, even when wages are allocative, downward wage rigidity can be consistent with weak macroeconomic effects. Firms have an incentive to compress wage increases as well as wage cuts when downward wage rigidity binds. By neglecting compression of wage increases, previous literature may have overstated the costs of downward wage rigidity to firms. Using microdata from the US and Great Britain, I find that evidence for compression of wage increases when downward wage rigidity binds. Accounting for this reduces the estimated increase in aggregate wage growth due to wage rigidity to be much closer to zero. These results suggest that downward wage rigidity may not provide a strong argument against the targeting of low inflation rates.

*Keywords:* Wage Rigidity; Unemployment; Inflation.

*JEL Codes:* E24, E31, J31, J64.

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A longstanding issue in macroeconomics has been the possible long run disemployment effects of low inflation. The argument can be traced back to Tobin (1972): If workers are reluctant to accept reductions in their nominal wages, a certain amount of inflation may “grease the wheels” of the labor market by easing reductions in real labor costs that would otherwise be prevented. This concern has resurfaced with renewed vigor among economists and policymakers in recent years as inflation has declined and evidence for downward rigidity in nominal wages has accumulated. A stylized fact of recent micro-data on wages is the scarcity of nominal wage cuts relative to nominal wage increases (Lebow, Stockton, & Wascher, 1995; Kahn, 1997; Card & Hyslop, 1997). This evidence dovetails with surveys of wage-setters and negotiators who report that they are reluctant to cut workers’ wages (see Howitt, 2002, for a survey). In an influential study, Bewley (1999) finds that a key reason for this reluctance is the belief that nominal wage cuts damage worker morale, and that morale is a key determinant of worker productivity.<sup>1</sup>

Exploring the macroeconomic implications of downward nominal wage rigidity from both a theoretical and an empirical perspective, I find that these effects are likely to be small. Section 1 begins by formulating an explicit model of worker resistance to nominal wage cuts.<sup>2</sup> Based on Bewley’s results, the model makes the simple assumption that wage rigidity arises because the productivity of workers declines sharply following nominal wage cuts.<sup>3</sup> Wage rigidity, according to Bewley’s evidence, is therefore allocative in the sense of Barro (1977), because it affects the productivity of workers. This simple assumption implies a key insight that has not been recognized in the literature – that nominal wage increases in this environment become irreversible to some degree. A firm that raises the wage today, but reverses its decision by cutting the wage by an equal amount tomorrow will experience a reduction in productivity: Today’s wage increase will raise productivity, but tomorrow’s wage cut will reduce productivity by a greater amount.<sup>4</sup>

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<sup>1</sup>While Bewley’s explanation has been influential, it is not the only possible explanation. Other studies have suggested that the tendency for past nominal wages to act as the default outcome in wage negotiations can lead to downward wage rigidity (MacLeod & Malcomson, 1993; Holden, 1994).

<sup>2</sup>Given the empirical evidence for worker resistance to wage cuts, it is surprising that there has not yet been an explicit model of such wage rigidity in the literature. The need for such a model has been noted by Shafir, Diamond & Tversky (1997, p.371): “Plausibly, the relationship [between wages and effort] is not continuous: there is a discontinuity coming from nominal wage cuts.... A central issue is how to model such a discontinuity.” This sentiment is echoed more recently by Altonji & Devereux (2000, p.423 note 7) who write: “[I]t is surprising to us that there is no rigorous treatment in the literature of how forward looking firms should set wages when it is costly to cut nominal wages.”

<sup>3</sup>Bewley also suggests that wage rigidity is enhanced by firms’ inability to discriminate pay across workers within a firm. For simplicity, I abstract from this possibility. For models that incorporate this feature, but abstract from downward nominal wage rigidity, see Thomas (2005), and Snell & Thomas (2007).

<sup>4</sup>In this sense, the model is formally similar to asymmetric adjustment cost models, such as the investment model of Abel & Eberly (1996) and the labor demand model of Bentolila & Bertola (1990).

Section 2 shows that this simple insight equips us with a fundamental prediction: Firms will compress wage increases as well as wage cuts in the presence of downward wage rigidity. This occurs through two channels. First, forward-looking firms temper wage increases as a precaution against future costly wage cuts. Raising the wage today increases the likelihood of having to cut the wage, at a cost, in the future. Second, even in the absence of forward-looking behavior, downward wage rigidity raises the level of wages that firms inherit from the past. As a result, firms do not have to raise wages as often or as much to obtain their desired wage level.

These two forms of compression of wage increases culminate in the perhaps surprising prediction that worker resistance to wage cuts has no effect on aggregate wage growth in the model. This result challenges a common intuition in previous empirical literature on downward wage rigidity. This literature has assumed (implicitly or otherwise) that the existence of downward wage rigidity has no effect on wage increases.<sup>5</sup> In addition, many studies go on to report positive estimates of the effect of downward wage rigidity on aggregate wage growth, seemingly in contradiction to the predictions of the model. The model suggests an explanation for this result: Neglecting compression of wage increases leads a researcher to ignore a source of wage growth moderation, and thereby overstate the increase in aggregate wage growth due to downward wage rigidity.

To assess the empirical relevance of firms' compression of wage increases as a response to downward wage rigidity testable implications of the model are derived to take to the data. The implied percentiles of the distribution of wage growth across workers can be characterized using the model. This reveals that the effects of downward wage rigidity on the compression of wage increases can be determined by observing the effects of the rates of inflation and productivity growth on these percentiles. Higher inflation eases the constraint of downward nominal wage rigidity which in turn reduces the compression of wage increases, raising the upper percentiles of wage growth. A symmetric logic holds for the effects of productivity growth.

Evidence on these predictions is presented in section 3 using a broad range of micro-data for the US and Great Britain. I find significant evidence for compression of wage increases related to downward wage rigidity, consistent with the implications of the model. Moreover, accounting for this limits the estimated increase in aggregate real wage growth due to downward wage rigidity from up to 1.5 percentage points to no more than 0.15 of a percentage point, an order of magnitude smaller.

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<sup>5</sup>This is a key identifying assumption in Card & Hyslop (1997). However, their analysis is no more subject to this criticism than other previous empirical work on downward wage rigidity: Kahn (1997), Altonji & Devereux (2000), Nickell & Quintini (2003), Fehr & Goette (2005), Dickens et al. (2006), among others, implicitly make the same assumption.

Section 4 then considers the implications of these results for the true implied costs of downward wage rigidity to firms. A simple approximation method allows these costs to be quantified using moments of the available micro-data on wages. This approximation reveals that the model implies that the costs of wage rigidity are driven by reductions in workers' effort that firms must accept when they reduce wages, contrary to the common intuition that downward wage rigidity increases the cost of labor. In addition, erroneously concluding that downward wage rigidity raises the rate of aggregate wage growth, as previous literature has done, leads to a substantial (more than twofold) overstatement of the costs of downward wage rigidity on firms. Finally, a sense of the magnitude of the implied long run disemployment effects of wage rigidity can be gleaned from the model. For rates of inflation and productivity growth observed in the data, the effects of downward nominal wage rigidity under zero inflation are unlikely to reduce employment by more than 0.25 of a percentage point.<sup>6,7</sup>

Based on these results, I conclude that the macroeconomic effects of downward wage rigidity are likely to be small, especially relative to the implications of previous empirical literature on wage rigidity. This suggests that downward nominal wage rigidity does not provide a strong argument against the adoption of a low inflation target. Importantly, however, this result is nevertheless consistent with the diverse body of evidence that suggests workers resist nominal wages cuts. This conclusion therefore complements recent research that has argued for the targeting of low inflation rates in the context of models in which wage rigidity has no allocative effects (see e.g. Goodfriend & King, 2001). The results of this paper suggest that such a conclusion also extends to a model of allocative wage rigidity based on evidence that workers resist wage cuts (Bewley, 1999).

## 1 A Model of Worker Resistance to Wage Cuts

This section presents a simple model of downward nominal wage rigidity based on the observations detailed in the empirical literatures mentioned above. Consider the optimal wage

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<sup>6</sup>Despite some common formal elements, the mechanism here is distinct from that emphasized by Caplin & Spulber (1987). They show that the uniformity of the effects of aggregate monetary shocks on individual real prices can yield monetary neutrality in an (s,S) pricing environment. In the current analysis, firms' endogenous wage setting response to idiosyncratic shocks allows them to obviate much of the costs of worker resistance to wage cuts.

<sup>7</sup>This result may also help to reconcile an apparent puzzle in the literature. In contrast to micro-level evidence, empirical support for the macroeconomic effects of downward wage rigidity has been relatively scant (Card & Hyslop, 1997; Lebow, Saks & Wilson, 1999; Nickell & Quintini, 2003; Smith, 2004). The results of this paper suggest a simple explanation: Since previous studies have ignored compression of wage increases, this has led researchers to overstate the increase in aggregate wage growth and thereby the implied costs of downward wage rigidity to firms.

policies of worker-firm pairs for whom the productivity of an incumbent worker (denoted  $e$ ) depends upon the wage according to

$$e = \ln(\omega/b) + c \ln(W/W_{-1}) \mathbf{1}^-, \quad (1)$$

where  $W$  is the nominal wage,  $W_{-1}$  the lagged nominal wage,  $\mathbf{1}^-$  an indicator for a nominal wage cut,  $\omega \equiv W/P$  the real wage, and  $b$  a measure of real unemployment benefits (which is assumed to be constant over time). The parameter  $c > 0$  varies the productivity cost to the firm of a nominal wage cut.

The key qualitative feature of this effort function is the existence of a kink at  $W = W_{-1}$  reflecting a worker's resistance to nominal wage cuts. The marginal productivity loss of a nominal wage cut exceeds the marginal productivity gain of a nominal wage increase by a factor of  $1 + c > 1$ . This characteristic is what makes nominal wage increases (partially) irreversible – a nominal wage increase can only be reversed at an additional marginal cost of  $c$ . Clearly, this irreversibility is the key feature of the model, and the parameter  $c$  determines its importance for wage setting.<sup>8</sup>

The effort function, (1), can be interpreted as a very simple way of capturing the basic essence of the motivations for downward wage rigidity mentioned in the literature. It is essentially a parametric form of effort functions in the spirit of the fair-wage effort hypothesis expounded by Solow (1979) and Akerlof & Yellen (1986), with an additional term reflecting the impact of nominal wage cuts on effort. Bewley (1999) also advocates such a characterization, but sees wage cuts rather than wage levels as critical for worker morale.<sup>9</sup>

Given the effort function (1), consider a discrete-time, infinite-horizon model in which price-taking worker-firm pairs choose the nominal wage  $W_t$  at each date  $t$  to maximize the expected discounted value of profits. For simplicity, assume that each worker-firm's production function is given by  $a \cdot e$ , where  $a$  is a real technology shock that is idiosyncratic to the worker-firm match, is observed contemporaneously, and acts as the source of uncertainty in the model. It is convenient to express the firm's profit stream in constant date  $t$  prices. To this end, define the price level at date  $t$  as  $P_t$  and assume that it evolves according to

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<sup>8</sup>The precise parametric form of (1) is chosen primarily for analytical convenience. None of the qualitative results emphasized in what follows depends on the specific parametric form of (1) – the key is that effort is increasing in the wage and kinked around the lagged nominal wage.

<sup>9</sup>In Bewley's words: "The only one of the many theories of wage rigidity that seems reasonable is the morale theory of Solow..." (Bewley, 1999, p.423), and "The [Solow] theory...errs to the extent that it attaches importance to wage levels rather than to the negative impact of wage cuts," (Bewley, 1999, p.415). However, such is the intricacy of Bewley's study, he would probably consider (1) a simplification, not least for its neglect of emphasis on morale as distinct from productivity, and of the internal wage structure of firms as a source of wage rigidity. I argue that it is a *useful* simplification as it provides key qualitative insights into the implied dynamics of wage-setting under more nuanced theories of morale.

$P_t = e^\pi P_{t-1}$ , where  $\pi$  reflects inflation.<sup>10</sup> Denoting the nominal counterparts,  $A_t \equiv P_t a_t$  and  $B_t \equiv P_t b$  and substituting for  $e_t$ , the value of a job with lagged nominal wage  $W_{-1}$  and nominal productivity  $A$  in recursive form<sup>11</sup> is given by

$$J(W_{-1}, A) = \max_W \left\{ A [\ln(W/B) + c \ln(W/W_{-1}) \mathbf{1}^-] - W + \beta e^{-\pi} \int J(W, A') dF(A'|A) \right\}. \quad (2)$$

where  $\beta \in [0, 1)$  is the real discount factor of the firm.

## 1.1 Some Intuition for the Model

To anticipate the model’s results, this subsection provides intuition for each of the predictions of the model. First, the model predicts that there will be a spike at zero in the distribution of nominal wage changes. This arises because of the kink in the firm’s objective function at the lagged nominal wage. Thus, there will be a range of values (“region of inaction”) for the nominal shock,  $A$ , for which it is optimal not to change the nominal wage. Since  $A$  is distributed across firms, there will exist a positive fraction of firms each period whose realization of  $A$  lies in their region of inaction that will not change their nominal wage.

Second, if a firm does decide to change the nominal wage, the wage change will be compressed relative to the case where there is no wage rigidity. That nominal wage cuts are compressed is straightforward: Wage cuts involve a discontinuous fall in productivity at the margin, so the firm will be less willing to implement them. It is only slightly less obvious why nominal wage increases are also compressed in this way. The reason is that, in an uncertain world, increasing the wage today increases the likelihood that the firm will have to cut the wage, at a cost, in the future.

An additional, perhaps more fundamental outcome of the model is that an inability to cut wages will tend to raise the wages that firms inherit from the past. Consequently, even in the absence of the forward-looking motive outlined above, wage increases will be compressed simply because firms do not have to increase wages by as much or as often in order to achieve their desired wage level.<sup>12,13</sup>

A final prediction concerns the effect of increased inflation on these outcomes. Com-

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<sup>10</sup>Strictly speaking,  $\pi$  is equal to the logarithm of one plus the inflation rate. Thus  $\pi$  approximates the inflation rate only when inflation is low.

<sup>11</sup>I adopt the convention of denoting lagged values by a subscript,  $_{-1}$ , and forward values by a prime,  $'$ .

<sup>12</sup>Identifying this additional effect is an important benefit of the infinite horizon model studied here. Although compression due to forward-looking behavior would arise in a “simpler” two-period model, this additional effect will be shown to be an outcome of steady state considerations, which cannot be treated in a two-period context.

<sup>13</sup>Compression of wage increases resulting from the impact of downward wage rigidity on past wages is implicit in the myopic model of Akerlof, Dickens & Perry (1996).

pression of wage increases will become less pronounced as inflation rises. Higher inflation implies that firms are less likely to cut wages either in the past or the future. As a result, forward-looking firms no longer need to restrain raises as much as a precaution against future costly wage cuts. Likewise, higher inflation implies that wages inherited from the past are less likely to have been constrained by downward wage rigidity. Thus, firms will raise wages more often to reach their desired wage level.

## 1.2 The Dynamic Model

To make the above intuition precise, consider the solution to the full dynamic model, (2). Taking the first-order condition with respect to  $W$ , conditional on  $\Delta W \neq 0$ , yields

$$(1 + c1^-) (A/W) - 1 + \beta e^{-\pi} D(W, A) = 0, \quad \text{if } \Delta W \neq 0, \quad (3)$$

where  $D(W, A) \equiv \int J_W(W, A') dF(A'|A)$  is the marginal effect of the current wage choice on the future profits of the firm. A key step in solving for the firm's wage policy involves characterizing the function  $D(\cdot)$ . For the moment, however, note that the general structure of the wage policy is as follows:

**Proposition 1** *The optimal wage policy in the dynamic model is given by*

$$W = \begin{cases} U^{-1}(A) & \text{if } A > U(W_{-1}) & \text{Raise} \\ W_{-1} & \text{if } A \in [L(W_{-1}), U(W_{-1})] & \text{Freeze} \\ L^{-1}(A) & \text{if } A < L(W_{-1}) & \text{Cut} \end{cases} \quad (4)$$

where the functions  $U(\cdot)$  and  $L(\cdot)$  satisfy

$$\begin{aligned} (U(W)/W) - 1 + \beta e^{-\pi} D(W, U(W)) &\equiv 0 \\ (1 + c)(L(W)/W) - 1 + \beta e^{-\pi} D(W, L(W)) &\equiv 0. \end{aligned} \quad (5)$$

Proposition 1 states that the firm's optimal wage takes the form of a trigger policy. For large realizations of the nominal shock  $A$  above the upper trigger  $U(W_{-1})$ , the firm raises the wage. For realizations below the lower trigger  $L(W_{-1})$ , the wage is cut. For intermediate values of  $A$  nominal wages are left unchanged.<sup>14</sup>

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<sup>14</sup>Concavity of the firm's problem in  $W$  ensures that the first order conditions (3) characterize optimal wage setting when the wage is adjusted. The remainder of the result follows from the continuity of the optimal value for  $W$  in  $A$ . Intuitively, since the firm's objective, (2), is continuous in  $A$  and concave in  $W$ , realizations of  $A$  just above the upper trigger  $U(W_{-1})$  will lead the firm to raise the wage just above the lagged wage. A symmetric logic holds for wage cuts. Formally, continuity of the optimal value of  $W$  in the state variable  $A$  follows from the Theorem of the Maximum (see e.g. Stokey & Lucas, 1989, pp. 62-63).



To complete the characterization of the firm's wage policy, it is necessary to establish the functions  $U(\cdot)$ , and  $L(\cdot)$ . It can be seen from (5) that, in order to solve for these functions, one requires knowledge of the functions  $D(W, U(W))$  and  $D(W, L(W))$ . This is aided by Proposition 2:

**Proposition 2** *The function  $D(\cdot)$  satisfies*

$$D(W, A) = \int_{L(W)}^{U(W)} [(A'/W) - 1] dF - \int_0^{L(W)} c(A'/W) dF + \beta e^{-\pi} \int_{L(W)}^{U(W)} D(W, A') dF, \quad (6)$$

which is a contraction mapping in  $D(\cdot)$ , and thus has a unique fixed point.

The first term on the right hand side of (6) represents tomorrow's expected within-period marginal benefit, given that  $W'$  is set equal to  $W$ . To see this, note that the firm will freeze tomorrow's wage if  $A' \in [L(W), U(W)]$ , and that in this event a wage level of  $W$  today will generate a within-period marginal benefit of  $(A'/W) - 1$ . Similarly, the second term on the right hand side of (6) represents tomorrow's expected marginal cost, given that the firm cuts the nominal wage tomorrow. Finally, the last term on the right hand side of (6) accounts for the fact that, in the event that tomorrow's wage is frozen, the marginal effects of  $W$  persist into the future in a *recursive* fashion. It is this recursive property that provides the key to determining the function  $D(\cdot)$ .<sup>15</sup>

For the purposes of the present paper, a specific form for  $F(\cdot)$  is used. Assume that real shocks,  $a$ , evolve according to the geometric random walk,

$$\ln a' = \mu + \ln a - \frac{1}{2}\sigma^2 + \varepsilon', \quad (7)$$

where the innovation  $\varepsilon' \sim N(0, \sigma^2)$  and  $\mu$  reflects productivity growth. Given that prices evolve according to  $P' = e^\pi P$ , this yields the following process for nominal shocks,  $A$ ,

$$\ln A' = \mu + \pi + \ln A - \frac{1}{2}\sigma^2 + \varepsilon', \quad (8)$$

where  $\pi$  reflects inflation. Note that this has the simple implication that  $\mathbb{E}(A'|A) = \exp(\mu + \pi)A$ , so that average nominal productivity rises in line with inflation and productivity growth.

This information can be used to determine the full solution as follows. First, the functions  $D(W, U(W))$  and  $D(W, L(W))$  can be solved for using equation (6) via the method of

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<sup>15</sup>Proposition 2 states that this recursive property takes the form of a contraction mapping in  $D$ . To see that (6) is a contraction, note that Blackwell's sufficient conditions can be verified. Monotonicity of the map in  $D$  is straightforward. To see that discounting holds, note that  $\beta e^{-\pi} < 1$  and the probability that  $A'$  lies in the inaction region  $[L(W), U(W)]$  is less than one.

undetermined coefficients. Given these, the solutions for  $U(W)$  and  $L(W)$  can be obtained using the equations in (5). Proposition 3 shows that this method yields a wage policy that takes a simple piecewise linear form.

**Proposition 3** *If nominal shocks evolve according to the geometric random walk, (8), the functions  $U(\cdot)$  and  $L(\cdot)$  are of the form*

$$U(W) = U \cdot W, \text{ and } L(W) = L \cdot W, \quad (9)$$

where  $U$  and  $L$  are given constants that depend upon the parameters of the model,  $\{c, \beta, \mu, \pi, \sigma\}$ .

## 2 Predictions

Anticipating the empirical results documented later, this section draws out a set of relationships predicted by the model that can be estimated using available data.

### 2.1 Compression of Wage Increases

An important outcome of the model is that it naturally implies that downward wage rigidity leads firms to reduce the magnitude of wage increases, and that this occurs through two effects. The first channel is implied by the properties of the coefficients of the optimal wage policy,  $U$  and  $L$  in (9). While closed-form solutions for  $U$  and  $L$  are not available, it is straightforward to compute them numerically. Doing so establishes that  $U > 1 > L$  in the presence of downward wage rigidity (when  $c > 0$ ).

It is instructive to contrast this result with some simple special cases of the model. First, consider the frictionless model where  $c = 0$ . Denoting frictionless outcomes with an asterisk, it is straightforward to show that  $U^* = 1 = L^*$ , so that frictionless wages  $W^*$  are equal to the nominal shock  $A$ , and wage changes fully reflect changes in productivity. The result that  $L < 1$  in the general model therefore means that firms are avoiding wage cuts that they would have implemented in the absence of wage rigidity. This is a simple implication of the discontinuous fall in effort at the margin following a wage cut.

Likewise, the result that  $U > 1$  when  $c > 0$  implies that firms are reducing the wage in the event that they increase pay relative to a frictionless world. As a result, for a given level of the lagged wage, this will serve to reduce the magnitude of wage increases, leading to one form of compression of wage increases. To understand the intuition for this result, a useful point of contrast is the special case of the model in which firms are myopic,  $\beta = 0$ . In this case, it is simple to show that  $U_{\beta=0} = 1 > L_{\beta=0} = 1/(1+c)$ . It follows that the

result that  $U > 1$  in the general model is driven by the forward looking behavior of firms. Intuitively, raising the nominal wage today increases the likelihood that a firm will wish to cut the wage, at a cost, in the future.

The second source of compression of wage increases relates to the effect of downward wage rigidity on the lagged wages of firms. Specifically, firms' inability to reduce wages in the past will place upward pressure on the wage that they inherit from previous periods. As a result, firms do not need to raise wages as often or as much to achieve any given level of the current wage, further serving to reduce the magnitude of wage increases. The joint forces of these two effects culminate in the following, perhaps surprising, result:

**Proposition 4** *Downward wage rigidity has no effect on aggregate wage growth in steady state.*

This result can be interpreted as a simple requirement for the existence of a steady state in which average growth rates are equal. Since productivity shocks grow on average at a constant rate, so must wages grow at that same rate in the long run. Even a model with downward wage rigidity must comply with this steady state condition in the long run.<sup>16</sup>

Note that this result holds regardless of how forward looking firms are. Even if firms are myopic ( $\beta = 0$ ), so they do not reduce wages in the event that they increase pay, wage rigidity will still have no effect on aggregate wage growth. The reason is that the second channel through which wage increases are compressed dominates because firms inherit higher wages from the past.

## 2.2 Implications for the Literature on Wage Rigidity

Surprisingly, none of the previous research on downward wage rigidity has taken account of the compression of wage increases that is implied by worker resistance to wage cuts (see among others, Kahn, 1997; Card & Hyslop, 1997; Altonji & Devereux, 2000). This section shows that neglecting this compression can lead a researcher to overstate the effects of downward wage rigidity on the aggregate growth of real wages.

Figure 1 illustrates the point. It shows three simulated wage growth distributions derived from the model of section 1. The histogram shows the distribution of real wage growth in the presence of wage rigidity ( $c > 0$ ), whereas the solid line illustrates the true frictionless wage growth density ( $c = 0$ ). Comparing these two distribution provides a visual impression of the results highlighted above: Downward wage rigidity leads to both fewer wage cuts, as well as fewer wage increases. Figure 1 also includes a “median symmetric” density (dashed

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<sup>16</sup>A similar result has been established in the investment literature by Bloom (2000).

line) that is implied if one assumes erroneously that downward wage rigidity has no effect on wage increases.<sup>17</sup> It can be seen that, by using the median symmetric counterfactual, one obtains an overestimate of the increase in average wage growth due to wage rigidity. This occurs as a direct result of the compression of the upper tail of wage growth. Neglecting this compression leads to an overstatement of the mass of desired frictionless wage cuts, and thereby of the effects of wage rigidity on average wage growth.

This observation has important implications for the conclusions of the previous literature. Many studies go on to report positive estimates of the increase in aggregate real wage growth driven by downward rigidity as a measure of the costs of wage rigidity imposed on firms. For example, Card & Hyslop (1997) provide results which suggest that downward wage rigidity increases average real wage growth by around one percentage point in times of low inflation. Similar exercises are performed in Nickell & Quintini (2003), Fehr & Goette (2005), Dickens et al. (2006), among others. These results are surprising in the light of the model above: If downward wage rigidity had any effect on average real wage growth, it would imply a violation of steady state in the labor market. A natural question in the light of this is whether it is empirically the case that firms compress wage increases in the face of downward wage rigidity.

## 2.3 Empirical Implications

The model implies two simple approaches to testing the prediction that firms compress wage increases as a response to downward wage rigidity. The first is anticipated in Figure 1: If firms compress wage increases, one should observe the upper tail of the distribution of wage growth shifting inwards as downward wage rigidity binds. The model also suggests when this will occur. When inflation is high, firms' desired wage growth,  $\Delta \ln W^* = \Delta \ln A$  is unlikely to be negative. Thus, downward rigidity of nominal wages is unlikely to bind now or in the future, firms will not compress wage increases, and the distribution of wage growth will converge to the solid line in Figure 1. When inflation is low, however, downward wage rigidity will bind for many firms, wage increases will be compressed and the distribution of wage growth will look like the histogram in Figure 1.<sup>18</sup> This suggests a simple visual test of the model by inspecting the distribution of real wage growth in high compared to low inflation periods.

Second, the model yields predictions on the effect of inflation and productivity growth

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<sup>17</sup>This is derived by imposing symmetry in the upper tail of the distribution of wage growth with  $c > 0$ . This is, in fact, the method used by Card & Hyslop (1997) to generate an estimate of the frictionless wage growth distribution.

<sup>18</sup>Likewise, high levels of productivity growth,  $\mu$ , will also relax the constraint of downward wage rigidity.

on the percentiles of the distribution of real wage growth. These percentiles can be approximated as follows:

**Proposition 5** *The percentiles of the distribution of real wage growth satisfy*

$$\mathbb{E}(P_n|\mu, \pi) \approx \begin{cases} \mu - c\mathbf{p}^{-*}(\mu, \pi) + \text{const}_n & \text{if } P_n > -\pi \\ -\pi & \text{otherwise} \\ \mu + c\mathbf{p}^{+*}(\mu, \pi) + \text{const}_n & \text{if } P_n < -\pi, \end{cases} \quad (10)$$

where  $\mathbf{p}^{-*}(\mu, \pi)$  and  $\mathbf{p}^{+*}(\mu, \pi)$  are respectively the frictionless ( $c = 0$ ) probabilities of reducing or increasing the nominal wage.

A number of observations can be gleaned from Proposition 5. First, setting  $c = 0$  reveals that the frictionless percentiles of real wage growth are simply determined by the rate of productivity growth,  $\mu$ , as one would expect. Second, the existence of wage rigidity reduces the upper percentiles of wage growth relative to the frictionless case, reflecting firms' compression of wage increases. Moreover, as inflation,  $\pi$ , and productivity growth,  $\mu$ , rise, the frictionless probability that a firm wishes to reduce nominal wages,  $\mathbf{p}^{-*}(\mu, \pi)$ , declines. Thus, on average one should observe the upper percentiles of real wage growth rising more than one-for-one with productivity growth,  $\mu$ , and rising with inflation,  $\pi$ .

Downward wage rigidity also implies that a non-negligible range of the lower percentiles of wage growth will exactly correspond to zero nominal wage growth, or real wage growth at minus the rate of inflation,  $-\pi$ . In this regime in equation (10), the lower percentiles of wage growth fall one-for-one with the rate of inflation by definition. It is through this effect that increases in inflation “grease the wheels” of the labor market by allowing firms to achieve reductions in labor costs without resorting to costly nominal wage cuts.

Finally, equation (10) implies that very low percentiles of the wage growth distribution that correspond to nominal wage cuts (real wage cuts of greater magnitude than  $-\pi$ ) also will rise with inflation and productivity growth. To see this, note that these percentiles are increasing in the frictionless probability of raising wages,  $\mathbf{p}^{+*}(\mu, \pi)$ , which in turn is increasing in  $\mu$  and  $\pi$ . This last result can seem odd at first. However, the logic behind it mirrors the intuition for the effects of  $\mu$  and  $\pi$  on upper percentiles. When inflation and real wage growth are large, a firm expects that it will likely reverse nominal wage cuts in the near future. As a result, the firm is less inclined to incur the costs of reducing wages, and wage cuts are reduced in magnitude for a given lagged wage. Moreover, high inflation and productivity growth relax the upward pressure downward wage rigidity places on the wages firms inherit from the past. As a result, firms do not need to reduce wages as often or as

much to achieve any given level of the current wage, further reducing the magnitude of wage cuts.

### 3 Empirical Implementation

The data used in the empirical analysis are taken from the Current Population Survey (CPS) and the Panel Study of Income Dynamics (PSID) for the US, and from the New Earnings Survey (NES) for Great Britain. For all datasets, the relevant wage measure used is the basic hourly wage rate for respondents aged 16 to 65. The CPS samples are taken from longitudinally linked Merged Outgoing Rotation Group files from 1979 to 2002. The PSID data are taken from the random (not poverty) samples for the years 1971 to 1992. The NES for Great Britain is an individual level panel for each year running from 1975 through to 1999.

Since the descriptive properties of wage rigidity in these datasets have been well-explored in previous analyses<sup>19</sup> the purpose here is not to provide a full descriptive account of downward wage rigidity. For reference, though, Tables 1 and 2 present summary statistics for wage growth and key variables that will be used in the forthcoming analysis.

It should be noted, however, that the NES data for Great Britain have a number of key advantages for the purposes of this paper, especially in comparison with the CPS and PSID samples for the US. Most starkly, the NES yields comparatively very large sample sizes: one obtains sample sizes of 60–80,000 wage change observations each year. A second advantage of the NES data is its sample period, 1975–2001. This is useful because variation in the rate of inflation will be used in what follows to gauge the impact of wage rigidity on wage growth, and the UK experienced significant variation in inflation over this period relative to the US (see Figure 2). A final key advantage of the NES sample is that measurement error in these data is less problematic relative to the individually reported data of the CPS and PSID samples. The reason is that the NES is collected from employers’ payroll records, thereby leaving less scope for error (see Nickell & Quintini, 2003, for more on this). This is important because previous empirical studies have gone to some lengths to control for the effects of measurement error (Smith, 2000; Altonji & Devereux, 2000). The relative accuracy of the NES allows us to concentrate on substantive questions, and is thus an important virtue in this context.<sup>20</sup>

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<sup>19</sup>See Card & Hyslop (1997) for the CPS, Kahn (1997) and Altonji & Devereux (2000) for the PSID, and Nickell & Quintini (2003) for the NES.

<sup>20</sup>Nickell & Quintini (2003) compared the accuracy of hourly wage changes in the NES with those obtained from a sample whose payslip was checked in the British Household Panel Study and found remarkably similar properties in both datasets.

### 3.1 The Impact of Low Inflation on Wage Growth

This section explores whether the empirical predictions of section 2 are borne out in the data summarized above. First, visual evidence is presented for the compression of wage increases is presented using the empirical distribution of wage growth, as anticipated in Figure 1. In addition, evidence on the effects of inflation and real growth on the percentiles of wage growth based on equation (10) is also assessed.

**Visual Evidence from the Distribution of Wage Growth.** As noted in section 2.3, a particularly simple approach is to observe differences in the distribution of wage growth in periods of high inflation compared to periods of low inflation. To this end, figures 3(a) and 4(a) present estimates of the density of log real wage growth for periods with different inflation rates using the PSID for the US, and the NES for Britain.<sup>21</sup> Notice that lower inflation leads to a compression of the lower and, more importantly for the purposes of this paper, the upper tail of the wage change distribution, precisely in accordance with the predictions of section 2.

One could argue, however, that at least some of the observed differences are due to changes in other variables, such as the industrial, age, gender, regional etc. compositions of the workforce. To address this, a set of micro-level control variables are introduced for each dataset, which are summarized in Table 2. Changes in these variables are controlled for using the method of DiNardo, Fortin & Lemieux (1996), henceforth “DFL”. This method is useful because it requires no parametric assumptions on the effects of these controls on wage growth. Given the intrinsically non-linear character of the wage policy (4), this is especially helpful.

The DFL procedure is a simple re-weighting of the observed distribution of wage growth to estimate the counterfactual distribution that would prevail if the distribution of worker characteristics did not change.<sup>22</sup> Figures 3(b) and 4(b) display density estimates of the DFL re-weighted distribution of log real wage changes for different inflation periods for the PSID and NES. Again, one can clearly detect that lower rates of inflation are associated with a compression both of tails of the wage growth distribution, in line with the predictions of section 2.

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<sup>21</sup>The time-varying accuracy of the wage imputation flags in the CPS makes this a less useful exercise for the CPS data.

<sup>22</sup>Denote a “base year”,  $T$  (this will be the final sample year), worker characteristics,  $x$ , and the year of the relevant  $x$  distribution,  $t_x$ . The time  $t$  counterfactual distribution of wage growth can be written as  $f(\Delta \ln \omega_t; t_x = T) = \int f(\Delta \ln \omega | x) dF(x | t_x = T) = \int f(\Delta \ln \omega | x) \cdot \psi \cdot dF(x | t_x = t)$ , where  $\psi = \frac{dF(x | t_x = T)}{dF(x | t_x = t)} = \frac{\Pr(t_x = T | x)}{\Pr(t_x = t | x)} \cdot \frac{\Pr(t_x = t)}{\Pr(t_x = T)}$ , and where the second equality follows from Bayes’ Rule. The weights  $\psi$  are estimated using a probit model.

**Evidence from Percentile Regressions.** To assess whether the variation in the distribution of wage growth varies systematically with the impact of downward wage rigidity, the effects of inflation on the percentiles of real wage growth are now estimated based on the results of Proposition 5. In particular, regressions of the following form are estimated

$$P_{nrt} = \alpha_n + \beta_n \boldsymbol{\mu}_{rt} + \eta_n \boldsymbol{\pi}_t + z'_{rt} \varphi_n + \varepsilon_{nrt}, \quad (11)$$

where  $P_{nrt}$  is the  $n$ th percentile of the DFL re-weighted real wage growth distribution in region  $r$  at time  $t$  derived above, and  $z_{rt}$  is a vector of controls that could potentially affect the distribution of wage growth.

To estimate (11), measures of frictionless average real wage growth,  $\boldsymbol{\mu}_{rt}$ , and of the inflation rate,  $\boldsymbol{\pi}_t$ , are needed. For the latter, the CPI-U-X1 series for the US, and the April to April log change in the Retail Price Index for Great Britain are used. To measure  $\boldsymbol{\mu}_{rt}$ , the result of Proposition 4 is invoked – i.e. that wage rigidity has no effect on average wage growth in the model. Thus,  $\boldsymbol{\mu}_{rt}$  is measured using the observed regional average real wage growth rate.<sup>23</sup> In accordance with equation (10), (11) is estimated by Least Squares weighted by the size of the region at each date.

The control variables,  $z_{rt}$ , used are as follows. First, controls for the absolute change in the rate of inflation are included. This is motivated by the hypothesis that greater inflation volatility will yield greater dispersion in relative wages regardless of the existence of wage rigidity (see Groshen & Schweitzer, 1999). In addition, the current and lagged regional unemployment rates are included. This is motivated by the idea that the existence of downward wage rigidity may have unemployment effects. This will lead to workers “leaving” the wage change distribution, and so any resulting distributional consequences are controlled for.<sup>24</sup>

Based on the predictions of Proposition 5, the coefficients of interest in (11) for estimating the effects of wage rigidity are  $\eta_n$  and  $\beta_n$ . Recall that the key prediction that is being tested – that downward wage rigidity leads to compression of wage increases – implies that upper percentiles of real wage growth will rise with inflation, and will rise more than one-for-one with average real wage growth. Thus, the model predicts that  $\eta_n > 0$  and that  $\beta_n > 1$  for large  $n$ .

The results from estimating (11) for each dataset are reported in Table 3. The results provide strong evidence that the upper tail of the wage growth distribution is compressed as

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<sup>23</sup>A trimmed mean for regional real wage growth is used to exclude the effects of outliers on  $\boldsymbol{\mu}_{rt}$ . I trim log real wage growth below  $-50$  log points and above  $50$  log points. To see that such observations are rare, see Figures 3 and 4.

<sup>24</sup>Additionally, controls for any distortion to the wage growth distributions due to limitations of the datasets used are included.



a result of downward wage rigidity, consistent with the predictions of the model. To see this, first consider the results for the upper percentiles of real wage growth. For all datasets, the estimated impact of inflation is positive for the 70th–90th percentiles, and is often significant. Likewise, the coefficients on aggregate wage growth exceed unity for these upper percentiles of the real wage growth distribution, and are strongly significant. Recall from section 2.3 that these results are consistent with higher inflation and aggregate wage growth easing the compression of wage increases, as implied by the model of worker resistance to wage cuts.

It is worth noting that these effects are particularly significant in the NES data for Great Britain. This is to be expected given the advantages of these data noted above: The British economy experienced large variation in the rate of inflation over the sample period; the data are taken from employer records minimizing measurement error problems; and the sample sizes are large. These all aid the ability of the regressions based on equation (11) to detect the effects of inflation and mean wage growth where they exist.

For reference, Table 3 also reports estimates of the effects of inflation and average real wage growth on lower percentiles. Note that the predictions of the model on the  $\eta_n$  and  $\beta_n$  for lower percentiles depend on the position of zero nominal wage growth in the distribution of real wage growth. For percentiles that predominantly lie in the spike at zero nominal wage growth over the sample period, equation (10) implies that  $\eta_n < 0$ , and that the effects of  $\mu_{rt}$  will be attenuated toward zero. For very low percentiles of real wage growth that predominantly lie below the spike at zero, however, equation (10) implies that  $\eta_n > 0$  and  $\beta_n > 1$ .

The results in Table 3 for the lower tail of the wage growth distribution also are consistent with the predictions of the model. The spike at zero nominal wage growth appears between the 20th–30th percentiles in the CPS data, the 10th–30th percentiles in the PSID, and the 20th–40th percentiles in the NES. As predicted in section 2.3, higher inflation has a significantly negative effect and the effects of aggregate wage growth,  $\mu_{rt}$ , are attenuated toward zero at these percentiles. Likewise, for percentiles that lie below the spike at zero nominal wage growth it can be seen that the effect of higher inflation is diminished and the coefficient on average regional wage growth rises above unity once more.

Together, these results provide strong evidence for the prediction that the upper tail of the wage growth distribution will be compressed as a result of downward wage rigidity. In all datasets one can detect greater compression of wage increases as inflation and mean wage growth decline that is statistically significant. A natural question in the light of this is the economic significance of the estimates in Table 3. This is addressed by now estimating the increase in real wage growth implied by these estimates.

**The Effect of Downward Wage Rigidity on Aggregate Wage Growth.** Proposition

4 showed that downward wage rigidity should have no effect on aggregate wage growth. This contrasts with previous literature that has reported positive estimates of the effects of downward wage rigidity on average real wage growth. A possible reason is that this literature has neglected the compression of wage increases as a result of worker resistance to wage cuts. This section derives estimates of the effect of downward wage rigidity on aggregate wage growth based on the results in Table 3. Specifically, the difference between average real wage growth when inflation is low ( $\pi_L$ ) and average real wage growth when inflation is high ( $\pi_H$ ) is estimated,

$$\hat{\lambda} = \widehat{\mathbb{E}}(\Delta \ln \omega | \pi_L, x, z) - \widehat{\mathbb{E}}(\Delta \ln \omega | \pi_H, x, z). \quad (12)$$

To do this, note that the mean of a random variable may be expressed as a simple average of its percentiles, so that  $\widehat{\mathbb{E}}(\Delta \ln \omega | \pi_L, x, z)$  can be estimated as a simple average of the predicted values of the percentiles of wage growth obtained from estimating equation (11).

These predicted percentiles also allow a discretization of the entire distribution of wage growth, so that the increase in aggregate wage growth due to downward wage rigidity can be decomposed into two components. The first is the increase in wage growth due to restricted nominal wage cuts in times of low inflation. Following the literature, this is referred to as the “wage sweep up” (*wsu*). The second component is the reduction in average wage growth due to compressed wage increases under low inflation, the “wage sweep back” (*wsb*).<sup>25</sup> The sum of the wage sweep up and the wage sweep back is therefore equal to  $\lambda$ . Since the literature has ignored the wage sweep back effect, the wage sweep up provides an estimate of the increase in aggregate wage growth comparable to the estimates in the literature. Therefore, comparison of *wsu* with  $\lambda$  provides a sense of the overestimate of the increase in aggregate wage growth implied by ignoring compression of wage increases.

This procedure is performed on 99 estimated wage growth percentiles using a value for  $\pi_H$  equal to 20% (the midpoint of the sample maxima in the US and Britain; see Figure 2) and a value for  $\pi_L$  equal to 1% (the sample minimum for both the US and Britain). The results are reported in lower panel of Table 3. Consistent with previous literature, estimates of the wage sweep up due to constrained wage cuts range from 0.75 percentage points to 1.5 percentage points. These values span the estimates from Card & Hyslop (1997) which

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<sup>25</sup>Specifically, the wage sweep up and sweep back are equal to,

$$\begin{aligned} \widehat{wsu} &= \widehat{\mathbb{E}}(\Delta \ln \omega \cdot \mathbf{1}(\Delta \ln \omega < -\pi) | \pi_L) - \widehat{\mathbb{E}}(\Delta \ln \omega \cdot \mathbf{1}(\Delta \ln \omega < -\pi) | \pi_H), \\ \widehat{wsb} &= \widehat{\mathbb{E}}(\Delta \ln \omega \cdot \mathbf{1}(\Delta \ln \omega \geq -\pi) | \pi_L) - \widehat{\mathbb{E}}(\Delta \ln \omega \cdot \mathbf{1}(\Delta \ln \omega \geq -\pi) | \pi_H), \end{aligned}$$

where  $\widehat{\mathbb{E}}(\Delta \ln \omega \cdot \mathbf{1}(\Delta \ln \omega < \pi) | \pi)$  is estimated from the predicted percentiles of wage growth and  $\mathbf{1}(\cdot)$  is the indicator function.

suggest that the wage sweep up due to low inflation is on the order of 1 percentage point. However, the wage sweep back due to compressed wage increases is of similar magnitude, ranging from  $-0.71$  to  $-1.37$  percentage points, and serves to offset the effects of constrained wage cuts, exactly along the lines of the predictions of section 2. Together, these lead to estimates of the increase in aggregate wage growth under low inflation to be in the range of 0.02 to 0.15 percentage points. These values are an order of magnitude smaller than the estimates a researcher would obtain by neglecting the compression of wage increases in times of low inflation.

Thus, as anticipated by the theoretical predictions of section 2, there is abundant empirical evidence that firms compress wage increases as a response to downward wage rigidity. Moreover, the evidence is both statistically and economically significant: Neglecting the compression of wage increases leads to a substantial overestimate of the increase in wage growth due to downward wage rigidity.

## 4 Macroeconomic Implications

The preceding sections have shown, both as a theoretical and an empirical issue, that there is little reason to believe that downward wage rigidity imposes costs on firms by raising the rate of growth of real wages. This section turns to the question of how exactly downward wage rigidity imposes costs on firms, and whether or not these costs are large.

### 4.1 Approximating the Costs of Wage Rigidity to a Firm

A simple approximation to the reduction in the average value of a match due to wage rigidity can be derived from the model. Denote the latter as  $C \equiv \mathbb{E}(J^* - J)$  where  $J^*$  is the frictionless ( $c = 0$ ) value of a match. It is straightforward to show that  $C$  can be approximated by<sup>26</sup>

$$C(\mu, \pi) \approx \gamma(\mu, \pi) \cdot \frac{\mathbb{E}(\omega^*)}{1 - \beta e^\mu}, \quad \text{where } \gamma(\mu, \pi) \equiv c \left| \mathbb{E}(\Delta \ln W^* \mathbf{1}^- | \mu, \pi) \right|. \quad (13)$$

Equation (13) is useful from a number of perspectives. First, it shows that the costs of wage rigidity to firms are driven by the reductions in productivity that firms must accept when they reduce wages, rather than by direct increases in the cost of labor. To see this, note from

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<sup>26</sup>Note that, for  $c \approx 0$ , one can write  $C \approx \frac{dC}{dc}|_{c=0} \cdot c$ . Then note that  $\frac{dC}{dc}|_{c=0} = -\mathbb{E} \left[ \frac{\partial J}{\partial c} + \frac{\partial J}{\partial W} \frac{\partial W}{\partial c} \right] |_{c=0} = -\mathbb{E} \left[ \sum_{t=0}^{\infty} \beta^t a_t \Delta \ln W_t^* \mathbf{1}_t^- \right] = -\mathbb{E}(\Delta \ln W^* \mathbf{1}^-) \frac{E(a)}{1 - \beta e^\mu}$  where the second equality follows from the envelope theorem and the third follows from the independence of  $\Delta \ln A$  and  $a$ . Noting that, when  $c = 0$ ,  $\omega^* = a$  leads to equation (13).

equation (2) that  $C$  is equal to the average decline in worker effort due to wage cuts. The latter suggests another attractive feature of equation (13): It provides an approximation to the costs of wage rigidity to firms that is unaffected by the (simplifying) assumption that workers' productivity depends on the log real wage in (1). Finally, noticing that  $\mathbb{E}(\omega^*) / (1 - \beta e^\mu)$  is the discounted value of real frictionless labor costs, equation (13) also has the simple interpretation that the reduction in the value of a match due to wage rigidity is approximately equivalent to increasing the level of average real wages by a factor  $\gamma$ , which is equal to the marginal productivity cost of a one percent nominal wage cut,  $c$ , times the expected frictionless nominal wage cut,  $|\mathbb{E}(\Delta \ln W^* \mathbf{1}^-)|$ . Thus  $\gamma$  can be interpreted as a *compensating wage differential* that compensates firms for the costs induced by downward wage rigidity.

To get a quantitative sense for  $\gamma(\mu, \pi)$ , it is necessary to quantify  $c$  and  $|\mathbb{E}(\Delta \ln W^* \mathbf{1}^- | \mu, \pi)|$ . To quantify the latter in the model, note that all one needs is a value for the dispersion of idiosyncratic shocks,  $\sigma$ . The wage growth distributions summarized in Figures 3 and 4 imply a value for  $\sigma$  approximately equal to 0.1.<sup>27</sup>

Quantifying the marginal effort cost of a one percent wage cut,  $c$ , is less straightforward. In the model,  $c$  is closely related to the size of the spike at zero in the distribution of nominal wage growth. Obtaining a value for the spike at zero nominal wage growth is complicated by measurement error in wages, which can bias down the observed spike by making true wage freezes appear as small changes (Altonji & Devereux, 2000). To address this, Table 4 reports the implied values for the compensating wage differential for an array of values for the spike at zero nominal wage growth that would prevail under zero inflation and productivity growth in the model. Values for the spike between 0.075 (approximately the maximum value observed in the NES data; see Table 1) and 0.4 (more than double the largest values observed in the datasets in Table 1) are considered.

A number of observations can be gleaned from Table 4. First, for any value of the spike, the compensating differential imposed by downward wage rigidity declines as inflation and productivity growth rise. The intuition for this is simple: Higher inflation and productivity growth imply that desired wage growth is higher, and consequently downward wage rigidity is less binding, thereby imposing smaller costs on firms. Second, higher values of the spike are associated with larger compensating differentials. The simple reason is that larger values of the spike are indicative of larger values of  $c$  which in turn raise the costs of wage rigidity.

Importantly, a third implication of Table 4 is that, for rates of inflation and productivity

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<sup>27</sup>The standard deviations in high inflation periods implied by Figures 3 and 4 are respectively 0.10 in the PSID data, and 0.11 in the NES data. These values differ from the standard deviations reported in Table 2 because the latter include outlier wage changes that are likely to be driven by measurement error.

growth observed in the data,<sup>28</sup> an upper bound on the costs of wage rigidity to firms is that they are equivalent to an increase in average real labor costs of around 0.68 percentage points. Interestingly, Table 4 also implies that this compensating differential would be much larger in the event of trend deflation in prices or negative productivity growth. For inflation rates of  $-5$  percent and productivity growth of  $-2.5$  percent, downward wage rigidity could be equivalent to an increase in aggregate real wages of up to 1.5 percentage points.

## 4.2 Are the Costs Large or Small?

A natural question is whether these costs are large or small. This question is examined from two important perspectives. In this subsection, the implied long run employment effects are addressed. It is possible to embed the model of an ongoing employment relationship from section 1 into a simple model of the aggregate labor market in the long run. Assume that there is free entry of firms into the creation of new jobs and that new jobs are *ex ante* identical. It follows that the expected profits of a firm upon creating a job must equal zero in equilibrium. By reducing expected profits relative to a frictionless environment, downward wage rigidity leads to a reduction in the level of average wages that is consistent with zero profits. The required reduction in average wages is that which is equivalent to the reduction in expected profits due to downward wage rigidity. Equation (13) tells us exactly that: It says that average wages must fall by the compensating differential factor  $\gamma$  relative to a frictionless world in order to maintain zero expected profits in the presence of downward wage rigidity. Firms achieve this in the model by reducing the average initial wage. The implied reduction in equilibrium employment due to downward wage rigidity, therefore, is simply equal to the long run percentage point reduction in the average real wage,  $\gamma$ , times the long run elasticity of the effective supply of workers.

In their analysis of the employment effects of long run reductions in wages of low skilled workers, Juhn, Murphy & Topel (1991) report estimates of the long run supply elasticity that lie below 0.4 for the US (see pp. 112–121). Applying this upper bound to the values of the compensating differential  $\gamma$  in Table 4 suggests that, for observed rates of inflation and productivity growth, the reduction in employment attributable to downward wage rigidity will lie below  $0.4 \times 0.68 = 0.27$  percentage points in the US.

There is no comparable estimate of the long run labor supply elasticity for Britain. However, because the NES data for Britain are drawn from payroll records, and therefore are relatively free from measurement error, it is arguable that the observed spike reported in Table 1 is likely to be representative of the true spike. Table 1 reveals that the spike

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<sup>28</sup>Inflation in both countries over the period remained above 1% (see Figure 2) and annual growth in output per hour remained above  $-1\%$ .

consistently lies below 7 percent in the NES data. Even if the the long run labor supply elasticity of the supply of workers were as high as 2, the values of  $\gamma$  in Table 4 suggest a reduction in employment attributable to downward wage rigidity of approximately  $2 \times 0.085 = 0.17$  percentage points for observed rates of inflation and productivity growth. Compared to either the cyclical or secular variation in the unemployment rate in the US and Britain experienced over the period considered in this paper, this number is very small.

The values for the compensating wage differential in Table 4 also highlight that matters could be different in a context of trend deflation or negative growth. The results of Table 4 suggest that in such an environment, the reduction in employment generated by wage rigidity could be as much as  $0.4 \times 1.5 = 0.6$  percentage points.

### 4.3 Overstatement of Costs in Prior Studies

A second sense in which the magnitude of the costs of downward wage rigidity can be assessed is in comparison to the implied costs if one neglects compression of wage increases, as previous literature has done. The preceding empirical results showed that this can lead one to conclude erroneously that downward wage rigidity raises the annual rate of growth of real wages by approximately one percentage point per year when inflation is low. Similar estimates are reported in Card & Hyslop (1997). To a first-order approximation this implies a rise in average real labor costs equal to<sup>29</sup>

$$\hat{C} \approx \hat{\gamma} \cdot \frac{\mathbb{E}(\omega^*)}{1 - \beta e^\mu} \quad \text{where } \hat{\gamma} \equiv 0.01 \frac{\beta e^\mu}{1 - \beta e^\mu}. \quad (14)$$

Equation (14) has an analogous interpretation to (13). It says that a one percentage point increase in the *rate of growth* of real wages is equivalent to a permanent increase in the average *level* of real wages by a factor of  $0.01 \times \beta e^\mu / (1 - \beta e^\mu)$ . To quantify this, note that if workers and firms separate with probability  $\delta$  each year, and the real interest rate is  $r$ , then the firm's discount factor is equal to  $\beta = (1 - \delta) / (1 + r)$ . In the US economy, the quarterly separation probability is approximately 0.1, implying a value of  $\delta = 0.344$  on an annual basis. Setting  $r = 0.05$  yields a value of  $\beta = 0.625$ . Given average productivity growth of 2 percent, this suggests that ignoring compression of wage increases implies costs of downward wage rigidity equivalent to a 1.76% increase in average real labor costs. For observed values of inflation and growth, the latter is more than double the upper-bound

<sup>29</sup>If downward wage rigidity raises the rate of real wage growth by  $g$ , this implies an increase in average discounted labor costs equal to  $\mathbb{E} \left[ \sum_{t=0}^{\infty} \beta^t e^{\mu t} (1 + g)^t \omega_t \right] - \mathbb{E} \left[ \sum_{t=0}^{\infty} \beta^t e^{\mu t} \omega_t^* \right]$ . For small  $g$ , the latter is approximately equal to  $g \frac{\beta e^\mu}{1 - \beta e^\mu} \frac{\mathbb{E}(\omega^*)}{1 - \beta e^\mu}$ .

estimate of the true costs of wage rigidity implied by the model above.

The results of Table 4 also provide an important perspective on the overstatement of the costs due to downward wage rigidity in prior research. They suggest that the estimated costs in studies that neglect the compression of wage increases exceed the true costs that would prevail even in the presence of 5 percent trend deflation and  $-2.5$  percent real growth. Thus, neglecting the compression of wage increases induced by downward wage rigidity provides a misleading picture of the true costs of wage rigidity imposed on firms.

## 5 Conclusions

In his presidential address, Tobin (1972) argued that, if workers are reluctant to accept reductions in their nominal wages, a certain amount of inflation may “grease the wheels” of the labor market by easing reductions in real labor costs. Exploring the macroeconomic implications of downward wage rigidity from both a theoretical and an empirical perspective, I find that these effects are likely to be small. An explicit model of worker resistance to nominal wage cuts reveals that firms will compress wage increases as well as wage cuts in the presence of downward wage rigidity. This compression of wage increases culminates in the prediction that worker resistance to wage cuts has no effect on aggregate wage growth in the model, challenging a common intuition in previous empirical literature on downward wage rigidity.

To assess the empirical relevance of these predictions, testable implications of the model are taken to micro-data for the U.S. and Great Britain. These data reveal significant evidence for compression of wage increases related to downward wage rigidity. Moreover, accounting for this limits the estimated increase in aggregate real wage growth due to downward wage rigidity to be much closer to zero.

Returning to the model, the implied costs of downward wage rigidity to firms can be approximated using available data. This reveals two senses in which the costs of wage rigidity are small for the rates of inflation and productivity growth observed in the U.S. and Britain over recent decades. First, erroneously concluding that downward wage rigidity raises the rate of aggregate wage growth, as previous literature has done, leads to a substantial (more than twofold) overstatement of the costs of wage rigidity to firms. Second, the implied long run disemployment effects of wage rigidity under zero inflation are shown to be unlikely to reduce employment by more than 0.25 of a percentage point. These results suggest that downward wage rigidity does not provide a strong argument against the adoption of a low inflation target.

Stepping back from this, one might ask whether the mechanism put forward in this paper

– that firms compress wage increases in the face of worker resistance to wage cuts – really rings true in the real world. Bewley (2000) reports survey evidence that firms temper wage increases in response to worker resistance to wage cuts:

“[Business leaders] take account of the fact that, if they raise the level of pay today, it will remain high in the future. I hear a lot about this last point now. [...] Some say that they are not now increasing pay [...] because they know they will not be able to reverse the increases during the next downturn.” Bewley (2000), p.46.

In addition, there is evidence of explicitly bargained mediation of wage growth as an alternative to wage cuts:

“General Motors Corp’s historic health care deal with the United Auto Workers will require active workers to forgo \$1-an-hour in future wage hikes [...] Allen Wojczynski, a 36-year GM employee, said the company’s proposal seems acceptable [...] He had been expecting the automaker to ask its workers for pay cuts to trim health care costs. ‘I could live with it, giving up \$1 an hour of my future pay raises,’ said Wojczynski [...]” *Detroit News*, October 21st 2005.<sup>30</sup>

Thus, compression of raises is used in practice as an approach to limiting labor costs in the face of poor economic conditions, and thereby can limit disemployment effects of worker resistance to wage cuts.

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<sup>30</sup>See <http://www.detnews.com/2005/autosinsider/0510/21/A01-356532.htm>.



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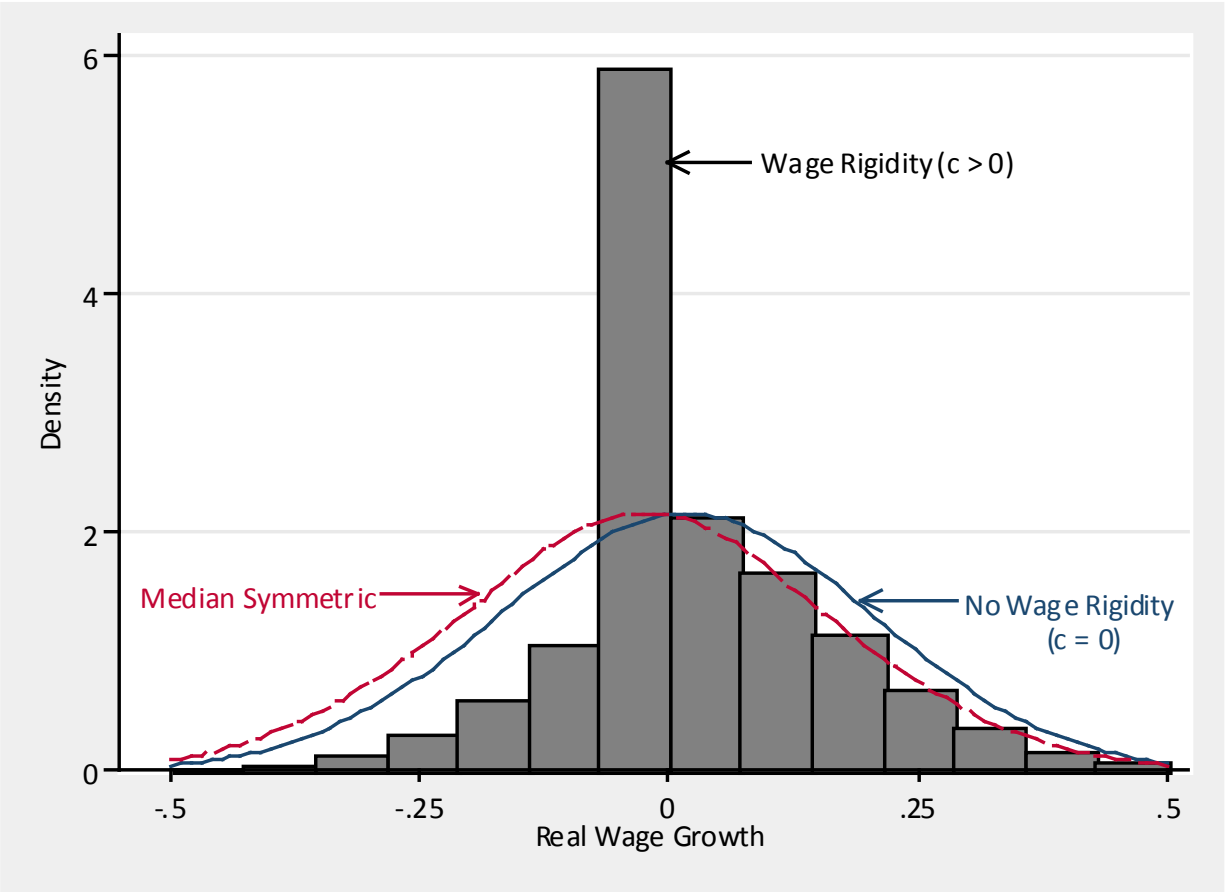


Figure 1: The Distribution of Real Wage Growth Implied by the Model. The histogram is simulated from the model with downward wage rigidity ( $c > 0$ ). The solid blue line is the true density of frictionless wage growth ( $c=0$ ). The dashed red line is the density implied by imposing symmetry in the upper tail of the histogram.

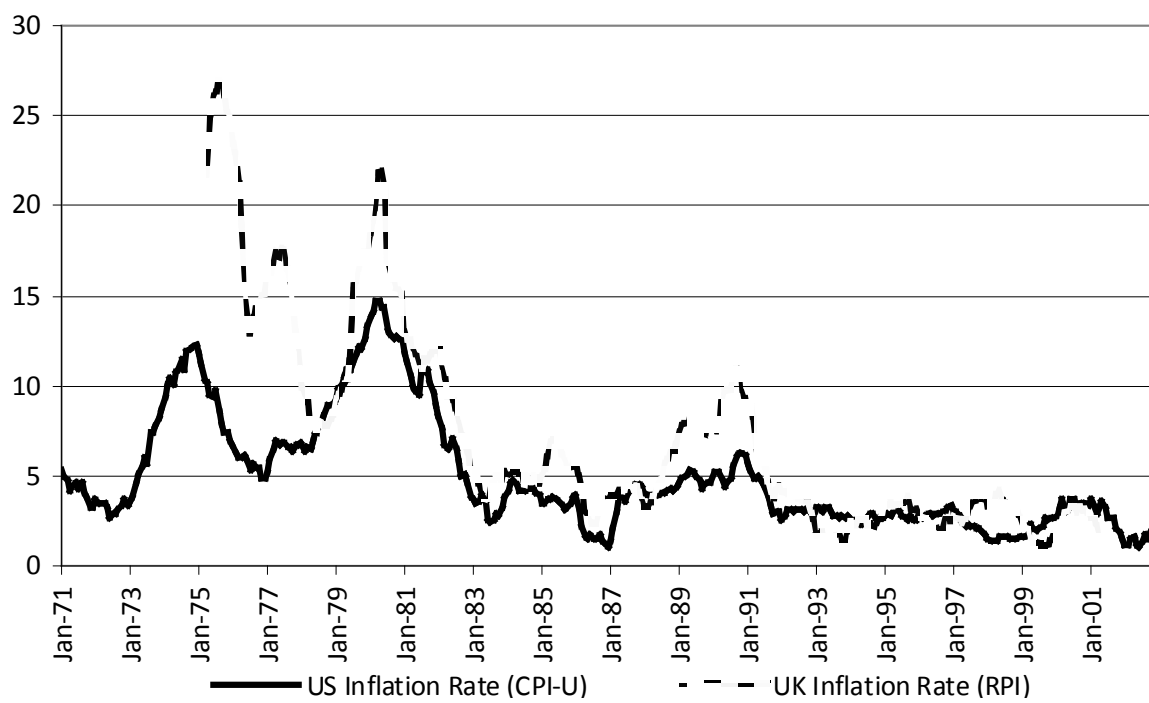


Figure 2: US and UK Inflation over the Sample Periods.

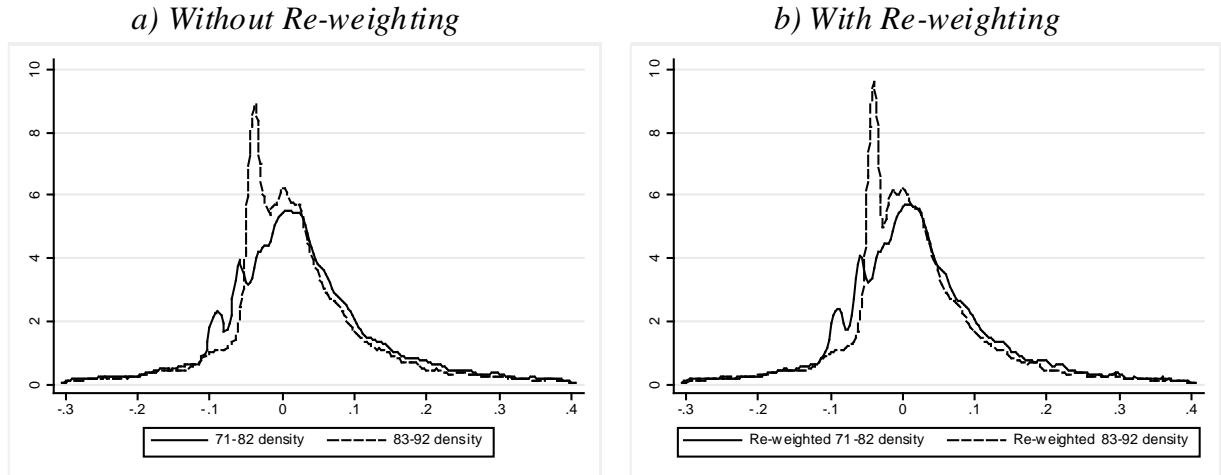


Figure 3: Density Estimates of Log Real Wage Growth Distributions (PSID). Results using an Epanechnikov kernel over 250 data points with a bandwidth of 0.005. Micro controls for re-weighted density are age, sex, education, 1-digit industry, 1-digit occupation, region, self employment, and tenure.

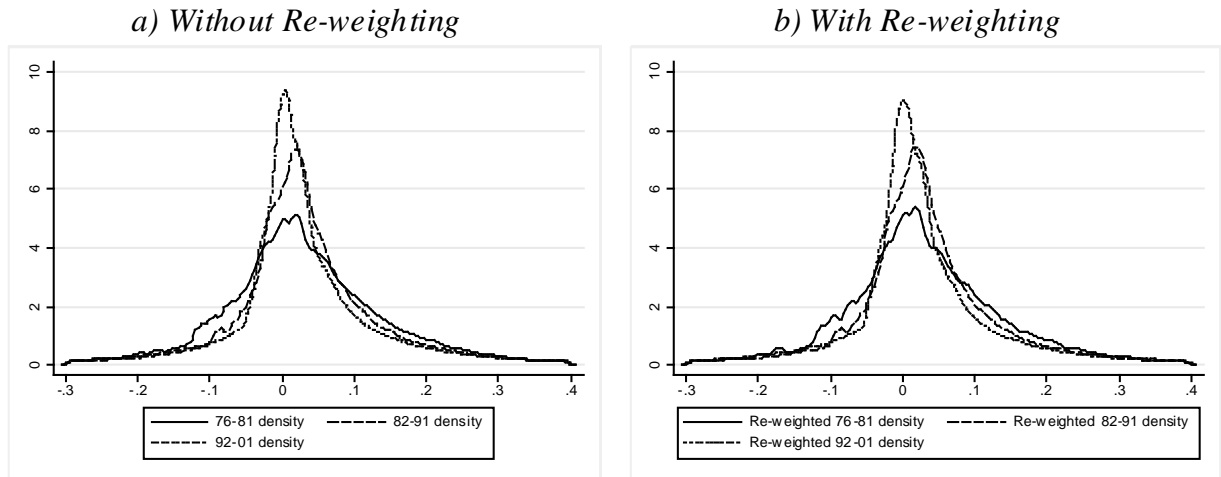


Figure 4: Density Estimates of Log Real Wage Growth Distributions (NES). Results using an Epanechnikov kernel over 250 data points with a bandwidth of 0.005. Micro controls for re-weighted density are age, sex, region (including London dummy), 2-digit industry, 2-digit occupation, and major union coverage.

Year	(a) CPS			(b) PSID			(c) NES		
	Obs.	spike	$\Delta\omega < 0$	Obs.	spike	$\Delta\omega < 0$	Obs.	spike	$\Delta\omega < 0$
1971				1,520	10.39	34.41			
1972				1,527	11.59	32.35			
1973				1,599	8.88	46.34			
1974				1,676	8.35	56.74			
1975				1,733	7.39	42.07			
1976				1,471	7.48	34.33	60,318	0.67	41.00
1977				1,468	8.65	36.72	64,838	1.43	77.64
1978				1,605	7.35	37.57	66,168	2.15	33.73
1979				1,704	6.51	51.35	65,619	2.33	38.39
1980	25,626	5.70	53.39	1,756	4.38	52.51	66,574	0.44	46.81
1981	28,343	5.79	48.07	1,746	7.22	50.29	70,431	2.62	40.53
1982	27,426	10.41	45.76	1,664	8.17	38.58	75,745	3.01	49.34
1983	26,521	12.73	45.99	1,606	14.51	44.46	77,910	2.06	19.93
1984	26,675	12.76	46.29	1,621	12.95	46.33	75,652	5.09	41.62
1985	13,122	12.28	43.72	1,702	11.16	41.07	75,311	1.69	50.80
1986	6,935	13.67	40.63	1,830	15.30	42.51	74,487	1.39	18.88
1987	27,348	13.68	45.94	1,801	15.16	49.53	74,848	2.52	24.97
1988	26,825	12.59	46.43	1,848	15.42	50.87	73,440	1.55	20.57
1989	26,736	11.99	47.90	1,863	13.96	53.30	72,278	2.13	44.91
1990	28,045	11.14	49.11	1,815	12.01	54.66	70,752	2.49	50.33
1991	28,688	11.61	46.52	2,441	13.93	49.77	72,065	2.75	26.40
1992	28,521	13.43	44.94	2,441	16.39	45.60	76,335	4.87	30.87
1993	28,468	13.25	45.73				78,171	6.95	27.91
1994	26,584	11.88	44.49				78,167	6.36	48.14
1995	10,227	12.20	45.32				79,644	5.55	51.37
1996	8,458	11.46	44.68				82,489	1.53	32.31
1997	25,386	10.67	41.53				80,221	1.71	33.52
1998	25,255	10.31	38.00				76,999	4.08	51.19
1999	25,489	9.80	41.02				77,227	4.38	25.93
2000	25,215	9.68	44.19						
2001	24,574	9.32	42.65						
2002	26,575	10.32	42.38						

Table 1: Descriptive Statistics of Wage Growth for the CPS, PSID, and NES. “Obs.” refers to the number of wage change observations per year. The spike is the fraction of wage changes equal to zero. “ $\Delta\omega < 0$ ” reports the fraction of real wage cuts each year.

(a) CPS:	Obs	Mean	Std. Dev.	Min	Max
<b>Change in log real wage</b>	547042	0.025061	0.310781	-5.72642	4.562072
<b>Age</b>	547042	38.01381	12.52692	16	65
<b>Female</b>	547042	0.501651	0.499998	0	1
<b>Education:</b>					
< High School	546516	0.175773	0.380628	0	1
High School	546516	0.451021	0.497596	0	1
Some College	546516	0.287882	0.452776	0	1
College Degree	546516	0.071936	0.258382	0	1
Advanced Degree	546516	0.013388	0.114931	0	1
<b>Metropolitan area</b>	521083	0.710509	0.453527	0	1
<b>Non-white</b>	547042	0.204385	0.403252	0	1
<b>Self-employed</b>	546877	0.000104	0.010209	0	1

**(b) PSID:**

<b>Change in log real wage</b>	33283	0.022087	0.337482	-3.72463	4.619859
<b>Age</b>	33283	38.24457	11.53739	18	65
<b>Female</b>	33283	0.196617	0.397446	0	1
<b>Education:</b>					
0-5 grades	30671	0.036256	0.186929	0	1
6-8 grades	30671	0.114375	0.318272	0	1
9-11 grades	30671	0.218382	0.413155	0	1
12 grades	30671	0.448469	0.497346	0	1
Some College	30671	0.130253	0.336587	0	1
College degree	30671	0.040201	0.196433	0	1
Advanced degree	30671	0.012064	0.109171	0	1
<b>Tenure:</b>					
[1, 1.5] years	30536	0.092907	0.290306	0	1
(1.5, 3.5) years	30536	0.204546	0.403376	0	1
[3.5, 9.5) years	30536	0.354008	0.47822	0	1
[9.5, 19.5) years	30536	0.236999	0.425249	0	1
19.5 years +	30536	0.111541	0.314805	0	1
<b>Self-employed</b>	33257	0.014313	0.118779	0	1

**(c) NES:**

<b>Change in log real wage</b>	1922184	0.026539	0.190503	-9.9292	9.757886
<b>Age</b>	1922184	41.01464	11.85092	16	65
<b>Female</b>	1922184	0.409069	0.491662	0	1
<b>Major union coverage</b>	1922029	0.426511	0.49457	0	1
<b>London dummy</b>	1919091	0.144433	0.351528	0	1

Table 2: Summary Statistics. The CPS sample also contains 2-digit industry classifications, and 50 regional dummies; the PSID sample also contains 1-digit industry and 1-digit occupation and 6 region dummies; the NES sample also contains 2-digit industry and 2-digit occupation and 10 region dummies.



Percentile	CPS (US, 1980-2002)		PSID (US, 1971-1992)		NES (UK, 1976-1999)	
	Coefft. on $\pi_t$	Coefft. on $\mu_t$	Coefft. on $\pi_t$	Coefft. on $\mu_t$	Coefft. on $\pi_t$	Coefft. on $\mu_t$
$P_{10}$	0.124 [0.080]	1.494 [0.160] **	-0.312 [0.094] **	0.695 [0.140] **	-0.117 [0.050] *	1.086 [0.120] **
$P_{20}$	-0.381 [0.054]**	0.821 [0.110] **	-0.551 [0.110] **	0.404 [0.110] **	-0.212 [0.020] **	0.835 [0.071] **
$P_{30}$	-0.312 [0.087]**	0.295 [0.058] **	0.003 [0.048]	0.902 [0.060] **	-0.142 [0.019] **	0.841 [0.051] **
$P_{40}$	-0.017 [0.021]	0.662 [0.032] **	0.013 [0.037]	0.927 [0.042] **	-0.0905 [0.015] **	0.883 [0.036] **
$P_{60}$	-0.018 [0.022]	0.792 [0.050] **	0.022 [0.037]	0.999 [0.046] **	0.0669 [0.013] **	1.065 [0.034] **
$P_{70}$	0.061 [0.029]*	1.015 [0.068] **	0.090 [0.053]	1.113 [0.048] **	0.151 [0.016] **	1.190 [0.043] **
$P_{80}$	0.101 [0.039]*	1.277 [0.072] **	0.205 [0.083] *	1.224 [0.082] **	0.184 [0.018] **	1.205 [0.054] **
$P_{90}$	0.205 [0.061]**	1.704 [0.094] **	0.301 [0.092] **	1.507 [0.110] **	0.153 [0.033] **	1.057 [0.082] **
$wsu$		+0.753%		+1.517%		+1.085%
$wsb$		-0.713%		-1.366%		-1.063%
$\lambda$		+0.040%		+0.150%		+0.021%

\* significant at the 5% level; \*\* 1% level.

Table 3: The Effect of Inflation and Mean Real Wage Growth on Percentiles of Real Wage Growth. Least squares regressions weighted by region size. Controls include the variables in Table 2, region, absolute change in inflation, as well as, CPS: 2-digit industry, current and lagged state unemployment rate, and dummies for the years 1989-93 and 1994-95 to control for the effects of imputed wage data; PSID: 1-digit industry and occupation; NES: 2-digit industry and occupation, current and lagged regional unemployment rate, and a dummy for the year 1977 to control for the incomes policy of that year. Standard errors in brackets robust to non-independence within years. The statistics  $wsu$ ,  $wsb$ , and  $\lambda$  are described in the main text.

<b>Spike = 0.075 (c = 0.02)</b>						
$\mu \setminus \pi$	-0.05	-0.025	0	0.025	0.05	0.1
-0.025	0.184%	0.147%	0.113%	0.085%	0.061%	0.029%
0	0.147%	0.113%	0.085%	0.061%	0.043%	0.018%
0.025	0.113%	0.085%	0.061%	0.043%	0.029%	0.011%
0.05	0.085%	0.061%	0.043%	0.029%	0.018%	0.007%

<b>Spike = 0.15 (c = 0.045)</b>						
$\mu \setminus \pi$	-0.05	-0.025	0	0.025	0.05	0.1
-0.025	0.414%	0.330%	0.255%	0.191%	0.138%	0.064%
0	0.330%	0.255%	0.191%	0.138%	0.096%	0.041%
0.025	0.255%	0.191%	0.138%	0.096%	0.064%	0.025%
0.05	0.191%	0.138%	0.096%	0.064%	0.041%	0.015%

<b>Spike = 0.4 (c = 0.16)</b>						
$\mu \setminus \pi$	-0.05	-0.025	0	0.025	0.05	0.1
-0.025	1.472%	1.172%	0.907%	0.679%	0.491%	0.229%
0	1.172%	0.907%	0.679%	0.491%	0.342%	0.146%
0.025	0.907%	0.679%	0.491%	0.342%	0.229%	0.090%
0.05	0.679%	0.491%	0.342%	0.229%	0.146%	0.053%

Table 4: Compensating Wage Differential  $\gamma(\mu, \pi)$  for Different Values of Inflation ( $\pi$ ), Real Productivity Growth ( $\mu$ ), and the Spike at Zero Nominal Wage Growth for  $\mu = 0, \pi = 0$ .