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ABSTRACT

Downward Real Wage Rigidity and Equal Treatment Wage Contracts: Theory and Evidence*

Recent dynamic contracting models of downward real wage rigidity with "equal treatment" – newly hired workers cannot price themselves into jobs by undercutting incumbents – imply that real wages are relatively rigid in "bad" times but upwardly flexible during "good" times. We use an administrative panel dataset to establish that such asymmetries are a feature of West German labor markets. We find that the elasticity of real wages with respect to output is very close to zero in downswings but large and highly significant in upswings. In a separate analysis we find that after controlling for match fixed effects the cyclicality of new hire wages is approximately the same as that for incumbent wages regardless of whether or not they joined the establishment from unemployment This is supportive of equal treatment. We also show that a four parameter version of the equal treatment contracting model of Snell and Thomas (2010) can replicate reasonably well the salient time series properties and co-properties of real wages, output, and unemployment, in particular the asymmetric response of wages to output that we find in the data.

JEL Classification: E24, E32, C23

Keywords: business cycles, employment, unemployment, real wage rigidity, GDP growth, models with panel data

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1 Introduction and Overview

There is now a sizeable literature devoted to estimating the cyclicality of real wages using large panel datasets to correct for composition bias (e.g., Solon et al. (1994) for the US, Devereux and Hart (2006) for the UK, Martins et al. (2012) for Portugal, and Stüber (2017) for Germany). However, recent models of dynamic wage contracting that exhibit downward real wage rigidity (in particular the models of Menzio and Moen (2010) and Snell and Thomas (2010)) suggest that wages will be asymmetrically cyclical — relatively rigid in "downswings" when productivity and output are falling but upwardly flexible during "upswings" when productivity and output are rising.[1] Such asymmetries are important for unemployment (and output) dynamics as we will show. They also matter for the *long-run level* of unemployment; Benigno et al. (2015) argue that long-run unemployment rates and the variance of productivity growth are positively associated. They explain this finding by asymmetric wage adjustments to productivity growth of the type we argue for here.[2]

In this paper we use a sample of workers drawn from an administrative German panel dataset for the years 1978–2014 to establish that — defining up- and downswings in terms of positive and negative growth in real GDP per capita[3] — asymmetries as predicted by models of dynamic wage contracting that exhibit downward real wage rigidity seem to be a feature of West German[4] labor markets. The key empirical feature to emerge from our study is that the elasticity of real wages with respect to GDP per capita (henceforth just "elasticity"[5] and henceforth real GDP per capita referred to as just "output" for brevity) is close to zero and insignificant in downswings. However

[1] The sign correlation of output and productivity growth is close to but not exactly 100% in our theoretical model. There are some rare occasions when productivity suffers a small drop but output rises. In our simulations these events occur less than 2% of the time.

[2] Using an *ad hoc* model of downward rigidity they demonstrate that higher variance of productivity growth translates into higher unemployment as downturns lead to higher unemployment whereas in upturns unemployment is the same as full employment ensues; a similar effect applies if trend productivity growth falls, again leading to higher unemployment.

[3] For precise data definitions see Section 3. The theoretical model we use predicts output, employment, and wages. The choice of output per capita is to match the counterpart in the model although this is not critical. For example, the asymmetries identified in the paper also hold for other measures of output such as output per member of the labor force.

[4] All of the data in this paper, apart from the TFP and the CPI series, are for West Germany only (the data for TFP and CPI are for West Germany prior to 1991 and the whole of Germany afterwards). Henceforth and unless otherwise stated we refer to West Germany as just "Germany" for brevity.

[5] Use of the term "elasticity" to denote the regression coefficient of wage on output growth is somewhat misleading as our estimate has no clear structural interpretation at this point. We use the term for brevity and for consistency with the cognate empirical literature.

in upswings the elasticity is positive and statistically significant. In a separate analysis we find that after controlling for match fixed effects the cyclicality of new hire wages is not significantly different from that of incumbents, regardless of which cyclical indicator is used (unemployment or output) and regardless of whether or not the worker was employed immediately before joining the firm. This result is particularly important: if wages are downwardly rigid in downswings then it suggests that the unemployed cannot price themselves into jobs by "undercutting" incumbents and hence labor markets will not clear (see, e.g., Hall, 2005; Gertler and Trigari, 2009; Snell and Thomas, 2010).

In the second part of this paper we show that a simple four parameter version of Snell and Thomas's (2010) equal treatment contracting model can generate a strong positive elasticity in upswings and an elasticity close to zero in downswings. In the model, risk neutral firms have an incentive to smooth the wage profiles of risk averse workers by offering a contract that limits the rate at which real wages fall in downswings. The rate of fall is the result of a trade-off for the firm between wanting to avail itself of cheaper new hires on the one hand and not wanting to create too much variability for the incumbents on the other. This results in a maximum rate of wage fall no matter how cheap new hires potentially become. The existence of an equal treatment constraint — new hires must be paid the same as incumbents — implies that the unemployed cannot price themselves into jobs by offering to undercut incumbent wages. As a result, if the economy suffers a negative and persistent productivity shock, downwardly sluggish wages will generate unemployment that will endure until either productivity recovers or until wages have fallen sufficiently far to clear the labor market. In this scenario, real wages will exhibit little covariation with output when productivity is falling. By contrast, wages adjust rapidly (upwards) in good times when productivity is high so that in upswings they will be strongly positively correlated with output. The reason for the asymmetric response is that workers are ex post mobile, so that in good times their outside opportunity has a high value; firms have no option but to raise wages to match this and so wages are upwardly flexible during upswings.

The model requires total factor productivity (TFP) as a sole input. To assess the model's fit to the data we follow the real business cycle (RBC) literature and generate a synthetic TFP series whose growth and first order autocorrelation matches that of German TFP growth. Using this series, the model generates wage and unemployment series that display the same asymmetric

response patterns we found in the data. In addition the first order autocorrelation coefficients and variances of the model's simulated real wage growth, unemployment and output growth broadly match their counterparts in the data. As far as we know, this is the first paper not only to look at the empirical downward real rigidity of wages for workers including new hires, but also to simulate a microfounded model that is capable of matching these observed regularities.[6]

The outline of the paper is as follows. In Section 2 we review both the empirical and theoretical literature on downward rigidity. In Section 3 we present an overview of the data. In section 4 we present tests of equal treatment and the evidence for asymmetric wage cyclicality. In section 5 we present the model and simulate it to see if its predictions for output, unemployment and wages match those of the data. In Section 6 we consider robustness checks and other caveats: the main results on asymmetry are robust with respect to dropping the "German reunification years" from the sample and dropping the early years from the sample. The results on equal treatment — that new hires have the same wage cyclicality as incumbents — are robust with respect to increasing the length of time an employee remains a new hire after joining the firm. We also show that the asymmetry result holds when we split the data into six broad industrial sectors providing some reassurance that the it is a pervasive feature of the West German economy. Section 7 contains concluding comments.

2 Related Empirical and Theoretical Literature

Empirics

Evidence for downward real wage rigidity (DRWR) has come in different forms, although the topic is understudied relative to downward nominal rigidity.[7,8] Broadly, there are three methodologically distinct approaches.

The first and most common approach has been to look for DRWR by comparing empirical wage-

[6] Snell and Thomas (2010) only perform unemployment simulations.

[7] Recent analyses have simultaneously estimated the incidence of both real and nominal downward rigidities. Doing so tends to reduce the estimated incidence of the latter relative to the former, see Goette et al. (2007).

[8] For a very useful survey of much of the literature relevant to downward nominal rigidity, and its implications for cyclicality of the relevant real cost of new hires, see Basu and House (2016). Their DSGE analysis, however, suggests that price rigidities play a more important role than nominal wage rigidities in generating fluctuations.

change distributions with notional distributions constructed under assumptions about how wage changes would be distributed were there no downward rigidities. The International Wage Flexibility Project which analyzed employee wage data from 16 OECD countries found evidence of wage changes being clumped around expected inflation in number of countries, and under assumptions about the shape of the notional distribution, fewer than the expected number of changes below the expected inflation rate, consistent with a degree of DRWR (for a summary, see Dickens et al. (2007); Dickens and Goette (2005) discuss the methodology in detail). Germany is around average in terms of the degree of wage rigidity by these measures. In a related analysis, Bauer et al. (2007) find substantial DRWR in Germany, with 30–70% of wages being subject to real rigidity. These studies typically use a model in which DRWR occurs as an absolute constraint on some wage changes, whereas we will allow for wage cuts that are dampened relative to wage increases. In addition we will be interested in how wages change over the business cycle, an issue that is not directly addressed in this literature which looks for incidence of downward-constrained individual wage changes.[9] Finally, the wage changes studied are for those in continuing employment. We are also interested in the cost of *new hires*, as that is likely to be particularly relevant for hiring decisions.[10]

A second source of evidence comes from surveys and interviews. Bewley (1999, pp. 208–209) finds for the US considerable evidence from unstructured interviews of both nominal and real wage downward rigidity, although for the latter the degree is not absolute and some firms were prepared to let real wages fall somewhat. Similar findings exist in a number of more structured surveys. Most relevant to the German labor market, Franz and Pfeiffer (2006), based on a survey of German firms and largely following the methodology of Campbell and Kamlani (1997), found that rigidity was accounted partly for by a desire to avoid fluctuations in wages in line with wage smoothing (less so amongst the highly skilled), although union agreements were cited as an important factor,[11]

[9] More precisely, the aim is to estimate the fraction of workers who, if they were scheduled for a real wage cut, actually receive one. This is independent of the business cycle: in a boom we would expect fewer workers to be scheduled for a cut but the idea is that the fraction of this smaller number actually receiving a cut is similar to the corresponding fraction in a recession.

[10] Holden and Wulfsberg (2009) do partially address the issue. They argue that firms may sidestep downward rigidities for example by cutting wages for new hires, or jobs may be shifted to firms with lower wages. To address this, and in a reversal of the usual composition arguments following Solon et al. (1994) discussed below, they look at *industry level average* wage changes across 19 OECD countries for the period 1973–1999, arguing that the average wage will capture the overall average cost of labor. Notional wage change distributions are estimated from years with high nominal and real wage growth, the idea being that downward rigidities would not come into play in such years, and actual distributions are compared. They find some evidence of DRWR in a subset of countries.

[11] Nevertheless, of the responding firms only 38% apply union contracts; even amongst these around half were paying

and a number of statements in line with efficiency wage theory also received assent.

A third approach is to take a more standard microeconometric model which models the real wage of each worker in terms of cyclical variables such as unemployment (common to all workers) as well as other control variables. In this paper we adopt the methodology of the microeconometric wage cyclicality literature, following Solon et al. (1994), in which composition bias – the tendency for lower paid workers to differentially end up unemployed in downturns, thus biasing downwards estimates of cyclicality based on average wages – is corrected for in a first stage regression that extracts a series of time effects. In a second stage we look to see if this series exhibits some form of downward rigidity with respect to cyclical variables. Martins (2007) has performed an exercise along these lines for Portugal. He defines upswings (downswings) in terms of rising (falling) unemployment rather than output growth. Using this definition he examines the extent of differential real wage cyclicality in the two regimes. However he finds that the semi elasticity of wages with respect to unemployment actually *increases* (in absolute value) when unemployment is rising.[12] The result that wages are relatively inflexible in times of falling unemployment but highly flexible when it is rising is hard to rationalize. Shin and Shin (2008) also estimate asymmetric wage responses to unemployment. However they focus on asymmetries across workers of different tenure at a point in time rather than asymmetries across different time periods for all workers. The asymmetries they find are consistent with what one would find in a Beaudry and DiNardo (1991) world of implicit contracts under worker mobility.[13] By contrast, when we measure cyclicality in terms of rising and falling output, we find evidence that all workers *regardless of tenure* are subject to the same wage cyclicality and that the effects are asymmetric across time rather than across tenure. In particular, when we estimate the composition and match quality controlled average wages of a) new hires from employment and b) new hires from unemployment they appear to have the same (asymmetric) cyclicality to other workers (incumbents). In addition Gartner et al. (2013) look at asymmetric wage adjustment with respect to unemployment changes for Germany, 1995–2004, for

"effective" wages above the collectively bargained wage, and overall there is some individual firm-worker bargaining over wages, either independently of or in addition to union contracts, in 83% of the firms. Babecky et al. (2010), in a cross-country study (but excluding Germany), find a positive relationship between collective bargaining coverage and downward real wage rigidity, where the latter is defined as some form of wage indexation.

[12] In addition he looks at each worker's wage growth rather than its level — a classic method to remove various fixed effects but also a limitation as it means that new hires must be omitted from the sample.

[13] In effect they find in favor of "minu" — the minimum unemployment rate during a worker's tenure — which Beaudry and DiNardo (1991) argue determines wages in this scenario and which has found to be significant in a host of other papers.

small and medium sized firms (fewer than 500 employees). They find evidence that wages adjust less in downswings to changes in regional unemployment, and that uncovered wages are more flexible than covered union wages in upswings, but uncovered wages do not adjust to rising unemployment.

None of the existing studies, as far as we are aware, have analyzed downward rigidity of wages of new hires, something integral to our analysis. Certainly existing wage cyclicality studies, following Bils (1985), suggest that wages of job "movers" are considerably more cyclical than "stayers", while Haefke et al. (2013) establish comparable results in the CPS for workers moving from non-employment to employment. Likewise Farès and Lemieux (2001) argue that in Canada new entrants bear most of the adjustments in real wages over the business cycle. These results then suggest wages of new hires have different cyclical properties to those in ongoing employment, so that any DRWR identified for those in continuing employment might not carry over to new hires. Likewise other papers have found evidence to support the existence of bilateral worker-firm implicit wage contracts (so that new hire wage contracts are bargained independently of existing contracts within a firm, with the implication that the cyclical properties of the start wage will be different from that of ongoing wages within the match); see for example Devereux and Hart (2007), Grant (2003), and the original seminal paper by Beaudry and DiNardo (1991). Both of these conclusions are controversial, however. Gertler and Trigari (2009) dispute whether new hire wages are in fact more cyclical: they suggest that cyclical upgrading may contaminate these new hire estimates, if say skilled workers end up taking less skilled jobs in a recession; the lower wage of such a "mover" in a recession might not be due to wage cuts within the less skilled jobs. In their study on US data controlling for job match effects offers support for equal treatment. Similarly, Hagedorn and Manovskii (2013) show that failing to control rigorously for worker-firm match (and within firm-job match) quality can lead to spurious tenure specific cyclicality of the kind consistent with implicit contracts and excess new-hire wage cyclicality. Following these arguments about the importance of controlling properly for match quality we include match fixed effects as in Gertler and Trigari (2009). Doing so we find no differential cyclicality across workers (new hires and incumbents). Instead we find differential cyclicality across time (upswings and downswings). In short we find that equal treatment and asymmetric adjustment are a key feature of German wages. In a further analysis we find that the magnitudes of the effects are broadly in line with those elicited from a calibrated version of Snell and Thomas's (2010) model of wage contracting subject to equal treatment. We now discuss this

theory in the context of other models of real wage rigidity.

Theory

There are very few theories that result in downward (but not upward) rigidity. Most efficiency wage models imply real wages that are too high for market clearing and are rigid in both directions (see Babecky et al. (2010) for further discussion). Models such as Hall (2005), Thomas and Worrall (1988), Rudanko (2009)[14] orMacLeod and Malcomson (1993) have wages that are both downward *and* upward rigid for a range of shocks, and outside that range adjust to external conditions.[15] Likewise models of worker-firm bargaining where workers are subject to habit formation or loss aversion can exhibit a range of real wage inertia, following Bhaskar (1990), but not readily asymmetry. A recent example is Holden and Wulfsberg (2009).[16] Insider-outsider theories where insiders, who are protected from layoffs, may be able to oppose wage cuts in recessions, but bargain for wage increases in booms, can in principle deliver asymmetric wage responses; see Lindbeck and Snower (2001). We simulate the contracting model of Snell and Thomas (2010) in Section 5 (where it is discussed further) which does have asymmetric responses of wages to up- and downturns, similar to Menzio and Moen (2010). An interesting model which shares some features with the latter two papers, is Bils et al. (2016), where a matching model with staggered wage bargaining is analyzed; effort is endogenous and sticky wages can lead to variation in effort of incumbents which transmits stickiness (but not asymmetry), via bargaining, to new hire wages.

Two other issues have arisen in recent debate relevant to this paper. First, of particular interest from the point of view of allocation, is not the average wage nor even the wage paid to new hires, but what Kudlyak (2014) calls the "user cost of labor", the cost of hiring a worker today relative to postponing this decision one period, which takes into account future wages and is the appropriate allocational variable (see also Basu and House (2016)). Assuming stickiness of real wages of those

[14]Rudanko (2009), who incorporates the limited-commitment Thomas-Worrall model into a directed search framework, shows that despite the within-match wage stickiness, this only has a marginal effect on job creation as any stickiness does not substantially transmit to the overall discounted cost of a new hire.

[15]In the latter model, with general investments and if there is inflation, nominal wages might be either rigid or move upwards, with rare downwards movements, because the worker's outside option will typically be rising in nominal terms. With contracts specifying real wages there is no presumption of asymmetry.

[16]They show that loss aversion can lead workers to bargain harder if their wage would fall leading to a higher real wage in a downturn relative to what they would get in the absence of loss aversion. However this does not lead to an asymmetric relationship between wages and outside options.

in continuing employment, she shows that the user cost may be much more cyclical than the new hire wage as, say, a low new hire wage in a recession will be followed by lower than average wages for that worker in the future. This implies a new hire at a low wage also tends to involves future wage savings relative to later hires made when the market has recovered, so that the user cost actually falls proportionately more than the wage in recessions, and vice versa in booms. The model we simulate below is one of equal treatment — workers that differ solely according to when they are hired by a firm will be paid the same within that firm. Because of equal treatment the future wage savings in a recession are by definition zero, and the user cost coincides with the new hire wage, which is therefore allocational. A second, related, issue arises with downward rigidities, namely that if they are anticipated, a firm will want to hold down current wages to relax future downward constraints (Elsby (2009)). Because downward rigidity in the model is a feature of optimal contracts rather than a constraint, the solution already takes this into account.

3 Data

Our panel of workers is drawn from the IAB Beschäftigten-Historik (BeH), the Employee History File of the Institute for Employment Research (IAB) of the German Federal Employment Agency. The BeH consists of data on the total of gainfully employed members of the German population who are covered by the social security system.[17] Not covered are self-employed, family workers assisting in the operation of a family business, civil servants (Beamten), and regular students. The BeH covers roughly 80% of the German workforce. Plausibility checks performed by the social security institutions and the existence of legal sanctions for misreporting guarantee that the earnings data are very reliable.

Due to protection of data privacy, we are not allowed to work with the entirety of the BeH. From the BeH (version 10.01) we use a 20% random sample of all workers that worked full-time[18] in at least one year since 1975. The BeH is organized by employment spells. A *spell* is a continuous

[17] The BeH also comprises marginal part-time workers employed since 1999.

[18] More precisely we focus on "regular workers" according to the definition used in the Administrative Wage and Labor Market Flow Panel (AWFP) dataset. In the AWFP a person is defined as a "regular worker" when he/she is full-time employed and belongs to person group 101 (employee s.t. social security without special features), 140 (seamen) or 143 (maritime pilots) in the BeH (see Seth and Stüber, 2017). Therefore all (marginal) part-time employees, employees in partial retirement, interns etc. are not accounted for as regular workers.

period of employment within a job within an establishment in a particular calendar year. Hence the maximum spell length is 366 days. For each identified full-time worker, the BeH has a record of all existing employment spells — including part-time employment, apprenticeships etc. For our analyses we restrict attention to employment spells of full-time workers[19] aged 16 to 65 years from West Germany and the years 1978 to 2014. We only keep employment spells if the workers are employed on December 31^{st} of the respective year.[20] We define a newly hired spell as the first spell of a worker at the firm.[21] Hence, the tenure of a worker in an establishment which spans more than one calendar year will consist of multiple spells, with the first being classified as a new hire spell. We also calculate tenure from the dataset. All data are collected at the establishment level but henceforth we refer to establishments as "firms" in keeping with the phrasing used in the discussion of the theory.[22]

Our dependent variable is the real average daily wage of worker over any spell. As the earnings data are right-censored at the contribution assessment ceiling ("Beitragsbemessungsgrenze"), only non-censored wage spells are considered in the analyses.[23] To calculate the average daily real wage and real output per capita in 2010 prices we use the German Consumer Price Index (CPI, see Table A2).

Further we drop all spells that have missing tenure. This means a worker only enters the data

[19]The BeH only documents total spell earnings and not hours worked in that spell. We therefore only consider full-time workers as these workers' hours are likely to be acyclical. In Section 6 we analyze the time series properties of an extraneous estimate of the average hours worked in a year by full-time employees in Germany. We find cyclicality — in the sense of having a significant correlation with output — to be relatively weak.

[20]This implies we only ever have a maximum of one spell per worker per year so that when we compute yearly averages over spells we do not weight more heavily those workers with multiple within year spells. It also excludes most short-lived spells in the data in particular temporary summer work.

[21]Re-hires are therefore not identified as new hires. Our decision to treat returning workers as incumbents is because of the relatively short time of absence; 70% of returners were returning after an absence of less than one year and the average length of time away for returners is about 20 months. This suggests that these spells are for workers who have long-term relationships with the firm and whose absences were temporary (for reasons such as paternity/maternity leave). As a final check we repeated our analyses on a dataset that excluded all "returning" spells – all spells where the worker had been away the previous year. There is little quantitative and no qualitative change in either the equal treatment or the asymmetric adjustment results.

[22]The main results of this paper hinge on estimates that control for match fixed effects with the underlying assumption being that matches are with establishments not firms. However, even if matches are formed at the firm level, then using worker-establishment fixed effects will in any event absorb them; their use in this case may be inefficient but would not bias the estimated year effects.

[23]We drop spells with wages ≥ 0.98 * the contribution assessment ceiling. Dropping top-coded spells leads to an under-representation of highly qualified workers, making the results somewhat less generalizable. Because the wages of highly qualified workers are less likely to be covered by a collective bargaining agreement (see, e.g., Düll, 2013) and because uncovered wages are more flexible than covered wages (see, e.g., Devereux and Hart, 2006), it is probable that we slightly underestimate the wage cyclicality. For a quantitative evaluation of the effect of dropping censored spells, see, for example, Appendix A of Stüber and Beissinger (2012).

when she joins a firm after January 1^{st}, 1975.[24] This implies we observe relatively few incumbents (relative to new hires that is) in the early years (see Table A1). Our estimation of new hire and incumbent cyclicality should not be biased by including these early years although the precision of the estimated cyclicalities may well be. However, in a sensitivity analysis we show that our results are largely unaffected when we drop the early years of the sample.

Our upswing/downswing variable is GDP per capita for West Germany excluding West Berlin. This data identifies 11 downswing years.[25] GDP data were obtained from the German Federal Statistical Office and the Federal Statistical Offices of the Federal States. The aggregated unemployment rates were obtained from the Federal Unemployment Agency (see Table A2).

As we noted above, the prime reason for our definition of up- and downswings is that wage contracting models of downward real wage rigidity usually rely on an insurance mechanism whereby risk averse workers are protected from large changes in their wages by risk neutral firms (Menzio and Moen, 2010; Menzio and Shi, 2011). When productivity (and hence output) falls in the model we study (Snell and Thomas, 2010), this insurance mechanism restricts wage falls whilst the necessity to retain workers in competitive labor markets forces firms to raise wages when productivity (and output) recovers.

The final dataset used in our analyses contains over 97.8 million employment spells of nearly 9 million workers working for more than 2.8 million firms.

4 Estimation

4.1 Testing for Equal Treatment

In this section we wish to assess the extent to which new hire wages are more cyclical than those of incumbents. There is already an extensive literature that does this and we briefly review the key methods here. In order to identify the cyclicality of wages one first of all needs to control for composition bias. Following Solon et al. (1994) this can be achieved by a two-step method applied

[24] For the analyses we only use the years 1978 to 2014, but for the identification of newly hired workers and the calculation of firm tenure we use BeH data from 1975 onwards.

[25] Identified downswing years are indicated by bold year numbers in Table A2.

to panel data. In the first stage, year effects are extracted from the panel using year dummies whilst controlling for worker-firm characteristics. In the second stage the year effects are regressed on a cyclical indicator — traditionally unemployment, occasionally average labor productivity — to estimate the cyclicality of wages. The use of panel data allows one to control for changes in the average worker quality over the business cycle whilst the use of a two-stage method delivers standard errors that are robust to within time period error clustering. The method is easily extended to examine the cyclicality of different classes of worker — in this context (two types of) new hires and incumbents. In this section we use the two-stage method to test for equal treatment, i.e., to examine whether or not new hire wages are more procyclical than those of incumbents. In the next section we use the method to examine our hypothesized asymmetric wage adjustment.

As noted above it is important to control for as much worker-firm heterogeneity as possible and a natural way to do this is to use worker-firm (match) fixed effects (MFE) as well as proxies for returns to tenure and experience. It is widely believed that match quality is procyclical (see the discussion in Gertler et al. (2016)) Our tests for equal treatment examine the relative cyclicality of new hire versus incumbent wages so failing to control for procyclical match quality will lead to misleading inferences in this respect (Gertler and Trigari (2009)).

As already stated, we identify new hires by their first spell in a firm. All other workers are "incumbents". To test for equal treatment we wish to identify three sets of composition-controlled yearly wage averages (henceforth "year effects"): one set for incumbents, one set for new hires joining the firm from unemployment (defined as those not employed[26] for at least 4 weeks prior to joining and referred to as ue's) and one for those coming from other employment (referred to as ee's). Our strategy is to estimate the cyclicality of these three sets of year effects and establish whether or not new hire year effects (either ee's or ue's) display significantly more cyclicality than those of incumbents. We emphasize that the first stage regressions have no causal or economic interpretation — they are devices to obtain yearly averages of (log) wages whilst controlling for different worker and worker-firm characteristics.

In the first stage the primary specification to be estimated is the panel regression

[26]Our dataset does not allow us to distinguish between new hires who were previously in the labor force but unemployed from those who were previously not in the labor force.

$$w_{ijt} = m_{ij} + \sum_{\tau=1}^{T} \beta_{\tau}^{I} I_t^{\tau} + \sum_{\tau=1}^{T} \beta_{\tau}^{E} E_t^{\tau} + \sum_{\tau=1}^{T} \beta_{\tau}^{U} U_t^{\tau} + \sum_{k=1}^{2} \lambda_k age_{it}^{k} + \sum_{k=1}^{4} \phi_k ten_{ijt}^{k} + v_{ijt}, \qquad (1)$$

where w_{ijt} is the log of real average daily wage of worker i in firm j during year t, and v_{ijt} is an error term assumed to be orthogonal to the regressors.

The equation allows for three distinct sets of year effects written in the first three summation terms. The first consists of the dummies I_t^{τ} $(\tau = 1, \ldots, 37)$ with coefficients β_{τ}^{I} where I_t^{τ} equals one if $t = \tau$ and the worker is an incumbent but is zero otherwise. The β^{I} coefficients are the incumbents' year effects. The second (third) set of dummies E_t^{τ} (U_t^{τ}) take the value one if the wage is from an ee (ue) new hire and $t = \tau$ but equal zero otherwise. The β_t^{E} (β_t^{U}) are the corresponding year effects. The variable age_{it} is the worker's age in years and ten_{ijt} is the worker's firm tenure measured in days at the end of the spell. Finally, m_{ij} is a MFE. Note that this effect controls for (estimates) the sum of a firm j effect plus a worker i effect plus a match quality effect. Whilst it is a general way of absorbing heterogeneity in the panel, a drawback is that if new hire wages are excessively sensitive to the state of the cycle at entry and if (part of) this effect remains constant throughout the entire relationship with the firm then it will be absorbed into the MFE and will not appear as "excess" new hire cyclicality; for example if new hire effects are procyclical and permanent they will be observationally equivalent to procyclical match quality effects.[27] We return to this issue below where we assess the impact of replacing MFE with less general worker fixed effects (WFE).

To test for equal treatment we see if the wage year effects (henceforth equivalently referred to as "wages") of the three types of workers have differential cyclicality. In this "second stage" we treat each set of year effects — the β_t^{k} coefficients — as separate time series and analyze their respective cyclicalities. Our prime measure of the cycle in this paper is output growth and it is natural we use this to examine the relative cyclicality of wages of our three different kinds of worker. However the traditional literature on cyclicality of new hire versus incumbent wages focuses on the aggregate

[27] Consider, for example, a worker who upgrades to a higher wage firm in a boom but who receives in addition a (non-equal treatment) higher wage than equivalent incumbents because of the tight labor market. Suppose first that this higher wage is a temporary hiring premium. Then, as argued by Gertler and Trigari (2009), the MFE will wash out the upgrading and the temporary premium will be picked up in β_t^{E}. If this is typical, the β_t^{E} series will be more cyclical than β_t^{I} and equal treatment is rejected (we find no evidence for such temporary non-equal treatment). Now suppose instead that the premium is a *permanent* addition to the wage; in this case the MFE will absorb this along with the upgrading, and the deviation from equal treatment is not picked up.

unemployment rate u_t rather than output. Incentives to deviate from equal treatment are arguably likely to be better related to the rate of unemployment than output; if unemployment is high, workers should be prepared to work at a lower wage than incumbents, while if the labor market is very tight firms may be more prepared to bring violate internal norms and pay above internal rates.[28] Consequently we conduct a second exercise using this measure also. The two second stage regressions are therefore

$$\Delta\beta_t^k = \alpha + \gamma_{\Delta y}^k \Delta y_t + \varepsilon_t \quad k = I, E, U \tag{2}$$

$$\beta_t^k = \alpha + \gamma_u^k u_t + \epsilon_t \quad k = I, E, U \tag{3}$$

where y_t is the log of output and Δ denotes the change in the variable.

The γ's are not causal parameters. They are merely estimates of the unconditional comovement (i.e., normalized unconditional covariance) between wages (wage growth) and unemployment (output growth). Estimating these unconditional comovements has become the focus of interest in the recent wage cyclicality literature.

One problem with (3) is that both unemployment and wages are highly persistent. Consequently (3) is a specification involving near unit root processes and this raises the possibility of spurious regression in small samples. Interestingly however, the residuals from (3) are not very persistent; their largest root is around 0.6 implying they are far less persistent than both wages and unemployment. This suggests that unemployment and wages share a common persistent component.[29]

Turning to (2) this specification is similar to that of Haefke et al. (2013). They use first differences to measure the elasticity of wage growth with respect to the growth of output per worker. The difference here is that we use output per capita. This elasticity — $\gamma_{\Delta y}^k$ — gives us an alternative and entirely different metric for the cyclicality of wages. Estimates of these quantities

[28] We are grateful to a referee for stressing this point.

[29] As a further check on our results we also estimated (3) in first differences (to remove the persistence). Whilst this is a different metric of cyclical comovement it does give us a robustness check on the equal treatment results with respect to removing persistence. We find significant coefficients in all cases (albeit estimates that are somewhat smaller in absolute value than their levels counterparts) and support for equal treatment (insignificant extra new hire cyclicality).

for our three classes of worker, incumbents, ee's and ue's, are given in Table 1.[30]

Table 1: The Cyclicality of Incumbent and New Hire Wages

Wage Elasticity (Output)	$\gamma^I_{\Delta y}$	$\gamma^E_{\Delta y}$	$\gamma^U_{\Delta y}$	$t_{\gamma^E_{\Delta y}-\gamma^I_{\Delta y}}$	$t_{\gamma^U_{\Delta y}-\gamma^I_{\Delta y}}$
MFE	0.821	0.799	0.954	-0.03	1.53
	(0.205)	(0.248)	(0.217)		
WFE	0.857	1.286	1.446	3.12	2.59
	(0.226)	(0.278)	(0.355)		
Wage Semi-Elasticity (Unemployment)	γ^I_u	γ^E_u	γ^U_u	$t_{\gamma^E_u-\gamma^I_u}$	$t_{\gamma^U_u-\gamma^I_u}$
MFE	-1.293	-1.332	-1.440	-0.050	-0.63
	(0.222)	(0.217)	(0.197)		
WFE	-1.483	-1.945	-2.23	-2.59	-2.50
	(0.244)	(0.303)	(0.333)		

Notes: Estimates of the parameters in equations (2) and (3). Robust standard errors (2) and Newey West standard errors with lag order 1 in brackets. t_{a-b} is the t-test for $a = b$.

Table 1 presents estimates using two sets of fixed effects. The first two rows are our main case of match fixed effects as per equation (1). The next two rows replace MFE with worker fixed effects (WFE).[31]

Starting with the $\gamma^k_{\Delta y}$ obtained using MFE, we see that there is little difference in incumbents' wage cyclicality and that of ue's and ee's. The t-ratios (columns 5 and 6) confirm that these small differences are wholly insignificant. The semi-elasticities of wages with respect to unemployment are also very close for all three categories of worker and the insignificance of the relevant t-tests confirms this closeness.

It is interesting to compare the WFE estimates with those obtained using MFE. Starting with the former we see these estimates imply substantially higher new hire versus incumbent wage cyclicality. Similar results have been found previously, see Haefke et al. (2013) and the literature summary in Pissarides (2009). However when we move to MFE we see that this extra cyclicality disappears. We would argue that this is evidence in favor of procyclical upgrading (where workers and the unemployed move to high paying firms in booms a low paying ones in recessions) and

[30]Standard errors are in brackets: These are robust for the elasticities but for the semi-elasticities where there was substantial first order autocorrelation they are Newey West with lag order one.

[31]In a random sample of workers we rarely see any firm with more than a single worker. This means that firm fixed effects are not separately identifiable from MFE. Hence we only study the WFE and MFE cases respectively.

procyclical match quality. Our results support the claims of Gertler and Trigari (2009) that cyclical up- and downgrading needs to be controlled for when testing for equal treatment. In that paper they also propose using MFE for this purpose.[32] Finally we note that the output elasticities are less well determined than their semi-elasticity counterparts. This raises the suggestion that the failure to reject "excess" cyclicality of the ue and ee over incumbent output elasticities may be due to poor power. However in the next section we repeat the equal treatment tests in a specification that allows for different elasticities in up- versus downswings. There we find very relatively large and well determined upswing elasticities and relatively small and insignificant downswing ones whilst the analogues of $\mathbf{t}_{\gamma^E_{\Delta y}-\gamma^I_{\Delta y}}$ and $\mathbf{t}_{\gamma^E_{\Delta y}-\gamma^I_{\Delta y}}$ remain insignificant. Therefore the failure to reject equal treatment when we use output growth as the cyclical measure is not a consequence of poorly determined estimates.

Summing up this section our empirical results are broadly supportive of equal treatment, and of the idea that the findings of unequal treatment in numerous other papers may be down to the failure to control for procyclical upgrading to better paying firms and procyclical upgrading in match quality.

4.2 Asymmetric Wage Adjustment

The purpose of this section is to establish a key stylized fact about the comovements of output and wages, namely that they positively comove when output is rising but are not well related when it is falling. As we have noted this property is a salient prediction of Snell and Thomas's (2010) equal treatment wage contracting model as we will show later. Of course the definition of downswings and upswings is not unambiguous and given that the target is to see if the theoretical model can match the time series co-properties we identify here, we could choose any measure of the cycle. However output growth is not only a familiar and natural measure of up- and downswings (a recession in many countries is defined as two quarters of consecutive negative GDP growth) but is a natural metric suggested by the model; in the model productivity (growth) is the sole exogenous input and

[32] Gertler et al. (2016), who use the SIPP and also estimate semi-elasticities separately for new hires from unemployment and from job-to-job transitions, find that in a WFE specification the ue semi-elasticity is not significantly different from the incumbent one and the ee one is significantly larger in absolute size. This may be partly accounted for by the difference in labor markets between Germany and the US, and the much shorter period each worker is followed in the SIPP. This casts however some doubt on the generality of their hypothesis that it is job to job cyclical upgrading that is behind the increased cyclicality of new hires.

when productivity rises (falls) so does output.

We analyze asymmetric adjustment of wages to output using the three sets of wage year effects (for incumbent workers, ue new hires, and ee new hires) that we estimated above. Here we focus only on those year effects derived where we have controlled for MFE in (1). Figure 1 plots the first differences of the year effects ("wage growth") for the three types of worker as a scatter plot against the growth in output. We provide separate scatters for positive and negative output growth respectively. All graphs in Figure 1 employ the same scale.

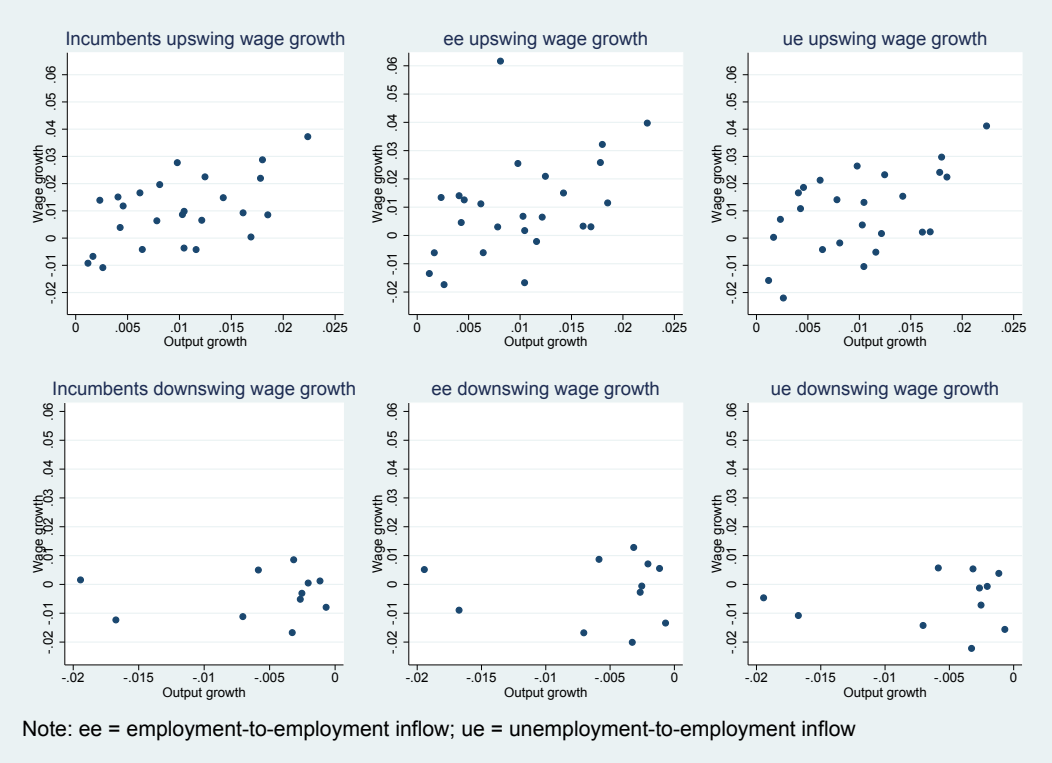

Figure 1: Scatter Plots of First Differences of the Year Effects ("Wage Growth") for Three Types of Workers Against Output Growth.

We may make three heuristic observations. Firstly all three types of workers have wage growth that display a "hockey stick" pattern; a clear positive slope during upswings but relatively flat in downswings. Second there seems to be a markedly higher variance of wage growth in upswings than downswings (the ratio of upswing over downswing wage growth (%) variance for the three types of worker are 2.54, 2.55, and 2.61, respectively). This higher upswing wage growth variance is not coincident with higher upswing output variance; the latter is practically the same as its downswing counterpart (0.38 versus 0.4 respectively where again we measure growth as a %). Thirdly the

upswing slopes appear to be similar in each of the three graphs. These three observations are what we would expect from a world of wage contracting subject to equal treatment. Our model (below) predicts that in most downswing periods, wages will most likely fall at an exogenously given rate — a rate below that (in absolute value) of the fall in productivity. This should generate downswing wages that are relatively less volatile and less well related to productivity growth compared with those in upswings; consistent with the first two observations. The third observation is consistent with equal treatment — an assumption that underpins our model. We now re-examine these apparent data features more formally via a regression model. Finally we note that average growth rates for each series are 0.6%, 0.6%, and 0.5% respectively — consistent with German TFP (see below) and output per capita whose growth rates are also around 0.6%.

The second-stage regression model we use to characterize the time series co-properties of wage growth for the three types of workers and output is

$$\Delta\beta_t^k = \alpha + \gamma_u^k \Delta y_t^+ + \gamma_d^k \Delta y_t^- + \varepsilon_t, \qquad k = I, E, U \tag{4}$$

where Δy_t^+ (Δy_t^-) equals Δy_t if output is growing (contracting) and is zero otherwise.

Table 2 gives estimates of γ_u^k and γ_u^k for each of the three types of worker along with t-tests of their equality. The table also gives the estimates obtained when we replace the three sets of year effects in (1) with one single set of common year effects — effectively imposing the constraint that all workers have the same wage cyclicality. The elasticities are denoted γ_u^A and γ_d^A ("A" for "*All*").

As we have noted already the model predicts that when output falls wages will likely fall but at a rate substantially lower than the output fall. By contrast in upswing periods, wages and output are likely to move one for one — particularly when we hit full employment. These properties of the model are borne out in estimates of the γ's in Table 2.[33] The downswing elasticities are close to zero and wholly insignificant whilst the upswing counterparts are close to but slightly above unity and highly significant. Revisiting the equal treatment hypothesis, the final four columns give t-tests of equality of the incumbent up- and downswing elasticities with the corresponding ones for ue's and ee's respectively. We see that the differences between the estimates across the three worker

[33]We also included an up- and downswing dummy to allow for an "up/down"change in mean. but it was not significant and made only a marginal difference to the estimates.

types are small and wholly insignificant. Again this is consistent with the impressions gained from the scatter plots. The "A" column shows the up- and downswing elasticities when we impose them to be equal across worker types. They are of course close to their worker-type counterparts. It is these values that we will try to match in our simulations below.

Table 2: Upswing and Downswing Elasticities

k	I	E	U	A	$t_{\gamma_d^E-\gamma_d^I}$	$t_{\gamma_u^E-\gamma_u^I}$	$t_{\gamma_d^U-\gamma_d^I}$	$t_{\gamma_u^U-\gamma_u^I}$
γ_d^k	0.184	−0.011	0.181	0.183				
	(0.346)	(0.403)	(0.289)	(0.349)	1.32	−0.71	0.00	−1.34
γ_u^k	1.163	1.234	1.369	1.196				
	(0.285)	(0.334)	(0.322)	(0.288)				

Notes: Estimates of the parameters in equation (4) with robust standard errors in brackets. Columns I, E and U contain estimates for incumbents, ee's and ue's respectively with the column headed A ("All") displaying estimates for the case where a single set of year effects for all workers are extracted from the panel. The columns headed t_{a-b} display t-ratios for the test of $a - b = 0$

5 A Simple Equal Treatment Wage Contracting Model

In this section we analyze the extent to which a simple equal-treatment wage contracting model can reproduce the empirical characteristics of output, wages, and unemployment of the West German data. Whilst the main focus is on the ability to match the (asymmetric effect) estimates in Table 2 we also assess the model's ability to match the univariate time series properties for each of the three variables and their sample covariances. The model we use is a simple extension of Snell and Thomas (2010). Like its predecessor the current version is very parsimonious, contains only four parameters and uses total factor productivity as its single exogenous driving process. Explicitly, we introduce habit formation into Snell and Thomas (2010). Here we give a brief overview of the model and its parameters; a fuller exposition of the basic model without habit formation can be found in Snell and Thomas (2010).

5.1 The Model

Time runs $t = 1, 2, \ldots, T$. There are a large (fixed) number of identical risk neutral firms producing a homogeneous good using only labor as an input in a diminishing returns (Cobb-Douglas with fixed capital) production process where production is subject to a shock common across firms a_t:

$$F(l, a_t) = a_t l^{\alpha}, \tag{5}$$

where l is employment, $\alpha \in (0, 1)$, and a_t follows a finite state Markov process with transition probabilities $\pi_{a,a'}$ and a_1 given. There is a continuum of risk averse workers, of measure 1 relative to the the number of firms, with utility $u(c, H) = (c - H)^{1-\gamma} / (1 - \gamma)$, $\gamma > 0$, $\gamma \neq 1$, where c is consumption and H is external habit. Workers choose to work full time or not to work at all, but cannot borrow or save so that consumption equals real wage w or unemployment benefit b. Labor markets are competitive and in equilibrium, all workers wish to work (no disutility of work). We assume that $a_t > b$ so that the "spot wage" is a_t (equalizes labor supply of 1 with the marginal product of labor). For H we follow standard practice (see, e.g., Dennis (2009)) and take $H_t = \mu c_{t-1}$ for the respective cases above, where c_{t-1} is lagged consumption of the relevant reference group and $\mu \in [0, 1)$; for an employed worker we assume that the reference group is the continuously employed so that the habit, denoted by H_t^E, is μw_{t-1}, regardless of whether or not the worker is a new hire. For an unemployed person the reference group is the continuously unemployed so that the habit, denoted by H^U, is μb.[34] We take the initial habit to be $H_1 = \mu a_1$.

At each date, a firm must pay its workers the same wage (equal treatment, no human capital).[35] At the start of each period a_t is revealed, before firms hire workers. A firm commits at the outset ($t = 1$) to a long-term history-dependent wage contract $(w_t(h_t))_{t=1}^{T}$ where $h_t = (a_1, a_2, \ldots, a_t)$; because of equal treatment this also fixes the wages offered to new hires since they simply slot into the existing wage contract. It is assumed that exogenous labor turnover $1 - \delta \in (0, 1)$ is sufficiently high relative to shocks to guarantee that at least some new workers per firm are employed each

[34] The equilibrium wage contract and employment are independent of b (and H^U), provided only that parameters are such that working at the putative equilbrium wage offers a higher utility than being unemployed. We assume below that this is satisfied, and for our calibrations it is satisfied for any reasonable replacement ratio (we do not need to calibrate b for the above reason).

[35] Snell and Thomas (2010) show that equal treatment is a property of optimal contracts under "at will" contracting. See Menzio and Moen (2010) for a similar argument with a frictional labor market.

period.[36] Firms and workers discount the future with respective factors β_f and β_w. We assume that $(1-\alpha)\gamma > 1$.

The lifetime utility of an employed worker at the start of period t is denoted V_t, and that of an unattached worker χ_t. The latter is also the utility an employed worker gets if they quit at the start of t. To be able to hire and to avoid losing its workforce firms must at least match χ_t (there is no on-the-job search, although the equilibrium is robust to this). We have

$$V_t = u(w_t, H_t^E) + \beta_w E\left[\delta V_{t+1} + (1-\delta)\chi_{t+1} \mid h_t\right], \tag{6}$$

with $V_{T+1}, \chi_{T+1} = 0$, and we assume all unattached workers have an equal chance of finding work:

$$\chi_t = \frac{l_t^* - \delta l_{t-1}^*}{1 - \delta l_{t-1}^*} V_t^* + \frac{1 - l_t^*}{1 - \delta l_{t-1}^*} U_t, \tag{7}$$

where * denotes an equilibrium value, U_t is the discounted utility of a worker who fails to find work at t given by $U_t(h_t) = u(b, H^U) + \beta_w E\left[\chi_{t+1} \mid h_t\right]$ and $1 - \delta l_{t-1}^*$ is the measure of workers unattached at t. ($\chi_1 = V_1^*$ as wages are flexible at $t = 1$.) The problem faced by the representative firm, which takes $(\chi_t)_{t=1}^T$ as parametric, is then:

$$\max_{(w_t(h_t)\geq 0)_{t=1}^T, (l_t(h_t)\geq 0)_{t=1}^T} E\left[\sum_{t=1}^{T} (\beta_f)^{t-1} \left(F(l_t(h_t), a_t) - l_t(h_t) w_t(h_t)\right)\right] \tag{Problem A}$$

subject to the participation constraint for all positive probability $h_t, T \geq t \geq 1$,

$$V_t(h_t) \geq \chi_t(h_t). \tag{8}$$

The firm has two conflicting objectives: a) to insure its risk-averse workforce by limiting the variability of wages over time and across states, and b) to take advantage positive unemployment rates in bad times by lowering the wages of new hires. The requirement to pay new hires and incumbents the same results in a compromise where wages do fall in bad times but where the fall does not exceed some maximum rate. Consider the consequence of a negative productivity

[36] That is we shall assume that optimal contracts involve hiring in every contingency and ignore the possibility of layoffs. Snell and Thomas (2010) derive sufficient conditions that guarantee this is optimal which extend straightforwardly here.

shock following a period when there was full employment. If the shock is sufficiently large, wages will not fall far enough to clear the labor market. At this point the firm gets no benefit from a further reduction in the wage because the extra risk-premium that has to be paid to earlier hires to compensate them for wage variability exactly equals the benefit from hiring more cheaply. Further slackness in the labor market leading to reductions in the utility needed to be offered to new hires, has no additional effect on the optimal wage contract. There will then be involuntary unemployment and this will persist until either productivity recovers or until wages have fallen sufficiently far to clear the labor market — whichever happens first. When productivity recovers and is rising however the firm must allow wages to respond fully to it in order to be able to make new hires (to replace workers who are separated), and to prevent their incumbents from quitting and, when there is full employment, immediately joining other firms (workers are fully mobile).

Proposition 1 *(i) In an equilibrium with positive hiring,*[37] *employment is at a level such that the marginal product of labor is equal to the contract wage,*

$$l_t = (w_t/\alpha a_t)^{-\frac{1}{1-\alpha}}; \tag{9}$$

(ii) Define $\hat{w}_{t+1}(w_{t-1}, w_t, a_t, a_{t+1})$ *to be the solution to*

$$\left(\frac{w_{t+1} - \mu w_t}{w_t - \mu w_{t-1}}\right)^{\gamma} = \lambda \left(\frac{w_t a_{t+1}}{w_{t+1} a_t}\right)^{-\frac{1}{1-\alpha}}, \tag{10}$$

where $\lambda \equiv \delta\beta_w/\beta_f$. *Then wages will satisfy* $w_{t+1} = \max\{\hat{w}_{t+1}, a_{t+1}\}$, $t > 1$, *with* $w_0 = w_1 = a_1$.[38]

The proposition allows for the dynamics of wages and employment to be computed in a very simple recursive manner. For the case where $\mu = 0$ we can simplify even further, so that current wages and employment depend only on current and lagged productivity and lagged wages, where

[37] Existence and uniqueness can be established as in Snell and Thomas (2010) *mutatis mutandis* under analogous conditions that guarantee positive hiring (negative shocks cannot be too large), provided μ is not so close to 1 that surplus $(c - H)$ falls below zero. Their proof that a relaxed version of Problem A is a concave program extends to the model with habits.

[38] A proof is provided in Appendix B.

a ˜ above a variable denotes logs:

$$\tilde{w}_{t+1} = \max\{(A_{t+1} + \tilde{w}_t), \tilde{a}_{t+1}\}, \tag{11}$$
$$\text{where } A_{t+1} = \frac{1-\alpha}{(1-\alpha)\gamma - 1}\tilde{\lambda} - \frac{1}{(1-\alpha)\gamma - 1}\Delta\tilde{a}_{t+1}$$

and

$$\tilde{l}_{t+1} = \frac{1}{1-\alpha}\log\alpha + \frac{1}{1-\alpha}\tilde{a}_{t+1} - \frac{1}{1-\alpha}\tilde{w}_{t+1}. \tag{12}$$

5.2 The Fit of the Model With the Data

As noted above we follow standard practice and calibrate the model to German data. We generate a synthetic productivity series with the same time series properties corresponding to the actual TFP for Germany and "feed" this series to the model to generate model simulated time series for output, unemployment and wages. We then characterize the time series properties (and co-properties) of these three variables and compare these characterizations to those obtained from their real counterparts: annual time series data on wages (wage year effects), unemployment, and output for Germany from 1978 to 2014. We derive simulated series for two versions of the above model. The first is the one presented above with habits and where workers have identical separation hazards $1-\lambda$, assuming $\beta_f = \beta_w$ so $\lambda = \delta$, as we henceforth do. We call this the *habits model*. The second version – called the *baseline model* – is the one used in Snell and Thomas (2010). It has no habits ($\mu = 0$) and workers are assumed to have heterogeneous separation rates. In the baseline model $1-\lambda$ becomes the smallest separation rate of all workers at the representative firm.[39] This raises a problem as λ has no empirical counterpart whilst in the habits model homogenous quit rates allow us to easily calibrate it using completed tenure. The habits model also has an unidentified parameter. This time it is μ that, as with the λ of the baseline, is not identified empirically. We resolve both of these issues by choosing λ in the baseline model and μ in the habits model respectively to target the standard deviation of unemployment.

[39]That is, the equilibrium contract of the no habits model ($\mu = 0$) with homogeneous λ, as in Section 5.1, can be shown to be an equilibrium of the model with heterogeneous separation rates across workers where the minimum separation rate equals $1-\lambda$. In addition, if $\beta_w > \beta_f$ the separation rate is higher than $1-\lambda$.

With respect to the other parameters, we use $\alpha = 0.66$, $\gamma = 4$. In our model (and in growth/RBC models) α is the labor share so 0.66 is a reasonable choice. In the macro literature values of γ anywhere between 1 and 10 are in common usage so 4 seems likewise reasonable. The value of baseline λ that allows us to hit the standard deviation of unemployment is 0.985. The value of μ in the habits model that achieves the same end is 0.45. The average of completed tenure lengths in 2014 in our sample is around 7.5 years giving us a value for λ in the habits model of 0.87.

Data for TFP[40] were taken from the Federal Reserve Bank of St Louis (FRED). This data shows (log of) TFP to be a unit root so we deal henceforth with productivity growth (the change in log TFP) which we denote as m_t. We summarize the time series properties of (m_t) using a simple AR(1) process:[41] $m_t = \rho_p m_{t-1} + \varepsilon_t$, with $var(\varepsilon_t) = \sigma_p^2$. and where we take ε_t to be normally distributed.[42] The values for σ_p and ρ_p were chosen to match those obtained using the FRED time series from 1978 to 2014. The standard deviation was 1.6% and the autocorrelation coefficient was 0.36.

Both versions of the model have three endogenous stationary variables; wage growth, output growth and unemployment (equivalently, employment as labor supply is assumed constant). We simulate the model using the parameter configurations above and assess its abilities to match the time series properties of the actual data including of course the key property of asymmetric cyclical response of wage growth to output growth. As we have a relatively small number of observations in the data (36 annual data points) we use a parsimonious AR(1) process to summarize the univariate dynamic time series properties of the three variates. Given that the model assumes equal treatment we use $\Delta\beta_t$, the "common" year effects from (4), as our wage growth measure. Results for the AR(1) coefficients (ρ_z) and the standard deviation (σ_z) of each data series and their model counterparts are given in the top half of Table 3. Further down the table we give the correlations between the

[40] Unlike all other data in the paper, TFP is only available for the whole of Germany after 1991. This is not a major issue; we only use the series indirectly to calibrate the time series properties of the synthetic simulated TFP series and we would not expect these properties to be much changed by the inclusion of the old East Germany after 1991.

[41] We add a 0.7% p.a. deterministic trend to match the trend found in the FRED data — a trend that is also roughly in line with that of our GDP per capita series.

[42] For the baseline model (but not for the habits model) the productivity draws had to be truncated where they fell outside the model's permitted limits. The persistence and standard deviation of the TFP input were adjusted to make sure that ex post its AR(1) representation was as in the data but of course the truncation operation implies that the TFP input was not normally distributed. We revisit this issue below.

variates together with the up- and downswing elasticities estimated above again from the data and the two models.[43]

Table 3: Data and Model Properties of Wage Growth ($\Delta\beta_t$), Unemployment (u_t) and Output Growth (Δy_t).

Data Variable(z)	ρ_z	σ_z			
$\Delta\beta$	0.52	1.31			
Δy	0.28	0.97			
u	0.82	1.71			
Baseline Model Variable(z)					
$\Delta\beta$	0.39	1.67			
Δy	0.20	2.34			
u	0.61	–			
Habits Model Variable(z)					
$\Delta\beta$	0.44	1.64			
Δy	0.06	2.30			
u	0.45	–			
	$cor(\Delta\beta, \Delta y)$	$cor(\Delta\beta, u)$	$cor(\Delta y, u)$	$\gamma_{\Delta} y^{+}$	$\gamma_{\Delta} y^{-}$
Data	0.62	−0.24	−0.05	1.19	0.18
Baseline Model	0.76	−0.42	−0.59	0.61	0.24
Habits Model	0.64	−0.26	−0.59	0.74	0.23

Notes: Estimates of the AR(1) coefficients (ρ_z) and standard deviation (σ_z) of wage growth (%), output growth (%), and the unemployment rate (%) from the data and models (top half of table). The bottom half of the table gives correlation coefficients between the three variates ($cor(a, b)$) along with the upswing and downswing elasticities from the data and the models.

Given the parsimony of the models — the habits version has only four parameters and the baseline three — it reproduces the main features of the data quite well. All quantities have the correct sign. The upswing elasticity found in the models is lower than in the data but in both of the models and in the data the downswing elasticities are small. In the data the persistence of output is below that of the productivity "input" whilst that of wage growth and unemployment are higher with the latter being highest of all. These data features are reproduced by both of the models. The standard deviation of wage growth generated by both models is fairly close to that found in the data and the correlation coefficients from both models – aside from that between unemployment and output growth – are a reasonable fit with the data. However the models fare poorly in matching the standard deviation of output growth and its correlation with unemployment.

Comparing the performance of the baseline with its habit counterpart we see neither is uniformly

[43]Estimates derived from a single simulated time series of 1,000 periods. The productivity growth shock is normally distributed for the habits model and truncated normal for the baseline — see footnote 44 below.

superior. The habits model underestimates unemployment persistence more than the baseline but does better on wage growth persistence and unemployment variance. An important reason to prefer the habits version over the baseline is that the latter places more severe restrictions on the maximum size of downward productivity shock that is admissible. In fact the two largest TFP falls we observe in the data are not admitted by the baseline under its current calibration.[44] The restriction on the support of productivity shocks may be eased by lowering baseline's value of λ but doing so undermines its fit with the data. We therefore consider the habits version to be more general in terms of the economies it may represent.

In sum the models, despite their simplicity, can account for many of the features and co-features of wages, unemployment, and output, especially the asymmetrical response of wages to output.

6 Caveats, Robustness Checks and Methodological Issues

Issues with the early years and reunification

Here we examine two issues that may impact our estimates and for which we need a robustness check. First of all we had to drop workers who were incumbents before January 2^{nd}, 1975 because their tenure is censored. This gives us relatively few incumbents in the early years of the sample. Consequently, the precision of the year effects in these early years will be relatively low and this in turn may reduce the power of any test of extra new hire cyclicality. Omitting these early years and focusing the test on the relatively more precise new hire and incumbent year effects may improve the test power. By 1982 we get a ratio of new hires to incumbents that roughly represents that in the uncensored years of the sample (see Table A1) and so we re-estimate (3) and (2) from 1982–2014 dropping the early years. The t-tests for equal treatment — $\mathbf{t}_{\gamma^E-\gamma^I}$ and $\mathbf{t}_{\gamma^E-\gamma^I}$ — in Table 1 are now 0.52 and 1.05 respectively.

Second, reunification and the years just after were traumatic years for Germany. We do not have a view on how this may impact labor markets in general and the asymmetrical response of wages

[44] As we have already footnoted, in the baseline simulations we truncate productivity draws that are too large by resetting them to the maximum allowed fall. The variance and persistence of the TFP input was adjusted to ensure that after such truncation the AR(1) parameter was 0.36 and unconditional standard deviation was 1.6% as per the data.

to output in particular. Nonetheless we assess the impact on the main results of dropping the years 1989 to 1992 in the second stage regression. We re-estimated upswing and downswing elasticities for the "*All*" case above (the case where we estimate a single wage year effect for incumbents and new hires together). The numbers are virtually unchanged at 1.12 and 0.24 respectively, as are their standard errors.

The Issue of Small Samples

An issue with our study, and indeed with all work of this nature on wage cyclicality, is the small number of observations we have to work with — 36 years in all. Like the rest of the literature we only have the business cycles that an economy undergoes and these are small in number. However we can re-estimate the "*All*" up and downswing elasticities for each of six broad industrial sectors. While this offers up no extra business cycles it allows us to see whether the asymmetry in response to the business cycle applies at a more disaggregated level (and may allay fears that our results hinge on just 36 data points).

Table 4: Upswing and Downswing Elasticities (γ_u and γ_d) for six Broad Industrial Sectors ($S1, ..S6$)

	All	$S1$	$S2$	$S3$	$S4$	$S5$	$S6$
γ^d	0.183	0.139	1.144	−0.858	−0.488	−0.069	−0.352
	(0.349)	(0.614)	(0.220)	(0.640)	(0.342)	(0.281)	(0.451)
γ^u	1.196	1.061	1.280	0.983	1.728	1.182	1.078
	(0.288)	(0.273)	(0.281)	(0.350)	(0.428)	(0.250)	(0.322)

Note: Robust standard errors in brackets.

The six sectors are:

1. agriculture, hunting and forestry (A), fishing (B), mining and quarrying (C),
2. manufacturing (D),
3. electricity, gas and water supply (E),
4. construction (F),

5. wholesale and retail trade; repair of motor vehicles, motorcycles and personal household goods (G), and

6. hotels and restaurants (H), transport, storage and communication (I), financial intermediation (J), real estate, renting and business activities (K), public administration and defense; compulsory social security (L), education (M), health and social work (N), other community, social and personal service activities (O), private households with employed persons (P), and extra-territorial organizations and bodies (Q).

The up- and downswing γ's are displayed in Table 4 under the columns headed $S1, S2, ..., S6$. Apart from sector two (manufacturing) where the downswing elasticity is significant and only marginally less than its upswing counterpart the main result remains intact: downswing elasticities are wholly insignificant and either perverse in sign or close to zero whilst their upswing counterparts are relatively large and significantly positive.

Cyclical Variation in Hours Worked

One drawback of the BeH noted above is that it documents total earnings rather than earnings per hour. It was for this reason that we chose to work with only full-time employees because nearly all such workers work a standard length of week in Germany. While it is not possible to show definitively the hours worked by the workers in our panel are unrelated to the output growth, there is some extraneous evidence that cyclicality of hours is very low as we claim.

We have obtained estimates of the average number of hours worked in a year for West German full-time workers for each of the years 1977 to 2009.[45] These data are confidential but we are able to summarize their time series properties. We measure the log of hours which we henceforth refer to as just "hours". We find that hours[46] are nonstationary (ADF test with quadratic trend -1.34 compared with a 5% critical value of -3.8) and so we first difference them to analyze their covariation with output growth.

The growth in hours is virtually acyclical; regressing it on output growth gives a coefficient of 0.09 with a (robust) t-ratio of 0.88. The corresponding estimate for HP detrended (log) hours on

[45] Source: IAB Arbeitszeitrechnung, data status March 2013.
[46] Once again we allow for a quadratic trend — weekly hours have a secular downward trend in Germany.

HP detrended output is 0.12 with a (robust) t-ratio of 1.83 respectively.

Additionally the volatility (standard deviation) of hours growth is only one quarter that of output growth whilst the volatility of HP filtered hours is only one-fifth that of HP filtered output. Overall, although there appears to be some variation in hours worked by full time workers in Germany, such variation would appear to be small and acyclical.

Finally, we note that even if hours were procyclical this would lead to us overestimate the extent of wage cyclicality and yet we find cyclicality in downswings that is close to zero and insignificant. Similarly, with respect to equal treatment, it is hard to see how procyclicality in hours for all workers, per se, could lead to false inferences on this matter.[47]

Varying the definition of a newly hired worker

So far we have defined a new hire spell as one where the worker has joined the firm for the first time. By definition of a spell and our selection criteria, this means a continuous period of employment within a calendar year with the spell end technically defined as December 31^{st}. It would be interesting to see how the equal treatment test is affected by varying this definition to allow workers to remain new hires for a longer period of time — up to two years. In a sensitivity analysis we identify a "new hire" spell as above (as the first spell with a firm) but in addition we identify any second spell with the firm as a "new hire" too, when tenure at the end of the second spell is below 2 years (≤ 732 days). In that case we also apply the information concerning the origin of the flow (from unemployment/nonemployment or employment) from the first to the second spell. Re-estimating unemployment semi elasticities (γ) under this new definition of incumbents/new hires barely changes the results at all. In particular the tests for extra new hire cyclicality yield t-ratios of 0.17 and 0.71 for ee's and ue's respectively. The t-test for extra ue cyclicality with respect to output becomes -1.34 whilst for ee's the elasticity is marginally lower than that for incumbents.

Collective bargaining

Centralized wage bargaining in Germany occurs mostly at the sectoral level between unions and employers' associations (Fitzenberger et al., 2013). In the late 1990s, approximately 73% of

[47] In fact we would require *differential* procyclicality of hours for this to happen. To see this suppose that an upswing (downswing) increases (decreases) new hire wages above (below) that of incumbents. For this to be hidden by the BeH it would be necessary for new hires to work fewer (more) hours than incumbents in the upswing (downswing).

the workforce was covered by union agreements (Dustmann and Schönberg, 2009), although this has declined since. However there is reason to believe that the impact of these agreements on the cyclicality of wages is not substantial. First, clauses in collective contracts allow firms to deviate from sectoral agreements if jobs are at risk (Addison et al., 2007). Second, nearly 50% of firms that recognize a union pay wages above union wages (Dustmann and Schönberg, 2009).[48] These so-called wage cushions can easily be reduced if the economic situation worsens (Jung and Schnabel, 2011). According to Gerlach and Meyer (2010) "for the period before the reform of the Works Constitution Act (2002) most studies suggest that collective agreements and unions have only small, even zero effects on wages". As discussed in Section 2 however, Gartner et al. (2013) find some differential in wage cyclicality between workers covered by unions and those not covered.

7 Conclusions

As far as we know, this is the first paper not only to look at the empirical downward real rigidity of wages for workers including new hires, but also to simulate a microfounded model that is capable of matching observed regularities (Snell and Thomas (2010) only perform unemployment simulations).

We use a sample of West German workers drawn from a large administrative German panel dataset for the years 1977–2014 to estimate the elasticity of wages with respect to output. We define up- and downswings in terms of positive and negative output growth to allow asymmetrical response of wage growth to output growth. The key empirical feature to emerge from our study is that the elasticity of wage growth with respect to output growth is close to zero and insignificant for both new hires and incumbents in downswings. However in upswings the elasticity is close to one and highly significant for both classes of worker. We also find no extra cyclicality in new hire wages when we use unemployment as the cyclical indicator instead of output. These results for new hires are particularly important: if wages are downwardly rigid in downswings then it suggests such workers cannot price themselves into jobs by "undercutting" incumbents and labor markets will not clear (see, e.g., Hall, 2005; Gertler and Trigari, 2009; Snell and Thomas, 2010). The paper also presented results that offered tentative support for equal treatment of newly hired and incumbent workers in both up- and downswings.

[48] See also footnote 11.

We further show that both a three and a four parameter version of Snell and Thomas' (2010) equal-treatment contracting model can generate the asymmetrical response of wage growth to output growth seen in the data. The model(s) can also match moderately well the key dynamic time series features and co features of output and wage growth although both overestimate the variance of output. It may be that adding search frictions to the model may solve this last shortcoming and research along these lines is underway.

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A Further Tables

Table A1: No. of Spells of Incumbent and Newly Hired Workers

Year	Newly Hired	Incumbents
1978	536,480	860,131
1979	580,482	1,070,423
1980	562,231	1,254,231
1981	472,966	1,423,195
1982	383,748	1,535,036
1983	384,038	1,607,852
1984	421,761	1,650,744
1985	433,296	1,703,623
1986	480,197	1,829,471
1987	467,208	1,925,379
1988	501,192	2,008,610
1989	580,223	2,080,315
1990	674,453	2,164,259
1991	651,557	2,284,766
1992	569,494	2,394,251
1993	482,607	2,431,712
1994	496,822	2,428,188
1995	516,571	2,416,687
1996	481,872	2,408,716
1997	481,019	2,405,614
1998	524,318	2,392,430
1999	580,765	2,385,722
2000	601,915	2,445,300
2001	558,655	2,454,149
2002	471,745	2,444,711
2003	424,415	2,505,278
2004	395,014	2,473,805
2005	391,361	2,443,718
2006	441,206	2,449,759
2007	487,477	2,465,401
2008	474,157	2,506,474
2009	400,230	2,502,328
2010	462,299	2,502,616
2011	444,522	2,409,295
2012	430,893	2,480,722
2013	418,203	2,519,325
2014	432,368	2,521,718
Total	18,097,160	79,785,954

Note: Newly hired workers identified using the first employment spell in a firm.

Table A2: GDP, CPI, Population, and Unemployment Rate

Year	Nominal GDP (in Mill. Euros)	CPI	Population (in 1,000)	Unemployment rate (in %)
1978	678,940	47.6	61,322	4.3
1979	737,370	49.5	61,439	3.8
1980	788,520	52.2	61,658	3.8
1981	825,790	55.5	61,713	5.5
1982	860,210	58.4	61,546	7.5
1983	898,270	60.3	61,307	9.1
1984	942,000	61.8	61,049	9.1
1985	984,410	63.0	61,020	9.3
1986	1,037,130	63.0	61,140	9
1987	1,065,130	63.1	61,238	8.9
1988	1,123,290	63.9	61,715	8.7
1989	1,200,660	65.7	62,679	7.9
1990	1,306,680	67.5	63,726	7.2
1991	1,415,800	70.2	64,485	6.2
1992	1,485,759	73.8	65,289	6.4
1993	1,503,858	77.1	65,740	8.0
1994	1,556,575	79.1	66,007	9.0
1995	1,606,164	80.5	66,342	9.1
1996	1,625,847	81.6	66,583	9.9
1997	1,664,512	83.2	66,688	10.8
1998	1,711,722	84.0	66,747	10.3
1999	1,751,665	84.5	66,946	9.6
2000	1,799,706	85.7	67,140	8.4
2001	1,856,557	87.4	65,323	8.0
2002	1,879,896	88.6	65,527	8.5
2003	1,888,205	89.6	65,619	9.3
2004	1,933,051	91.0	65,680	9.4
2005	1,960,396	92.5	65,698	11
2006	2,038,803	93.9	65,667	10.2
2007	2,142,032	96.1	65,664	8.3
2008	2,180,829	98.6	65,541	7.2
2009	2,088,073	98.9	65,422	7.8
2010	2,191,138	100.0	65,426	7.4
2011	2,298,449	102.1	64,429	6.7
2012	2,345,295	104.1	64,619	6.6
2013	2,401,853	105.7	64,848	6.7
2014	2,483,514	106.7	65,223	6.7

Note: Identified downswing years are indicated in bold year numbers. Real GDP per capita calculated using nominal GDP, CPI, and population. Sources for the nominal GDP for West Germany: German Federal Statistical Office & the Federal Statistical Offices of the Federal States. Source German CPI: Federal Reserve Bank of St. Louis (FRED Economic Data). Source West German Population: German Federal Statistical Office. Source West German unemployment rate (in % of total civilian workforce): Sachverständigenrat.

B Proof of Proposition 1

Proof. (i) This follows because with equal treatment and positive hiring in all states next period, the user cost of labor (see Kudlyak (2014)) equals the current wage (an extra hire at t can be offset by reduced hiring at $t+1$). (ii) Start from an optimal contract and take some h_t given. Increase $w_{t+1}(h_t, a)$ by a small amount $\Delta_{t+1} > 0$, and change $w_t(h_t)$ by $\Delta_t < 0$ to leave an incumbent worker in the firm at t indifferent (otherwise leave the contract unchanged) so that:

$$\partial u\left(w_t, H_t^E\right)/\partial w \Delta_t + \pi_{a_t a}\delta\beta_w \partial u\left(w_{t+1}, H_{t+1}^E\right)/\partial w \Delta_{t+1} \simeq 0, \tag{13}$$

where we suppress the state arguments for presentational simplicity. V_τ, $\tau \geq 0$, is unchanged except at $t+1$ after (h_t, a) where it increases, so no participation constraints are violated. The change in discounted profits at h_t is $\Delta P = -\left(l_t \Delta_t + \pi_{a_t a}\beta_f l_{t+1}\Delta_{t+1}\right)$ (where $l_{t+1} \equiv l_{t+1}\left(h_t, a\right)$ etc.). Using (13) to eliminate Δ_t gives the change in profits as

$$\Delta P \simeq -\pi_{a_t a}\beta_f l_{t+1}\Delta_{t+1} + \frac{\pi_{a_t a}\delta\beta_w \partial u\left(w_{t+1}, H_{t+1}^E\right)/\partial w l_t \Delta_{t+1}}{\partial u\left(w_t, H_t^E\right)/\partial w}. \tag{14}$$

By optimality, $\Delta P \leq 0$, so rearranging and letting $\Delta_{t+1} \to 0$ to make the approximation precise, we get:

$$\frac{w_{t+1} - H_{t+1}^E}{w_t - H_t^E} \geq \left(\frac{\lambda l_t}{l_{t+1}}\right)^{\frac{1}{\gamma}}. \tag{15}$$

If the participation constraint at $t+1$ in state a is slack, then the above argument can be repeated but now front-loading wages ($\Delta_{t+1} < 0$) to demonstrate the reverse inequality: V_{t+1} falls but by assumption the participation constraint (8) is not violated for small enough Δ_{t+1}. In this case (15) holds with equality, and substituting for l from (9) and using the assumption that $H_{t+1}^E = \mu w_t$ we get (10). Suppose that $\hat{w}_{t+1}$, is below the spot wage a_{t+1}. By definition of the latter, if the equilibrium wage was at $\hat{w}_{t+1}$, there would be excess demand for labor and a firm would improve its profits by setting $w_{t+1} > \hat{w}_{t+1}$ (by a small amount) so being able to hire as many workers as it desires. Since all firms will want to do this, equilibrium can only be restored

at $w_{t+1} = a_{t+1}$. At this point (8) will bind since a worker faces no unemployment risk and can move to another firm offering the same utility. A higher wage as a deviation by a single firm would imply (8) slack, and so violate (10). Equally the equilibrium wage cannot be above a_{t+1} as again (8) would be slack due to the existence of unemployment. The result follows. ■