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The extent of downward nominal wage rigidity: New evidence from payroll data ☆

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ABSTRACT

We use over a decade of representative payroll data from Great Britain to study the nominal wage changes of employees who stayed in the same job for at least one year. We show that basic hourly pay drives the cyclicality of marginal labour costs, making this the most relevant measure of wages for macroeconomic models that incorporate wage rigidity. Basic hourly pay adjusts much less frequently than previously thought in Britain, particularly in small firms. We find that firms compress wage growth when inflation is low, which indicates that downward rigidity constrains firms' wage setting. We demonstrate that the empirical extent of downward nominal wage rigidity (DNWR) can theoretically cause considerable long-run output losses. Combined, our results all point to the importance of including DNWR in macroeconomic and monetary policy models.

1. Introduction

Over eighty years have passed since Keynes (1936) proposed that workers simply refuse to accept nominal wage cuts, thus preventing the real price of labour from falling during recessions and leading to rising unemployment. An implication of Keynes' theory is that moderate inflation can *"grease the wheels of the labor market"* (Tobin, 1972) by bringing down real wages and boosting employment. With low average inflation being a persistent feature in many developed economies over recent decades, the question of whether labour markets display signs of downward nominal wage rigidity (DNWR) has attracted renewed attention. The answer has wide-ranging consequences for policy-makers; macroeconomic interventions can be justified if excess supply in the labour market does not self-correct through wage adjustments (Schmitt-Grohé and Uribe, 2016).

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Furthermore, the effects of monetary policy on the real economy depend crucially on the degree of nominal wage rigidity in the workhorse model of monetary policy analysis (Christiano et al., 2005).

Despite being one of the central issues in macroeconomics, the empirical extent of downward nominal wage rigidity remains an open question. The key reason why economists disagree is that studies on DNWR have used datasets that were ill-suited to the task. The findings from household survey data have frequently been discounted on the grounds that self-reported wages contain substantial response errors, which can bias estimates.[1] Recent studies have turned to more accurate administrative or payroll data, which suggest that wages are far more flexible than previously thought. The wealth of evidence has indeed become so great that researchers now question the often invoked assumption of DNWR (e.g., Elsby and Solon, 2019). But the datasets that have been used in these recent studies typically give total earnings, which consist of basic wages and extra payments, such as overtime or commission. This makes it tricky to interpret any results and inform macroeconomic models; nominal wage rigidity is typically incorporated to dampen the cyclical response of marginal labour costs, hence only the pay components that drive the cyclical responsiveness of the marginal costs actually matter for these models.[2]

Our study overcomes these challenges and provides novel empirical evidence on the extent of DNWR, using a unique longitudinal dataset from Great Britain, the Annual Survey of Hours and Earnings (ASHE), which offers six main advantages. First, the dataset comprises a one percent random sample of income tax-paying workers, allowing us to derive results that are representative of the entire labour market. This matters because we will document substantial cross-sectional heterogeneity over workers and firms in the extent of nominal wage changes; for example, wage freezes are notably more frequent among smaller firms than larger firms. Second, this survey is administered to employers who are legally obliged to report information from their payrolls, making the data more accurate than those obtained from household surveys (Elsby et al., 2016). Third, employers are explicitly asked whether an employee has been working in the same job and role for more than a year, meaning that we can study actual *job* stayers instead of firm stayers. This distinction matters because we are interested in a firm's tendency to reduce its employees' pay for the same work. Fourth, the data provide detailed records on basic wages, hours worked, and extra pay components. These allow us to study basic wages *per hour* separately from extra pay components, comparing like-for-like measures of hourly pay over time, as well as to analyse separately the cyclicality of each pay component. Fifth, we can distinguish between hourly-paid and salaried (non-hourly-paid) employees. Previous research has found conflicting evidence on the extent to which nominal wage adjustments appear to differ between salaried and hourly-paid workers, questioning whether studies based on only hourly-paid workers generalise to the aggregate labour market.[3] Sixth and finally, the data cover a period of substantial macroeconomic instability, with significant variation in unemployment and low inflation. This matters, since there are reasons to expect that high inflation would hide clear signs of DNWR over the business cycle (Card and Hyslop, 1996).

Our study makes three main contributions to the literature. First, we add a second set of data points on the adjustments and cyclicality of basic wages to those recently documented by Grigsby et al. (2021b) for the US. We confirm that basic wages in Great Britain are similarly procyclical. Furthermore, other extra pay components, for job stayers who receive them, do not substantively increase the estimated cyclicality of hourly earnings. We also show that changes to an employee's basic wages are longer-lasting than changes to extra pay, implying that the former tend to have the greater impact on labour costs. Combined, these findings suggest that the measure of basic wages is the most relevant empirical counterpart to the notion of a wage in macroeconomic models that incorporate nominal wage rigidities to generate cyclical fluctuations in unemployment. Furthermore, we show that the distributions of basic wage changes fall off sharply to the left of zero, which supports the recent US evidence and was previously undocumented for Great Britain.

Our second contribution goes further than Grigsby et al., by presenting some evidence that firms' wage setting is actually constrained by downward nominal rigidity. To do so, we leverage the theoretical insights of Elsby (2009). His model predicts that forward-looking firms, if constrained by DNWR, will refrain from raising nominal wages today, because this increases the likelihood of having to cut wages, at some cost, in the future. We use unconditional quantile regression to show that the distribution of job-stayer wage growth is indeed considerably compressed according to the prevailing rate of consumer price inflation and regional productivity growth.

Our third contribution documents substantial heterogeneity in basic wage adjustments within payroll data. We find that firm size is especially significant in accounting for the frequency of wage freezes and cuts. In small firms with up to 50 employees, the conditional likelihood of a year-to-year wage freeze for job stayers is 27 percent for salaried workers and 34 percent for hourly-paid workers. These values drop to 15 percent in firms with more than 5,000 employees. These differences between jobs, as well as others discussed later, such as across industry sectors or depending on whether wages

[1] Studies on nominal wage rigidity using US household surveys include: McLaughlin (1994); Akerlof et al. (1996); Card and Hyslop (1996); Kahn (1997); Altonji and Devereux (2000); Lebow et al. (2003), and more recently Barattieri et al. (2014); Elsby et al. (2016). Smith (2000) and Fehr and Goette (2005) similarly analysed household survey data from Great Britain and Switzerland, respectively. Dickens et al. (2007) provide results for a sample of European countries and the US.

[2] Administrative data on total earnings show little evidence of DNWR, except in countries where nominal wage cuts are legally impossible, e.g., Portugal and Sweden (see the recent survey by Elsby and Solon, 2019).

[3] For example, Card and Hyslop (1996) analysed the Current Population Survey, concluding that DNWR is not lower for salaried than for hourly-paid workers in the US. Contrary to this, Kahn (1997) found that hourly wage rates exhibit substantially more signs of DNWR than salaries in the US Panel Study of Income Dynamics.

are affected by collective bargaining, highlight the importance of using nationally representative data when assessing the prevalence and macroeconomic significance of DNWR.

Combined, our findings support the assumption of DNWR invoked in recent macroeconomic models of business cycle fluctuations (e.g., Daly and Hobijn, 2014; Dupraz et al., 2019), as well as the degree of nominal rigidity typically assumed in New Keynesian models (e.g., Christiano et al., 2005). Our findings also imply that DNWR might cause sizeable output losses. To demonstrate this, we calibrate the dynamic stochastic general equilibrium model of Benigno and Ricci (2011), which incorporates downward rigid wage setting by firms, to match our empirical estimates on the prevalence of wage freezes and cuts. Simulations of this model suggest that the *long-run* output loss caused by DNWR is around 0.7 to 1.3 percent of GDP in a low-inflation environment of two to one percent per annum.

There are three previous studies on nominal wage changes in Great Britain, which are highly relevant to our own. Smith (2000) found that cuts in weekly earnings were quite common among a subsample of respondents to the 1991-96 waves of the British Household Panel Survey who were prompted to check their payslips when asked about pay. Nickell and Quintini (2003) studied the precursor to the datasets that we are using, the New Earnings Survey for 1975-99, which neither identified hourly-paid workers, nor separated basic wages from extra pay components besides overtime. Nickell and Quintini confirmed Smith's findings: job-stayer earnings were frequently cut in Great Britain in the early 1990s. Recent work by Elsby et al. (2016) updated the study of Nickell and Quintini, finding that job-stayer earnings per hour, excluding overtime, are frequently cut in Great Britain and earnings freezes do not occur excessively often, concluding that DNWR may be less binding than is often supposed. We replicate those findings, but we also show that the ASHE survey design likely leads to previously undocumented recording errors in the data on hours worked, implying that earlier studies may have over-estimated the frequency of nominal wage changes.

Three research teams have recently investigated nominal wage adjustments in US administrative or payroll data for job stayers.[4] Jardim et al. (2019) and Kurmann and McEntarfer (2019) used administrative data from the State of Washington. Unusually for the US, Washington requires firms to report hours worked, and so these authors could derive measures of total earnings per hour. Both studies have documented a considerable proportion of cuts among job-stayer total earnings per hour, and Jardim et al. also found this in a subsample of employees where overtime was likely to have been rare. Their results provide important insights for total labour costs, but they cannot separate cyclical from non-cyclical pay components, nor do they identify hourly-paid workers.

Using a proprietary dataset from a US payroll processing firm, Grigsby et al. (2021b) found that changes to basic wages occur significantly less frequently than was previously thought. We confirm many of their results, suggesting that their findings are unlikely to be driven by idiosyncrasies of the US labour market, and thus providing a valuable second set of data points on nominal basic wage adjustments. We extend their insightful work in two important ways: first, we document that nominal wages are rigid downwards and assess what the consequences of DNWR for the aggregate economy might be, and second, we study basic wages for a sample of jobs that is representative of an entire national labour market. Importantly, as Grigsby et al. acknowledged, the data they used under-represented very large firms and they excluded firms with 50 or fewer employees from their analysis.[5]

The rest of the paper is structured as follows: Section 2 describes the data and our sample selection; Section 3 argues that basic wages drive (marginal) labour costs; Section 4 analyses job-stayer basic wages, separately for hourly-paid and salaried workers, and documents wage growth compression; Section 5 uncovers heterogeneity across workers and firms in the conditional probability of basic wage freezes and cuts; Section 6 discusses the macroeconomic implications; and Section 7 concludes.

2. Description of the annual survey of hours and earnings

Our analysis of nominal wage adjustments uses the Annual Survey of Hours and Earnings (ASHE) (Office for National Statistics, 2019). The ASHE is an ongoing longitudinal panel of employees, starting in 2004, based on a one percent random sample of workers in Great Britain who pay income tax or make National Insurance contributions. The last observations in our study are from 2018. Employers respond to the survey by providing information from the pay period that includes a specific date in April, either by returning a survey questionnaire or directly through their payroll by a special arrangement with the Office for National Statistics (ONS). This setup implies that we only have data each year for individuals in the panel who were employees on the survey reference dates.[6]

[4] Hazell and Taska (2020) find substantial evidence of DNWR for new hires within online vacancy data from the US. They argue that this evidence is consistent with DNWR at the job level being the key for unemployment fluctuations. They do not study wages of incumbent employees.

[5] Carneiro et al. (2014) studied Portuguese administrative microdata and found strong signs of DNWR, with around 45 percent of job stayers having exactly the same basic wage in 2012 as in 2011. However, as the authors explained, nominal wage cuts are explicitly prohibited by law in Portugal. Sigurdsson and Sigurdardottir (2016) analysed Icelandic payroll-based data, where they observed that wage cuts were rare and the share of year-to-year basic wage freezes for job stayers was around 16 percent. These studies did not analyse whether firms were constrained by DNWR and what the consequences for the aggregate economy might be.

[6] We only use data starting from 2006, because questionnaire changes in 2005 and 2006 introduced inconsistencies between these years. Specifically, new instructions were included on how firms should report employee hours worked. See Schaefer and Singleton (2019, 2020) for further descriptions of the dataset.

The ASHE offers a unique combination of features which make it ideal for this study. First, employers are legally obliged to report employee earnings with reference to payrolls, making the data more accurate than those obtained from household surveys (Nickell and Quintini, 2003; Elsby et al., 2016). Second, employers are explicitly asked whether an employee has been working in the same job and role for more than a year, meaning that we can study actual *job* stayers instead of firm stayers. This distinction matters, because we are interested in a firm's tendency to reduce its employees' pay for the same work; a promotion or change in the job may cause some adjustment of an employee's wage, but there is little reason to expect much nominal rigidity for such job changers. Third, the ASHE has a large sample size, with up to 100,000 wage-change observations of job stayers per year. Finally, the ASHE is representative of jobs in Great Britain, being based on a one percent random sample of employees.[7]

Relative to its precursor, the well-studied New Earnings Survey Panel Dataset (NESPD), the ASHE contains two major improvements. First, it identifies workers who received an hourly pay rate, hereafter 'hourly-paid' workers. We refer to all other employees as 'salaried'. This allows us to assess how far results based on hourly-paid workers generalise to the aggregate labour market, as is often implicitly assumed to be the case (e.g., Barattieri et al., 2014). Second, the ASHE contains details on a worker's composition of pay, reporting separately basic pay and extra pay components. The latter include overtime pay, shift premium pay, incentive pay received for work carried out in the April pay period, and other pay (e.g., meal or travel allowances).[8] The ASHE reports the amounts of basic pay, extra pay components, and hours worked for the pay period. For example, if an employee is paid weekly, the dataset contains the amounts received by the employee in the week that includes ASHE reference date. In practice, most employees in Great Britain are paid once per calendar month. We observe basic wages for hourly-paid workers directly from the hourly basic rates of pay recorded by their employers. For salaried workers, we compute their average hourly basic wages within their surveyed pay periods as the ratio of basic pay to basic hours worked. Other studies have analysed basic pay directly, either due to a lack of data on hours worked or due to a perceived lack of reliability when tracking salaried employees' hours. Here we prefer to analyse basic wages because Borowczyk-Martins and Lalé (2019) have documented that fluctuations in part-time employment play a major role in movements in hours per worker during cyclical swings in the labour market. That evolution of part-time employment is predominantly explained by transitions from full-time to part-time employment at the same employer. Additionally, Borowczyk-Martins and Lalé also found that hours worked within full-time and part-time jobs are mildly procyclical. Even if basic pay per hour was constant during recessions, such cyclical reductions in hours worked would tend to increase the amount of cuts in basic pay. Since our main objective is to understand how flexibly employers can adjust nominal wages downward for the same work, we want to exclude pay changes that are only due to hours changes. We provide more details on the pay components and their exact definitions in Appendix A.

We study employees aged 16-64, who did not incur any loss of pay in the April reference period (e.g., unpaid sick leave) and who were not paid at an apprenticeship or a trainee rate. We drop person-year observations if a worker held multiple jobs, was reported as having worked on average less than one or more than 100 hours per week in April, was reported as being paid less than 80 percent of the age-relevant statutory National Minimum Wage, or had missing or imputed values for any of the pay variables which we are interested in. Altogether, our sample selection criteria result in a working dataset of 1,843,172 employee-year observations over our 13-year sample period, 2006-2018. Appendix A describes and justifies our sample construction in more detail. We define a 'job stayer' as an employee whom we observe working in the same job as in the previous April, such that we can measure within-job year-to-year wage changes.

Table 1 shows descriptive statistics for the samples of job stayers and all employees in the working dataset, where the latter includes job switchers, (re-)entrants to employment and job stayers in 2006. On average, the ASHE suggests that around 92 percent of British employees who remain in employment from one year to the next are job stayers, as opposed to job switchers.[9] Hourly-paid job stayers are more likely to be working for a private sector company, are slightly younger, and are less likely to be employed on a full-time basis than salaried job stayers. Around half of all job stayers are covered by a collective agreement, defined as any arrangement affecting the pay of more than one employee. The median and average basic wages are higher for salaried job stayers. Firms in the industry sectors of wholesale & retail trade and hotels & restaurants represent 32 percent of hourly-paid job stayers, while only 13 percent of salaried job stayers work in those industries. Professional services and financial services employ around 42 percent of the salaried job stayers (see Appendix Table A2).

Basic wages are the primary source of labour income for the vast majority of job stayers: in the April pay period, 94 percent of an employee's income is accounted for by basic earnings (basic wages times basic hours worked) on average, and over half of all job stayers have no other labour income besides basic wages. Fig. 1A shows the share of basic earnings in total earnings (basic plus extra earnings for the month of April) along the basic wage distribution. To generate this figure, first we group job stayers into percentiles of the basic wage distribution, and then compute the average share of basic

[7] The ASHE does not include the very low-paid employees; around 3-4 percent of employees in Great Britain (ONS estimates of this undercoverage). The design of the sampling frame implies that it contains no observations of employees with earnings below the National Insurance threshold or who work for businesses that have a turnover below the Value Added Tax (VAT) threshold, e.g., £5,564 and £73,000 per year in 2012-13, respectively.

[8] Using the NESPD, the previous studies by Nickell and Quintini (2003) and Elsby et al. (2016) were restricted to analysing a worker's total earnings per hour, excluding overtime. Additionally, these authors could not distinguish hourly-paid from salaried workers.

[9] We can observe a small minority of job stayers who switch between being hourly-paid and salaried, but all our analysis only considers job stayers who are paid in the same way in consecutive years. This does not affect any of our results.

Table 1
Descriptive statistics of employees in Great Britain, Annual Survey of Hours and Earnings, 2006-18.

	Job stayers		All employees
	Hourly-paid (I)	Salaried (II)	(III)
Private sector (%)	76.3	60.5	66.5
Female (%)	51.8	49.8	51.1
Age (years)	42.6	41.7	40.7
Full-time (≥ 30 hours, %)	65.4	79.7	73.0
Collective agreement (%)	49.3	49.5	46.6
Firm size (no. of employees, median)	2,570	2,640	2,200
Weekly basic hours (median)	36.8	37.0	37.0
Basic wage (mean, £)	10.65	15.42	13.80
Basic wage (median, £)	8.91	12.95	11.10
N	320,087	594,709	1,843,172

Notes: Basic wages are deflated to 2015 GB Pounds (GBP) using the UK Consumer Price Index. Firm size rounded to the nearest ten for statistical disclosure control.

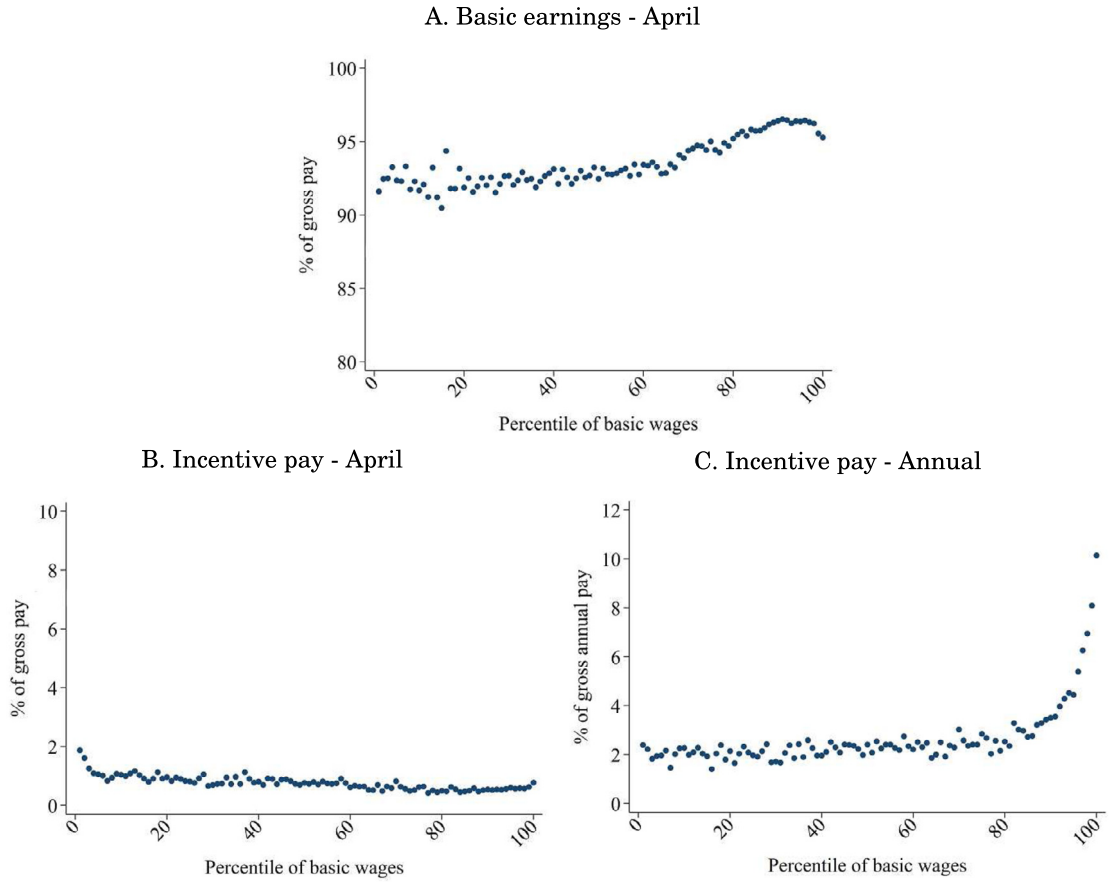

Fig. 1. Importance of basic earnings along the basic wage distribution. *Notes*: Panel A: Average shares of basic earnings in total earnings within the corresponding percentile of the basic wage distribution. Data are pooled across the sample period, 2006-2018. Panel B: Incentive pay in total earnings within the corresponding percentile of the basic wage distribution in April. Panel C: Average shares of annual incentive pay in annual earnings within the corresponding percentile of the basic wage distribution. Data pooled across all years. See Appendix Figs. B1 for equivalent statistics on the contributions of other components of pay to gross earnings.

earnings in total earnings within each percentile. The share of basic earnings in total earnings is roughly increasing with the level of the basic wage, reaching over 95 percent in the top percentile for both hourly-paid and salaried job stayers.

Fig. 1B shows that incentive pay, i.e., bonuses and commission for work carried out during the reference period in April, contributes less to total weekly earnings when moving up the basic wage distribution. When Nickell and Quintini (2003) studied incentive pay in Great Britain, they found that almost 22 percent of job stayers in the New Earnings Survey received such payments, compared with only 7 percent in our sample. This difference might be explained by a change in the

incentive pay definition between their dataset and the ASHE. The new definition in the ASHE questionnaire, by focusing on incentive payments earned and paid in the April pay period, is more precise and gives more consistent estimates between years (Office for National Statistics, 2005). Hence, Fig. 1A is likely to understate the relative importance of annual bonuses, because these are typically paid between January and March in the UK (Schaefer and Singleton, 2020).

To assess the importance of bonus payments outside the April reference period, we compute the share of *annual* incentive pay in *annual* earnings. Both values refer to the preceding tax year, and so complete information about those variables should have been available to employers when the questionnaire was completed. Fig. 1C shows that the share of incentive pay in annual earnings increases along the basic wage distribution. This contrasts with the results for incentive pay earned and received in April. Within the highest decile, the importance of annual incentive payments is greater, especially among the top percentiles. This last finding is also consistent with recent US evidence from the National Compensation Survey, presented in Makridis and Gittleman (2021). The differences between Fig. 1B and Fig. 1C most likely originate in the composition of incentive pay. While the left panel probably reflects a larger share of commission-type payments earned throughout the year, annual incentive pay captures bonus payments, particularly for salaried high-earners. Appendix B provides further detail and statistics regarding the composition of employee earnings in Great Britain, including benefits-in-kind, such as employer provided health insurance, which have a much less important role compared with the US.

3. The cyclicality of basic wages and extra pay components

Nominal wage rigidity is typically incorporated into macroeconomic frameworks to dampen the cyclical movements of firms' marginal cost of labour (e.g., Christiano et al., 2005; Smets and Wouters, 2007). Intuitively, if rigidities prevent the nominal marginal cost of labour from falling sufficiently in response to a negative shock, then firms will produce less output and demand less labour. Therefore, the relevant wage concept for macroeconomic models is best captured by the pay components with the largest impact on the cyclicality of marginal labour costs. In the previous section, we showed that basic wages are the only income source for the majority of workers and make up 94 percent of all labour income, on average. However, basic wages would only be the most relevant variable for the cyclicality of marginal labour costs if they were procyclical, while the extra pay components did not move systematically with the business cycle (Grigsby et al., 2021b).

To understand which pay components drive the cyclicality of growth in real wages for job stayers, we estimate the response to regional unemployment rates, a proxy for the state of the business cycle, using least squares:

$$\Delta \log(w_{ijrt}) = \theta_{ij} + \beta^u U_{rt} + \mathbf{x}_{it}'\boldsymbol{\delta} + \varepsilon_{ijrt} \ , \tag{1}$$

where w_{ijrt} are the various potential measures of real wages for individual i, who has worked in job j for two consecutive years, t and $t-1$, in region r. The unemployment rate (in percent) in region r and year t is given by U_{rt} and θ_{ij} is a fixed effect for a continuous match between employer and employee. As such, since we focus on within-match wage growth, we only include job stayers who have at least two observed wage changes per match. The coefficient of interest is β^u, which measures the semi-elasticity of real wage growth to the regional unemployment rate within a match. This approximates how responsive real wage growth is to whether the labour market facing a job stayer and an employer is relatively slack or tight over the duration of their relationship. The vector $\mathbf{x}_{it}$ contains the April-to-April change in the log UK Consumer Price Index, time-varying controls for employee age and its square, and tenure squared.[10] The regions are the eleven EU-NUTS1 administrative regions of Great Britain (e.g., London, Wales, Scotland, North West).

Table 2 displays the estimates of β^u from Equation (1) separately for salaried and hourly-paid employees, showing that real basic wages are considerably procyclical. When the regional unemployment rate increases by one percentage point, real basic wage growth is on average 0.71 percent lower among these salaried workers and 0.61 percent lower among these hourly-paid workers. These effects are quantitatively large, given that average annual real wage growth was only 1.4 percent and 1.1 percent for job stayers over the sample period.

Column (II) of Table 2 shows the estimates when including the extra pay components except overtime pay in the measure of real wage growth. Compared to Column (I) in absolute terms, the semi-elasticity estimates with respect to regional unemployment rates are unchanged for salaried job stayers and smaller for hourly-paid job stayers, though not substantially so. In the last column of Table 2, we include overtime pay, such that the coefficient estimates give the cyclical responses of real total earnings per hour. The cyclicality of total earnings per hour exceeds that of basic wages for salaried job stayers, but not for hourly-paid job stayers. In summary, this set of estimates shows that basic wages are substantially procyclical and extra pay components, especially overtime, do tend to increase that cyclicality, though not substantially. The results are also consistent with studies on the cyclicality of US real wages. Devereux (2001) and Shin and Solon (2007) argue that adjustments in extra pay components tend to increase the procyclicality of real earnings. Taken together, these results suggest that the cyclicality of basic wages drives the majority of the cyclicality of firms' marginal labour costs of job stayers.

There are some theoretical reasons to question whether the cyclicality of current ('spot') wages has any consequences for employment and output. When workers and firms form long-term employment relationships, current wages are better

[10] A linear control for tenure is excluded because it would be perfectly collinear with an employee's age within an employer-employee match.

Table 2
Estimated cyclicality of real wage growth for job stayers.

	Basic wages (I)	Basic wages plus shift, incentive, and other pay (II)	As (II) plus overtime (III)
All job stayers			
1. Salaried	-0.711	-0.711	-0.742
	(0.058)	(0.061)	(0.059)
2. Hourly-paid	-0.613	-0.569	-0.612
	(0.059)	(0.061)	(0.064)

Notes: Least squares estimates of the semi-elasticity of real wages with respect to the regional unemployment rate (in %), β^u, in Equation (1), separately both for salaried and hourly-paid job stayers and for job stayers who had only basic wages or not. Controls are employee age, age squared, and tenure squared, in addition to worker-firm match fixed effects.
Standard errors in parentheses robust to two-way clustering over year-NUTS1-regions and worker-firm matches.
Sample sizes of job stayers, after dropping singletons: All job stayer - salaried, 532,217; All job stayer - hourly-paid, 277,794;
Sources: NUTS1 regional unemployment and consumer price inflation rates are from the Office for National Statistics (ONS) for April of each year, corresponding to the reporting period of the ASHE.

understood within a stream of payments in which year-to-year fluctuations might not be allocative for employment (Becker, 1962). Any stream of *remitted* wages that adds up to the same present value should not affect a firm's employment decisions. Instead, what matters to a firm when deciding to continue an employment relationship is whether the expected present value of a worker's output exceeds the expected present value of her labour costs. To understand the typical effects of changes in current wages on expected labour costs, we follow Grigsby et al. (2021b) and estimate the persistence of each pay component for job stayers. Intuitively, the more persistent a pay component is, the larger will be its impact on the present value of labour costs. In Appendix C, we show that receiving a certain extra pay component in one year significantly increases the likelihood of receiving this same pay component again the next year, within the same job. However, relatively high amounts of extra pay earned in one year tend to be followed by relatively low amounts in the next year. In contrast, if the current basic wage was high relative to the stream of past and future basic wages within a job, then a worker expects next year's basic wage also to be relatively high. This implies that a rise in basic wages generally leads to an increase in labour costs exceeding the initial value of that rise, while the opposite is true for extra pay.

As long as the present value of the ex post rent of a worker-firm match is positive, dissolving such an employment relationship is inefficient; both worker and firm could agree on a way to share the rent so that neither prefers to end the match (Barro, 1977). It therefore seems reasonable that extra pay components might still be relevant occasionally. For example, if an employee is threatened by job loss unless their total pay is slightly decreased, but basic wages are rigid, then the employee and firm should agree to marginally decrease extra pay to prevent an inefficient separation. Such small adjustments in extra pay likely suffice to smooth over small fluctuations in the firm's share of the match rent. When the economy is hit by a large aggregate shock, adjustments in the main component of labour costs - basic wages - are more likely to be necessary to preserve the match. But the implicit contract between employee and firm might not be sufficiently thorough: workers may be unable to credibly commit to stick with the firm when the labour market tightens again, or firms may be unable to credibly commit to increase wages after the negative shock dissipates. Indeed, the empirical regularity that firms lay off workers into depressed labour markets during recessions suggests such commitment failures. The evidence presented in this and the preceding section supports the notion that basic wages are the most relevant measure of remuneration for macroeconomic models that rely on wage rigidities to generate muted responses of a firm's marginal labour costs to aggregate shocks.

4. The extent of downward nominal wage rigidity

This section explores the data on job-stayer basic wages for evidence that nominal wages are rigid downwards. We begin by displaying commonly used statistics of nominal wage adjustments. Subsequently, we apply insights from the theoretical framework developed by Elsby (2009) to investigate empirically whether downward rigidity constrains firms' nominal wage setting.

4.1. Statistical indicators

To give a first impression of the possible extent of downward nominal wage rigidity, we construct histograms of year-to-year nominal log basic wage changes. Fig. 2 displays these distributions for hourly-paid and salaried job stayers, pooled across all years in the sample period. Four key characteristics are visible. First, large numbers of job stayers experience year-to-year basic wage freezes: 21 percent of hourly-paid workers and 17 percent of salaried job workers receive no basic

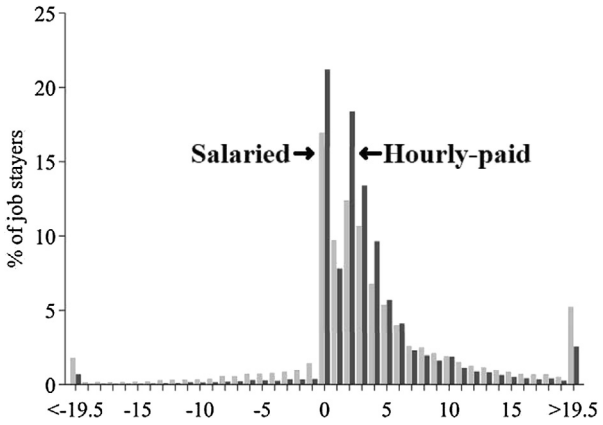

Fig. 2. Frequency distribution of year-to-year changes in log basic wages of job stayers. *Notes*: The zero bin includes log changes in the interval $[-0.5, 0.5]$. The other bins are similarly one log point wide, with the positive changes excluding the lower limit and including the upper limit, and *vice versa* for negative changes. Data are pooled across all years in 2006-2018. **Light bars**: salaried. **Dark bars**: hourly-paid job.

wage change. The height of these spikes at zero is striking and shows that wage freezes occur substantially more frequently than previously thought in the UK. Nickell and Quintini (2003) and Elsby et al. (2016) documented comparable spikes never exceeding 10 percent in Britain, though they were unable to study basic wages and did not account for some probable, but previously undocumented, sources of measurement errors in how payroll records were transferred into the datasets. This may have caused true zero changes in nominal wages to be recorded as small non-zero changes. We discuss the likely impact of this source of measurement error further below, and justify our preferred approach of counting as freezes any absolute change in log basic wages of less than 0.005 (see also Appendix D). Second, the distribution of basic wage changes shown by Fig. 2 is markedly asymmetric, dropping off sharply below zero. Although the sample period spans a severe recession between 2007 and 2009, on average only 11 percent of salaried and 4 percent of hourly-paid job stayers experienced a year-to-year decrease in nominal basic wages. Third, the histograms show a relative lack of small positive wage changes, directly to the right of zero. This would be consistent with the presence of adjustment costs, or 'menu costs', when firms adjust basic wages (e.g., Kahn, 1997). Fourth, basic wages appear to be more downward rigid for hourly-paid than salaried employees; the spike at zero in Fig. 2 is 4 percentage points higher for hourly-paid than salaried employees, and the share of cuts is 7 percentage points lower.

Table 3 displays the relative frequencies of year-to-year basic wage freezes and cuts among job stayers for each year. Wage freezes were more frequent during the Great Recession and its aftermath. More than one-in-four job stayers experienced year-to-year basic wage freezes at the height of the recession, peaking at 28 percent and 27 percent of hourly-paid and salaried job stayers, respectively.[11] However, like most of the aforementioned literature, we only observe employee wages at an annual frequency. This might give rise to time aggregation issues. Suppose that wages are cut in response to negative economic conditions, but firms then reverse these cuts within the course of one year. In this case, we could underestimate the true extent of wage cuts among employees. Grigsby et al. (2021a) found some evidence that the extreme labour market conditions of the COVID-19 pandemic led to relatively short-lived and reversed wage cuts, especially among high earners. Unfortunately, we cannot observe whether the Great Recession in Great Britain was associated with short-lived wage cuts becoming more common.

Our evidence contrasts with the results of two recent US studies on basic wages. First, Barattieri et al. (2014) analysed the Survey of Income and Program Participation (SIPP), reporting basic wage freezes of 40-50 percent in the US from year-to-year. However, wages can be reported with rounding errors in household surveys, tending to bias upward the observed prevalence of nominal wage freezes (Smith, 2000; Elsby and Solon, 2019). Second, Grigsby et al. (2021b) used data from a large US payroll service provider, finding that around a third of job stayers experience year-to-year basic wage freezes and only 2.4 percent of job stayers receive a basic wage cut.

Their results likely differ from ours, at least partially, because of differences in the analysed periods and differences between the US and UK labour markets. The sample of Grigsby et al. covers the period from 2008 to 2016, while we additionally analyse also the pre-recession years 2006-08 and the post-recession years 2016-18. For the same shorter sample

[11] Basic wages are the ratio of basic pay to basic hours. Basic pay excludes shift premium pay, while basic hours include shift premium hours. Although the ASHE questionnaire provides instructions to respondents to ensure that changes in shift hours do not affect basic wages, some respondents might incorrectly report hours worked. Following the excellent suggestion of an anonymous reviewer, we have checked how excluding job stayers with positive shift hours (6.7 percent of observations) affects our estimates of basic wage freezes and cuts. Pooled over 2006-07 to 2017-18, the relative frequency of basic wage cuts is virtually unchanged, but the relative frequency of basic wage freezes increases to 17.3 percent and 22.9 percent for salaried and hourly-paid job stayers, respectively. The increase in basic wage freezes follows no cyclical patterns.

Table 3
Year-to-year changes in nominal basic wages of job stayers.

Years	Salaried		Hourly-paid			
	Freezes (%)	Cuts (%)	Freezes (%)	Cuts (%)	Unemployment rate (%)	Inflation rate (%)
	(I)	(II)	(III)	(IV)	(V)	(VI)
2006-07	10.0	11.3	14.6	4.7	5.4	2.7
2007-08	7.5	10.0	11.9	3.4	5.4	2.9
2008-09	15.0	11.1	18.1	5.5	5.2	2.4
2009-10	21.1	14.5	26.5	4.6	7.6	3.7
2010-11	21.4	11.9	28.0	3.9	7.9	4.4
2011-12	27.2	12.2	27.4	3.4	7.8	3.0
2012-13	24.3	12.3	25.0	6.3	8.1	2.4
2013-14	13.9	9.9	22.7	3.2	7.8	1.8
2014-15	13.0	10.1	16.8	3.1	6.4	-0.2
2015-16	17.6	11.1	19.5	5.7	5.6	0.3
2016-17	14.4	10.8	17.9	2.8	4.9	2.7
2017-18	15.1	11.2	19.8	2.7	4.4	2.4
Average	16.7	11.4	20.7	4.1	6.4	2.4

Notes: Freezes and cuts show the percentage of job stayers with year-to-year no change and a negative change in basic wages. See Appendix Table E1 columns (II) and (III) for annual sample sizes. See Appendix Fig. E1 for time series plots of the percentages of wage freezes. Inflation is measured as the April-to-April log change in the UK Consumer Price Index (CPI). The unemployment rate refers to UK individuals aged 16 and over, seasonally adjusted and for the second April of each period, expressed as a percentage of the economically active population. Both series are from the Office for National Statistics.

period as the US study, we find that the share of basic wage freezes among British job stayers increases by 3 percentage points compared with the longer 2006-2018 period.[12]

Furthermore, the annual US inflation rate was lower than in the UK over the respective study periods, on average, and the US experienced a significant period of deflation from March 2009 to October 2009, plummeting to an annualised inflation rate of -2.1 percent in July (see Appendix Fig. E4). This deflationary episode approximately matches the period with the largest relative frequency of basic wage freezes among US job stayers, measured by Grigsby et al. In contrast, the UK inflation rate remained positive throughout the recession.

The US and UK labour markets also differ markedly in the proportions of employees covered by collective pay agreements (bargaining), which provides a proxy for the degree to which unions are capable of providing common standards of wages, working hours and working conditions. Holden and Wulfsberg (2014) have shown that the coverage of collective bargaining is negatively correlated with the incidence of wage cuts. According to OECD data, the proportion of US employees covered by a collective pay agreement was 12.8 percent on average throughout 2008-16, compared with 29.9 percent in the UK throughout 2006-18. All else equal, we would expect to observe fewer nominal wage cuts among job stayers in the UK than in the US, but the opposite is the case empirically. Finally, benefits-in-kind (e.g., private health insurance) provide an additional margin of adjustment for employers (Bewley, 1999; Lebow et al., 2003). The share of employees who receive fringe benefits is much smaller in the UK than in the US: over 75 percent of employees receive benefits-in-kind in the sample of Grigsby et al., while the share is only around 12 percent in the UK.[13] It is possible that firms prefer to cut benefits-in-kind rather than wages, because this labour cost adjustment might be less salient for employees. Finally, Grigsby et al. exclude firms with 50 or fewer employees from their analysis. In Section 5, we will show that job stayers in such small firms are significantly more likely to receive basic wage freezes than in larger firms, which makes the large frequency of wage freezes documented by Grigsby et al. in the US data even more striking. Taken together, it seems most likely that the greater prevalence of wage freezes found by Grigsby et al. in the US than in our analysis of Great Britain is a result of the notably different inflation and recessionary environments across the two studies. The much greater tendency of employees to be compensated with benefits-in-kind in the US labour market than in the UK provides another plausible contributing factor.

Although the previous Section 3 argued that basic wages are the most relevant wage variable for macroeconomic models of wage stickiness, for comparison to the previous literature for Great Britain, specifically Nickell and Quintini (2003) and Elsby et al. (2016), we repeat the above analysis for exactly the same pay measure used in those studies: average earnings

[12] Grigsby et al. (2021b) winsorised wage observations that fell below the US federal minimum wage. Since that minimum wage remained unchanged over their sample period from May 2008 to December 2016, apart from a single increase in July 2009, this potentially swept some true wage cuts into wage freezes, which would tend to overestimate freezes and underestimate wage cuts. However, the number of affected wage changes is likely not large enough to affect their estimates significantly: according to the Bureau of Labor Statistics, the share of employees paid at or below the federal minimum wage was 3 percent in 2008 and reached 6 percent in 2010, before falling back to around 3 percent in 2016 (data available at https://www.bls.gov/cps/minwage2010.htm)

[13] We discuss the relevance of benefits-in-kind and evidence on their use in the UK in more detail in Appendix D.

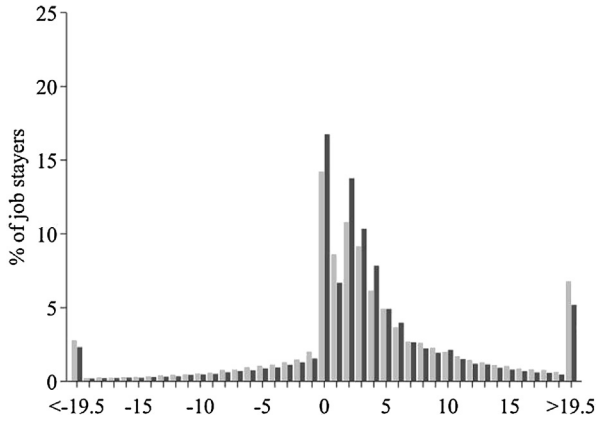

Fig. 3. Frequency distribution of year-to-year changes in log earnings per hour, excluding overtime, of job stayers. *Notes*: See Fig. 2. **Light bars**: salaried. **Dark bars**: hourly-paid.

Table 4
Year-to-year changes in nominal earnings per hour, excluding overtime, of job stayers.

Years	*Exact* Freezes (%) (I)	*Exact* Cuts (%) (II)	Freezes (%) (III)	Cuts (%) (IV)
2006-07	3.1	20.3	9.1	16.5
2007-08	3.2	17.9	7.4	14.4
2008-09	5.8	20.4	12.6	16.5
2009-10	8.7	24.3	17.7	18.8
2010-11	7.8	22.8	18.2	17.2
2011-12	9.7	23.4	20.6	17.0
2012-13	9.9	23.0	19.5	17.3
2013-14	6.5	20.4	13.8	16.1
2014-15	5.5	18.9	12.1	14.7
2015-16	6.6	20.7	14.5	16.1
2016-17	6.0	19.8	12.7	15.3
2017-18	6.4	18.8	13.8	14.4
Average	6.8	21.0	14.6	16.3

Notes: "*Exact* Freezes" show the percentage of job stayers with year-to-year changes in log earnings per hour, excluding overtime, of exactly zero. "*Exact* Cuts" show the percentage of job stayers with year-to-year changes in log earnings per hour, excluding overtime, of less than zero. "Freezes" and "Cuts" show the percentage of job stayers with year-to-year log changes in the interval [-0.5,0.5] and log changes less than -0.5, respectively, in earnings per hour, excluding overtime. See Appendix Table E1 column (I) for annual sample sizes.

per hour, excluding overtime. We find evidence that this broader pay measure also exhibits an asymmetric pay change distribution (Fig. 3), albeit to a lesser degree than basic wages. Possible reasons why our conclusion differs from the previous UK literature, even when analysing the same pay measure, are that the rate of inflation was generally higher in earlier sample periods and that we define log changes of less than 0.005 as freezes to account for slight rounding errors in hours worked. Specifically, if an employee's pay period is a calendar month, but working hours are weekly, then the ASHE asks employers to multiply the weekly hours by 4.348 and to report the result as hours per calendar month. In our sample, almost 75 percent of job stayers are paid per calendar month. Because the ASHE questionnaire only allows employers to report hours and minutes worked, respondents have to round decimal values that result from the conversion of weekly hours. Unfortunately, no guidelines are provided to employers on how they should round in such cases. As Table 4 shows, using a range around zero of 0.005 to define zero nominal log wage changes increases the relative frequency of year-to-year nominal earnings per hour freezes from 6.8 percent to 14.6 percent for all job stayers in 2006-18, see columns (I) and (III), respectively. Similarly, when only log wage changes less than -0.005 are counted as cuts, the frequency of earnings per hour cuts in 2006-18 decreases from 21 percent to 16.3 percent. These results are consistent with findings in Elsby et al. (2016), who documented that for job stayers in 2008-09, for example, including small absolute changes in log earnings per hour of less than 0.01 within the definition of a freeze would increase the estimated frequency of wage freezes from 4.6 percent to 11.2 percent and reduce the estimated frequency of wage cuts from 19.4 percent to 16.1 percent.[14]

[14] We thank an anonymous reviewer for making us aware of the similarity between our results and those in Elsby et al. (2016).

Table 5
Predicted effects of the inflation rate and productivity growth on the percentiles of the real basic wage growth distribution, according to Elsby (2009).

n-th percentile of the real wage growth distribution (P_n)	Coefficient on	
	Inflation rate	Productivity growth
$P_n >$ minus inflation rate	> 0	> 1
$P_n \approx$ minus inflation rate	< 0	< 1 (attenuates toward zero)
$P_n <$ minus inflation rate	> 0	> 1

4.2. Wage growth compression

Though striking, our discoveries, that wage freezes are far more likely than previously thought and that wage cuts are rare in Great Britain, do not provide clear evidence for the presence of DNWR on their own. For example, if wages were set according to implicit contracts between firms and workers, then this could account for the observed spike without wages necessarily being subject to DNWR (Barro, 1977). Therefore, to investigate whether firms are constrained by DNWR, we go beyond purely statistical indicators using the main insights and predictions derived from the theoretical framework of Elsby (2009).[15]

In Elsby's intertemporal framework, firms have a non-trivial wage-setting decision: they can cut nominal wages if they wish, but it will lead to a sharp reduction in worker productivity. This assumption is based on Bewley (1999), who was told by employers that the main reason they did not cut nominal wages was their belief that this would harm employee morale, a key determinant of worker productivity.[16] In this way, if a firm raises nominal wages to increase productivity but has to cut them by an equal amount in the future, then the result will be an overall loss in productivity. This means that nominal wage increases become partially irreversible. In an uncertain world, forward-looking firms would thus refrain from raising wages today, or at least be conservative when doing so, because otherwise there would be an increased likelihood of having to cut wages in the future. This wage-setting power of firms can be rationalised by, for example, search frictions in the labour market generating a positive *ex post* surplus once employer and employee are matched.

In Elsby's framework, when an idiosyncratic productivity shock hits an employer-employee match, the response of the nominal wage depends on the extent of DNWR. Without DNWR, the nominal wage change would equal the change in nominal productivity. With binding DNWR, the optimal wage change policy would instead take the form of a trigger strategy. In this case, large positive productivity shocks lead to wage increases, while large negative shocks lead to wage cuts. For intermediate values of the shock, there is a range of inaction where the nominal wage remains unchanged. When match-specific productivity grows at a common rate in the absence of shocks, and shocks are i.i.d. across employer-employee matches, this region of inaction shows up in the aggregated nominal wage change distribution as a spike at zero. Another consequence of DNWR implied by this theory is that if nominal wage changes occur, then they will be compressed relative to a world without DNWR.

According to Elsby (2009), DNWR can be detected by observing the differential effects of inflation and aggregate productivity growth on the percentiles of the nominal wage growth distribution. In the absence of DNWR, *real* wages should move one-to-one with aggregate productivity growth and inflation should have no effect. In contrast, if DNWR constrains firms' wage setting, then the theory predicts three effects: (1) A firm constrained by DNWR will moderate nominal wage raises, because raising today increases the likelihood of having to cut at a cost in the future. As inflation and productivity growth increase, the frictionless likelihood that the firm wishes to cut declines, and so the firm compresses nominal wage growth less. Therefore, on average, we should observe the upper percentiles of the real wage change distribution rising with inflation and more than one-for-one with productivity. (2) Optimal wage setting under DNWR implies a range of inaction where nominal wages are kept constant. Equivalently, real wage growth equals minus the inflation rate. This is where inflation can *"grease the wheels of the labor market"* (Tobin, 1972), by bringing down the real labour cost without cutting nominal wages. (3) In very low percentiles of the wage growth distribution, nominal cuts will be compressed because of the disproportionate fall in productivity that they would cause. Higher productivity growth and/or inflation will increase wage growth in this lowest range, because firms expect that they will likely be able to reverse nominal cuts in the future and so refrain from making them in the first place. These effects should lead to a more than one-for-one increase in wage growth with productivity growth in the lowest percentiles. Table 5 summarises these predicted effects of inflation and productivity growth on the real wage growth distribution.

To estimate the effects of inflation and productivity growth across the real wage growth distribution, we apply an unconditional quantile regression (UQR) approach (Firpo et al., 2009). As Stüber and Beissinger (2012) explain, this approach is preferable to the seemingly unrelated regressions (SUR) adopted by Elsby (2009) to test his theory, as UQR allows the whole distribution of the chosen set of explanatory variables to be taken into account when modelling real wage growth.

[15] In a related study, Stüber and Beissinger (2012) also used the insights from Elsby (2009) to analyse real wage changes in West Germany.

[16] The explanation of Bewley (1999) for DNWR is not the only one possible. For example, MacLeod and Malcomson (1993) and Holden (1994) argue that past wages are the baseline while a worker and a firm are negotiating a new level of pay.

To maintain consistency with the statistical evidence presented above, we estimate the UQR models separately for salaried and hourly-paid job stayers and for selected quantiles, τ:

$$\widehat{Q}_\tau + \frac{\tau - \mathbf{1}\{y_{irt} \leq \widehat{Q}_\tau\}}{f_y(\widehat{Q}_\tau)} = \beta_{0,\tau} + \beta_{1,\tau}\text{Inf}_t + \beta_{2,\tau}\text{Prod}_{rt} + \beta_{3,\tau}U_{rt} + \beta_{4,\tau}U_{r,t-1} + \mathbf{x}'_{it}\boldsymbol{\delta}_\tau + \psi_{r,\tau} + \varepsilon_{irt,\tau} \ . \tag{2}$$

The dependent variables are the job-stayer re-centred influence functions (RIFs) for each selected quantile of log real basic wage changes, y_{irt}, where $\widehat{Q}_\tau$ gives the estimate of an unconditional quantile of y_{irt} from the estimation sample and $f_y(\cdot)$ is the density of the marginal distribution of those log real basic wage changes in a given year, estimated using the standard combination of a Gaussian kernel and a Silverman plugin bandwidth. Our first explanatory variable is the national inflation rate, Inf_t, measured as the change in the log of the UK Consumer Price Index (April-to-April). To proxy for the common rate of match-specific productivity growth in Elsby's framework, we follow Elsby (2009) and Stüber and Beissinger (2012) by using the average annual log real wage growth among all the job stayers in ASHE from the same EU-NUTS1 region r as an individual i, given by Prod_{rt}. Average real wage growth is a reasonable proxy, because Proposition 4 in Elsby (2009) states that, in steady state, DNWR has no effect on aggregate real wage growth. For robustness, we also carried out all the estimations using regional log gross value added per worker as an alternative proxy for productivity growth, finding that this did not alter the results notably. Having to rely on proxies for match-specific productivity growth likely introduces measurement error and attenuates the estimated effects of productivity growth towards zero. We prefer the regional log real wage growth among job stayers, as the proxy, because it takes into account the composition of our job stayer sample and indicates the alternatives for employees. We also include current and one-year lagged regional unemployment rates in the models as control variables, U_{rt} and $U_{r,t-1}$, as well as region fixed effects, $\psi_{r,\tau}$. At the job-year level, we include further control variables in $\mathbf{x}_{it}$ for the gender, age, relative pay-level and collective agreement status of the employee, plus the private sector status and industry of the employer, as well as its size and employment growth. The latter set of control variables is also used in the heterogeneity analysis later (Section 5) and are further described in Appendices A & G. The coefficients in the UQR models can be interpreted as the effects on the τth quantile of real wage growth from a unit change in the associated explanatory variable for everybody in the estimation sample, i.e., all job stayers over all years.[17] For example, $\widehat{\beta}_{1,50}$ provides the estimated effect on median real wage growth from inflation being one percentage point higher in every year represented in the sample, holding all the other variables in the model constant.

The results from estimating these UQRs are reported in Table 6 for selected percentiles, displaying only the coefficients for the explanatory variables of interest, inflation and productivity growth, as well as the means (percentiles) of the dependent variable, where we are primarily interested in whether the signs of these estimates match the predictions in Table 5. The results provide clear evidence that the upper tail of the wage growth distribution in Great Britain is compressed by DNWR, for both hourly-paid and salaried job stayers. The estimated coefficients on inflation and productivity growth are consistent with the theoretical predictions in Elsby (2009). Specifically, at the 80-90th percentiles, the influence of inflation is significantly positive and the coefficients on productivity growth are substantially larger than one.

Table 6 also displays the estimates for the impact of productivity growth and inflation on the lower percentiles of the wage growth distribution. The theoretical predictions for these percentiles depend on the position of zero real wage growth in the overall distribution, which varies year-to-year and with the inflation rate. Over our whole sample period, annual average CPI inflation in the UK was 2.4 percent. As predicted by the theory, we find the most negative coefficient on inflation at the 20th percentile, and the coefficient on productivity growth is the most attenuated toward zero at this percentile. The results for the 10th percentile are also consistent with the theory, because relative to the 20th percentile the effect of inflation is diminished and the effect of productivity growth is larger. The evidence is somewhat mixed for intermediate percentiles of the wage growth distribution. Wage growth above the rate of inflation is predicted to increase with higher inflation rates, and the coefficient on productivity growth should theoretically be above one. However, annual inflation rates fluctuated from -0.2 to 4.4 percent over 2006-2018. These values imply that the 10-50th percentiles of the real wage growth distribution were at some point equal to minus the rate of inflation, for which the theory predicts a negative coefficient on inflation and an attenuation toward zero for the coefficient on productivity growth. Taken together, our findings provide significant evidence for compression across the basic wage growth distribution, and hence for the presence of binding DNWR.

5. Heterogeneity in wage freezes and cuts across workers and firms

The ASHE data contain detailed job characteristics reported by employers (e.g., collective pay agreements) or retrieved from administrative data sources (e.g., number of employees in the firm). To isolate the effects of various worker, job, and firm characteristics on the probability that a year-to-year basic wage cut or freeze is observed, we estimate probit models separately for salaried and hourly-paid job stayers. We include year-fixed effects to account for the state of the aggregate business cycle. Appendix G contains full details and results, and here we provide a brief summary, focusing on the most salient patterns.

[17] See Firpo et al., 2009; Rios-Avila, 2020; Rios-Avila and de New, 2022 for discussions on the interpretation of unconditional partial effects using RIF-regressions and UQR specifically.

Table 6
The estimated effects of inflation and productivity growth on percentiles of real basic wage growth for job stayers.

	Salaried			Hourly-paid		
Percentile τ	Wage growth ($\widehat{Q}_\tau$) (I)	Inflation ($\widehat{\beta}_{1,\tau}$) (II)	Productivity ($\widehat{\beta}_{2,\tau}$) (III)	Wage growth ($\widehat{Q}_\tau$) (IV)	Inflation ($\widehat{\beta}_{1,\tau}$) (V)	Productivity ($\widehat{\beta}_{2,\tau}$) (VI)
p10	-0.047	-0.247	0.354	-0.029	-0.281	0.299
		(0.028)	(0.033)		(0.011)	(0.011)
p20	-0.027	-0.393	0.226	-0.023	-0.621	0.075
		(0.008)	(0.008)		(0.010)	(0.009)
p30	-0.017	-0.311	0.765	-0.014	-0.399	1.053
		(0.014)	(0.015)		(0.025)	(0.023)
p40	-0.005	-0.138	0.911	-0.004	-0.196	0.752
		(0.008)	(0.009)		(0.015)	(0.015)
p50	0.003	-0.156	0.757	0.002	-0.351	0.520
		(0.007)	(0.006)		(0.011)	(0.013)
p60	0.013	-0.199	0.843	0.010	-0.580	0.575
		(0.012)	(0.012)		(0.019)	(0.021)
p70	0.027	0.062	0.952	0.019	-0.348	0.820
		(0.020)	(0.018)		(0.023)	(0.021)
p80	0.055	0.374	1.244	0.033	0.420	1.249
		(0.030)	(0.028)		(0.036)	(0.044)
p90	0.115	0.789	1.651	0.073	1.576	3.045
		(0.052)	(0.048)		(0.102)	(0.104)

Notes: Results of unconditional quantile regressions, Equation (2): selected coefficients; bootstrapped standard errors in parentheses, 50 replications; Gaussian kernel and Silverman's plug-in optimal bandwidth.
First and fourth columns give the percentiles of real wage growth (i.e., the means of the respective dependent variables in Equation (2)).
Sample sizes: Salaried job stayers, 725,324; hourly-paid job stayers, 319,822.
Controls included: regional unemployment rate and its one-year lag, indicator variables for NUTS1 British regions, as well as the control variables included in the probit model estimates described in Section 5 & Appendix G, except the indicator for a rounded hourly rate of pay.
The explanatory variables are 'Inflation': measured as the change in the log of the UK CPI (April-to-April); and 'Productivity': the year-to-year change in average log real wages in the corresponding region for salaried or hourly-paid job stayers.

We find statistically significant gender differences in conditional year-to-year basic wage changes. Cuts are more common for job stayers who are male rather than female, and basic wages freezes are more commonly found among hourly-paid men (Tables G1 and G2, first and second rows). However, the magnitudes of these differences do not seem economically significant for the average job stayers.[18] Private sector job stayers are less likely to experience wage freezes than non-private sector workers. Job stayers in a firm where wages are set according to a collective agreement are on average significantly less likely to see their wages cut or frozen. We find stark age-specific differences in the conditional probabilities of having basic wages cut or frozen: Job stayers aged 15-29 years are significantly less likely to receive a wage freeze than 45-64 year-olds (salaried, 9.6 percentage points less; hourly-paid, 7.4 percentage points less), and their probabilities of basic wage cuts are also lower. Note that these results control for firm growth and the place of workers in the earnings distribution, which control to some extent for worker life-cycle effects. Job stayers with earnings below 2/3 of the median are both significantly less likely to receive the same wage next year and significantly more likely to receive a basic wage cut, compared to median or high earners. The model estimates also show that the probability of a wage cut is significantly higher outside the "Wholesale & Retail Trade, Hotels & Restaurants" sectors, and basic wage freezes for hourly-paid job stayers occur significantly more frequently (5.5 percentage points) outside this sector.

Focusing on one of the starker sets of differences between jobs, Fig. 4 displays the distribution of job-stayer log changes in basic wages separately for small firms with less than 50 employees and those with at least 50. As rows 13-16 in Table G1 show, wage freezes in very large British firms with more than 5,000 employees are strikingly less common than in smaller firms, conditional on several other observable characteristics of job stayers. The conditional probability of basic wage freezes for salaried employees in small firms is 12.0 percentage points greater than in very large firms, and 18.2 percentage points greater for hourly-paid job stayers. This is mainly accounted for by less common moderate basic wage growth rather than

[18] At the sample average and conditional on other characteristics, salaried (hourly-paid) male job stayers are 0.008 (0.013) more likely to have their wages cut than salaried (hourly-paid) female job stayers.

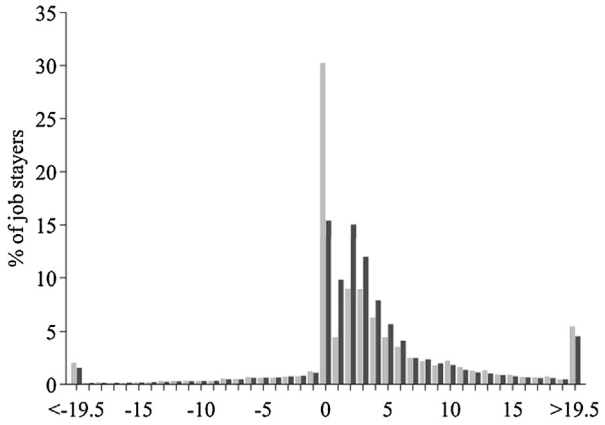

Fig. 4. Frequency distribution of year-to-year changes in log basic wages of salaried and hourly-paid job stayers by firm size. *Notes*: See Fig. 2. Pooled data for 2006-18. **Light grey bars**: small firms ($<$ 50 employees). **Dark grey bars**: medium and large firms ($\geq$ 50 employees). The size of a job stayer's firm is defined in the first of two consecutive years. See Appendix Fig. E2 for a breakdown of the distribution for firms $\geq$ 50 employees into medium (50-249) and large (250+).

fewer wage cuts in smaller firms, as Fig. 4 shows. These results support the US-based findings of Kurmann and McEntarfer (2019), who documented similar features for the distribution of changes in total earnings per hour (basic wages plus extra pay) by firm size. The US payroll dataset studied by Grigsby et al. (2021b) substantially under-represents very large firms with more than 5,000 employees, which can account for a sizable portion of employment - the median firm size in our British payroll data for job stayers is over 2,500 employees (see Table 1). Grigsby et al. acknowledged this as a limitation in their study.

After controlling for other observable differences between job stayers and the state of the aggregate business cycle, wage freezes are significantly more likely in shrinking than expanding firms, approximately by 4-5 percentage points (rows 19-21, Tables G1 & G2). These results support the same inverse relationship between the frequency of total earnings per hour freezes and firm growth found by Kurmann and McEntarfer (2019) in the US. However, our data do not allow us to assess empirically how many workers in shrinking firms lost their jobs because of the nominal rigidity in basic wages, since we cannot exclude that negative idiosyncratic shocks to firm-level productivity caused both more layoffs and more freezes when comparing shrinking and expanding firms.[19]

Lastly, we focus on hourly-paid workers, for whom employers directly report basic wage rates in the ASHE. We find that year-to-year freezes are significantly more common among hourly-paid job stayers who had basic wages in the previous year that were multiples of ten pence (rows 22-23, Table G1).[20] There are two possible explanations. First, employers are incorrectly reporting rounded basic wages. Second, round basic wages are accurately reported and just happen to be more rigid, for example, if round basic wages are somehow preferred. This idea can be found in the price-point literature, where a set of pre-specified prices, or wages in our case, can simplify the decision problem of boundedly rational workers and employers. For example, Hahn and Marenčák (2020) have shown that incorporating output-price points can improve how New Keynesian models match key business cycle statistics, such as the dynamics of the inflation rate. The extent to which 'wage-points' can improve the performance of monetary models might be a promising area for future research.

6. Macroeconomic consequences of downward nominal wage rigidity

What are the macroeconomic implications of our main findings? In the New Keynesian model, the workhorse model of monetary policy analysis, wage rigidity is the crucial nominal friction required to match the persistence of inflation and output, and for monetary policy to have real effects (Christiano et al., 2005). This class of models normally assumes that nominal wages can be adjusted every quarter with a constant probability, so-called 'Calvo wage setting' (Calvo, 1983). Our findings that basic wage freezes affect on average 17 percent of salaried job stayers and 21 percent of hourly-paid job stayers imply average quarterly wage-change probabilities of 0.36 and 0.32, respectively.[21] These values support the degree

[19] We also find that the results are not notably different when we focus on firms with more substantial employment changes of at least 10% or 1000 employees. Further, see Appendix Fig. E3 for the distribution of year-to-year log basic wage changes, dependent on whether a firm's total number of employees was shrinking or expanding between the same years. A relatively large zero spike for shrinking firms is clearly visible, and positive wage growth is more likely in expanding firms. Note, job stayers in 2007-08 and 2017-18 are excluded from this analysis because it appears as though the ONS imputed the number of employees in firms using the previous years' values.

[20] Kahn (1997), using data on household heads from the Panel Study of Income Dynamics in 1970-1988, documented that hourly pay rates ending in exact dollar or half-dollar amounts made up 50 percent of the job stayers with hourly rate freezes.

[21] The values are converted as follows: $p_q = 1 - (1 - p_y)^{1/4}$, with p_q denoting the quarterly wage-change probability, and p_y the yearly wage-change probability.

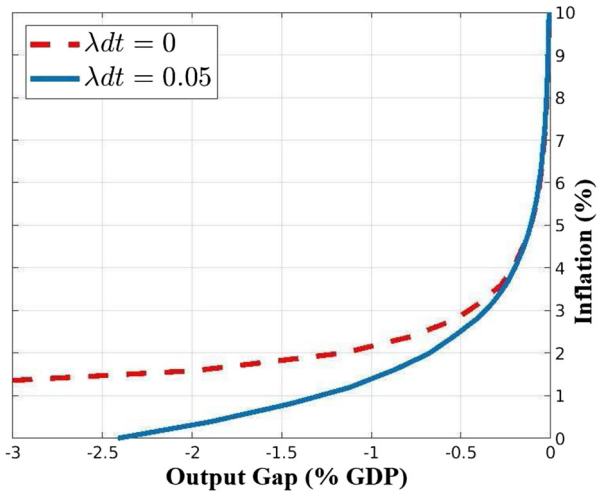

Fig. 5. Long-run Phillips curve for different degrees of DNWR. *Notes*: Equivalent to Benigno and Ricci (2011): Fig. 6, p. 1459. Simulation uses the same parameter values as BR, except calibrated $\lambda dt = 0.05$. The dashed line shows the long-run output gap (in percent of GDP) when nominal wages can never be cut. The solid line shows the gap when nominal wages become downward flexible once every five years, on average.

of nominal wage rigidity that is required as an assumption in New Keynesian models to fit the observed persistence of output, inflation, and unemployment in the US (Christiano et al., 2005) and the UK (Faccini et al., 2013).

Our estimates for the extent of DNWR in Great Britain have potentially sizeable output consequences. We demonstrate this using the theoretical framework of the Phillips curve from the dynamic stochastic general equilibrium model of Benigno and Ricci (2011) (hereafter BR).[22] In their model, the long-run inflation-output trade off caused by DNWR is the result of nominal rigidities that distort wage adjustments. Aggregate and idiosyncratic shocks lead to intratemporal and intertemporal shifts of real wages and employment across sectors. If a negative demand shock hits a firm, then it would like to reduce its real wages. When inflation is low, firms are more likely to need to decrease the nominal wage to bring about the desired real wage cut. With binding DNWR, nominal wages cannot be cut and, as a consequence, firms will instead reduce their employment and output. By allowing real wages to fall sufficiently, moderate inflation in the model can grease the wheels of the labour market. We provide more details of this framework and further results in Appendix H.

We first calibrate the model to match the shares of basic wage freezes and cuts that we observe in British payroll data (Section 4), and then we simulate the long-run Phillips curve. The solid line in Fig. 5 shows the long-run relationship between the annual rate of inflation (vertical axis) and the equilibrium output gap (in percent), implied by our calibration.[23] For comparison, we also add a long-run Phillips curve for the extreme scenario in which nominal wages can never be cut (dashed line). The long-run output loss is around 0.2 percent of GDP, relative to an economy with flexible wages, when the annual rate of inflation is 4 percent. When the annual rate of inflation decreases to 2 (1) percent, the output gap becomes more substantial: for our calibrated parameter values, the solid line shows that the equilibrium output loss amounts to around 0.7 (1.3) percent of GDP. When the annual inflation rate is low, the constraint on downward nominal wage changes is more likely to bind and be more costly in terms of higher unemployment. The substantial economic costs point to an optimal rate of inflation that may be significantly positive rather than zero or negative (the Friedman rule).

7. Conclusion

Recent periods of stubbornly low inflation in many developed countries have pushed the topic of DNWR back to the centre stage of macroeconomics. In this paper, we use unique longitudinal employer-employee data from Great Britain, the Annual Survey of Hours and Earnings (ASHE), to analyse the extent of DNWR. These payroll-based data allow us to accurately distinguish between basic wages and extra pay components, such as overtime and incentive pay. Since a wealth of recent findings from administrative data has led researchers to question whether DNWR is actually a pervasive and consequential feature of labour markets, the need for additional evidence on this subject is great.

We provide several new findings. First, basic wages, which we argue are the relevant wage measure from a macroeconomic perspective, are downward rigid. Among employees who are constantly employed in the same job from year-to-year, every fifth job stayer, on average, receives a constant basic wage and this figure increased to around 28 percent during the Great Recession. Basic wage cuts occur far less frequently than previously thought, with 11 percent of salaried job

[22] We use and adapt the model's replication code available on the website of the *American Economic Review*. Daly and Hobijn (2014) develop a similar framework of the Phillips curve, assuming a different wage setting process than Benigno and Ricci (2011), however, this does not affect the model's long-run outcomes.

[23] We impose the constraint that the long-run equilibrium employment level cannot exceed the population size.

stayers and only 4 percent of hourly-paid job stayers receiving them on average each year. We show that the distribution of wage changes is markedly asymmetric, and provide strong evidence for the compression of wage growth in continuing employment relationships, suggesting that firms are constrained by binding DNWR.

Our findings support the anecdotal evidence presented by Bewley (1999), who gathered information on nominal pay setting by interviewing US employers. Bewley found that employers were reluctant to cut nominal wages because they feared it would damage worker morale, and in this way it would negatively impact productivity, labour turnover, and the recruitment of new employees. However, Bewley also found that most managers believed that cutting incumbent workers' wages would not prevent layoffs; labour is only a small share of variable costs and the short-run price-elasticity of product demand is low, such that pay cuts would create little extra work.[24] Although it is not clear how this anecdotal evidence generalises to the aggregate economy, it highlights the need to explore channels other than layoffs through which DNWR can have real effects.

Our second contribution demonstrates substantial heterogeneity in the apparent extent of DNWR, conditional on observable firm and worker-characteristics. Most notably, we find a strong negative correlation between firm size and the share of employees that experience basic wage freezes. Job stayers in firms with less than 50 employees are around twice as likely to receive the same wage year-to-year as job stayers in very large firms with more than 5,000 employees.

Our findings have important implications for macroeconomic models and monetary policy. We find empirical support in representative payroll microdata for the degree of nominal rigidity typically required in New Keynesian models to match the persistence of output and inflation (Christiano et al., 2005). Additionally, our results justify the assumption of downward nominal rigidity invoked in recent macroeconomic models of business cycle fluctuations (e.g., Benigno and Ricci, 2011; Daly and Hobijn, 2014; Dupraz et al., 2019). Researchers who are investigating macroeconomic variables in a low-inflation environment should consider incorporating DNWR into their models. Our result that basic wage freezes are far more common when wage rates are in multiples of ten pence suggests a potentially fruitful area for future research. Akin to the literature on price-points, where a set of pre-specified prices can simplify the decision problem of boundedly rational agents and improve the match of New Keynesian models to key business cycle statistics (Hahn and Marenčák, 2020), wage-points could improve the performance of monetary models further. Related, there are other patterns in these data which merit further thought and study, such as the fact that basic wage freezes are far more common in smaller firms.

Data availability

The data that has been used is confidential.

Appendix. Supplementary material

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.red.2022.11.006.

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[24] Employers that responded to financial distress during a recession with pay cuts reported to Bewley only minor problems with worker morale and productivity. However, it is possible that those employers that faced the least adverse consequences were exactly the ones enacting pay cuts.

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