Reservation Wages and the Wage Flexibility Puzzle*

Felix Koenig, Alan Manning and Barbara Petrongolo

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Abstract

Using micro data for the UK and Germany, we provide novel evidence on the cyclical properties of reservation wages and estimate that wages and reservation wages are characterised by moderate and very similar degrees of cyclicality. Several job search models that quantitatively match the cyclicality of wages tend to overpredict the cyclicality in reservation wages. We show that this puzzle can be addressed when reservation wages display backward-looking reference dependence. Model calibrations that allow for reference dependence match the empirically observed cyclicality of wages and reservation wages for plausible value of all other model parameters.

Keywords: job search; reservation wages; wage cyclicality; reference dependence.

JEL classification: E24; J63; J64.

*Koenig: Carnegie Mellon University and CEP (LSE), fkoenig@andrew.cmu.edu; Manning: London School of Economics and CEP (LSE), a.manning@lse.ac.uk; Petrongolo: University of Oxford and CEP (LSE), barbara.petrongolo@economics.ox.ac.uk. We would like to thank Claudio Michelacci, Rob Shimer, Thijs van Rens and seminar participants at the NBER Summer Institute, the CEPR Annual Symposium in Labour Economics, the CEPR-Bank of Italy Conference on Labour Markets, LSE, Sciences Po, ETH Zurich, EUI, UPF, University of Amsterdam-Tinbergen, University of Essex, University of Warwick, for useful comments on this paper; and the ESRC for funding this research through the Centre for Economic Performance at the LSE.

1 Introduction

Reservation wages play a central role in models of job search, channeling the impact of job finding prospects and welfare policies on unemployment duration and re-employment wages. This paper provides novel evidence on their cyclical behaviour and studies its implications for our understanding of wage and unemployment volatility. Based on micro data for the UK and Germany spanning over two decades, we estimate that wages and reservation wages are characterised by moderate and very similar degrees of cyclicality. We obtain an estimate for the elasticity of wages with respect to unemployment of -0.17 for the UK, and a much lower (in absolute value) and imprecise estimate for Germany. For reservation wages, we obtain an elasticity of about -0.15 for the UK, and again a smaller and only bordeline significant elasticity for Germany.

These results have implications for the quantitative predictions of search and matching models. Since Shimer (2005) and Hall (2005) pointed out that the canonical search model struggled to replicate the weak cyclicality of wages (the wage flexibility puzzle), a number of papers have proposed modifications that introduce some wage rigidity. These include high replacement ratios (Hagedorn and Manovskii, 2008), weakly cyclical hiring costs (Pissarides, 2009), and infrequent or backward-looking wage negotiations (Pissarides, 2009; Rudanko, 2009; Haefke et al., 2013; Kudlyak, 2014; Gertler et al., 2008; Gertler and Trigari, 2009). While these models offer solutions to the wage flexibility puzzle, we show that they predict reservation wages to be more strongly cyclical than wages. The intuition is that reservation wages embody the procyclical behaviour of both expected wage offers and job finding rates: even if wages were acyclical, reservation wages would be pro-cyclical because they positively respond to job-finding rates, which are strongly cyclical. However, our evidence shows that wages and reservation wages display similarly low elasticities with respect to unemployment. Hence, while elements of wage rigidity can address the wage flexibility puzzle, a "reservation wage flexibility puzzle" arises.

We propose that the reservation wage flexibility puzzle can be addressed if reservation wages are shaped by reference-dependent preferences with backward-looking anchoring. Reference-dependence has often featured in labour supply modelling (see Blanchard and Katz 1999, Farber 2008, Della Vigna 2009 and, closely related to our setting, Falk et al. 2006 , Della Vigna et al. 2017, 2022 and Eliaz and Spiegler 2014). In several contexts reference dependence is shaped by past experiences, implying less cyclical reservation wages than a fully forward-looking model whenever reference points are less cyclical than labour market conditions. The underlying mechanism is that reference dependence anchors reservation wages to backward-looking variables such as past earnings, which are typically less cyclical than current and future labour market conditions. Low reservation wage cyclicality then translates into low wage cyclicality, as wages track reservation wages up to a roughly acyclical mark-up. In addition, reference-dependence during job search is also consistent with limited impacts of potential benefit duration on reservation wages (Schmieder et al., 2016; Le Barbanchon et al., 2019; Jäger et al., 2020).

We embed reference dependence in a framework that nests most existing models of wage rigidity and show that the enriched model can quantitatively match the observed cyclicality in both wages and reservation wages for plausible values of parameters. Because reference dependence helps explain moderate cyclicality in actual wages and not simply reservation wages, additional sources of wage rigidity become less relevant to match empirical cyclicality estimates once reference dependence is included. In principle, reference dependence is sufficient to account for the observed sluggish movement of wages and reservation wages.

The rest of the paper is organised as follows. Section 2 shows estimates of wage and reservation wage elasticities to unemployment for the UK and Germany. Section 3 lays out a job search model with reference-dependent reservation wages. Section 4 derives cyclicality predictions in the special case without reference dependence. Section 5 shows cyclicality results under reference dependence. Section 6 concludes.

2 Empirical wage and reservation wage curves

We estimate wage and reservation wage cyclicality, to which model predictions of later sections will be benchmarked, using micro data for the UK and West Germany (referred to as Germany for simplicity), from the BHPS and the SOEP, respectively. Both are longitudinal studies, providing information on wages and reservation wages for the period 1991-2009 for the UK and 1984-2010 for Germany.

2.1 Estimates of the wage curve

Wage cyclicality is estimated as an elasticity with respect to the unemployment rate, in the wage-curve approach of Blanchflower and Oswald (1994). The dependent variable is the log pre-tax wage of an individual. All specifications control for individual characteristics (gender, age, education, job tenure, household composition) and individual and region fixed-effects. Our baseline specifications use national unemployment as a business cycle indicator and include a quadratic trend to capture the effects of productivity growth (the Appendix reports estimates based on regional unemployment for completeness). Descriptive statistics are reported in Table A1.[1]

[1]While it is convenient to report wage elasticities that are directly comparable to their reservation wage counterparts, a plethora of wage-curve estimates is also available from previous work, see Blanchflower and Oswald (1994, 2005) and Card (1995) for international evidence; Bell et al. (2002), Faggio and Nickell

Estimates are presented in Table 1.[2] In column 1 the unemployment elasticity of wages for the UK is -0.169 and highly significant. This is the benchmark estimate that we will compare to the predicted cyclicality of wages in our job search model. Columns 2 and 3 distinguish between new and continuing jobs, including an interaction term between the unemployment rate and an indicator for having started the current job within the past year. Estimates in column 2 imply that wages in new jobs are about 50% more cyclical than on continuing jobs, in line with infrequent wage negotiations. However, even wages on continuing jobs significantly respond to the state of the business cycle, consistent with some degree of on-the-job renegotiation. When job fixed-effects are included in column 3, the cyclicality differential is much smaller and more imprecise. Possibly, we have limited power to identify an elasticity within job spells, which are on average only observed over 2.6 waves. The alternative explanation is that the (permanent) quality of newly-created jobs is procyclical, and once this is captured by job fixed-effects the excess cyclicality in new jobs is much reduced (see Gertler and Trigari 2009 for a similar result for the US; see also Bellou and Kaymak 2021 and Figueiredo 2022 for evidence and discussions on the role of job quality in estimates of wage cyclicality). The specification of column 4 delivers a slightly smaller elasticity with respect to lagged unemployment than the benchmark specification of column 1. In all specifications the wage elasticity to unemployment is negative and significant, and the point estimates do not fall below -0.169.

For Germany (columns 5-8), the estimated wage cyclicality is markedly lower than in UK, in line with earlier evidence, and is only significant for new matches (column 6) or when lagged unemployment is used (column 8). Similarly as in the UK, the estimated cyclicality is higher for new hires than for continuing jobs, but such difference becomes

(2005), Devereux and Hart (2006) and Gregg et al. (2014) for the UK; Wagner (1994), Baltagi et al. (2009) and Ammermüller et al. (2010) for Germany.

[2]Full estimation results corresponding to specification 2 of Table 1 are reported in A2.

statistically insignificant when controlling for job fixed-effects (column 7). Specifications that control for regional rather than aggregate unemployment are shown in Panel A of Table A3. For both countries, and across various specifications, the estimated wage cyclicality is lower than when using aggregate unemployment as a business cycle indicator.

2.2 Estimates of the reservation wage curve

To the best of our knowledge there are no previous estimates on the cyclicality of reservation wages. No US data sets cover a long enough period (see for example rich survey data built and used by Krueger and Müller 2016; Hall and Müller 2018; Mui and Schoefer 2020). In some research (Nekoei and Weber 2017; Jäger et al. 2020) the behaviour of reservation wages is often inferred from the relationship between changes in benefit entitlement, unemployment duration, and re-employment wages.

The BHPS asks unemployed respondents about the lowest weekly take-home pay that they consider accepting for a job, and the hours they expect to work for this amount. From this information we build a measure of the hourly net reservation wage. In the SOEP, information on reservation wages is elicited in monthly terms since 1987 and is not supplemented by information on expected hours; thus specifications for Germany use monthly reservation wages as the dependent variable, and control for whether an individual is looking for a full-time or part-time job.

While there may be concerns about the quality of reservation wage data, Appendix B shows that their correlation with job search outcomes has the sign predicted by search theory: ceteris paribus, higher reservation wages lead to longer job search spells and higher re-employment wages. Though likely noisy, reservation wage data thus embody meaningful information about job search.

Our reservation wage equations control for the same variables as the wage curves to capture the role of the wage offer distribution, plus welfare benefits as a proxy for utility while out of work. The estimates are reported in Table 2. Column 1 for the UK shows an elasticity of reservation wages to unemployment of -0.146. Columns 2, controlling for lagged unemployment instead, delivers an elasticity of -0.112. Columns 3 and 4 estimate similar specifications for Germany. The estimated elasticity with respect to current unemployment is positive but very imprecise, while the elasticity to lagged unemployment is negative, significant, and somewhat smaller than the corresponding value for the UK. As for wage cyclicality, estimates based on regional unemployment tend to deliver lower reservation wage cyclicality, as shown in Panel B of Table A3 for both countries.

The main take-away point is that wages and reservation wages display limited and very similar degrees of cyclicality. In the UK, the estimated elasticity is -0.169 for wages and -0.146 for reservation wages. These estimates are not statistically difference from each other (with a p-value of 0.55). In Germany, both elasticities are close to zero when using current unemployment, and fall to -0.065 and -0.082, respectively, when using lagged unemployment. Whether using current or lagged unemployment, the wage and reservation wage elasticities are not significantly different from each other.

3 The model

We lay out a job search model to derive implications for the cyclicality of wages and reservation wages, to be compared to estimates from the previous section. Our set-up encompasses elements of wage rigidity proposed by earlier work on unemployment fluctuations, namely acyclical hiring costs (Pissarides, 2009), infrequent wage negotiations in ongoing matches, and backward-looking elements in wage setting for new hires (Gertler et al., 2008; Gertler and Trigari, 2009; Rudanko, 2009; Haefke et al., 2013; Kudlyak, 2014). We additionally allow for backward-looking reference dependence in the determination of reservation wages.

For simplicity, we assume homogeneous workers and jobs, implying homogeneous wages and reservation wages in steady-state. Outside steady-state, there is heterogeneity across wages set at different times, due to infrequent negotiations, and heterogeneity across wages set at the same time, due to heterogeneous reservation wages, shaped by reference-dependence.

3.1 Workers

To introduce reference-dependent preferences, we let the utility flow of working in a job paying w depend on one's previous wage w^l:

$$u(w|w^l) = w + \alpha_\rho \left[w - (\alpha_l w^l + (1-\alpha_l)w^*)\right], \tag{1}$$

where $\alpha_\rho \geq 0$ measures the importance of reference dependence (with $\alpha_\rho = 0$ corresponding to the canonical model) and the reference point is assumed to be the average of the lagged wage w^l (with weight α_l) and the time-invariant, steady-state wage w^* (with weight $1-\alpha_l$). Conditional on the current wage w, the worker experiences an utility gain (loss) whenever w is above (below) the reference wage.

This modelling of backward-looking reference dependence is standard in the literature (Kahneman and Tversky, 1979; Loomes and Sugden, 1986; Koszegi and Rabin, 2006). The role of reference points in labour supply has been emphasized by Farber (2008) and Della Vigna (2009), among others. Closely related to our approach, the experiment of Falk et al. (2006) shows that minimum wages have lasting effects on subjects' reservation wages, even after their removal; and Della Vigna et al. (2017, 2022) and Marinescu and Skandalis (2020) show evidence on the role of past earnings as reference points during job search.

Within a job match, wages are occasionally renegotiated and renegotiation opportunities are assumed to arrive at an exogenous rate ϕ,[3] leading to a staggered wage setting process à la Calvo (1983). Upon renegotiation, neither party has the option to continue the match at the current wage, which thus plays no role in wage bargaining. The renegotiated wage, denoted by $w^r(w^l, t)$, depends on the past wage as well as on other factors absorbed in time dependence.

Given these assumptions and the utility function (1), the value of employment is given by:

$$\begin{aligned} rW(w; w^l, t) =& \, u(w|w^l) + \phi[W(w^r(w^l, t); w^l, t) - W(w; w^l, t)] \\ & - s\big[W(w; w^l, t) - U(w^l, t)\big] + E_t \frac{\partial W(w; w^l, t)}{\partial t}, \end{aligned} \tag{2}$$

where $U(w^l, t)$ is the value of unemployment at time t when one's previous wage is w^l, and s denotes the (exogenous) separation rate. The second term in (2) captures changes in the value of employment related to prospects of wage renegotiation, which embody the assumption that the lagged wage is not re-set upon renegotiation and stays equal to the wage in the previous job. The third term captures changes related to job loss. The presence of backward-looking reference dependence makes the previous wage a state variable in the value of employment, as it shapes the reservation wage and future negotiations.

[3] Renegotiation opportunities are not triggered by a threatened separation caused by a demand shock. This amounts to assuming that demand shocks never cause the surplus in continuing matches to become negative. Allowing for this possibility would introduce an extra source of cyclicality as it implies more frequent renegotiations in recessions.

The value of being unemployed at time t is given by:

$$rU(w^l,t) = z + \lambda(t)E_t[W(w;w^l,t) - U(w^l,t)] + E_t\frac{\partial U(w^l,t)}{\partial t}, \tag{3}$$

where z is the flow utility when unemployed and $\lambda(t)$ is the rate at which the unemployed find jobs, which varies over time with labour market tightness. The term $E_t[W(w;w^l,t)]$ captures uncertainty about wages in future matches. When a firm and a worker match, they negotiate a wage with probability α, while with probability $1-\alpha$ a pre-existing ("old") wage is paid, randomly drawn from the existing cross-section. The extent of job creation at old wages (represented by $1-\alpha$) is a backward-looking element in wage setting. Values of α and ϕ determine the relative cyclicality of wages in new versus continuing matches. In Section 2.1 we found suggestive evidence that wages in new matches are more procyclical than in continuing matches. This is predicted whenever the opportunity to renegotiate the wage in an ongoing job happens infrequently (low ϕ), relative to the chance to negotiate a new wage upon hiring (high α).

The reservation wage $\rho(w^l,t)$ is defined as the wage that makes the worker indifferent between working at that wage and unemployment:

$$W(\rho(w^l,t);w^l,t) = U(w^l,t). \tag{4}$$

The following Proposition, proved in Appendix C.1, provides an expression for reservation wages conditional on the time path of wages and the job-finding rate:

Proposition 1. *The reservation wage satisfies the following differential equation*

$$\begin{aligned}[r+\lambda(t)+s]\rho(w^l,t) = {} & (r+\phi+s)z + \lambda(t)[\alpha w^r(w^l,t) + (1-\alpha)w^a(t)] \\ & + (r+\phi+s)\frac{\alpha_\rho}{1+\alpha_\rho}[\alpha_l w^l + (1-\alpha_l)w^*] - \phi w^r(w^l,t) + E_t\frac{\partial \rho(w^l,t)}{\partial t}, \end{aligned} \tag{5}$$

where $w^a(t)$ denotes the average wage in the economy.

The first two terms on the right-hand size of equation (5) are standard, representing unemployment income and the expected return to job search, respectively, where $\alpha w^r(w^l, t) + (1-\alpha)w^a(t)$ denotes the expected wage at which new matches are formed. The third term captures the role of reference dependence, where $\alpha_l w^l + (1-\alpha_l)w^*$ denotes the reference wage, and the fourth term captures the impact of wage renegotiations, whose frequency ϕ makes employment relatively more attractive than unemployment.

Result (5) illustrates our central idea. When there is no reference-dependence ($\alpha_l = \alpha_\rho = 0$), the cyclicality of reservation wages depends on the cyclicality of wages and the job-finding rate $\lambda(t)$. Even if wages were completely acyclical, reservation wages would still be procyclical because they embody the cyclicality of $\lambda(t)$; hence the canonical model predicts greater cyclicality in reservation wages than actual wages. This result holds independently of the underlying model of wage setting, which is not yet outlined. Introducing reference-dependence makes reservation wages depend on lagged wages both via a direct effect on utility and because negotiated wages depend on lagged wages. The role of lagged wages makes the reservation wage less sensitive to current market conditions.

As (5) is conditional on the time path of wages and the job-finding rate, we next model employers' decisions and wage determination.

3.2 Employers

Each firm has one job. $J(w; w^l, t)$ denotes the value at time t of a filled job paying w to a worker whose wage in the previous job was w^l. This is given by

$$\begin{aligned} rJ(w; w^l, t) = &p(t) - w - s\big[J(w; w^l, t) - V(t)\big] \\ &+ \phi\big[J(w^r(w^l, t); w^l, t) - J(w; w^l, t)\big] + E_t \frac{\partial J(w; w^l, t)}{\partial t}, \end{aligned} \tag{6}$$

where $V(t)$ is the value of a vacant job at time t and $p(t)$ denotes the productivity of a match. The first term on the second line represents the change in job value resulting from renegotiation.[4] Conditional on the current wage, the lagged wage only affects the firm's value function through its role in future renegotiations.

The value of a vacant job at time t is

$$rV(t) = -c(t) + q(t)E_t[J(w; w^l, t) - V(t) - C(t)] + E_t \frac{\partial V(t)}{\partial t}. \tag{7}$$

Following Pissarides (2009) and Silva and Toledo (2009), hiring involves a flow cost, $c(t)$ and a fixed cost, $C(t)$; $q(t)$ is the rate at which vacancies are filled, varying over time via the impact of shocks on labour market tightness, and we can be agnostic about their nature. Free entry of vacancies implies $V(t) = 0$.

3.3 Wage determination

Under Nash bargaining, the wage negotiated at time $t, w^r(w^l, t)$, is such that:

$$w^r(w^l, t) = argmax_w [W(w; w^l, t) - W(\rho(w^l, t); w^l, t)]^{\beta} [J(w; w^l, t) - V(t)]^{1-\beta}, \tag{8}$$

where β denotes workers' relative bargaining power. Solving (8), Appendix C.2 proves the following result:

Proposition 2. *Newly-negotiated wages are given by:*

$$\begin{aligned} w^r(w^l, t) = (1-\beta)\rho(w^l, t) + \beta \Big\{ & (r+s+\phi)\mu(t) + [\alpha w^{ru}(t) + (1-\alpha) w^a(t)] \\ & + \chi(t)(r+s+\phi)[w^{lu}(t) - w^l] \Big\}, \end{aligned} \tag{9}$$

where $\mu(t) \equiv C(t) + c(t)/q(t)$, $w^{ru}(t)$ is the average newly-negotiated wage for workers

[4] Similarly as (2), equation 6 assumes that, individuals keep using the wage in the previous job as part of their reference point in negotiations in the current job.

recruited from unemployment, $w^{lu}(t)$ is the average lagged wage for the unemployed and $\chi(t) \equiv \frac{\partial J(w;w^l,t)}{\partial w^l}$.

The structure of (9) is intuitive. Negotiated wages are a weighted average of two terms, with weights given by the firm's and worker's bargaining power, respectively. The first term is the reservation wage. The second term has three components, which collectively capture the cost of replacing the current worker with a new recruit. The first component, $(r+\phi+s)\mu(t)$, is related to hiring costs, which the firm saves by hiring the current worker instead of searching for a new one. The second component, $\alpha w^{ru}(t) + (1-\alpha)w^a(t)$, is the expected wage the firm would pay if hiring another worker. The third component, $\chi(t)(r+s+\phi)[w^{lu}(t) - w^l]$, is related to the difference in the lagged wage between the average and the current unemployed worker, capturing differences in the respective costs of future renegotiations. This component is multiplied by the renegotiation rate ϕ and by the sensitivity of the value of a job to lagged wages, $\chi(t)$. Appendix C.3 shows that $\chi(t)$ only varies with time, and can be treated as exogenous from the perspective of individual wage negotiation.

Despite the relatively unrestricted nature of the model assumptions, (9) gives a fairly simple expression for the wage curve. The wage is expressed in terms of currently-dated variables, with the past and the future entering negotiations only to the extent that they affect the reservation wage and average wages. Moreover, as the negotiated wage for an individual worker is a function of a set of average wages (a property that follows from the linearity of value functions), we do not need to keep track of higher moments of the wage distribution.

Equation (9) implies that wage cyclicality reflects cyclicality in reservation wages and hiring costs $\mu(t) \equiv C(t) + c(t)/q(t)$. In what follows we impose constant μ. This assumption reduces wage cyclicality and is in line with findings that the fixed cost component C is more important than the flow cost, c. The dependence of wages on the reservation wage in (9) is a key property of this model, as it implies that any element that makes reservation wages less cyclical also makes wages less cyclical.

4 The Cyclicality of Wages and Reservation Wages

To measure cyclicality, we derive closed-form expressions for the linear projection of relevant (log) wage variables on (log) unemployment. Our analytical results for the elasticities of interest transparently highlight the role of various model elements in driving wage cyclicality. In addition, this approach is agnostic about the source of shocks in the model, as the derived relationships between wages and unemployment hold independently of whether shocks to labour demand stem from productivity shocks, macroeconomic policy, or other sources. This approach differs from the standard approach in this literature, which typically simulates the impact of productivity shocks in calibrated models. In Appendix D.7 we show that our closed-form solutions produce results that closely resemble those produced by simulated models with productivity shocks.

4.1 Building Blocks

For any variable x, we define the parameter θ_x as the linear projection of $x(t)$ on $u(t)$:

$$E_t\left[(x(t) - x^*) \mid (u(t) - u^*)\right] = \theta_x(u(t) - u^*), \tag{10}$$

where x^* and u^* indicate steady-state values. Given θ_x, the elasticity of $x(t)$ with respect to $u(t)$ can be evaluated in steady state as $\varepsilon_x = u^*\theta_x/x^*$. This corresponds to the coefficient on $\log u(t)$ in a linear projection of $\log x(t)$ on $\log u(t)$.

We also define the speed of convergence of $x(t)$ to steady state, ξ_x, such that:

$$E_t\left[\frac{dx(t)}{dt} \mid (u(t)-u^*)\right] = -\xi_x E_t\left[(x(t)-x^*) \mid (u(t)-u^*)\right] = -\xi_x \theta_x (u(t)-u^*). \quad (11)$$

ξ_x is inversely related to the degree of persistence in $x(t)$; it is positive for backward-looking variables and negative for forward-looking ones.

4.2 Model dynamics without reference-dependence

We first describe dynamics in a fully forward-looking economy ($\alpha_\rho = 0$), providing a natural benchmark for the case with reference dependence. This additionally establishes that our model formulation is consistent with previous results on wage cyclicality. In this economy, lagged wages are irrelevant. Newly-negotiated wages and average wages may differ due to backward-looking wage determination ($\alpha < 1$) and occasional renegotiation ($\phi < \infty$).

Introducing $\eta = z/w^*$ as the steady-state replacement ratio and $\tilde{\beta} = \beta/(1-\beta)$ as workers' relative bargaining power, Appendix C.5 proves the following proposition:

Proposition 3. *With no reference dependence and a constant μ*

(a) the elasticity of newly-negotiated wages with respect to unemployment is given by:

$$\varepsilon_{w^r} = -(1-\eta)\frac{s-u^*\xi_u}{ru^*+s}\,\frac{r+\phi+s}{(r+\phi+s+\xi_\rho)(1+\widetilde{\beta}\Gamma)+\Gamma\left[\lambda^*(1+\widetilde{\beta})-\widetilde{\beta}\phi\right]}, \quad (12)$$

where:

$$\Gamma = \frac{(1-\alpha)\xi_w}{\alpha s+\phi+\xi_w}; \quad (13)$$

(b) the elasticity of average wages is given by:

$$\varepsilon_w = \frac{\alpha s+\phi}{\alpha s+\phi+\xi_w}\varepsilon_{w^r}; \quad (14)$$

(c) the elasticity of reservation wages is given by:

$$\varepsilon_\rho = (1 + \widetilde{\beta}\Gamma)\frac{w^*}{\rho^*}\varepsilon_{w^r}. \tag{15}$$

Equations (12), (14) and (15) provide closed-form elasticities for the wage concepts of interest. These encompass existing results in related work. Consider the special case with continuous wage negotiation, $\phi = \infty$. If so, (12) and (14) imply:

$$\varepsilon_w = \varepsilon_{w^r} = -(1-\eta)\frac{s - u^*\xi_u}{ru^* + s}. \tag{16}$$

As the job destruction rate s is much larger than the product of the unemployment rate and the rate of time preference, ru^*, and unemployment is highly persistent, i.e. ξ_u is positive but very low, the $(s - u^*\xi_u)/(ru^* + s)$ ratio is close to 1.[5] Equation (16) then implies that the elasticity of wages should be almost exactly equal to one minus the replacement ratio, so that a high replacement ratio is required to deliver weakly cyclical wages, consistent with the results in Hagedorn and Manovskii (2008), who propose a model calibration with $\eta = 0.95$.

The replacement ratio need not be as high if wage negotiation only happens occasionally and has backward-looking components. In the limiting case in which all new jobs are filled at existing wages ($\alpha = 0$) and these are never re-negotiated ($\phi = 0$), equation (14) implies that average wages are acyclical. By continuity, there must exist small enough values of α and ϕ that deliver a sufficiently low wage elasticity, providing a solution to the wage flexibility puzzle.

However, this solution would not address the reservation wage flexibility puzzle, as reservation wages are still predicted to be more cyclicality than both average wages and

[5] For the UK's parameter values from Table 3, $(s - u^*\xi_u)/(ru^* + s) = 0.96$, and corresponding values for Germany give an almost identical result.

newly-negotiated wages. This can be seen most directly from (15). Both terms $(1+\widetilde{\beta}\Gamma)$ and w^*/ρ^*, multiplying the elasticity of newly-negotiated wages, are larger than one. This implies that, for all parameter values, reservation wages are predicted to be more cyclical than newly-negotiated wages, in contrast to the evidence presented in Section 2.[6] Hence there is no combination of parameters that can match both the wage and reservation wage elasticities. The next section shows how reference dependence in reservation wages can solve this puzzle.

The results above are obtained analytically, without imposing a specific source and nature of shocks. In Appendix D.7 we consider instead numerical simulations of the canonical model, which are obtained by assuming an underlying stochastic process for labour productivity with standard characteristics. Panel A in Figure D1 plots analytical elasticities against simulated elasticities for alternative combinations of model parameters. The two methods produce near identical results, with a coefficient of correlation of 0.999. Our closed-form expression can therefore closely replicate results from simulated models based on productivity shocks.

5 Reference dependence in reservation wages

In a model with backward-looking reference dependence ($\alpha_\rho, \alpha_l > 0$), past wages matter for wage negotiation – both for the unemployed, upon hiring, and for the employed, whenever renegotiation opportunities arise. We therefore need to keep track of past

[6] While we can compare ε_w and ε_ρ to the estimates of Section 2, we have no empirical counterpart for ε_{w^r}, as the data contain no information on which wage observations are newly-negotiated. We can observe, however, wages in new matches. As the model implies that these are a weighted average of average wages and newly-negotiated wages with weights α and $1-\alpha$, respectively, Proposition 3 implies that their predicted elasticity is $\varepsilon_{w_n} = \frac{\alpha s+\phi+\alpha\xi_w}{\alpha s+\phi}\varepsilon_w$, i.e. wages in new matches are more cyclical than average wages, with the difference in their respective cyclicality rising with α and falling with ϕ. Estimates of Table 1 show that wages in new matches are more cyclical than average wages, but this difference is small and only borderline significant when jobs FE are included (columns 3 and 7). This finding is consistent with frequent renegotiations (high ϕ) and/or a large backward-looking component in wage negotiations (low α).

wages and distinguish between past employment and unemployment status. Appendix C.6 follows similar steps to those outlined above and derives analytical expressions for the elasticities of interest in terms of model parameters. These analytical results are less insightful than those summarized in Proposition 3 for the fully forward-looking case, because the model has ten endogenous variables[7] (and as many persistence parameters), leading to a system of ten equations in ten unknowns.

As we aim to show that a model with reference dependence can account for the empirical elasticties, we consider predictions for specific parameter values. These are described in the next subsection.

5.1 Benchmark parameters

We adopt a monthly calibration. For the UK, we use the Quarterly Labour Force Survey (LFS) to obtain the average unemployment rate and monthly separation rate during 1991-2009. This gives $u = 0.067$ and $s = 0.010$, implying $\lambda = s(1-u)/u = 0.139$. For Germany, we obtain $u = 0.078$ and $s = 0.012$ on the SOEP for 1984-2010, implying $\lambda = 0.142$. We set the bargaining power of workers at 0.05 (see estimates reported by Manning 2011, Table 4) and the monthly interest rate at 0.003. We assume an expected contract length of 12 months, corresponding to $\phi = 0.083$. This is the mode among medium and large firms according to the review of wage setting practices in the US by Taylor (1999). Gottschalk (2005) estimates that in the US the hazard of a change in wages peaks 12 months after the previous change and Fabiani et al. (2010) find that 60% of firms in a number of European countries change base wages once a year.

[7]These are: the negotiated wage, reservation wage and past wage for those previously employed and for those previously unemployed (six variables); the overall wage in the economy; the arrival rate of job offers; the derivatives of reservation and newly-negotiated wages with respect to lagged wages (two variables).

For the replacement ratio, Appendix C.7 calibrates η based on the steady-state relationship between wages and reservation wages and data on welfare benefits from the OECD Social Policy Database. This procedure gives $\eta = 0.69$ for the UK and $\eta = 0.75$ for Germany.

For the simulated model with productivity shocks (see Appendix D.7), we assume a productivity process with a monthly persistence of 0.983 and standard deviation of shocks equal to 0.075 (from Gertler and Trigari 2009). We use simulated data to estimate convergence parameters, obtaining $\xi_u = 0.0036$, $\xi_w = 0.0074$ and $\xi_\rho = -0.0253$. For unemployment, the persistence estimated on the simulated data is very close to the estimates we obtain by fitting AR(1) models on the monthly series for the unemployment rate in the UK and Germany.[8] As long, high-frequency, time series are not available for wages and reservation wages, we cannot estimate these directly, and use the values from the simulated data.

All parameters and their sources are summarized in Table 3.

5.2 Quantitative results

Having obtained analytical results, we compare them to those of a simulated model with productivity fluctuations, as we did in Section 4.2 for the canonical model. Panel B in Figure D1 shows evidence of a very high correlation of 0.993 between analytical and simulated results obtained across a range of parameter values.

[8] We estimate $\xi_u = 0.003$ for the UK on the monthly, seasonally adjusted, time series for the unemployment rate, available from the Office for National Statistics from 1971 onwards. For Germany, a harmonised, seasonally adjusted, series for the unemployment rate is available from the Bundesbank, from 1991 onwards, on which we obtain $\xi_u = 0.004$. We also use HP filtered series (with a conventional smoothing parameters of 129600 on monthly data), giving $\xi_u = 0.004$ for the UK and $\xi_u = 0.018$ for Germany, but the resulting trend component of unemployment for Germany retains some degree of cyclicality. This trend becomes less cyclical with higher smoothing parameters, also delivering higher persistence estimates. For both countries, estimates on log unemployment and/or quarterly series give very similar results to those obtained on the level of monthly unemployment.

To evaluate the quantitative performance of our model vis-à-vis the target elasticities, we consider the combinations of backward-looking behaviour in wages $(1 - \alpha)$, reference dependence in reservation wages (α_ρ), and backward-looking components in reference points (α_l) that yield model predictions close to our elasticity estimates for benchmark values of other parameters.

Figure 1 illustrates elasticity predictions for alternative combinations of α, α_ρ and α_l. We define target elasticities based on UK estimates from Tables 1 and 2. In particular we define the empirical targets as matched if the predicted wage elasticity is within 0.04 of -0.169, and the predicted reservation wage elasticity is within 0.04 of -0.146.[9] In each panel we present predictions for a given value of $\alpha = 0.4, 0.7, 1$ and we let α_ρ and α_l vary along the vertical and horizontal axes, respectively. Combinations of parameter values that can match both empirical targets are shaded in green. For other parameter combinations, the model fails by over- or underestimating at least one of the two targets, as indicated in the legend. For example, Panel (a), which considers the case $\alpha = 1$, shows that values of α_ρ above the (green) target area still match the reservation wage elasticity (ε_ρ✓) but underpredict the wage elasticity ($\varepsilon_w \downarrow$), while values of α_ρ below the target area overpredict both ($\varepsilon_\rho \uparrow, \varepsilon_w \uparrow$). Prior work on the wage flexibility puzzle would only target the wage elasticity and would therefore consider parameter combinations in both green and blue areas consistent with the empirical target.

The three panels show that reference dependence in reservation wages (i.e. $\alpha_\rho > 0$) is necessary to match the empirical estimates: for any value of α, there is no overlap between the green area and the horizontal axis ($\alpha_\rho = 0$). Hence it is not possible for a model with fully forward-looking reservation wages to match estimated elasticities, independent of

[9]Our choice of error margin corresponds almost exactly to the standard error on each parameter estimate.

the degree of backward-looking behaviour in wage setting (i.e. for any $0 \leq \alpha \leq 1$). On the contrary, it is possible for a model with fully forward-looking wage setting ($\alpha = 1$) to match both targets, provided there is sufficient reference dependence in reservation wages. As one would expect, the extent of reference dependence required to match the empirical targets increases with the forward-looking component of wage setting. This result shows that reference dependence reduces the need for alternative solutions to the wage flexibility puzzle based on backward-looking wage setting. The three panels also clearly illustrate that variation in α_ρ is much more relevant for matching elasticity targets than variation in α.

We also assess model predictions about unemployment volatility – the other side of the coin from wage flexibility – using the simulated model of Appendix D.7 with productivity fluctuations (see Table 3 for calibration details). We simulate both the canonical model and the general model with reference dependence. In the canonical model, we select parameter combinations that match the wage elasticity.[10] In this set, the ratio of the standard deviations of (log) unemployment and (log) productivity averages 6.7. In the HP filtered UK data for 1991-2019,[11] this ratio is 12.8; hence the canonical model underestimates unemployment volatility by 48%. In the model with reference dependence, we select parameter combinations that match both the wage and reservation wage elasticities: these deliver an average ratio of standard deviations of 8.8, 31% below the 12.8 target. Hence reference dependence closes about 34% of the gap between the predictions of the canonical model for unemployment volatility and the data. A failure to match perfectly the ratio of standard deviations is expected given that standard devi-

[10] In Figure 1, panel (c) with $\alpha = 0.4$ is the only case in which the model can match the wage elasticity on the horizontal axis, i.e. for $\alpha_\rho = 0$. Hence we set $\alpha_\rho = 0$ and $\alpha = 0.4$.

[11] 1991 coincides with the start of the sample period for our wage cyclicality estimates on the micro data.

ations are affected by noise in the data. We also considered the predicted elasticity of unemployment with respect to productivity a measure of unemployment volatility more akin to how we measure wage flexibility. In the canonical model, the predicted elasticity of unemployment to productivity is -6.3, while the backward-looking model predicts an elasticity of -8.1. In the data, the elasticity for the post-1991 period is -7.8, very close to the predictions of the backward-looking model.

Having established that there exist combinations of α, α_ρ and α_l that can match wage and reservation wage elasticities, we gauge which of these combinations deliver an empirically plausible amount of reference dependence. To this purpose, we link these parameters to an additional data moment, the elasticity of reservation wages to the lagged wage, which we denote by $\gamma \equiv \partial \ln(\rho)/\partial \ln(w^l)$. It can be shown that α_l is closely related to γ in the model, as implied by equations (74) and (75) in Appendix D.4. The parameter combinations that match the elasticity targets in panels (a)-(c) of Figure deliver values of γ values between 0.04 and 0.38.

While data on reservation wages and past wages can in principle provide evidence on γ, the identification of reference dependence involves challenges related to the confounding role of unobservable characteristics, wealth effects, and the mechanical relationship between reservation wages and past wages that arises when unemployment benefits are indexed to past wages. We discuss these challenges in Appendix E and suggest an identification method based on instruments for past wages in reservation wage equations. The resulting elasticity of reservation wages with respect to past wages is about 0.15, which implies $\gamma = 0.15\frac{\rho^*}{w^*} = 0.12$, within the range of plausible values produced by the model. The model with reference dependence can therefore match the observed elasticities in wages and reservation wages under standard assumptions about wage rigidity as well as in the presence of fully forward-looking wage setting.

6 Conclusions

This paper provides novel evidence on the cyclicality of reservation wages. Based on micro data for the UK and Germany, we find that wages and reservation wages display very similar and modest degrees of cyclicality. Job search models that are able to match the observed degree of wage cyclicality by introducing elements of rigidity in wage setting typically overpredict the cyclicality of reservation wages. We show that reference dependent preferences can deliver mildly cyclical reservation wages by anchoring them to backward-looking variables such as past earnings, which are typically less cyclical than labour market conditions. Weakly cyclical reservation wages are then reflected into weakly cyclical wages, as wages track reservation wages up to a roughly acyclical mark-up. We conclude that a model with reference dependence can match empirical elasticities of wages and reservation wages.

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Tables and Figures

Table 1: Estimates of Wage Equations for the UK and Germany

	UK (1991-2009)				Germany (1984-2010)			
	1	2	3	4	5	6	7	8
Log unemployment rate	-0.169	-0.137	-0.110		-0.028	-0.015	-0.005	
	(0.044)	(0.039)	(0.030)		(0.019)	(0.018)	(0.015)	
Log unemployment rate		-0.069	-0.021			-0.096	0.034	
* new job		(0.013)	(0.010)			(0.026)	(0.022)	
Log unemployment rate,				-0.126				-0.065
lagged				(0.032)				(0.018)
Individual fixed effects	✓	✓		✓	✓	✓		✓
Job fixed effects			✓				✓	
Observations	92,380	91,712	77,189	92,380	161,075	160,865	149,617	161,075
R-squared	0.810	0.810	0.889	0.778	0.415	0.415	0.199	0.415

Notes. The sample includes employees aged 18-65 with non-missing wage information. The dependent variable is the log gross hourly (monthly) wage for the UK (Germany), deflated by the aggregate consumer price index. The unemployment concept is national. All regressions include a quadratic time trend, a gender dummy, age and its square, three education dummies, a cubic trend in job tenure, a dummy for married, the number of children in the household, and region dummies. Regressions in columns 3 and 7 also include a dummy for the job having started in the previous 12 months. Standard errors use 2-way cluster-robust variance (Cameron and Miller, 2015). Source: BHPS and SOEP.

Table 2: Estimates of Reservation Wage Equations for the UK and Germany

	UK (1991-2009)			Germany (1984-2010)	
	1	2		4	5
Log unemployment rate	-0.146			0.038	
	(0.042)			(0.054)	
Log unemployment rate, lagged		-0.112			-0.082
		(0.026)			(0.045)
Individual fixed effects	✓		✓	✓	✓
Observations	10,774	10,774		7,911	7,911
R-squared	0.614	0.614		0.123	0.123

Notes. The sample includes unemployed jobseekers aged 18-65 with non-missing reservation wage information. The dependent variable is the log net hourly (monthly) reservation wage for the UK (Germany), deflated by the aggregate consumer price index. The unemployment concept is national. All regressions also include a quadratic time trend, a gender dummy, age and its square, three education dummies, a cubic trend in unemployment duration, a dummy for married, the number of children in the household, the log of unemployment benefits, and region dummies. For the UK, regressions additionally include a dummy for receipt of housing benefits; for Germany they additionally include dummies for looking for full-time, part-time or any job (omitted category: unsure about preferences), and months of social insurance contributions. For Germany, unemployment benefits are instrumented by months to benefit expiry. These are obtained by exploiting benefit entitlement rules, based on (nonlinear) functions of age and previous social security contributions. Standard errors use 2-way cluster-robust variance (Cameron and Miller, 2015). Source: BHPS and SOEP.

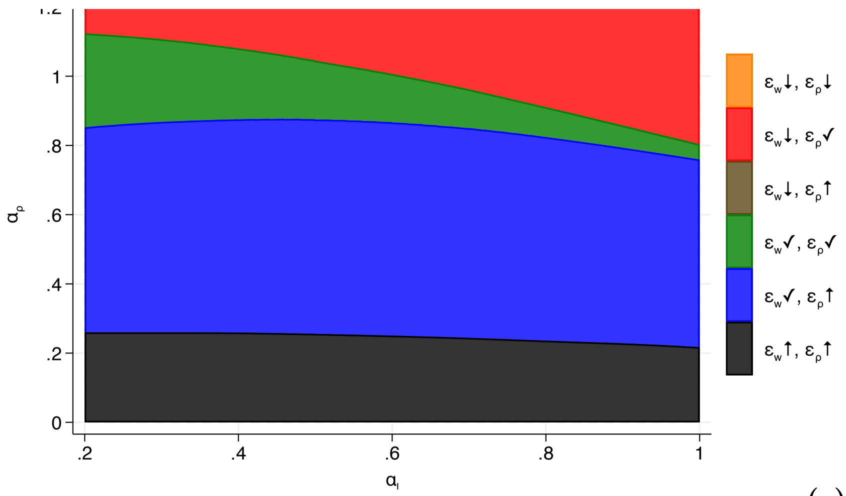
Table 3: Benchmark Parameters Values

Variable	Symbol	UK	Germany	Source
Unemployment rate	u	0.067	0.078	Quarterly LFP (UK) SOEP (Germany)
Separation rate	s	0.010	0.012	Quarterly LFP (UK) SOEP (Germany)
Job-finding rate	λ	0.139	0.142	Separation rate and unemployment rate ($\lambda = s(1-u)/u$)
Frequency of wage negotiations	ϕ	0.083	0.083	Annual frequency (Taylor, 1999)
Bargaining power of workers	β	0.05	0.05	Manning (2011)
Interest rate	r	0.003	0.003	Conventional value
Replacement rate	η	0.690	0.754	For UK: equation (43), using $\rho^*/w^* = 0.8$ (from BHPS) For Germany: benefit replacement ratio + extra utility of leisure during unemployment as implied by UK estimates
Productivity persistence parameter		0.983	0.983	Gertler and Trigari (2009)
St. dev. productivity shocks		0.075	0.075	Gertler and Trigari (2009)

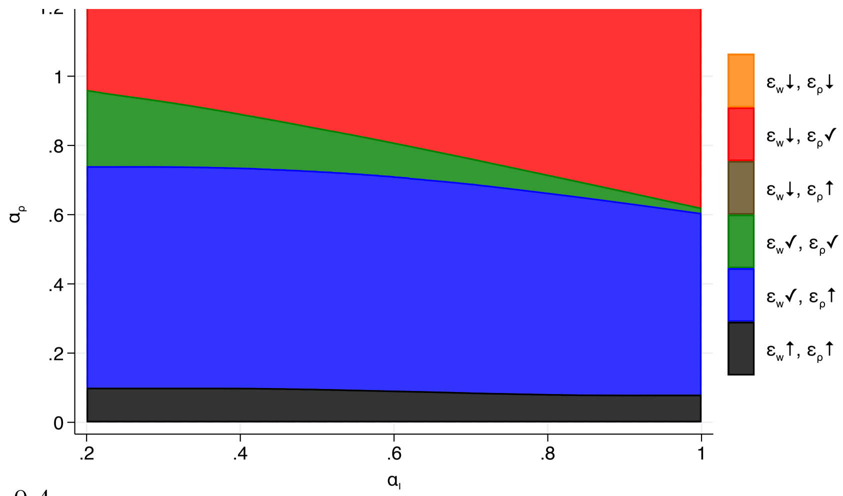
Notes: s, λ, ϕ and persistence parameters are expressed in monthly terms.

Figure 1: Parameter combinations that match the observed cyclicality of wages and reservation wages

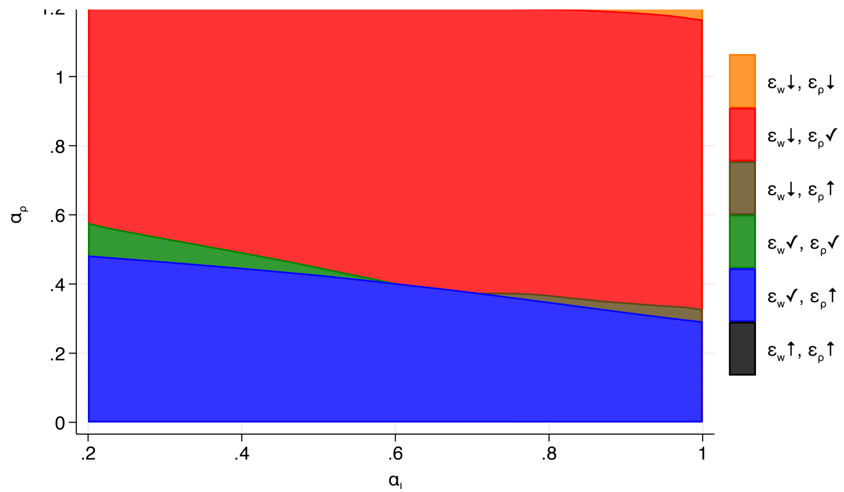
(a) $\alpha = 1$



(b) $\alpha = 0.7$



(c) $\alpha = 0.4$



Notes. The colors represent model performance under alternative combinations of α (probability of negotiating a wage on a new match), α_ρ (reference dependence), and α_l (weight on backward-looking reference points). ✓ indicates that an elasticity is matched (within 0.04 of -0.169 and -0.146 for wages and reservation wages, respectively). $\uparrow$ indicates that an elasticity is overpredicted; $\downarrow$ indicates that an elasticity is underpredicted. Other parameters are set at baseline values (Table 3).

Online Appendix. A. Supplementary Tables.

Table A1: Summary Statistics

	UK				Germany			
	Wage sample		Res. wage sample		Wage sample		Res. wage sample	
Variables:	Mean	St. dev.	Mean	St. dev.	Mean	St. dev.	Mean	St. dev.
Reservation wage			5.226	6.206			1180.4	703.2
Wage	9.866	6.203			2387.7	1898.0		
Female	0.521	0.500	0.546	0.498	0.430	0.495	0.616	0.486
Age	38.1	11.7	34.7	14.0	39.0	11.6	33.3	11.3
Higher education	0.117	0.321	0.247	0.431	0.254	0.435	0.143	0.350
Upper secondary education	0.269	0.443	0.353	0.478	0.528	0.499	0.549	0.498
Lower secondary education	0.405	0.491	0.314	0.464	0.178	0.382	0.211	0.408
No qualifications	0.209	0.407	0.085	0.280	0.040	0.040	0.097	0.086
Married	0.717	0.451	0.514	0.500	0.657	0.475	0.559	0.497
No. Kids	0.686	0.965	0.917	1.168	0.730	0.990	1.027	1.120
Duration in current status (years)	4.880	5.969	4.387	5.748	10.464	9.653	2.962	3.902
Benefit income			276.4	318.2			255.8	448.7
Receives housing benefits			0.196	0.397				
Looking for full-time work							0.482	0.500
Looking for part-time work							0.382	0.486
Looking for either							0.109	0.312
Unsure about working hours							0.027	0.161
Social insurance contributions (months)							5.242	6.878
Months to benefit expiry							1.109	3.679
Entitled to unemployment benefits							0.196	0.397
Hours worked					38.5	12.7		
Number of observations	96,270		14,874		166,614		11,221	

Notes. Samples include employees aged 18-65 with non-missing wage information (wage sample); unemployed jobseekers aged 18-65 with non-missing reservation wage information (reservation wage sample). Source: BHPS 1991-2009 and SOEP 1984-2010.

Table A2: Detailed Results on Wage and Reservation Wage Equations for the UK and Germany

	UK		Germany	
Dependent variable	log wage	log res wage	log wage	log res wage
Log national unemployment rate	-0.165	-0.175	0.002	0.001
	(0.044)	(0.058)	(0.025)	(0.065)
Female	-0.263	-0.102	-0.265	-0.188
	(0.009)	(0.011)	(0.015)	(0.018)
Age	0.073	0.033	0.082	0.018
	(0.002)	(0.002)	(0.002)	(0.003)
Age^2 (/100)	-0.084	-0.034	-0.009	-0.003
	(0.002)	(0.002)	(0.000)	(0.000)
Lower secondary qualification	0.193	0.068	0.023	-0.016
	(0.008)	(0.009)	(0.011)	(0.024)
Upper secondary qualification	0.361	0.157	0.230	0.093
	(0.007)	(0.011)	(0.015)	(0.023)
Higher education	0.710	0.352	0.562	0.276
	(0.004)	(0.013)	(0.019)	(0.029)
Married	0.092	0.042	0.032	-0.038
	(0.006)	(0.006)	(0.003)	(0.010)
No. kids in household	-0.019	0.018	-0.020	-0.006
	(0.003)	(0.004)	(0.004)	(0.005)
Duration in current status (years)	0.018	-0.002	0.037	0.013
	(0.001)	(0.002)	(0.002)	(0.005)
Duration in current $status^2$ (/10)	-0.010	-0.001	-0.012	-0.014
	(0.001)	(0.002)	(0.001)	(0.006)
Duration in current $status^3$ (/100)	0.017	0.003	0.002	0.003
	(0.002)	(0.003)	(0.000)	(0.002)
Log(Unemp benefits + 1)		0.004		0.004
		(0.001)		(0.003)
Receives housing benefits		0.017		-0.075
		(0.008)		(0.026)
Social insurance contributions (years)				0.005
				(0.001)
Looking for full-time work				0.151
				(0.036)
Looking for part-time work				-0.507
				(0.033)
Looking for any hours				-0.051
				(0.031)
Log hours worked			0.912	
			(0.042)	
Year	-0.009	0.004	0.022	0.027
	(0.007)	(0.007)	(0.002)	(0.008)
$(Year-1990)^2$	0.001	0.001	-0.696	-1.003
	(0.000)	(0.000)	(0.078)	(0.253)
Observations	96,270	14,847	166,614	11,221
R-squared	0.397	0.249	0.605	0.359

Notes. See notes to Table A1 for samples used. The wage measure is hourly for the UK and monthly for Germany. All regressions include region dummies. Standard errors are clustered at the year level. Source: BHPS 1991-2009 and SOEP 1984-2010.

Table A3: Estimates of Wage and Reservation Equations for the UK and Germany: Additional Estimates with Regional Controls

	UK		Germany	
	1	2	3	4
Panel A: Wage equations				
Log regional unemployment rate	-0.053		-0.008	
	(0.017)		(0.015)	
Log regional unemployment rate, lagged		-0.065		-0.044
		(0.013)		(0.014)
Individual fixed effects	✓	✓	✓	✓
Observations	92,380	92,380	160,865	101,526
R-squared	0.810	0.810	0.414	0.415
Panel B: Reservation wage equations				
Log regional unemployment rate	-0.034		0.034	
	(0.028)		(0.023)	
Log regional unemployment rate, lagged		-0.078		-0.031
		(0.023)		(0.023)
Individual fixed effects	✓	✓	✓	✓
Observations	10,774	10,774	7,911	7,911
R-squared	0.613	0.614	0.124	0.123

Notes. Panel A: See notes to Table 1 in the main text. Panel B: See notes to Table 2 in the main text. The unemployment concept is regional.

B The quality of reservation wage data

While there may be concerns about the quality of reservation wage data, we note that the impact of most covariates considered on reservation wages (e.g. age, education and gender) has the expected sign and is precisely estimated, as shown in Table A2. We further address concerns about the informative content of reservation wage data by testing whether their correlation with job search outcomes has the sign predicted by search theory. Ceteris paribus, a higher reservation wage should cause a longer remaining duration in unemployment and higher entry wages upon job finding.

Table B1 illustrates the effect of reservation wages on each outcome. Panel A shows estimates for the UK. Column 1 regresses an indicator of re-employment in the past year on the reservation wage recorded at the beginning of the year and a set of year and region dummies. The impact of the reservation wage is virtually zero, but this estimate is likely to be upward biased due to omitted controls for worker ability, as more able workers have both higher reservation wages and are more likely to find employment. Column 2 controls for individual covariates and the national unemployment rate and shows that, conditional on these, workers with higher reservation wages tend to experience significantly longer unemployment spells. Column 3 shows that the point estimate is robust to the introduction of individual fixed-effects, but it becomes less precise.

Columns 4-6 show the impact of reservation wages on wages for those who find jobs. In column 4, which does not control for individual characteristics, the estimated elasticity of reemployment wages with respect to reservation wages is positive and highly significant, but likely to be upward biased by unobserved individual factors that are associated to both higher reservation wages and higher reemployment wages. The elasticity falls by about a quarter in column 5, which controls for individual characteristics. Similarly as for the probability of finding employment, estimates that include individual fixed-effect in column 6 are imprecise: this specification requires repeated unemployment spells for the same individual, with non-missing wages at the end of each spell, and the resulting sample size is much reduced. Results for Germany are presented in Panel B, and they are in line with the UK results. The conclusion from this analysis is that the reservation wage data, though undoubtedly noisy, embody meaningful information about job search behaviour, and there is no particular reason to think that their cyclicality is systematically under-estimated.

Table B1: Reservation Wages, Post-unemployment Wages and Job Finding Probabilities

	Panel A: UK (1991-2009)					
	Whether found job			Log post-unemployment wage		
	1	2	3	4	5	6
Log reservation wage	-0.001	-0.022	-0.021	0.436	0.333	0.157
	(0.007)	(0.008)	(0.014)	(0.039)	(0.036)	(0.104)
Year dummies	✓			✓		
Trend	no	quadratic	quadratic	no	quadratic	quadratic
Further controls		✓	✓		✓	✓
Individual fixed-effects			✓			✓
Observations	15,277	14,700	10,642	2,677	2,586	602
R-squared	0.018	0.080	0.428	0.217	0.284	0.697
	Panel B: Germany (1984-2010)					
	Whether found job			Log post-unemployment wage		
	1	2	3	4	5	6
Log reservation wage	0.033	-0.081	-0.100	0.737	0.391	0.123
	(0.007)	(0.011)	(0.016)	(0.023)	(0.034)	(0.106)
Year dummies	✓			✓		
Trend	no	quadratic	quadratic	no	quadratic	quadratic
Further controls		✓	✓		✓	✓
Individual fixed-effects			✓			✓
Observations	11,534	11,534	8,156	2,984	2,984	755
R-squared	0.007	0.071	0.033	0.244	0.348	0.127

Notes. All specifications include eleven region dummies. Further controls in columns 2, 3, 5 and 6 are a gender dummy, age and its square, three education dummies, a cubic trend in unemployment duration, a dummy for married and the number of children in the household. Standard errors are clustered at the year level in columns 1, 2, 4 and 5; and using 2-way cluster-robust variance (Cameron and Miller, 2015) in columns 3 and 6. Source: BHPS and SOEP.

C Derivation of model results

C.1 Proof of Proposition 1: The reservation wage equation

The following result will be useful.

Lemma. *$J(w; w^l, t)$ and $W(w; w^l, t)$ are linear in w with a slope that does not depend on w^l or t.*

Proof. Equations (2) and (6) imply:

$$\frac{\partial W(w; w^l, t)}{\partial w} = \frac{1 + \alpha_\rho}{r + \phi + s}, \frac{\partial J(w; w^l, t)}{\partial w} = -\frac{1}{r + \phi + s}. \tag{17}$$

As (r, ϕ, s) are constant, (17) implies that $W(w; w^l, t)$ and $J(w; w^l, t)$ are separable and linear in w. This in turn implies that $\partial J(w; w^l, t)/\partial t$ and $\partial W(w; w^l, t)/\partial t$ do not depend on w. □

Using the assumption about wage determination in new jobs the value of being unemployed, (3), for a worker can be written as:

$$rU(w^l, t) = z + \lambda(t) E_t[\alpha W(w^r(w^l, t); w^l, t) + (1-\alpha) W(w^a(t); w^l, t) - U(w^l, t)] + E_t \frac{\partial U(w^l, t)}{\partial t}. \tag{18}$$

Given (17), one can write

$$W(w^r(w^l, t); w^l, t) - W(\rho(w^l, t); w^l, t) = \frac{(1 + \alpha_\rho)\left[w^r(w^l, t) - \rho(w^l, t)\right]}{r + \phi + s}. \tag{19}$$

Using (19) and (18), (4) can be written as:

$$(1 + \alpha_\rho)\rho(w^l, t) - \alpha_\rho\left[\alpha_l w^l + (1 - \alpha_l) w^*\right] + \frac{\phi(1 + \alpha_\rho)[w^r(w^l, t) - \rho(w^l, t)]}{r + \phi + s} =$$
$$z + \frac{\lambda(t)(1 + \alpha_\rho)[\alpha w^r(w^l, t) + (1 - \alpha) w^a(t) - \rho(w^l, t)]}{r + \phi + s} + E_t \frac{\partial U(w^l, t)}{\partial t} - E_t \frac{\partial W(\rho(w^l, t); w^l, t)}{\partial t}. \tag{20}$$

Equation (4) implies:

$$\frac{\partial U(w^l, t)}{\partial t} = \frac{\partial W(\rho(w^l, t); w^l, t)}{\partial t} + \frac{\partial W(\rho(w^l, t); w^l, t)}{\partial w}\frac{\partial \rho(w^l, t)}{\partial t}, \tag{21}$$

so that (20) becomes:

$$(1 + \alpha_\rho)\rho(w^l, t) - \alpha_\rho\left[\alpha_l w^l + (1 + \alpha_\rho) w^*\right] + \frac{\phi(1 + \alpha_\rho)[w^r(w^l, t) - \rho(w^l, t)]}{r + \phi + s} =$$
$$z + \frac{\lambda(t)(1 + \alpha_\rho)[\alpha w^r(w^l, t) + (1 - \alpha) w^a(t) - \rho(w^l, t)]}{r + \phi + s} + \frac{(1 + \alpha_\rho)}{r + \phi + s} E_t \frac{\partial \rho(w^l, t)}{\partial t},$$

which can be rearranged to give the differential equation for the reservation wage in (5).

C.2 Proof of Proposition 2: The wage equation

Maximizing the Nash maximand (8) with respect to $w^r(w^l,t)$ implies the first-order condition:

$$
\begin{aligned}
(1-\beta)\frac{\partial J(w^r(w^l,t);w^l,t)}{\partial w^r}&[W(w^r(w^l,t);w^l,t)-W(\rho(w^l,t);w^l,t)] \\
&+\beta\frac{\partial W(w^r(w^l,t);w^l,t)}{\partial w^r}J(w^r(w^l,t);w^l,t)=0,
\end{aligned}
\tag{22}
$$

where $V(t)=0$ has been imposed. The following result will be useful:

Lemma. *$J(w;w^l,t)$ and $W(w;w^l,t)$ are linear in w^l with a slope that does not depend on w.*

Proof. We assume and verify below that $\partial J(w;w^l,t)/\partial w^l$ is independent of w, and hence $\partial J(w;w^l,t)/\partial w^l = \partial J(w^r;w^l,t)/\partial w^l$. The derivative of the value functions with respect to w^l can be written as:

$$
\frac{\partial J(w;w^l,t)}{\partial w^l}\equiv\chi(t)=\frac{1}{r+s}\frac{\partial\chi(t)}{\partial t}-\frac{\phi\psi^J}{r+s}\pi(t)
\tag{23}
$$

with $\pi(t)\equiv\dfrac{\partial w^r(w^l,t)}{\partial w^l}$. This shows that lagged wages only affect the value functions through their impact on wage negotiation. The derivatives $\pi(t)$ and $\chi(t)$ are not known at this stage but, using an "assume and verify" approach, they turn out to be independent of w^l. (17) and (23) then imply that $J(w;w^l,t)$ is linear in w^l . □

As the value function (6) is linear in current wages (from the Lemma), $E_t[J(w;w^l,t)]$ in the value function (7) is equal to $\alpha J(w^{ru}(t);w^{lu}(t),t)+(1-\alpha)J(w^a(t);w^{lu}(t),t)$, where $w^{ru}(t)$ is the average newly-negotiated wage for workers hired from unemployment, $w^a(t)$ is the average wage among all employed workers and $w^{lu}(t)$ is the average lagged wage for those coming from unemployment. Using this and imposing $V(t)=0$, (7) gives:

$$
\alpha J(w^{ru}(t);w^{lu}(t),t)+(1-\alpha)J(w^a(t);w^{lu}(t),t)=C(t)+\frac{c(t)}{q(t)}=\mu(t),
\tag{24}
$$

i.e. the expected value of a newly-filled job equals the total expected cost of filling a vacancy, $\mu(t)$. Using (19) and (24), (22) can be written as:

$$
\begin{aligned}
(1-\beta)\frac{w^r(w^l,t)-\rho(w^l,t)}{r+\phi+s}=\beta\Big\{&J(w^r(w^l,t);w^l,t)-\alpha J(w^{ru}(t);w^{lu}(t),t) \\
&-(1-\alpha)J(w^a(t);w^{lu}(t),t)+\mu(t)\Big\}.
\end{aligned}
\tag{25}
$$

Using (17) and (23) to evaluate value functions in (25) gives

$$
\begin{aligned}
(1-\beta)[w^r(w^l,t)-\rho(w^l,t)]=&\beta\Big\{[\alpha w^{ru}(t)+(1-\alpha)w^a(t)-w^r(w^l,t)] \\
&-\chi(t)(r+\phi+s)[w^l-w^{lu}(t)]+(r+\phi+s)\mu(t)\Big\},
\end{aligned}
$$

which can be rearranged to give the wage equation (9). This proves the Proposition.

A result that will be useful later is the relationship between wages and reservation wages in steady state. From equation (9) this can be written as:

$$w^* = \rho^* + \widetilde{\beta}(r + \phi + s)\mu. \tag{26}$$

C.3 The linearity of the reservation and newly-negotiated wages in lagged wages

By taking derivatives of (9) and (5) with respect to w^l, we obtain, respectively:

$$\pi(t) = (1 - \beta)\gamma(t) - \beta\chi(t)/\psi^J \tag{27}$$

$$[r + \lambda(t) + s]\,\gamma(t) = (r + \phi + s)\frac{\alpha_\rho}{1 + \alpha_\rho}\alpha_l + [\alpha\lambda(t) - \phi]\pi(t) + E_t\frac{\partial\pi(t)}{\partial t}, \tag{28}$$

where $\gamma(t) \equiv \partial\rho(w^l, t)/\partial w^l$. One can then combine (27) and (28) together with (23) to solve for $\pi(t)$, $\chi(t)$ and $\gamma(t)$.

C.4 From individual to aggregate relationships

Taking averages of (5) gives the average reservation wage for the unemployed, $\rho^u(t)$, and the employed, $\rho^e(t)$, respectively:

$$\rho^u(t) = \rho(w^{lu}(t), t); \qquad \rho^e(t) = \rho(w^{le}(t), t)$$

where $w^{lu}(t)$ and $w^{le}(t)$ denote their respective average lagged wages and t denotes the time at which the average is taken. Taking averages of (9) gives the average renegotiated wage for the unemployed and the employed, respectively:

$$\begin{aligned} w^{ru}(t) =& (1 - \beta)\rho^u(t) + \beta\left\{(r + \phi + s)\mu(t) + [\alpha w^{ru}(t) + (1 - \alpha)w^a(t)]\right\} \\ w^{re}(t) =& (1 - \beta)\rho^e(t) + \beta\Big\{(r + \phi + s)\mu(t) + [\alpha w^{ru}(t) + (1 - \alpha)w^a(t)] \\ & \qquad + \chi(t)(r + s + \phi)[w^{lu}(t) - w^{le}(t)]\Big\}. \end{aligned}$$

C.5 Proof of Proposition 3.

Without reference dependence, the lagged wage does not affect the negotiated wage, nor any of the value functions; hence $\chi(t) = 0$ and the wage equation (9) can be written as:

$$w^r(t) = (1 - \beta)\rho(t) + \beta\left\{(r + \phi + s)\mu + [\alpha w^r(t) + (1 - \alpha)w(t)]\right\}. \tag{29}$$

Taking the linear projection and defining θ_x as in (10), (29) can be written as:

$$\theta_{w^r} = (1 - \beta)\theta_\rho + \beta[\alpha\theta_{w^r} + (1 - \alpha)\theta_w], \tag{30}$$

Average wages follow the differential equation:

$$\frac{dw^a(t)}{dt} = \frac{\lambda(t)u(t)}{1-u(t)}\alpha\left[w^{ru}(t) - w^a(t)\right] + \phi\left[w^{re}(t) - w^a(t)\right], \tag{31}$$

i.e. $w^a(t)$ changes through wage renegotiation for the employed (at rate ϕ) and through new hires, some of whom negotiate a new wage (at rate $\lambda(t)u(t)\alpha$). Without reference dependence, $w^{ru}(t) = w^{re}(t)$. Hence, linearising (31) around steady-state leads to:

$$\xi_w\theta_w = (\alpha s + \phi)(\theta_{w^r} - \theta_w), \tag{32}$$

where ξ_x has been defined in equation (11). This can be re-arranged as:

$$\alpha\theta_{w^r} + (1-\alpha)\theta_w = (1-\Gamma)\theta_{w^r}, \tag{33}$$

where $\Gamma = (1-\alpha)\xi_w/(\alpha s + \phi + \xi_w)$.

Unemployment follows the differential equation:

$$\frac{du(t)}{dt} = s\left[1 - u(t)\right] - \lambda(t)u(t). \tag{34}$$

Linearizing and taking the linear projection gives

$$\theta_\lambda = -(s + \lambda^* - \xi_u)/u^*. \tag{35}$$

Substituting (33) into (30) gives:

$$\theta_{w^r} = \theta_\rho - \widetilde{\beta}\Gamma\theta_{w^r}. \tag{36}$$

Linearizing and taking the linear projection of (5) leads to the following expression for the sensitivity of the reservation wage:

$$(r + \lambda^* + s + \xi_\rho)\theta_\rho = \lambda^*[\alpha\theta_{w^r} + (1-\alpha)\theta_w] - \phi\theta_{w^r} + \theta_\lambda(w^* - \rho^*). \tag{37}$$

Substituting (33) and (36) into (37) gives:

$$[(r + \lambda^* + s + \xi_\rho)(1 + \widetilde{\beta}\Gamma) - \lambda^*(1-\Gamma) + \phi]\theta_{w^r} = \theta_\lambda(w^* - \rho^*). \tag{38}$$

Converting (35) to an elasticity gives:

$$\varepsilon_{w^r} = -\frac{w^* - \rho^*}{w^*}\,\frac{\lambda^* + s - \xi_u}{(r + \lambda^* + s + \xi_\rho)(1 + \widetilde{\beta}\Gamma) - \lambda^*(1-\Gamma) + \phi}. \tag{39}$$

The $(w^* - \rho^*)/w^*$ term can be obtained from the steady-state relationship between the endogenous reservation wage and the benefits replacement ratio.

In steady state, when all wages are equal to w^* and the value of being employed at a wage w (possibly different from w^*) is given by:

$$rW(w) = w - s[W(w) - U] + \phi[W(w^*) - W(w)]. \tag{40}$$

The steady-state value of being unemployed is given by:

$$rU = z + \lambda[W(w^*) - U], \tag{41}$$

where z is the flow utility from being unemployed. The steady-state reservation wage ρ^* satisfies $W(\rho^*) = U$. Using (40) and (41), this can be written as:

$$\rho^* + \phi[W(w^*) - U] = z + \lambda[W(w^*) - U]$$

Rearranging using the comparison of (40) and (41) leads to:.

$$\rho^* = z + (\lambda - \phi)[W(w^*) - U] = z + \frac{\lambda - \phi}{r + \lambda + s}(w^* - z), \tag{42}$$

From (42) it follows that

$$1 - \frac{\rho^*}{w^*} = (1 - \eta)\frac{r + \phi + s}{r + \lambda^* + s}. \tag{43}$$

Substituting (43) into (39) gives the elasticity of the negotiated wage in equation (12). The elasticities of the average wage and the reservation wage can be expressed as a function of ε_{w^r} using (32) and (36) respectively. This gives equations (14) and (15).

C.6 The model with reference dependence

This subsection derives results akin to those presented in Proposition 3 for the model with reference dependence. Taking the linear projection of the reservation wage equation (5) gives:

$$[r + \lambda(t) + s]\,\theta_\rho = (r + \phi + s)\frac{\alpha_\rho \alpha_l}{1 + \alpha_\rho}\theta_{w^l} + \lambda^*[\alpha\theta_{w^r} + (1 - \alpha)\theta_w] + \theta_\lambda w^* - \phi\theta_{w^r}. \tag{44}$$

Averaging this expression for the unemployed and employed respectively, we obtain:

$$[r + \lambda(t) + s]\,\theta_{\rho^e} = \quad (r + \phi + s)\frac{\alpha_\rho \alpha_l}{1 + \alpha_\rho}\theta_{w^{le}} + \lambda^*[\alpha\theta_{w^{re}} + (1 - \alpha)\theta_w] + \theta_\lambda w^* - \phi\theta_{w^{re}} \tag{45}$$

$$[r + \lambda(t) + s]\,\theta_{\rho^u} = \quad (r + \phi + s)\frac{\alpha_\rho \alpha_l}{1 + \alpha_\rho}\theta_{w^{lu}} + \lambda^*[\alpha\theta_{w^{ru}} + (1 - \alpha)\theta_w] + \theta_\lambda w^* - \phi\theta_{w^{ru}} \tag{46}$$

Similarly for newly-negotiated wages, taking averages of (9) for those coming from unemployment and employment, respectively, gives

$$\theta_{w^{ru}} = (1 - \beta)\theta_{\rho^u} + \beta\left[\alpha\theta_{w^{ru}} + (1 - \alpha)\theta_w\right] \tag{47}$$

$$\theta_{w^{re}} = (1 - \beta)\theta_{\rho^e} + \beta\Big\{\left[\alpha\theta_{w^{ru}} + (1 - \alpha)\theta_w\right] + \chi(t)(r + s + \phi)\left[\theta_{w^{lu}} - \theta_{w^{le}}\right]\Big\}, \tag{48}$$

where the solution for $\chi(t)$ follows from (23), (27) and (28).

The next set of equations are related to wage dynamics. Average wages follow the differential equation (31). Linearizing and taking the linear projection this becomes:

$$\xi_w \theta_w = \alpha s(\theta_{w^{ru}} - \theta_w) + \phi(\theta_{w^{re}} - \theta_w). \tag{49}$$

The lagged wage for the unemployed follows the differential equation:

$$\frac{dw^{lu}(t)}{dt} = \frac{s(1-u(t))}{u(t)}(w_a(t) - w^{lu}(t)), \tag{50}$$

as it changes only with the inflow of workers from employment, who have average wage $w_a(t)$. Linearizing and taking the linear projection, (50) gives:

$$\xi_{lu}\theta_{w^{lu}} = \lambda^*(\theta_w - \theta_{w^{lu}}). \tag{51}$$

The lagged wage for the employed follows the differential equation:

$$\frac{dw^{le}(t)}{dt} = \frac{\lambda(t)u(t)}{1-u(t)}(w^{lu}(t) - w^{le}(t)), \tag{52}$$

as it changes only with the inflow of workers from unemployment, who have a lagged wage $w^{lu}(t)$. Linearizing and taking the linear projection, (52) gives:

$$\xi_{le}\theta_{w^{le}} = s(\theta_{w^{lu}} - \theta_{w^{lu}}). \tag{53}$$

Finally, there is the linear projection of the expression for unemployment dynamics (35) obtained above:

$$\theta_\lambda = -(s + \lambda^* - \xi_u)/u^* \tag{54}$$

Equations (45)-(49), (51), (53), (54), (23), (27) and (28) form a system of 11 equations that can be solved for the unknowns $\theta = (\theta_w, \theta_{\rho^e}, \theta_{\rho^u}, \theta_{w^{re}}, \theta_{w^{ru}}, \theta_{w^{le}}, \theta_{w^{lu}}, \theta_\lambda, \pi(t), \gamma(t), \chi(t))$, in terms of the model parameters. The elements of the θ vector can be converted into elasticities using $\varepsilon_x = u^*\theta_x/x^*$.

C.7 Calibration of the replacement ratio η

We calibrate η from the steady state relationship between wages and reservation wages in (43). In the BHPS, unemployed workers are asked about their reservation wage and their expected wage upon re-employment, and the answers to these questions can be used to estimate ρ^*/w^*, whose median value is 0.80. As the duration of a wage contract, $1/\phi$, is typically longer than the duration of an unemployment spell, $1/\lambda$, equation (43) implies $\eta < 0.80$. Using UK data ($\lambda = 0.139$ monthly) and assuming annual renegotiations ($\phi = 0.083$ on monthly data) gives $\eta = 0.69$, in line with the calibrations of Hall and Milgrom (2008); Mas and Pallais (2019); Faberman et al. (2021). This value is somewhat higher than the benefit replacement ratio of 0.60 estimated from the OECD data,[12] For

[12]The OECD Social Policy Database computes the portion of net in-work income that is maintained when a worker becomes unemployed, by household composition and unemployment duration. In 2001, the overall average of this ratio across worker types in the UK and Germany was 0.60 and 0.66, respectively.

Germany, there is no available information on expected wages during unemployment, thus we calibrate the replacement ratio assuming that it exceeds the unemployment benefit ratio (0.69) by the same amount as in the UK, i.e. 9 percentage points. This is equivalent to assuming that the extra utility of home time during unemployment is the same in both countries, giving $\eta = 0.75$ in Germany.

D The model in discrete time

This section builds the discrete-time equivalent to the model of Section 3, where all building blocks and notation are defined. The discrete-time model will be used to deliver numerical simulations for wage and reservation wage elasticities, obtained by imposing a stochastic process for labour productivity, to be compared to our analytical solutions. We present the general model with reference dependence, where the special case $\alpha_\rho = 0$ denotes the canonical model.

D.1 Employers

The value at time t of a job that pays a wage w_t to worker with lagged wage w^l is

$$\begin{aligned} J_t(w_t, w^l) &= p_t - w_t \\ &+ \frac{1}{1+r}\left\{(1-s)\left[(1-\phi)E_t J_{t+1}(w_t, w^l) + \phi E_t J_{t+1}(w^r_{t+1}(w^l), w^l)\right] + sE_t V_{t+1}\right\}. \end{aligned} \tag{55}$$

From (55) two results follow, which will be used in later derivations:

$$\frac{\partial J_t(w_t, w^l)}{\partial w_t} = -\frac{1+r}{(1+r)-(1-s)(1-\phi)} \equiv -\psi^J \tag{56}$$

$$\begin{aligned} \frac{\partial J_t(w_t, w^l)}{\partial w^l} =& \frac{1-s}{1+r}\left[(1-\phi)\frac{\partial E_t J_{t+1}(w_t, w^l)}{\partial w^l}\right. \\ &\left. + \phi\left(\frac{\partial E_t J_{t+1}(w^r_{t+1}(w^l), w^l)}{\partial w^r_{t+1}}\pi_{t+1} + \frac{\partial E_t J_{t+1}(w^r_{t+1}(w^l), w^l)}{\partial w^l}\right)\right], \end{aligned} \tag{57}$$

with $\pi_t \equiv \partial w^r_t(w^l)/\partial w^l$. Using (56) and $\chi_t = -\partial J_t(w_t, w^l)/\partial w^l$, which turns out to vary with time only, (57) can be rewritten as:

$$\chi_t = \frac{(1-s)\phi\psi^J}{1+r}\pi_{t+1} + \chi_{t+1}\frac{1-s}{1+r}. \tag{58}$$

The value of a vacant job is given by:

$$V_t = -c_t + \frac{1}{1+r}\left\{q_t E_t[\alpha J_{t+1}(w^{ru}_{t+1}, w^{lu}_{t+1}) + (1-\alpha)J_{t+1}(w^a_t, w^{lu}_{t+1}) - C_t] + (1-q_t)E_t V_{t+1}\right\}. \tag{59}$$

Imposing free entry and $\mu_t = \mu$, (59) can be re-arranged to give:

$$E_t[\alpha J_{t+1}(w^{ru}_{t+1}, w^{lu}_{t+1}) + (1-\alpha)J_{t+1}(w^a_t, w^{lu}_{t+1})] = \mu \tag{60}$$

which, using (56), can be rewritten as:

$$E_t J_{t+1}(w^{ru}_{t+1}, w^{lu}_{t+1}) = \mu - (1-\alpha)\psi^J (w^{ru}_{t+1} - w^a_t). \tag{61}$$

Evaluating (55) at the expected newly-negotiated wage and the expected lagged wage for the unemployed ($J_t(w^{ru}_t, w^{lu}_t)$) and rearranging yields:

$$\begin{aligned}&(1+r)\left[\mu - (1-\alpha)\psi^J (w^{ru}_t - w^a_{t-1})\right] = (1+r)(p_t - w^{ru}_t)\\ &+ (1-s)\left\{(1-\phi)\left[J_{t+1}(w^{ru}_t(w^{lu}_t), w^{lu}_t) - J_{t+1}(w^{ru}_{t+1}, w^{lu}_{t+1})\right] + \mu - (1-\alpha)\psi^J (w^{ru}_{t+1} - w^a_t)\right\}.\end{aligned} \tag{62}$$

Using (56) and (58), (62) leads to yield a job creation curve, relating average negotiated wages for the unemployed, w^{ru}_t to labour productivity p_t:

$$\begin{aligned}&(1+r)\left[\mu - (1-\alpha)\psi^J (w^{ru}_t - w^a_{t-1})\right] = (1+r)(p_t - w^{ru}_t)\\ &+ (1-s)\left\{(1-\phi)\left[\psi^J (w^{ru}_{t+1} - w^{ru}_t) + \chi_{t+1}(w^{lu}_{t+1} - w^{lu}_t)\right] + \mu - (1-\alpha)\psi^J (w^{ru}_{t+1} - w^a_t)\right\},\end{aligned} \tag{63}$$

D.2 Workers

The value at time t of being employed at wage w_t for a worker with lagged wage w^l is:

$$\begin{aligned}&W_t(w_t, w^l) = w_t + \alpha_\rho\left[w_t - (\alpha_l w^l + (1-\alpha_l)w^*)\right]\\ &+ \frac{1}{1+r}\left\{sE_t U_{t+1}(w^l) + (1-s)\left[\phi E_t W_{t+1}(w^r_{t+1}(w^l), w^l) + (1-\phi)E_t W_{t+1}(w_t, w^l)\right]\right\},\end{aligned} \tag{64}$$

in turn implying:

$$\frac{\partial W_t(w_t, w^l)}{\partial w_t} = \frac{(1+\alpha_\rho)(1+r)}{(1+r) - (1-s)(1-\phi)} = \psi^W \tag{65}$$

D.3 Reservation wage determination

The value function for unemployment is:

$$U_t(w^l) = z + \frac{1}{1+r}\left\{(1-\lambda_t)E_t U_{t+1}(w^l) + \lambda_t\left[\alpha E_t W_{t+1}(w^r_{t+1}(w^l), w^l) + (1-\alpha)E_t W_{t+1}(w^a_t, w^l)\right]\right\}. \tag{66}$$

The reservation wage satisfies $W_t(\rho_t(w^l), w^l) = U_t(w^l)$. Hence, combining (64) and (66) gives:

$$\begin{aligned}&(1+r)\left\{\rho_t(w^l) + \alpha_\rho\left[\rho_t(w^l) - \left(\alpha_l w^l + (1-\alpha_l)w^*\right)\right]\right\}\\ &+ \psi^W (1-s)\left[\phi E_t(w^r_{t+1}(w^l) - \rho_{t+1}(w^l)) + (1-\phi)E_t(\rho_t(w^l) - \rho_{t+1}(w^l))\right]\\ =&(1+r)z + \psi^W \lambda_t\left[\alpha E_t(w^r_{t+1}(w^l) - \rho_{t+1}(w^l)) + (1-\alpha)E_t(w^a_t - \rho_{t+1}(w^l))\right],\end{aligned} \tag{67}$$

imposing $U_{t+1}(w^l) = W_{t+1}(\rho_{t+1}(w^l), w^l)$. Differentiating (67) with respect to w^l gives:

$$(1+r)[\gamma_t(1+\alpha_\rho) - \alpha_l\alpha_\rho] + \psi^W(1-s)(\phi E_t(\pi_{t+1} - \gamma_{t+1}) + (1-\phi)E_t(\gamma_t - \gamma_{t+1})) \\ = \psi^W E_t\left\{\lambda_t\left[\alpha(\pi_{t+1} - \gamma_{t+1}) - (1-\alpha)(\gamma_{t+1})\right]\right\}. \quad (68)$$

where $\gamma_t = \partial\rho_t(w^l)/\partial w^l$. (68) provides a difference equation relating the derivative of the reservation wage with respect to the lagged wage γ_t to the derivative of the negotiated wage with respect to the lagged wage π_t.

D.4 Wage determination

The Nash bargaining solution can be written as:

$$(1-\beta)\frac{\partial J_t(w^r(w^l), w^l)}{\partial w^r}[W_t(w^r(w^l); w^l) - W_t(\rho(w^l), w^l)] \\ + \beta\frac{\partial W_t(w^r(w^l), w^l)}{\partial w^r}J_t(w^r(w^l), w^l) = 0. \quad (69)$$

Using (65) one can write:

$$W_t(w^r(w^l), w^l) - W_t(\rho(w^l), w^l) = \psi^W[w^r(w^l) - \rho(w^l)]. \quad (70)$$

Using (70) in (69), adding and subtracting $\beta\psi^W J_t(w_t^{ru}, w_t^{lu})$ on the right hand side and using (61) yields:

$$(1-\beta)\psi^J(w_t^r(w^l) - \rho_t(w^l)) = \beta\left\{J_t(w_t^r(w^l), w^l) - J_t(w_t^{ru}, w_t^{lu}) + \mu - (1-\alpha)\psi^J(w_t^{ru} - w_{t-1}^a)\right\}. \quad (71)$$

Finally, substituting (56) and (58) into (71) and rearranging gives:

$$(1-\beta)(w_t^r(w^l) - \rho_t(w^l)) = \beta\left\{\alpha w_t^{ru} + (1-\alpha)w_{t-1}^a - w_t^r(w^l) - \chi_t/\psi^J(w^l - w_t^{lu}) + \mu/\psi^J\right\}. \quad (72)$$

The derivative of (72) with respect to w^l gives:

$$(1-\beta)(\pi_t - \gamma_t) = -\beta\left(\pi_t + \frac{\chi_t}{\psi^J}\right). \quad (73)$$

Together, (68) and (73) solve for π_t and γ_t in terms of model parameters. Neither depends on wage levels confirming the assumption that w_t^r and ρ_t are linear in w^l. Using (58), these derivatives simplify in steady state to:

$$\gamma = \pi\Theta \quad (74)$$

$$\pi\left(\Theta(1+\alpha_\rho)(1+r) + \psi^W(1-s)\phi(1-\Theta) + \psi^W\lambda^*(\Theta - \alpha)\right) = (1+r)\alpha_l\alpha_\rho \quad (75)$$

with $\Theta = \frac{r+s+\beta(1-s)\phi}{(r+s)(1-\beta)}$.

D.5 Aggregate relationships

Taking averages of (72) for those previously unemployed and employed, respectively gives:

$$w_t^{ru} = (1-\beta)\rho_t^u + \beta\left\{w_t^{ru} + \mu/\psi^J - (1-\alpha)(w_t^{ru} - w_{t-1}^a)\right\}, \tag{76}$$
$$w_t^{re} = (1-\beta)\rho_t^e + \beta\left\{w_t^{ru} + \mu/\psi^J - (1-\alpha)(w_t^{ru} - w_{t-1}^a) - \chi_t/\psi^J(w_t^{le} - w_t^{lu})\right\}. \tag{77}$$

Similarly, evaluating w^l for the employed and unemployed in (67), respectively, gives:

$$(1+r)\left\{\rho_t^u + \alpha_\rho\left[\rho_t^u - (\alpha_l w^{lu} + (1-\alpha_l)w^*)\right]\right\} + \psi^W(1-s)\left[\phi E_t(w_{t+1}^{ru} - \rho_{t+1}^u) + (1-\phi)(\rho_t^u - \rho_{t+1}^u)\right]$$
$$= (1+r)z + \psi^W E_t\left\{\lambda_t\left[\alpha(w_{t+1}^{ru} - \rho_{t+1}^u) + (1-\alpha)(w_t^a - \rho_{t+1}^u)\right]\right\}, \tag{78}$$
$$(1+r)\left\{\rho_t^e + \alpha_\rho\left[\rho_t^e - (\alpha_l w^{le} + (1-\alpha_l)w^*)\right]\right\} + \psi^W(1-s)\left[\phi E_t(w_{t+1}^{re} - \rho_{t+1}^e) + (1-\phi)(\rho_t^e - \rho_{t+1}^e)\right]$$
$$= (1+r)z + \psi^W E_t\left\{\lambda_t\left[\alpha(w_{t+1}^{re} - \rho_{t+1}^e) + (1-\alpha)(w_t^a - \rho_{t+1}^e)\right]\right\}. \tag{79}$$

Average lagged wage for the unemployed and the employed, are given by the following dynamic equations, respectively:

$$w_t^{lu} = \frac{(1-\lambda_{t-1})u_{t-1}w_{t-1}^{lu} + s(1-u_{t-1})w_{t-1}^a}{(1-\lambda_{t-1})u_{t-1} + s(1-u_{t-1})} \tag{80}$$
$$w_t^{le} = \frac{\lambda_{t-1}u_{t-1}w_{t-1}^{lu} + (1-s)(1-u_{t-1})w_{t-1}^{le}}{\lambda_{t-1}u_{t-1} + (1-s)(1-u_{t-1})}. \tag{81}$$

Finally, the average wage is given by:

$$w_t^a = \frac{(1-s)(1-u_{t-1})\left[\phi w_t^{re} + (1-\phi)w_{t-1}^a\right] + \lambda_{t-1}u_{t-1}\left[\alpha w_t^{ru} + (1-\alpha)w_{t-1}^a\right]}{\lambda_{t-1}u_{t-1} + (1-s)(1-u_{t-1})}. \tag{82}$$

D.6 Elasticities

The wage setting process is captured by ten equations: the two Nash bargaining solutions (76), (77); two reservation wage equations ((67) evaluated at w^{le} and w^{lu} respectively); the three laws of motion for average wages (lagged and current) (80), (81), (82) and the derivatives (73) and (68). These can be jointly solved for the nine endogenous variables regarding wages: w_t^a, w_t^{re}, w_t^{ru}, w_t^{le}, w_t^{lu}, ρ_t^e, ρ_t^u, π_t, γ_t, conditional on market tightness λ_t. The model is closed by the job creation curve (63), expressing λ_t as a function of the exogenous productivity process p_t.

To study how the system responds to shocks, we use the linear projection definition for a hypothetical variable x on the unemployment rate (as in Section 4.1):

$$E(x_t - x^*|u_t - u^*) = \theta_x(u_t - u^*)$$
$$E(x_{t+1} - x_t|u_t - u^*) = \xi_x E(x_t - x^*|u_t - u^*) = \xi_x\theta_x(u_t - u^*).$$

Starting with negotiated wages, we take linear projections of (76) and (77) to obtain, respectively:

$$(1-\alpha\beta)\theta_{w^{ru}} = (1-\beta)\theta_{\rho^u} + \beta(1-\alpha)(1-\xi_a)\theta_w, \tag{83}$$

$$\theta_{w^{re}} = (1-\beta)\theta_{\rho^e} + \beta\left[(1-\alpha)(1-\xi_w)\theta_w + \alpha\theta_{w^{ru}} - \frac{\chi^*}{\psi^J}(\theta_{w^{le}} - \theta_{w^{lu}})\right]. \tag{84}$$

Equations (67) and (80)-(82) are nonlinear because they involve the product between various wage concepts and λ_t. We linearise around steady state and then apply the linear projection. Define $R_x \equiv \frac{\partial f(x)}{\partial x}|_{ss}$ as the derivative of a function $f(x)$ evaluated at the steady state value of x, x^*. Starting with (78), and using (65) and (26), we obtain:

$$\theta_{\rho^u}R_{\rho^u} = \tilde{\beta}\mu\theta_\lambda + (1+\xi_{w^{ru}})R_{w^r}\theta_{w^{ru}} + R_w\theta_w + \theta_{w^l}R_{w^{lu}}, \tag{85}$$

where $R_w = \psi^W\lambda^*(1-\alpha)$, $R_{w^r} = \psi^W\lambda^*\alpha - (1-s)\phi\psi$, $R_{w^l} = (1+r)(\alpha_l\alpha_\rho)$ and $R_{\rho^u} = \psi^W[(1+r) + [\lambda^* - (1-s)](1+\xi_{\rho^u})]\}$. Similarly for (79):

$$\theta_{\rho^e}R_{\rho^e} = \tilde{\beta}\mu\theta_\lambda + (1+\xi_{w^{re}})R_{w^r}\theta_{w^{re}} + R_w\theta_w + \theta_{w^l}R_{w^{le}}, \tag{86}$$

where $R_{\rho^e} = \psi^W[(1+r) + [\lambda^* - (1-s)](1+\xi_{\rho^e})]\}$. Linearising (82) gives:

$$w_t = f_{w^{ru}}(w_t^{ru} - w^*) + f_{w^{re}}(w_t^{re} - w^*) + f_u(u_{t-1} - u^*) + f_\lambda(\lambda_{t-1} - \lambda^*) + f_w(w_{t-1}^a - w^*), \tag{87}$$

where $f_x \equiv \frac{\partial w}{\partial x}|_{ss}$, with $f_u = f_\lambda = 0$, $f_{w^{ru}} = \alpha s$, $f_{w^{re}} = (1-s)\phi$ and $f_w = (1-\alpha)s + (1-s)(1-\phi)$. Taking the linear projection of (87) and (80) gives:

$$\theta_w(1+\xi_w - f_w) = \theta_{w^{ru}}(1+\xi_{ru})f_{w^{ru}} + \theta_{w^{re}}(1+\xi_{re})f_{w^{re}}. \tag{88}$$

$$\theta_{w^{lu}}(1+\xi_{lu}) = \frac{(1-\lambda^*)u^*\theta_{w^{lu}} + s(1-u^*)\theta_w}{(1-\lambda^*)u^* + s(1-u^*)}.$$

Imposing the steady state condition $s(1-u^*) = \lambda^*u^*$ and re-arranging gives:

$$\theta_{w^{lu}} = \frac{\lambda^*\theta_w}{\xi_{lu} + \lambda^*}. \tag{89}$$

Finally, repeating the same steps for (81) gives:

$$\theta_{w^{le}} = \frac{s\theta_{w^{lu}}}{\xi_{le} + s}. \tag{90}$$

The elasticity of lagged wages for the unemployed and the employed follow from (89) and (90), respectively:

$$\varepsilon_{lu}(\xi_{lu} + \lambda^*) = \lambda^*\varepsilon_w \tag{91}$$

$$\varepsilon_{le} = \frac{s}{\xi_{le} + s}\varepsilon_{lu} \tag{92}$$

and the elasticity of the average wage follows from (88):

$$\varepsilon_w(1+\xi_w - f_w) = \varepsilon_{ru}(1+\xi_{ru})f_{w^{ru}} + \varepsilon_{re}(1+\xi_{re})f_{w^{re}}. \tag{93}$$

The elasticities of renegotiated wages for the unemployed and the employed follow from (72) and (84) respectively:

$$(1-\alpha\beta)\varepsilon_{ru} = (1-\beta)\varepsilon_{\rho^u}\frac{\rho^*}{w^*} + \beta(1-\alpha)(1-\xi_a)\varepsilon_w \tag{94}$$

$$\varepsilon_{re} = (1-\beta)\varepsilon_{\rho^e}\frac{\rho^*}{w^*} + \beta\left[(1-\alpha)(1-\xi_w)\varepsilon_w + \alpha\varepsilon_{ru} - \frac{\chi^*}{\psi^J}(\varepsilon_{le}-\varepsilon_{lu})\right]. \tag{95}$$

Finally, the elasticities of the reservation wage for the unemployed and the employed follow from (78) and (79), respectively, also using $\theta_\lambda = -(s+\lambda_{ss}-\xi_u)/u_{ss}$:

$$\varepsilon_{\rho^e}R_{\rho^e}\frac{\rho^*}{w^*} = -(1-\eta)\frac{1+r}{ru^*+s}(s-\xi_u u^*) + (1+\xi_{w^{re}})R_{w^r}\varepsilon_{w^{re}} + R_w\varepsilon_w + R_{w^l}\varepsilon_{w^{le}} \tag{96}$$

$$\varepsilon_{\rho^u}R_{\rho^u}\frac{\rho^*}{w^*} = -(1-\eta)\frac{1+r}{ru^*+s}(s-\xi_u u^*) + (1+\xi_{w^{ru}})R_{w^r}\varepsilon_{w^{ru}} + R_w\varepsilon_w + R_{w^l}\varepsilon_{w^{lu}} \tag{97}$$

We next solve for the elasticities of the seven wage variables by combining (91)-(97).

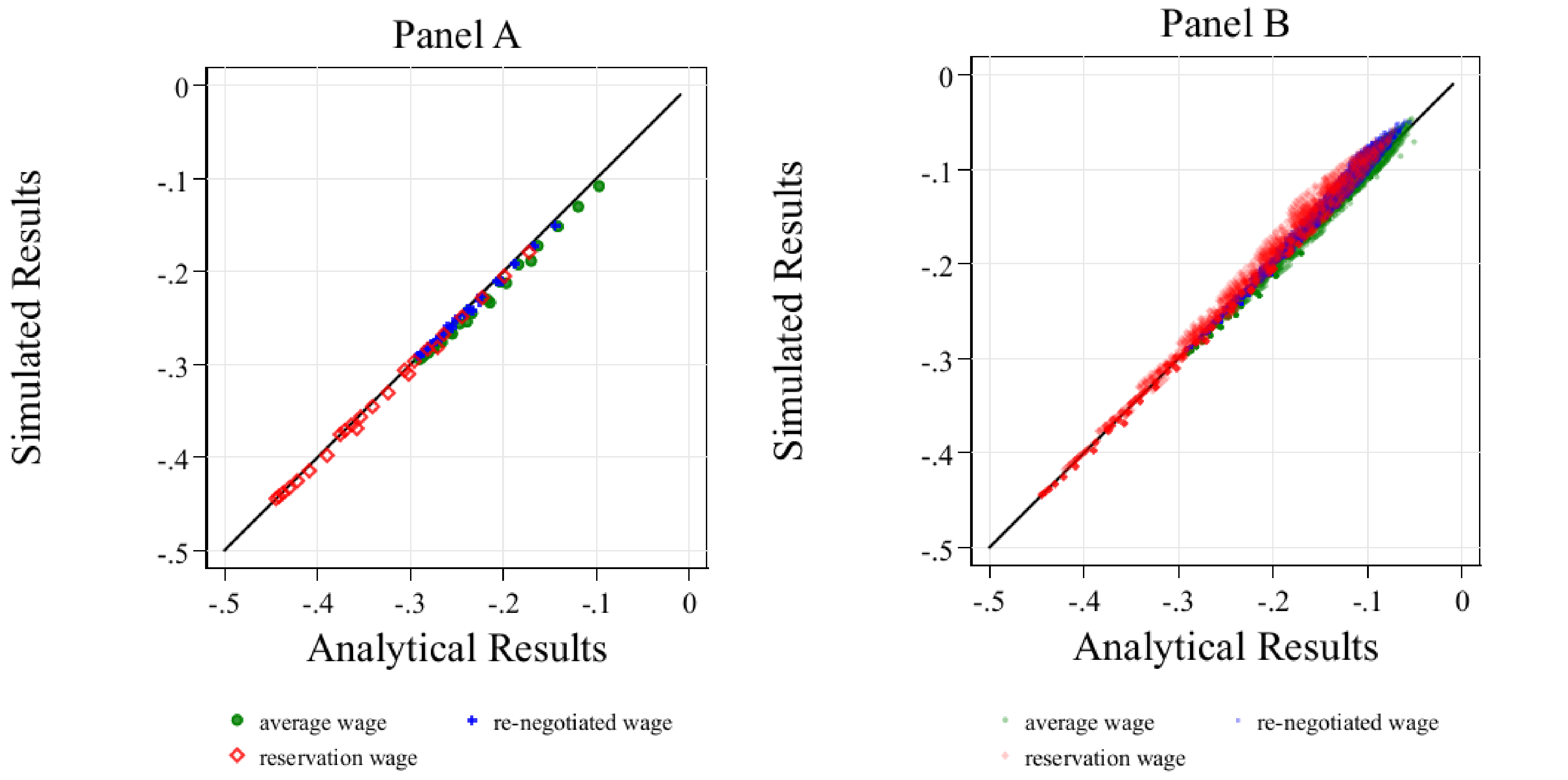
D.7 Analytical results vs. simulations

In the simulated model, the source of shocks is given by productivity fluctuations, which directly impact the job creation condition (63). We assume an autoregressive productivity process with a monthly persistence parameter of 0.983 and a standard deviation of 0.007 (Gertler and Trigari, 2009; Gertler et al., 2020). We also normalize steady state productivity to 1. We simulate 10,000 months and discard the first 500.

Panel A in Figure D1 plots analytical against simulated elasticities in the canonical model ($\alpha_\rho = 0$) for alternative combinations of $\alpha \in [0.3, 1]$ and $\phi \in [0.08, 0.2]$, keeping all other parameters at benchmark values. For the analytical results, as we do not have estimates for ξ_w and ξ_ρ, we calibrate all persistence parameters (including ξ_u) to those predicted by the simulated model. For the simulated results, elasticities are obtained from regressions of log simulated wages and reservation wages on log simulated unemployment. The two methods produce near identical results, with a coefficient of correlation of 0.999. Our closed-form expression can therefore closely replicate results from simulated models based on productivity shocks.

Panel B comparer analytical and numerical simulations for alternative combinations of $\alpha \in [0.3, 1]$, $\phi \in [0.08, 0.2]$, $\frac{\alpha_\rho}{1+\alpha_\rho} \in [0, 0.7]$ and $\alpha_l \in [0.3, 1]$. The plot shows that analytical results closely track the simulated results, with a correlation of 0.993.

Figure D1: Analytical and Simulated Results



Notes. Panel A plots simulated against analytical elasticity results for the forward-looking model, for 72 parameter combinations of $\alpha \in [0.3, 1]$ and $\phi \in [0.06, 0.16]$. Panel B plots corresponding results for the model with reference dependence, for 4608 parameter combinations of $\alpha \in [0.3, 1]$, $\phi \in [0.06, 0.16]$, $\frac{\alpha_\rho}{1+\alpha_\rho} \in [0, 0.7]$, $\alpha_l \in [0.3, 1]$. The correlation coefficient between simulated and analytical results is 0.999 in Panel A and 0.993 in Panel B.

E Estimates of reference dependence in reservation wages

The observed relationship between reservation wages and pre-unemployment wages is informative of backward-looking reference dependence, but may be subject to biases. For example, a direct link between unemployment benefits and past wages (as in Germany), will give a role for lagged wages in determining reservation wages. But in the UK benefits only vary (coarsely) with family composition, and are not directly linked to previous wages. We thus restrict the analysis that follows to the UK.

A second possible source of bias comes from unobserved productivity components of past wages, which are reflected in reservation wages in the canonical model via their effect on the wage offer distribution. Our approach consists in isolating the component of past wages that can be reasonably interpreted as rents – as opposed to productivity – and observe its correlation with reservation wages. A rational worker would not use past rents in forming their current reservation wage (absent wealth effects, which we find to be unimportant in our sample), whereas a worker who uses past wages as a reference point might do so. Consider a simple empirical model for the reservation wage:

$$\ln \rho_t = \beta_1 X_t + \beta_2 w^* + \beta_3 R_{t-d} + \varepsilon_t,$$

where X_t denotes observable characteristics, w^* denotes worker ability, and R_{t-d} denotes rents in the last job observed, d periods earlier. The coefficient of interest is β_3. Assume the following model for the last observed wage:

$$\ln w_{t-d} = \gamma_1 X_{t-d} + w^* + R_{t-d} + u_{t-d}.$$

If one regresses the reservation wage on the last observed wage as in:

$$\ln \rho_t = \delta_1 X_t + \delta_2 \ln w_{t-d} + \varepsilon_t, \tag{98}$$

the OLS estimate for δ_2 would capture the effect of both unobserved heterogeneity and rents on the reservation wage. Identification of the effect of interest requires an instrument that represents a component of past rents, while being orthogonal to worker ability.

We use wage differentials associated with industry affiliation as a proxy for the size of rents, in line with a long-established literature concluding that part of inter-industry wage structure reflects rents (see Krueger and Summers 1988; Gibbons and Katz 1992 for classic references and Benito 2000; Carruth et al. 2004 for UK evidence). Specifically, we instrument previous wages using the predicted, inter-industry wage differential obtained on administrative data from the Annual Survey of Hours and Earnings (ASHE). We estimate a log wage equation for 1982-2009 on ASHE, controlling for 4-digit industry effects, unrestricted age effects, region, and individual fixed effects. These capture the component of inter-industry wage differentials that is uncorrelated to individual unobservables, which is important for our exclusion restriction. We match the estimated industry effects to individual records in the BHPS, and use them as an instrument for last observed wages in reservation wage regressions.

Having controlled for unobserved heterogeneity in the construction of our instrument, the exclusion restriction would still be violated if rents in previous jobs would contribute to savings, in turn affecting utility during unemployment. This does not seem to be a major issue in our working sample, in which more than three quarters of unemployed workers have no capital income, and another 11% have capital income below 100GBP per year. But we control for wealth effects, if any, by including indicators for household assets and housing tenure in the estimated reservation wage equations.

Table E1 reports IV estimates of the reservation wage equation (98). The sample is smaller than the original sample of Table 2, as for about 45% of the reservation wage sample no previous jobs are recorded. The coefficient on the wage in the last job is positive and significant, and robust to the inclusion of individual fixed-effects (in which case the coefficient of interest is identified by the sample of individuals with multiple unemployment spells originating from different 4-digit industries). The stability of the coefficient across the two specifications implies that the estimated impact of past wages is not substantially confounded by unobserved ability, as one would expect when past wages are instrumented by their rent components.

Table E1: Reservation Wages and Rents in Previous Jobs

	1	2
Estimation method	IV	IV
Last observed log wage	0.134	0.145
	(0.017)	(0.062)
Individual fixed effects		✓
Observations	7,789	5,566
First stage, F-stat	674.6	314.8

Notes. Regressions also control for log unemployment rate, a quadratic time trend, a gender dummy, age and its square, three education dummies, a cubic trend in the number of years since the last job was observed, a dummy for married, the number of children in the household, the log of unemployment benefits, three dummies for levels of capital income, three dummies for housing tenure and eleven region dummies. The instruments used for last observed wage is the predicted industry wage (4-digit) in the previous job. Standard errors are clustered at the year level. Source: BHPS, 1991-2009.