Labor-market Frictions, Incomplete Insurance and Severance Payments*

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Abstract

We analyze the effects of government-mandated severance payments in a rich life-cycle model with search-matching frictions in the labor market, risk-averse agents and imperfect insurance against idiosyncratic shocks. Our model emphasizes a tension between worker-firm wage bargains and consumption smoothing: entry wages respond to expected future severance payments by tilting downwards, which runs counter to having a smooth consumption path. Quantitatively, we find that these wage-shifting effects are sizable enough for severance payments to produce large welfare losses. Our assessment contrasts sharply with previous studies that restricted the extent of worker-firm bargaining to analyze the welfare implications of severance payments.

Keywords: Severance Payments, Labor-market Frictions, Precautionary Savings, Welfare

JEL codes: E21; I38, J63, J65

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1 Introduction

The effects of government-mandated severance payments on equilibrium allocations and welfare is a topic of keen interest in macro and labor economics.[1] Two approaches dominate the literature. In the first one, bargaining between firms and workers plays a key role. The insight is that, in tune with Lazear [1988, 1990]'s bonding critique, the outcomes of the bargaining process determine whether or not severance payments have any effect on equilibrium allocations.[2] Most papers in this vein of the literature, however, assume risk-neutral preferences, making it hard to rely on welfare considerations to explain why severance payments should be introduced in the first place. In the other approach, agents are risk averse and severance payments have non-trivial welfare implications. A strand of the literature following this approach, and which we discuss below, proceeds using incomplete market models. Meanwhile, due to the complexity of this class of models, this research typically rules out worker-firm bargaining. As a result, not much is known about the equilibrium and welfare effects of severance payments when workers care about consumption smoothing and bargain with firms.

This paper contributes to filling this gap in the literature. We revisit the classic question of how severance payments affect equilibrium labor market allocations and workers' welfare, using a model that combines the strengths of the two approaches described above.

We bring together mainly three ingredients to study the effects of severance payments. First, we use the search-matching model with incomplete markets developed by Krusell et al. [2010], in which we introduce endogenous job separations as in Bils et al. [2011]. Our motivation for including this feature is that one of the purposes of severance payments is to improve job security by deterring firms from laying off workers. Second, we consider two-tier employment relationships between firms and workers along the lines of Mortensen and Pissarides [1999]'s textbook model. So doing, we aim to capture the fact that severance payments affect new hires and incumbent workers differently. Third, given the strong age components of worker productivity, job separations and asset holding decisions, and their importance for understanding the effects of severance payments, we cast the model in a life-cycle setting. Our framework therefore also captures the implications of a finite working life-time on labor market trajectories (Chéron et al. [2011, 2013]). We use data moments and policies for the United States (U.S.) to inform the model and proceed with a quantitative analysis.

The main results of the paper are as follows. We emphasize that severance payments lead to a steepening of the wage profile, as the wages paid to newly-hired workers are discounted to (partially) offset future severance payments. This outcome is a reflection of Lazear [1988, 1990]'s bonding critique, although severance payments are not fully neutralized in our quantitative exercise due to the sources of incompleteness embedded in the model. The key observation is

[1] Government-mandated severance payments are widespread in OECD countries (OECD [2013]). A key distinction is that between the firing tax paid by the employer and the compensation transferred to the dismissed employee. In this paper, we focus on the transfer component of severance payments and disregard the other costs (e.g. red tape, bureaucracy) that might be involved in the dismissal procedure.

[2] Lazear [1988, 1990]'s bonding critique states that severance payments can be undone by efficient worker-firm bargains. Agents agree to lower the entry wage by an amount compensating for the expected future transfer, leaving unchanged the cumulative wage bill and, therefore, employment decisions. The name 'bonding critique' refers to the fact that the reduction in entry wages is akin to a bond issued by the newly-hired worker.

that this tilted wage profile runs counter to having a smooth consumption path. Consequently, we find that severance payments produce mostly negative welfare effects for workers. In the baseline experiment, introducing the severance pay rates that prevail in Southern European countries reduces welfare in a way that is equivalent to reducing consumption at every stage of the life cycle by more than 1 percent. We also tabulate that no less than 40 percent and up to 80 percent of the figure is driven by the wage-shifting response of severance payments. Although these figures include wage changes that are coming from general equilibrium responses of the economy, they give a sense of the importance of the wage-shifting effect highlighted by our model. In particular, faced with high government-mandated severance payments, firms open up fewer vacant jobs.[3] Employment deteriorates because severance payments reduce its inflows (the probability to find a job), while at the same time they have little impact on employment outflows (the probability to lose a job).

We provide several analyses to complement these results. We show that life-cycle factors – namely, the hump-shaped profile of worker productivity and the higher risk of job separation among young workers – must be accounted for in order to capture the full welfare cost of severance payments. We also show that pension benefits mitigate the welfare cost somewhat, while a tighter borrowing limit turns out to have little impact on the results. In these variants of the model, the wage-shifting effects remain the key mechanism to understand the welfare consequences of severance payments.

Related literature. A key antecedent of this paper is Alvarez and Veracierto [2001]. We actually delve into examining the converse of some of the assumptions made in their study. Alvarez and Veracierto use a Hopenhayn and Rogerson [1993] firm-level dynamics model (with incomplete insurance markets), whereas we consider a one-worker-one-firm setup *à la* Mortensen and Pissarides [1994]. Their model features a single wage level which is competitively determined, whereas wages in our economy are set through worker-firm bargains splitting the rents from employment. Alvarez and Veracierto assume that workers choose their own probability of employment by making search efforts, whereas a matching function pins down the amount of search frictions (congestion externality) in our economy. Besides these and other differences, Alvarez and Veracierto [2001]'s model yields the conclusion that severance payments improve welfare via their *firing penalty role*, by preventing workers from going unemployed too often.

What is the main reason explaining the difference between Alvarez and Veracierto [2001]'s conclusions and ours? As pointed out by Ljungqvist [2002], the firm-level dynamics vs. the one-worker-one-firm setup is not essential to determine the employment effects of severance payments. It is instead the rigid wage contracts of Alvarez and Veracierto's model that drive this difference.[4] These contracts lead to socially wasteful separations, which in turn opens up a role for severance payments to enhance welfare. This benefit vanishes in our model as we allow workers and firms to make efficient decisions over job separations.

[3] As we have just mentioned, the decrease in entry wages does not fully offset severance payments, meaning that firms adjust at the extensive margin by lowering job creation. We evaluate that the dip in entry wages would have to be up to 30 percent larger to fully offset severance payments.

[4] Alvarez and Veracierto [2001] assume a single wage level mainly for tractability reasons. Fella [2000] demonstrates that if wages are downward rigid, then the layoff rate can be inefficiently elevated and a firing tax has the potential to Pareto-improve the resource allocation of the labor market.

Another contribution closely related to this paper is Cozzi and Fella [2016]. Their model economy resembles ours in many ways: insurance markets are incomplete, production takes place in one-worker-one-firm units and wages are set through Nash bargaining. However, Cozzi and Fella set the bargaining power of firms to zero, hence effectively giving all the match surplus to workers and shutting down the response of firms' job creation efforts. Another difference is that job separations are exogenous in Cozzi and Fella's model. But the fundamental point of departure between theirs and our analysis is that they introduce permanent earnings losses after job displacement to study severance payments (see, also, Rogerson and Schindler [2002]). By carefully making their model reproduce those earnings losses, Cozzi and Fella [2016] show that severance payments can play a positive *insurance role*. This role is muted in our model since, as is well known (e.g., Davis and von Wachter [2011]), earnings losses generated by the standard Mortensen and Pissarides [1994] model are mostly transitory.

The few other contributions in the literature that study severance payments in labor market models populated by risk-averse workers do not consider a full-blown model of incomplete markets. Bertola [2004] analyzes a stylized model with uninsurable income shocks, where severance payments can play a useful role by redistributing reallocation costs towards risk-neutral firms. Pissarides [2004] establishes that optimal employment contracts should include a severance pay component so as to help workers smooth consumption. Fella and Tyson [2013] provide the foundations for privately-optimal severance payments in response to government mandates. Although their model features risk-averse agents and incomplete asset markets, they rule out wealth effects to obtain tractability (they use a constant absolute risk-aversion utility function). Last, Dolado et al. [2016] discuss the political economy problem of reforming severance payments in 'dual' labor markets with risk-averse agents. Our work complements the research in these papers by offering a quantitative study of severance payments in a realistic model with labor-market frictions, incomplete insurance and savings.

The rest of the paper is organized as follows. Section 2 presents the model economy. Section 3 proceeds with the calibration and describes some properties of the model. Section 4 contains the main results and discussion of the effects of severance payments. Section 5 provides a sensitivity analysis. Section 6 concludes.

2 The model

The model borrows from various sources: there are search-matching frictions in the labor market; job creation is endogenous; workers and firms bargain over wages and decide over match formation and job separations; there is a distinction between recent hires and incumbent workers; workers go through a life cycle that affects productivity and unemployment risk; they have access to an interest-bearing asset. The next subsection details these features.

2.1 Environment

Demographics and preferences. Time is discrete and runs forever. One side of the market is populated by overlapping generations of individuals who work, retire and die. The duration

of the working life and retirement are exogenous and fixed to N_w and N_r periods, respectively. A retired individual who dies is replaced by a new entrant in the labor market, so that the population size remains at a constant unit level. Agents are indifferent to their offspring. In every period, they derive utility from consumption $c_t > 0$ according to a constant relative risk-aversion function, $u(.)$, which is assumed to be strictly increasing and strictly concave. τ denotes an individual's age, and β is the subjective discount factor.

On the other side of the market, there is a continuum of risk-neutral, infinitely-lived firms. Firms maximize the expected value of the sum of profit streams. They use the net real interest rate r to discount the future.

Production technology. The unit of production is a matched worker-firm pair. The flow of output that it produces is given by $zf(y_t, \tau)$. z is a parameter common across all worker-firm pairs, which encapsulates the use and cost of capital (see Section 3 and Appendix A.2). y_t is idiosyncratic to the worker-firm pair and evolves stochastically over time according to a persistent Markov process. Hereafter $G(.|y)$ denotes the transition function for y_t, i.e. $G(y'|y) = \Pr\{y_{t+1} < y'|y_t = y\}$. Finally, since τ is the worker's age, the function $f(.,.)$ allows for an interaction between age and idiosyncratic match productivity. It is assumed, in addition, that a worker-firm pair is dissolved exogenously with a per-period probability λ_τ, that is also allowed to depend on the worker's age.

Labor-market frictions. Workers and firms come together via search. The number of contacts per unit of time is given by a constant-returns-to-scale matching function $m(u_t, v_t)$, where u_t is the number of unemployed people and v_t is the measure of vacancies. Letting $\theta_t = {}^{v_t}/_{u_t}$ denote labor-market tightness, the probability of a meeting is $q(\theta_t) = m\left(\theta_t^{-1}, 1\right)$ for a prospective firm, and $\theta_t q(\theta_t)$ for a prospective worker. On meeting, the potential worker-firm pair draws a productivity level y_t from the distribution $G_0(.)$, and the two agents decide whether to stay together or to walk away from one another. If they choose to stay together, the worker-firm pair starts producing using the technology described in a previous paragraph. Otherwise, they are returned to the pool of unmatched agents. Firms incur a per-period cost $\eta > 0$ as long as they hold a vacant position.

Government policies. There are three government-run programs in this economy:

1. The government provides pension benefits to retired individuals. Pension benefits consist of a fixed amount s and are financed by a flat-rate tax κ_s levied on labor income.

2. Newly unemployed workers are eligible to receive unemployment insurance (UI) benefits. The UI system pays a constant amount of benefits b_1 that is subject to exhaustion. After these benefits have expired, individuals move on to social assistance, meaning that they receive a lower level of benefits b_0 for an indefinite period of time. The provision of b_1 and b_0 is financed by means of a flat-rate tax on wages κ_b.

3. Employed workers with a sufficiently long tenure at their job are protected by severance payments (SP) in the process of bargaining. SP consist of a pure transfer T_τ from the

firm to the worker, and is allowed to depend on the worker's age.

Hereafter we use an index $i_u \in \{0, 1\}$ for unemployed workers to indicate whether or not they are eligible to receiving UI benefits. Likewise, for employed workers $i_e = 1$ means that they are protected by SP while $i_e = 0$ indicates otherwise. To economize on the state space, we assume that the exhaustion of UI benefits and the activation of SP are stochastic events. They are governed, respectively, by transition matrices

$$p_{i_u,j_u} = \begin{bmatrix} 1 & 0 \\ p_u & 1-p_u \end{bmatrix} \quad \text{and} \quad p_{i_e,j_e} = \begin{bmatrix} 1-p_e & p_e \\ 0 & 1 \end{bmatrix}$$

with $i_u, j_u, i_e, j_e \in \{0, 1\}$. Thus, p_u is the per-period probability of exhausting UI benefits and p_e is the per-period probability of becoming eligible to receiving SP.

Let us underline here that SP imply a two-tier employment system: after some period, SP shift the threat points of both the firm and the worker. The same mechanism operates in the textbook model of Mortensen and Pissarides [1999].[5] As long as $i_e = 0$, the firm's and worker's threat points are those that prevailed when the worker was first hired. For this reason, we call *entry-level* decisions and *entry* wages those indexed by $i_e = 0$ and, by contradistinction, refer to *continuation* decisions and *continuation* wages when $i_e = 1$. Last, it is also worth pointing out that SP are assumed to be enforced only in the bargaining process. That is, SP are waived when the worker retires from the workforce or when the job is destroyed by the exogenous λ_τ shock.[6] The reason is that our interest lies in the interaction between SP and shocks that can be contracted on. We nevertheless verify in Section 5 that this assumption is inconsequential for our analysis.

Other market arrangements. Workers and retirees face incomplete insurance markets. Hence they are subjected to a sequence of inter-temporal budget constraints:

$$c_t + a_{t+1} \leq (1 + r)a_t + x_t^d.$$

x_t^d denotes disposable income at time t and a_t is a risk-free asset that agents can save. Before retirement, agents are allowed to borrow up to an exogenous limit $\underline{a} \geq 0$, i.e. $a_t \geq -\underline{a}$. After retirement, they face the constraint that $\underline{a} = 0$.

Last, there is a mutual fund that owns all the firms in the economy. The role of the fund is to collect all profits and to pay out all SP earned by workers, so that no single firm can end up defaulting on its severance pay obligations.[7]

[5] Ljungqvist [2002] offers an examination of the outcomes of Mortensen and Pissarides [1999]'s two-tier employment model obtained under different assumptions on how firing costs alter the firm's threat point. Garibaldi and Violante [2005] provide an insightful discussion of the equilibrium implications of severance payments in a two-tier labor market, with wage rigidities that may have a 'bite' on the outsiders' wages or on the insiders' wages.

[6] Although retirement allows workers and firms to escape government-mandated SP in this setting, we find that the results are similar when we revoke that assumption. These results are available upon request.

[7] We thank an anonymous referee for drawing our attention to the possibility of defaulting and for suggesting using the 'mutual fund assumption' to remedy this issue.

2.2 Bellman equations

We will confine ourselves to stationary equilibria. In order to formulate workers' decision problems in recursive form, denote by R, U, W the asset values of retirement, unemployment and employment, respectively. For employers, denote by J the asset value of having a filled job. Hereafter, a prime ($'$) indicates the one-period-ahead value of a variable. Since age evolves deterministically, we have $\tau' = \tau + 1$.

Beginning with retired workers, their asset value solves the equation:

$$R(a,\tau) = \max_{c,a'} \{u(c) + \beta R(a',\tau')\} \tag{1}$$

subject to

$$\begin{aligned} c + a' &\leq (1+r)a + s \\ a' &\geq 0 \end{aligned}$$

for every $N_w + 1 \leq \tau \leq N_w + N_r$, and where $R(a, N_w + N_r + 1) = 0$ for every a.

For unemployed workers, there are two asset values indexed by their eligibility status for UI benefits, $i_u \in \{0,1\}$. These asset values are the solution to:

$$\begin{aligned} U_{i_u}(a,\tau) = \max_{c,a'} \Bigg\{ & u(c) + \beta \sum_{j_u=0,1} p_{i_u,j_u} \Big((1-\theta q(\theta)) U_{j_u}(a',\tau') \\ & + \theta q(\theta) \int \max\{W_0(y',a',\tau'), U_{j_u}(a',\tau')\} dG_0(y') \Big) \Bigg\} \end{aligned} \tag{2}$$

subject to

$$\begin{aligned} c + a' &\leq (1+r)a + (1-\kappa_s) b_{i_u} \\ a' &\geq -\underline{a} \end{aligned}$$

for every $1 \leq \tau \leq N_w$, and where $U_{i_u}(a, N_w + 1) = R(a, N_w + 1)$ for every i_u and a.

For employed workers, the asset values depend on a and τ, on their eligibility status for SP, $i_e \in \{0,1\}$, and on match productivity y. These asset values solve:

$$\begin{aligned} W_{i_e}(y,a,\tau) = \max_{c,a'} \Bigg\{ & u(c) + \beta \Bigg(\lambda_{\tau'} U_1(a',\tau') \\ & + (1-\lambda_{\tau'}) \sum_{j_e=0,1} p_{i_e,j_e} \int \max\{W_{j_e}(y',a',\tau'), U_1(a' + T_{\tau,j_e}, \tau')\} dG(y'|y) \Bigg) \Bigg\} \end{aligned} \tag{3}$$

subject to

$$\begin{aligned} c + a' &\leq (1+r)a + (1-\kappa_s-\kappa_b) w_{i_e}(y,a,\tau) \\ a' &\geq -\underline{a} \end{aligned}$$

for every $1 \leq \tau \leq N_w$, and where $W_{i_e}(y, a, N_w + 1) = R(a, N_w + 1)$ for every i_e, y and a. In equation (3) we use T_{τ,j_e} as a short notation for $T_\tau \times \mathbb{1}\{\tau < N_w, j_e = 1\}$, i.e. T_{τ,j_e} depends on age and eligibility status. $w_{i_e}(y, a, \tau)$ in the budget constraint denotes the worker's wage, which is determined through bargaining (details follow).

Associated with equation (1) is a decision rule for asset holdings $\overline{a}^R(a, \tau)$. Similarly, associated with equations (2) and (3) are sets of decisions rules for asset holdings $\overline{a}_0^U(a, \tau)$, $\overline{a}_1^U(a, \tau)$, and $\overline{a}_0^W(y, a, \tau)$, $\overline{a}_1^W(y, a, \tau)$, respectively.

Last, we turn to the asset values of firms. There is free entry of firms, so that the asset value of holding a vacant position is always zero. For firms with a filled job matched to a worker whose eligibility status for SP is $i_e \in \{0, 1\}$, the asset values solve:

$$J_{i_e}(y, a, \tau) = zf(y, \tau) - w_{i_e}(y, a, \tau) + \frac{1 - \lambda_{\tau'}}{1 + r} \sum_{j_e=0,1} p_{i_e,j_e} \int \max\{J_{j_e}(y', a', \tau'), -T_{\tau,j_e}\} dG(y'|y) \tag{4}$$

for every $1 \leq \tau \leq N_w$, and where $J_{i_e}(y, a, N_w + 1) = 0$ for every i_e, y and a. T_{τ,j_e} is, as in equation (3), a short notation for $T_\tau \times \mathbb{1}\{\tau < N_w, j_e = 1\}$, and $a' = \overline{a}_{i_e}^W(y, a, \tau)$: the firm recognizes that the worker's next period asset decision is given by the policy function $\overline{a}_{i_e}^W(y, a, \tau)$.

2.3 Wage setting

Wages are set via Nash bargaining. To define the Nash product, we assume that the outside option of the worker is the asset value of receiving UI benefits, $U_1(.)$. We think this is relevant for a number of reasons. First, in standard search-matching models, UI benefits are supposed to exert a push effect on wages throughout the duration of employment. In order to generate this outcome, one should let the incumbent worker use $U_1(.)$ as her threat point to bargain with the firm. An empirical justification for this is that fair and unfair dismissals cannot be distinguished, but generally the burden of the proof that a dismissal was fair lies with the employer.[8] Next, consider newly-hired workers. For those receiving UI benefits, $U_1(.)$ is the relevant outside option on meeting an employer. For those currently under social assistance, one could use $U_0(.)$ as the initial outside option and switch it to $U_1(.)$ after one period of employment.[9] There is however little gain in insight from adopting this approach, and, in our view, it is far outweighed by the computational cost of adding a state variable for the first employment period. Therefore we use $U_1(.)$ to define the outside option of all workers.

[8]See, for instance, the case study of unemployment insurance law in the State of California discussed in Hagedorn et al. [2015]. The authors argue that in general a worker can bargain for a higher wage by threatening the employer to induce a firing. That is, a worker fired for misconduct is not eligible for UI benefits, but proving misconduct is very costly for the employer. In other words, the worker is *de facto* able to use the value of receiving UI benefits as her outside option.

[9]We clearly abstract from details of UI eligibility in this discussion. To take one example, a common rule in many U.S. states is 'monetary eligibility': it dictates that, in order to be eligible for UI benefits, the worker must have received a minimum level of earnings in the base period, which is typically four calendar quarters prior to the start of the unemployment spell. Understanding the effects of such eligibility requirements is interesting in its own right and lies beyond the scope of our analysis.

It follows from this discussion that the wage schedule $w_{i_e}(.)$, indexed by $i_e \in \{0,1\}$, is defined for all (y,a,τ) by

$$w_0(y,a,\tau) = \arg\max \left\{ (W_0(y,a,\tau) - U_1(a,\tau))^{\phi} J_0(y,a,\tau)^{1-\phi} \right\} \tag{5}$$

for those not yet protected by SP, and by

$$w_1(y,a,\tau) = \arg\max \left\{ (W_1(y,a,\tau) - U_1(a+T_\tau,\tau))^{\phi} (J_1(y,a,\tau) + T_\tau)^{1-\phi} \right\} \tag{6}$$

in all subsequent employment periods. In equations (5) and (6), $\phi \in (0,1)$ is the worker's bargaining power.

2.4 Match decision rules

Entry-level decisions are based on the comparison between the asset value of hiring a worker and the asset value of continued search. Similarly, match-continuation decisions follow from comparing the asset value of continuing employment with that of dissolving the match. Thus there are two threshold functions $\overline{y}_0(a,\tau)$ and $\overline{y}_1(a,\tau)$ defined by:

$$J_0(\overline{y}_0(a,\tau), a, \tau) = 0 \tag{7}$$

$$J_1(\overline{y}_1(a,\tau), a, \tau) = -T_\tau \tag{8}$$

for all (a,τ).

2.5 Aggregate conditions

Labor-market tightness θ, pension benefits s and the tax rate κ_b are pinned down by aggregate equilibrium conditions. To write these conditions, denote by $\mu^R(a,\tau)$, $\mu_0^U(a,\tau)$, $\mu_1^U(a,\tau)$, $\mu_0^W(y,a,\tau)$, $\mu_1^W(y,a,\tau)$ the population distribution of agents in, respectively, retirement, unemployment and employment.

Free entry. Free entry into the market implies that firms exhaust the present discounted value of job creation net of the cost of a vacancy. As vacant jobs and unemployed workers meet by the end of a model period, the free-entry condition yields:

$$\frac{\eta}{q(\theta)} = \frac{1}{1+r} \sum_{\tau=1}^{N_w-1} \sum_{i_e=0,1} \int_{\mathcal{Y},\mathcal{A}} \max\left\{ J_0\left(y', \overline{a}_{i_e}^U(a), \tau'\right), 0 \right\} dG_0(y') \frac{\mu_{i_e}^U(a,\tau)}{u_{N_w-1}} da. \tag{9}$$

$\mathcal{Y}$ and $\mathcal{A}$ denote the support for match productivity and asset holdings, respectively. To obtain the relevant conditional distribution on the right-hand side of the equation, $\mu_{i_e}^U(.)$ is scaled by the size of the pool of job seekers, which is denoted as u_{N_w-1} (the subscript indicates agents of age less than $N_w - 1$ periods). Notice that we have already made use of the free-entry condition in equations (4), (5)–(6) and (7)–(8).

Balanced budget. Last, the balanced-budget conditions are:

$$\kappa_s \sum_{\tau=1}^{N_w} \left(\sum_{i_e=0,1} \int_{\mathcal{Y},\mathcal{A}} w_{i_e}(y,a,\tau)\, d\mu_{i_e}^W(y,a,\tau) + \sum_{i_u=0,1} b_{i_u} \int_{\mathcal{A}} d\mu_{i_u}^U(a,\tau) \right) = \sum_{\tau=N_w+1}^{N_w+N_r} \int_{\mathcal{A}} s d\mu^R(a,\tau), \tag{10}$$

$$\kappa_b \sum_{\tau=1}^{N_w} \sum_{i_e=0,1} \int_{\mathcal{Y},\mathcal{A}} w_{i_e}(y,a,\tau)\, d\mu_{i_e}^W(y,a,\tau) = \sum_{\tau=1}^{N_w} \sum_{i_u=0,1} b_{i_u} \int_{\mathcal{A}} d\mu_{i_u}^U(a,\tau). \tag{11}$$

Equation (10) gives the value of pension benefits s for a given tax rate κ_s. Equation (11) pins down the UI tax rate κ_b.

2.6 Equilibrium

We are in a position to define a stationary equilibrium of the model. A stationary equilibrium is a list of asset values $(R(a,\tau),\ U_0(a,\tau),\ U_1(a,\tau),\ W_0(y,a,\tau),\ W_1(y,a,\tau),\ J_0(y,a,\tau),\ J_1(y,a,\tau))$, a list of decisions rules for asset holdings $\left(\overline{a}^R(a,\tau),\ \overline{a}_0^U(a,\tau),\ \overline{a}_1^U(a,\tau),\ \overline{a}_0^W(y,a,\tau),\ \overline{a}_1^W(y,a,\tau)\right)$, a list of match entry-level and continuation rules $(\overline{y}_0(a,\tau),\ \overline{y}_1(a,\tau))$, a list of wage functions $(w_0(y,a,\tau),\ w_1(y,a,\tau))$, a population distribution across labor market status, match productivity, assets and age $\left(\mu^R(a,\tau),\ \mu_0^U(a,\tau),\ \mu_1^U(a,\tau),\ \mu_0^W(y,a,\tau),\ \mu_1^W(y,a,\tau)\right)$, a value of labor-market tightness θ, pension benefits s and tax rate κ_b such that:

1. Optimal asset-holding decisions: given pension benefits s, the asset-holding decision $\overline{a}^R(a,\tau)$ solves the inner maximization problem in equation (1); given labor-market tightness θ, tax rate κ_b and the wage schedules $w_0(y,a,\tau)$, $w_1(y,a,\tau)$, the asset-holding decisions $\overline{a}_0^U(a,\tau)$, $\overline{a}_1^U(a,\tau)$, $\overline{a}_0^W(y,a,\tau)$, $\overline{a}_1^W(y,a,\tau)$ solve the inner maximization problem in equations (2) and (3).

2. Firms optimize: given the wage schedules $w_0(y,a,\tau)$, $w_1(y,a,\tau)$ and the asset-holding decisions of workers $\overline{a}_0^W(y,a,\tau)$, $\overline{a}_1^W(y,a,\tau)$, the asset values $J_0(y,a,\tau)$, $J_1(y,a,\tau)$ satisfy equation (4).

3. Optimal match entry-level and continuation decisions: given firms' asset values $J_0(y,a,\tau)$ and $J_1(y,a,\tau)$, the match-entry and the match-continuation rules $\overline{y}_0(a,\tau)$, $\overline{y}_1(a,\tau)$ are the solution to equations (7) and (8).

4. Nash bargaining: given the asset values $U_1(a,\tau)$, $W_0(y,a,\tau)$, $W_1(y,a,\tau)$, $J_0(y,a,\tau)$, $J_1(y,a,\tau)$, the wage functions $w_0(y,a,\tau)$, $w_1(y,a,\tau)$ are the solution to the maximization problem defined by equations (5) and (6).

5. Free-entry condition: given the asset value $J_0(y,a,\tau)$, asset-holding decisions $\overline{a}_0^U(a,\tau)$, $\overline{a}_1^U(a,\tau)$ and the population distribution $\mu_0^U(a,\tau)$, $\mu_1^U(a,\tau)$, labor-market tightness θ is pinned down by equation (9).

6. Balanced-budget conditions: given the wage schedules $w_0(y,a,\tau)$, $w_1(y,a,\tau)$ and the population distributions $\mu^R(a,\tau)$, $\mu_0^U(a,\tau)$, $\mu_1^U(a,\tau)$, $\mu_0^W(y,a,\tau)$, $\mu_1^W(y,a,\tau)$, pension benefits s and the tax rate κ_b satisfy, respectively, equations (10) and (11).

7. Equilibrium distribution: $\left(\mu^R(a,\tau),\ \mu_0^U(a,\tau),\ \mu_1^U(a,\tau),\ \mu_0^W(y,a,\tau),\ \mu_1^W(y,a,\tau)\right)$ satisfies the equilibrium stock-flow equations implied by the sets of decision rules $\left(\overline{a}^R(a,\tau),\ \overline{a}_0^U(a,\tau),\ \overline{a}_1^U(a,\tau),\ \overline{a}_0^W(y,a,\tau),\ \overline{a}_1^W(y,a,\tau)\right)$ and $(\overline{y}_0(a,\tau),\ \overline{y}_1(a,\tau))$, and by the job-finding probability implied by labor-market tightness θ.

The stock-flow equations across the different states of the economy (condition 7 in the above definition) can be deduced from the model's description in Subsection 2.1. We complete this description by assuming that newborn agents ($\tau = 1$) start off their lives in unemployment (U_{i_u}), without UI benefits ($i_u = 0$), and with zero asset holding ($a = 0$).

The numerical methodology and algorithm used to compute a stationary equilibrium of the model are presented in Appendix A.1.

3 Calibration

This section proceeds with the calibration of the model with no government-mandated SP (i.e. $T_\tau = 0$ for all τ). We use U.S. data and policies to conduct this exercise.[10] In the first step of the calibration, we choose the value of several parameters using auxiliary *a priori* information. This includes several data moments of our own based on data from the Current Population Survey, which we describe in Appendix B. The remaining parameters are jointly calibrated in a subsequent step. Before we move on to the numerical experiments, we discuss some properties of the model with no SP.

3.1 Parameters set externally

One model period is set to be half a quarter. We interpret the working life as a 40-year period (starting at age 20) and retirement as a 15-year period. Accordingly, $N_w = 320$ and $N_r = 120$. The intra-period utility function is

$$u(c) = \frac{c^{1-\gamma} - 1}{1-\gamma}.$$

We set the coefficient of relative risk aversion γ to 2, which is a standard value in the literature. The discount factor β is 0.9951 to target an annual rate of 4 percent.

Idiosyncratic match productivity evolves according to a first-order autoregressive process:

$$y' = (1-\rho)\,\varphi + \rho y + \varepsilon'.$$

φ is the unconditional mean of the process, $\rho \in (0,1)$ is the persistence and $\varepsilon' \sim \mathcal{N}(0,\sigma^2)$ is the innovation term. In addition, we assume that $G_0(.) = G(.|\varphi)$. The unconditional mean, φ, is normalized to 1. We use the estimates shown in Table 1 of Chang and Kim [2006] for the persistence of the stochastic process. The authors report a value of 0.781 for men and 0.724 for

[10] Government-mandated SP are virtually non-existent in most U.S. states. This suggests that the dynamics of the U.S. labor market is directly informative for the model, in that we need not control for an unobserved part of the empirical dynamics that would be driven by SP.

women in annual data. The average of these numbers is 0.752, which yields $\rho = 0.752^{1/8} = 0.965$ at the semi-quarterly frequency. The value of the standard deviation of shocks, σ, is set below as part of the second step of the calibration exercise.

We assume complementarity between match productivity and the productivity of a worker of age τ. Following a long tradition in macro and labor economics (e.g., Hansen [1993]), we construct an age-productivity profile by looking at the behavior of wage rates over the life cycle. Specifically, data from the Current Population Survey (CPS) strongly support a hump shape for this profile (see Appendix B). Therefore we use the functional form:

$$f(y, \tau) = y \times \left(\xi_0 + \xi_1 \tau + \xi_2 \tau^2\right).$$

The parameter values for ξ_0, ξ_1, ξ_2 are those that we obtain from CPS data. Starting from 0.54 on entering the labor market, the profile $\xi_0 + \xi_1 \tau + \xi_2 \tau^2$ increases initially, passes through 1.0 after 14 years, peaks at 1.16, and decreases to the value of 1.07 at the end of the working life.

We use a standard Cobb-Douglas matching function for the computations, namely

$$m(u, v) = M u^{\chi} v^{1-\chi}.$$

The parameter for matching efficiency, M, is calibrated below in the next subsection. We set the elasticity of the job filling probability with respect to labor-market tightness, χ, to 0.50. As is standard (e.g. Bils et al. [2011]), we use the same parameter value for the bargaining power of workers, ϕ, in the baseline calibration.

CPS data analyzed in Appendix B show that the job separation rate decreases in a convex fashion over the life cycle. Accordingly, the functional form we choose for λ_τ is

$$\lambda_\tau = \bar{\lambda} \times \exp\left(\varsigma_0 + \varsigma_1 \tau + \varsigma_2 \tau^2\right).$$

ς_0, ς_1, ς_2 are set to the values computed from the data. $\bar{\lambda}$ is what we refer to as the job separation scale parameter. As the name suggests, $\bar{\lambda}$ allows to scale, or control, the relative importance of λ_τ in explaining the job separation rate. Thus, the value of $\bar{\lambda}$ is set internally within the calibration (next subsection).

The remaining parameter values that we set using *a priori* information are κ_s, p_u, p_e. First, for pension benefits, we take the sum of the two largest U.S. federal payroll taxes, namely the 12.4 percent tax to fund Social Security and the 2.9 percent tax to fund Medicare.[11] Thus we set κ_s to be 15.3 percent. The probability p_u is set to 0.250 to make UI benefits expire after 26 weeks, in line with U.S. policies. Last, $p_e = 0.125$ so that workers become eligible for SP on average 1 year after being hired.[12] Of course, p_e plays no role in the baseline equilibrium since SP are set equal to zero.

[11] See, e.g., figures reported by the Tax Policy Center at the Urban Institute and Brookings Institution: https://www.taxpolicycenter.org/briefing-book/key-elements-us-tax-system.

[12] The value we choose for p_e is mainly motivated by the fact that, in most countries with government-mandated SP, there is an entry phase (a temporary contract, a probationary period, etc.) during which the firm incurs little to no cost in case of dismissal (OECD [2013]). The entry phase period typically lasts between 3 months and 2 years, depending on country-specific institutional arrangements.

Table 1: Parameter values of the baseline model

Description	Parameter	Value
A. Parameters set externally		
Periods in the labor force	N_w	320
Periods in retirement	N_r	120
Subjective discount factor	β	0.9951
Relative risk aversion coefficient	γ	2.0
Mean of match productivity	φ	1.0
Persistence of match productivity	ρ	0.9650
Life-cycle profile, worker productivity	ξ_0	0.5338
	ξ_1 $(\times 10^2)$	0.5466
	ξ_2 $(\times 10^4)$	-0.1186
Elasticity of job filling w.r.t. tightness	χ	0.5
Bargaining power of workers	ϕ	0.5
Life-cycle profile, job separation	ς_0	-3.6795
	ς_1 $(\times 10^2)$	-0.7579
	ς_2 $(\times 10^4)$	0.1368
Pension benefits tax	κ_s	0.153
Probability of exhausting UI benefits	p_u	0.250
Probability of becoming eligible to SP	p_e	0.125
B. Parameters set internally		
Net real interest rate	r $(\times 10^2)$	0.4725
Borrowing limit	$\underline{a}$	4.5936
Volatility of match productivity	σ	0.1916
Matching efficiency	M	0.2747
Job separation scale parameter	$\bar{\lambda}$	1.4331
Vacancy posting cost	η	1.2259
Social assistance benefits	b_0	0.1191
UI benefits	b_1	1.0725

Notes: One model period is half a quarter. Panel A: The parameter value for the persistence of match productivity, ρ, is based on Chang and Kim [2006]'s estimates from the Panel Study of Income Dynamics. The parameter values for the life-cycle profiles of worker productivity, ξ_0, ξ_1, ξ_2, and job separation, ς_0, ς_1, ς_2, are our own estimates based on data from the Current Population Survey; see Appendix B. Panel B: The interest rate is pinned down by equilibrium on a competitive market for capital that allows firms to rent capital and use the production function $k^{\alpha}\ell^{1-\alpha}$; the parameter α is set to 0.3334 and the depreciation rate for capital is $\delta = 0.0125$; see Appendix A.2.

3.2 Calibrated parameters

To set parameter values for r, $\underline{a}$, σ, M, $\bar{\lambda}$, η, b_0, b_1, we use a set of calibration targets discussed in this subsection. Let us emphasize that, since the relevant model-generated moments are determined jointly, the calibrated parameters are also set jointly.

First and foremost, the net real interest rate, r, deserves special comments. We pin down its value by introducing a competitive rental market for capital and a Cobb-Douglas production function $k^{\alpha}\ell^{1-\alpha}$ running in the background of the model economy. k denotes physical capital, which depreciates at rate δ, and ℓ denotes labor inputs in efficiency units (so that $\ell = f(y,\tau)$). As explained in Appendix A.2, the flow profits of firms boil down to $zf(y,\tau) - w_{i_e}(y,a,\tau)$, i.e. the flow profits of the model in Section 2. z is a function of α, δ, and of the interest rate r whose value is pinned down by the equilibrium of the market for capital. For α we use a value of one third, and we set δ to 0.0125 to accord with an investment-to-output ratio of 20 percent. Given the very high computational cost of calculating the interest rate, we keep its value unchanged in the experiments of Section 4.[13]

Next, we target the following data moments for $\underline{a}$, σ, M, $\bar{\lambda}$, η, b_0, b_1. First, the fraction of agents with negative asset holdings is 12.5 percent, as suggested by the empirical evidence on the number of liquidity-constrained households (see Zeldes [1989] and Gorbachev [2011]). Second and third, the long-run monthly separation rate and monthly job finding rate are, respectively, at 3.5 percent and 45 percent (Krusell et al. [2010]). Fourth, we target a ratio of 50 percent between the number of endogenous job separation and the total number of job separations. That is, without a clear guidance from the data, we use a 50:50 split between exogenous and endogenous job separations in the baseline scenario and check the sensitivity to this choice in Section 5.[14] Fifth, the vacancy-posting cost amounts to 60 percent of the average monthly labor productivity (Hagedorn and Manovskii [2011]). Sixth and seventh, the replacement ratio of benefits is 5 percent for social assistance and 45 percent for UI benefits, in line with U.S. policies.[15]

3.3 Model outcomes

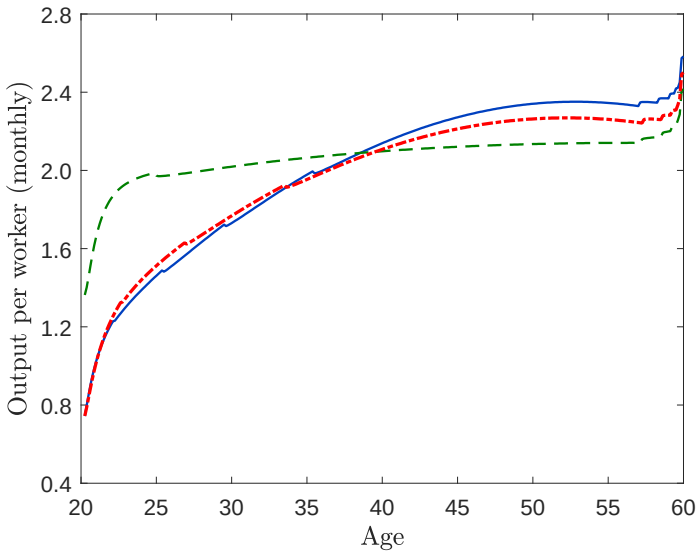
The parameter values of the baseline model are given in Table 1. Each parameter in Panel B of the table turns out to be closely related to a specific moment targeted by our calibration exercise. For instance, σ is closely related to the separation rate while M tightly controls the job finding rate.[16] As a result, we are able to match the targeted data almost exactly.

[13] However, whenever we consider a variant of the baseline model, we recalibrate r alongside the other parameters discussed in this subsection. As Table C1 in the appendix shows, each variant of the model has its own equilibrium value for the interest rate.

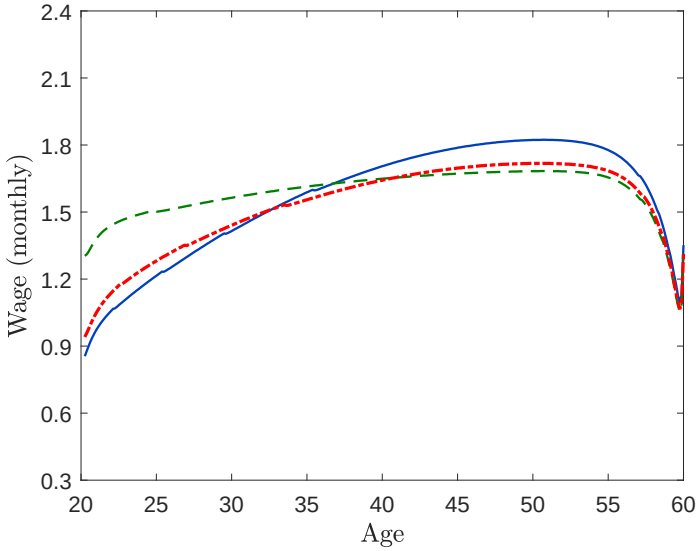
[14] In the data, layoffs account for only a share of all job separations, and some job separations must be caused by exogenous reasons that cannot be impacted by SP. It is unclear, however, how one should use the data on the reason for job separation to inform the model's calibration. It is likely that the reported reason for job separation *itself* is endogenous to SP, since this might affect the decision of firms and workers to label the job separation a quit or a layoff (Fella and Tyson [2013], Postel-Vinay and Turon [2014]).

[15] In the model, we measure the replacement ratio by taking the ratio between b_{i_u} and the average wage.

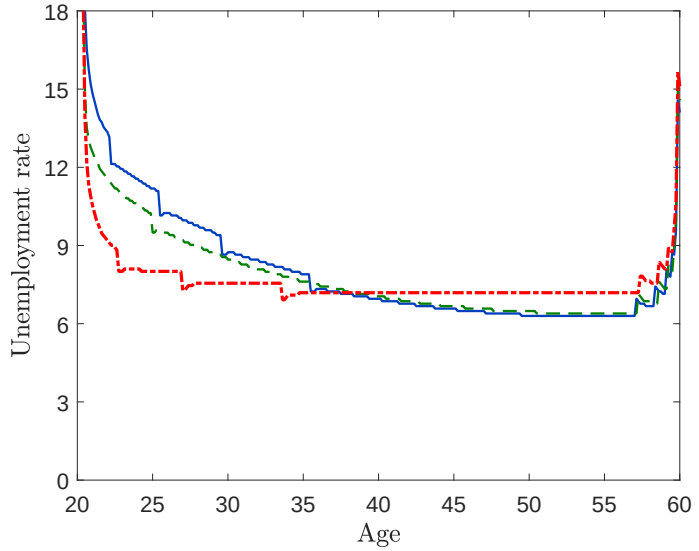
[16] The job finding probability is $\theta q(\theta)$. The job finding rate depends on this probability, and also on the decision for match formation $\overline{y}_0(a,\tau)$, match productivity draws $G_0(y)$, the cross-sectional distributions of unemployed agents $\mu_0^U(a,\tau)$ and $\mu_1^U(a,\tau)$ and their asset holding decisions $\overline{a}_0^U(a,\tau)$ and $\overline{a}_1^U(a,\tau)$.



(a) Worker productivity

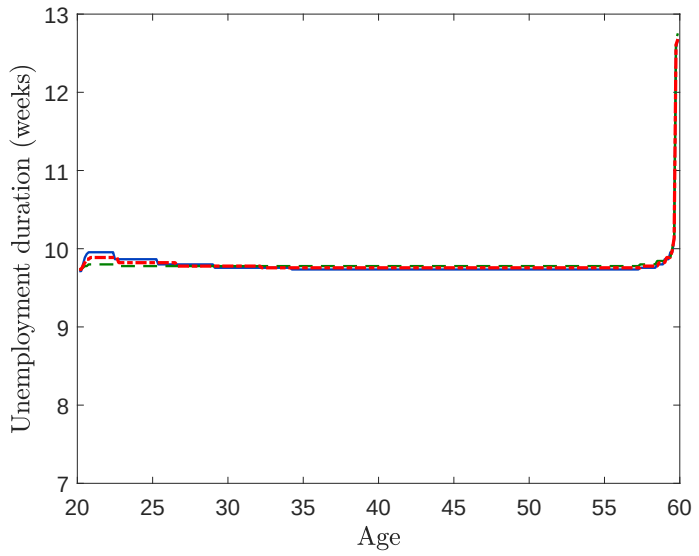


(b) Average wage

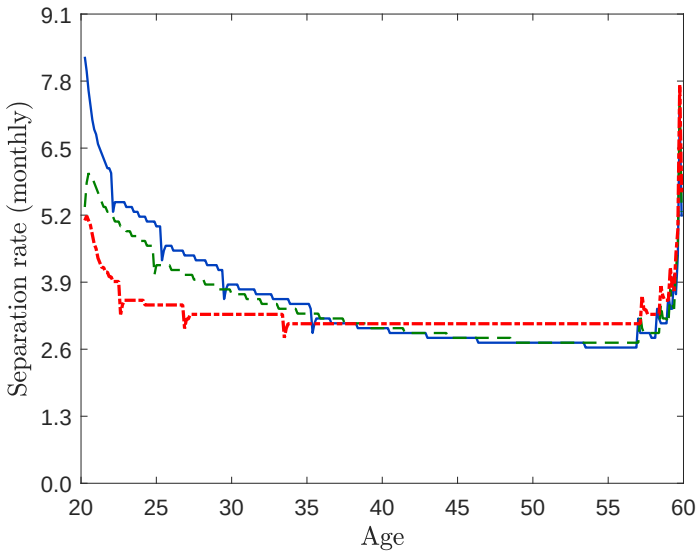


(c) Unemployment

Figure 1: Labor market outcomes over the life cycle



(d) Unemployment duration



(e) Job separation

Figure 1 (continued): Labor market outcomes over the life cycle

Notes: The solid line in each plot denotes the baseline model; see Table 1. The dashed and dashed-dotted lines denote models with, respectively, a flat profile for worker productivity ($\xi_0 = 1$, $\xi_1 = \xi_2 = 0$) and a flat profile for job separation ($\varsigma_0 = \varsigma_1 = \varsigma_2 = 0$). Parameter values for these models are reported in Appendix C.

Figure 1 illustrates that the model can replicate certain life-cycle aspects of labor market outcomes. In this figure, the solid lines refer to the baseline model. The dashed and dashed-dotted lines denote variants of the calibration in which we assume a flat life-cycle profile for, respectively, worker productivity and the job separation rate.

To begin with, Plot 1a shows that the productivity of workers, measured by their output on the job, increases throughout the working life. The main ingredient for this is the exogenous profile that is fed into $f(y, \tau)$. It is worth noting that the exogenous profile, $\xi_0 + \xi_1\tau + \xi_2\tau^2$, is actually hump-shaped as it decreases after age 50 (Figure B1a in the appendix). Thus, in the

model there is a selection effect towards the end of the working life, whereby only jobs with a high enough match productivity are formed or kept alive. Chéron et al. [2013] call it the 'horizon effect': match surplus depends more heavily on current match productivity when the worker gets closer to retirement.

Plot 1b displays the life-cycle profile of wages in the baseline model and its variants. Wages evolve in a mildly hump-shaped fashion. Clearly, they exhibit less variation than their empirical counterparts. The exogenous profile for worker productivity is most instrumental in explaining why wages are lower at the beginning of the working life. The two profiles for worker productivity and job separation then coalesce to make the average wage plateau when workers are in their mid-forties and fifties. The decrease in wages at the end of the working life is too abrupt compared to the data, which is partly explained by the fact that retirement in the model is deterministic. This also explains the blip in wages just before age 60. Although these features are counterfactual, they are not essential for the results obtained in the next sections.

Next, Plot 1c shows the unemployment rate conditional on age. As can be seen, unemployment decreases rapidly at the beginning of the working life, which is in line with the data. According to Plot 1c, unemployment is lower among prime-age workers, and then it increases abruptly for those aged 57 to 60. This feature is consistent with the fact that older workers reduce labor force participation even before the retirement age, though in our model they are not allowed to exit the workforce prior to age $\tau = N_w + 1$. Put differently, the model does not distinguish between nonparticipation and unemployment, but it is consistent with the hump-shaped profile of employment over the life cycle.

The life-cycle profile of unemployment (Plot 1c) is driven by the behavior of the job separation rate (Plot 1e), while unemployment duration does not contribute to this dynamics (Plot 1d). Consistent with Figure B1b in the appendix, the job separation rate is strongly decreasing at the beginning of the working life. The exogenous profile fed into λ_τ is key for obtaining this outcome. As can be seen, Plot 1e also depicts a large increase of the separation rate at the end of the working life. While this feature is absent from the empirical behavior of the employment-to-unemployment probability, it is consistent with the behavior of the employment-to-nonparticipation probability (Choi et al. [2015]). Last, in the data unemployment duration is almost constant before age 45 and then starts increasing. The model clearly misses this aspect of the behavior of the job finding rate.

4 Quantitative analysis

This section contains the main discussion of the effects of government-mandated severance payments on equilibrium allocations and welfare. After analyzing the effects in the baseline model, we discuss results obtained under several variants of the model's specification.

4.1 Preliminaries

We aim to make connections with the key features of SP observed in countries that implement this type of policy. Typically, SP is denominated in months of wages per years of service

(henceforth m.w.y.s.); see OECD [2004, 2013] and Boeri et al. [2017]. Our model does not keep track of job tenure, but we can remedy this issue by exploiting the correlation between age and job tenure. Specifically, in Appendix B we show that the linear function $\omega_0 + \omega_1 \tau$, with $\omega_0 = 0.5081$ and $\omega_1 = 0.0423$, closely predicts average job tenure (in years) among workers of age τ.[17] Therefore we specify government-mandated SP as

$$T_\tau = \overline{T} \times \widetilde{w} \times (\omega_0 + \omega_1 \tau).$$

$\widetilde{w}$ denotes the average monthly wage, so that $\overline{T}$ is effectively measured in m.w.y.s. Accordingly we refer to $\overline{T}$ as the rate of SP. Notice that since $\widetilde{w}$ is an equilibrium object, we must add an outer loop to iterate on this variable in the experiments that follow.

In the sequel, we draw a comparison between welfare in the steady-state equilibrium with no SP and welfare in other economies. This comparison is based on a standard compensated variation measure. Let $\overline{U}_0(0,1)$ denote the lifetime value of a newborn agent in the base equilibrium, and denote by $\widetilde{U}_0(0,1)$ her lifetime utility in an equilibrium with SP. The value

$$\left(\frac{\widetilde{U}_0(0,1) + B}{\overline{U}_0(0,1) + B}\right)^{\frac{1}{1-\gamma}} - 1, \quad \text{with } B = \frac{1}{1-\gamma}\frac{1-\beta^{N_w+N_r}}{1-\beta}$$

measures the change in her lifetime consumption relative to the base economy. Hereafter we express this change in percentage points.

Let us comment on two features of the experiments analyzed below. First, as we mentioned in Subsection 3.2, we keep the interest rate fixed to the value computed in the equilibrium with no SP. As such, the experiments are conducted in partial equilibrium with respect to the asset market. They enable us to study how an individual fares in economies that pay the same return to the risk-free asset while implying different earnings and labor market trajectories due to SP. Second, since the complexity of the model precludes computing the transition dynamics, we only consider steady-state comparisons.[18] Observe that the welfare criterion that we use is fully justified in the context of such comparisons.

4.2 Changes in severance payments

Table 2 shows the effects of government-mandated SP on equilibrium allocations and welfare. The first column ('base') is the baseline economy with no SP. The other columns characterize steady-state equilibria where the rate of SP, $\overline{T}$, is gradually increased. In the rightmost column, SP grant 1 month's wages per year of service. For workers aged 20, this amounts to 2 weeks' wages given our estimates for ω_0 and ω_1. At the other end of the spectrum, for workers who are about to retire, SP in the rightmost column amount to 14 months of wages. This is a

[17] Recall that $\tau = 1, \ldots$ is measured semi-quarterly. The estimate $\omega_1 = 0.0423$ implies that average job tenure increases by four months for each additional year of age.

[18] What makes the computation of the transition dynamics especially difficult is the financing of government-run programs through payroll taxes. That is, both s and κ_b are sluggish variables, which in turn implies that labor-market tightness θ cannot 'jump' to its new steady-state value after a policy change. Dolado et al. [2016] tackle this issue. They must rule out savings to keep the computational task manageable.

Table 2: Quantitative effects of severance payments: Baseline results

	Base	Rate of SP (in m.w.y.s.)				
		0.20	0.40	0.60	0.80	1.00
Pension benefits	100	100.0	98.7	97.3	95.7	94.3
UI benefits tax	2.60	2.81	2.91	3.02	3.12	3.22
Unemployment rate	8.60	9.32	9.52	9.70	9.88	10.1
Separation rate	3.50	3.56	3.53	3.52	3.49	3.47
Job finding rate	45.0	41.2	39.7	38.5	37.2	36.0
Average wage, all	100	100.7	99.4	98.1	96.5	95.2
Average wage, $i_e = 0$	100	91.2	87.6	85.0	82.5	80.4
Average wage, $i_e = 1$	100	104.5	103.7	102.5	101.1	99.7
Vacancies	100	95.5	90.3	87.7	85.4	83.4
Output per worker	100	100.4	99.9	99.4	98.7	98.0
Assets	100	100.9	100.3	99.9	99.1	98.4
Welfare	0.00	-0.20	-0.36	-0.59	-0.89	-1.26

Notes: The rate of severance payments (SP) is expressed in months of wages per years of service (m.w.y.s.). The unemployment insurance (UI) benefit tax, unemployment rate, separation rate and job finding rate are all expressed in percentage points. The separation rate and the job finding rate are converted to monthly values. Welfare figures are percentage-point changes in lifetime consumption. Statistics without meaningful units of measurement are normalized to 100.0 in the base column.

substantial departure from the base scenario meant to represent the U.S. labor market. Indeed, according to Table 1 of Boeri et al. [2017], 14 months' wages is the maximum compensation required for fair economic dismissals in Portugal.[19]

The first remarks concern the effects of SP on wages. Table 2 indicates that SP lower the average wage. The insights of Lazear [1988, 1990]'s bonding critique help understand the mechanism driving this result. At the entry level, workers accept lower wages in order to be hired and to remain employed until they become eligible to receive SP. At the same time, the wages of incumbent workers increase as SP strengthen their bargaining position.[20] But the reduction in entry wages is so large that the wage averaged across both new/recent hires and incumbent workers decreases. We will argue below that this steepening of the wage profile is key to understand the full welfare effect of SP.

From the firm's perspective, the decrease in entry wages helps reduce the costs of SP, but the adjustment is not enough to leave the expected sum of payments to the worker unchanged (details follow). The value of having a filled job decreases as the rate of SP increases, and firms then open up fewer vacant jobs as shown in Table 2. Consequently, the job finding rate falls

[19]Southern European countries tend to have more stringent employment protection laws. In Greece, the maximum compensation required for fair economic dismissals is 12 months' wages. It is similarly elevated in Spain, at 12.5 months' wages. There are also very high levels of maximum compensation required for *unfair* dismissals, namely 36.5 months' wages in Spain and 62.9 months' wages in Portugal (Boeri et al. [2017]).

[20]However, for high levels of SP (such as those in Figure 2), this effect is counteracted by the decrease in the job finding probability. As a result, the wages of incumbent workers eventually decrease.

off. It is worth noting that, at the same time, the separation rate remains roughly constant. On the one hand, SP deter firms from dissolving the match; Alvarez and Veracierto [2001] call it the 'firing penalty' role of SP. On the other hand, SP lower the costs of job separation for workers. We find that these effects roughly compensate each other. Thus, according to our model, SP reduce aggregate employment by lowering employment inflows and have little impact on employment outflows.

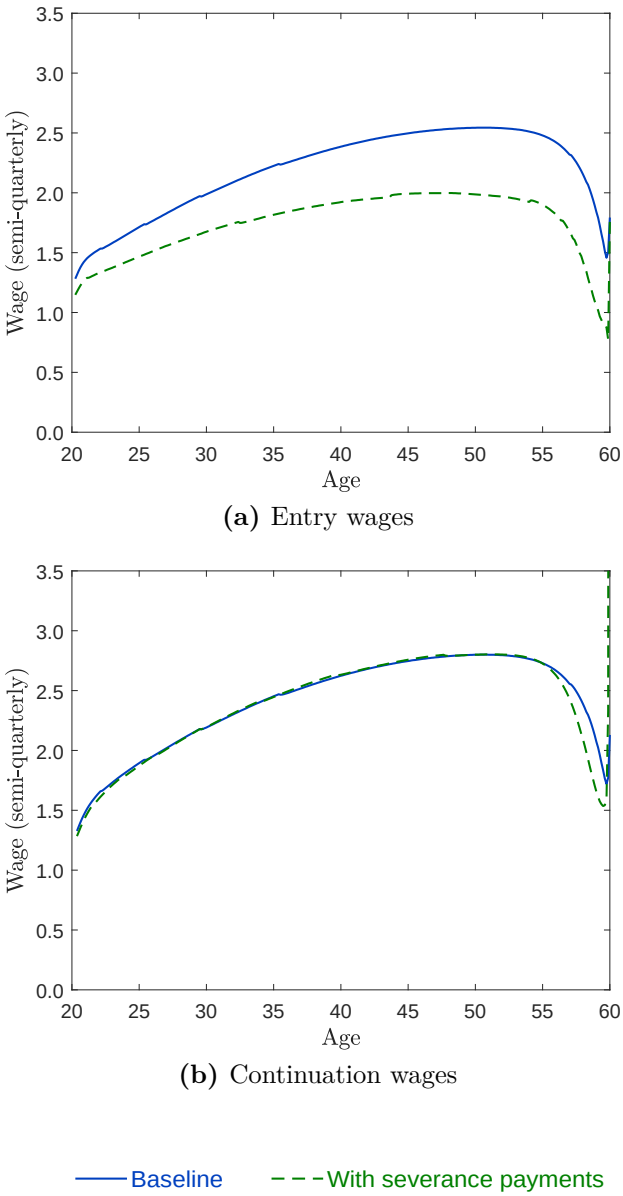
The last row of Table 2 indicates that SP produce negative welfare effects. First, expected SP generate a 'dip' in the profile of labor income which, in turn, is detrimental to workers as they value consumption smoothing. Second, workers expect to have longer unemployment durations as the rate of SP increases. Third, since SP lower the average wage, pension benefits decrease and the UI benefits tax increases, meaning that agents' disposable income goes down. These forces add up to reduce workers' welfare. For instance, moving from the U.S. setting to the Portuguese one lowers lifetime consumption by 1.3 percent according to Table 2. In our view, the main result is not the magnitude of the welfare effect but its sign, as it stands in contrast to the findings of Alvarez and Veracierto [2001] and Cozzi and Fella [2016].

Further considerations on the wage effects of SP. We indicated earlier that while lower entry wages help firms cushion the costs of paying high SP in the future, the adjustment would have to be larger to fully offset this cost. To substantiate this claim, in the top plot of Figure 2, we report average entry wages conditional on age in the economies with and without SP. Continuation wages are shown in the bottom plot of Figure 2, which we will discuss momentarily. As Figure 2 shows, there is a decrease in entry wages at all ages as a response to SP. We perform a simple illustrative calculation to put this response in measurable perspective. Using the separation rate of the economy without SP, we tabulate for each age the present value of the expected severance pay (from the economy with SP).[21] We divide this value by 8 to compare it to Plot 2a, as entry wages are expected to be paid for 8 model periods. The results shown in Figure C1 of the appendix indicates that the 'pass-through' becomes incomplete as workers age. That is, after about age 35 the decrease in entry wages would have to be roughly 30 percent larger to offset the future cost of SP.

There is a simple reason why, unlike in Lazear [1988, 1990]'s analysis, SP are not fully passed into entry wages. Workers have a diminishing marginal value of consumption, they save at a rate lower than their subjective discount rate and they face a borrowing constraint. This creates frictions when firms attempt to borrow from workers, through a reduction in entry wages, against their future SP.

Plot 2b seems to suggest another departure from Lazear [1988, 1990]'s bonding critique. That is, it appears that continuation wages do not respond to SP, whereas the critique states that they should increase by an amount equal to the interest posted on this 'bond' (i.e. the reduction in entry wages). However, one must bear in mind that there are several forces at

[21] Denote by s^r_τ the separation rate at age τ, and by $s^{r,e}_\tau$ the endogenous separation rate at age τ (since only endogenous separations are followed by SP). Then the present value of expected SP is given by $\sum_{i=1}^{N_w-\tau} s^{r,e}_{\tau+i} \frac{T_{\tau+i}}{(1+r)^i} \left(1-(1-p_e)^i\right) \prod_{j=0}^{i-1} \left(1-s^r_{\tau+j}\right)$. In this formula, the term $1-(1-p_e)^i = \sum_{j=0}^{i-1} (1-p_e)^j p_e$ is the probability that the worker becomes eligible for SP before the i-th period of employment.



(a) Entry wages

(b) Continuation wages

Figure 2: Wage effects of severance payments over the life cycle

Notes: In each plot, the solid line denotes the baseline model with no severance pay while the dashed line denotes the model with the rate of severance pay set at one month's wage per years of service.

work conflated in this picture. On the one hand, SP strengthen the bargaining position of incumbent workers by increasing their wealth in case of job separation. On the other hand, SP reduce the job finding rate and therefore lower the outside option of workers. But the comparison of average wages conditional on age in Plot 2b is also subject to compositional effects, as the cross-sectional distribution of workers across productivity and asset holdings changes after SP are introduced. At any rate, as discussed further below, the apparent lack of increase in continuation wages is not a robust prediction of the model.

How important is the wage effect in explaining the welfare losses caused by SP? To answer this question, we compare the asset value of newborn agents facing the wage schedules of either the base economy or the economy with high SP, while removing all other differences between the two settings. In order to remove the other differences, we can choose to keep pension

benefits, the UI benefit tax, the job finding probability, and match formation and continuation decisions fixed to their value in the base economy. Alternatively, we can choose to set these variables to their value in the economy with SP. These two calculations indicate respectively that the welfare loss coming from differences in the wage schedules is -0.54 percent and -0.98 percent. Compared to the number reported in the last column of Table 2, this suggests that between 43 to 78 percent of the welfare loss is driven solely by the wage effects of SP. Notice that the figures include the 'direct' effect coming from changing the threat points of workers and firms (one could call it the 'bonding critique' effect), and the 'indirect' effect coming from changes in the aggregate equilibrium variables θ, s and κ_b.

Characterizing the welfare effects. Next, we seek to characterize factors that increase or decrease the welfare effects of SP. We do so by considering four variants of the model, each of which shuts down one specific feature of the base economy. The first two variants look at the effects of removing the life-cycle components of worker productivity and job separation. The other two variants focus on factors related to precautionary savings. In all instances, we recalibrate the model to match the data moments discussed in Section 3. Parameter values and detailed results of the experiments are provided in Appendix C. Figure 3 plots the welfare effects obtained in the baseline model and the four alternative calibrations.

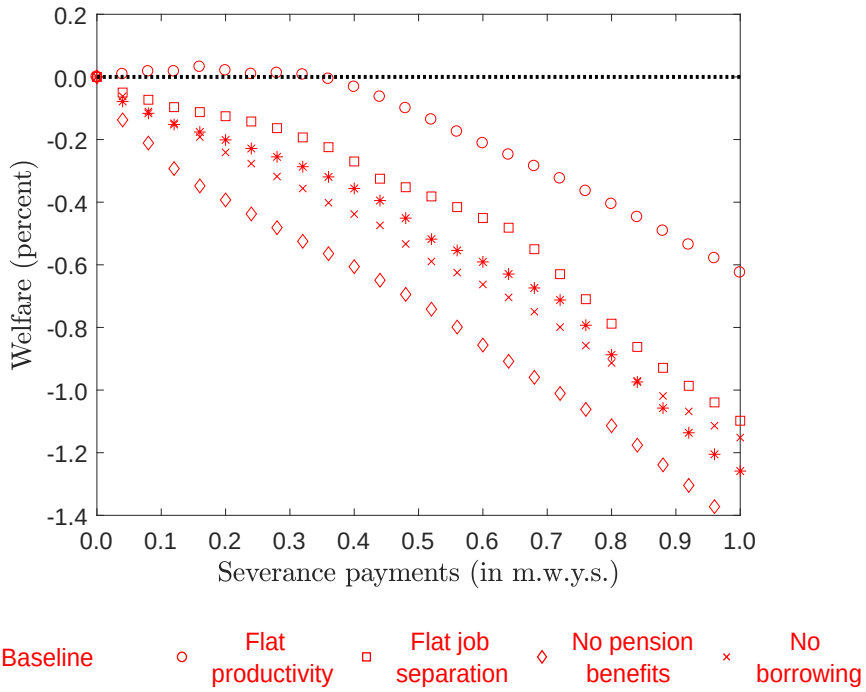


Figure 3: Welfare effects of severance payments under different model specifications

Notes: Asterisks denote the baseline model; see Table 1. Circles, squares, diamonds and crosses denote models with, respectively, a flat profile for worker productivity ($\xi_0 = 1$, $\xi_1 = \xi_2 = 0$), a flat profile for job separation ($\varsigma_0 = \varsigma_1 = \varsigma_2 = 0$), no pension benefits ($\kappa_s = 0$) and no borrowing ($\underline{a} = 0$). Parameter values for these models are reported in Appendix C.

As can be seen, with a flat life-cycle profile for worker productivity, the welfare losses are lower and low rates of SP are even desirable. Assuming a flat profile for job separation also

seems to mitigate the welfare loss of SP. One possible explanation is that, in the baseline model, younger workers receive lower wages as they are less productive and more likely to separate from the firm, and thus suffer more from the wage-shifting effects of SP. Conversely, in Figure 3 we observe larger welfare losses when removing pension benefits. In this version of the model workers have a much higher willingness to save, which this similar to the scenario considered by Alvarez and Veracierto [2001]. Yet the order of magnitude of the welfare figures remain similar to that of the baseline experiment.[22] Last, perhaps, surprisingly, we find that setting the borrowing limit to zero has little to no effect on the welfare losses.

In the four variants of the model, the wage-shifting effects remain the key mechanism to understand the welfare consequences of severance payments. We illustrate this point in Figure 4 by plotting entry and continuation wages for each set of numerical experiments. The picture conveyed by Plot 4a is similar to that of Plot 2a, viz. the importance of the downward shift in entry wages. On the other hand, we observe that, under an alternative calibration, average continuation wages conditional on age may increase after SP are introduced.

To complement these experiments, we performed another exercise where we shut down the job tenure component of SP, i.e. we set ω_1 to 0 and set ω_0 to average job tenure.[23] We found welfare losses to be much larger under this assumption. For instance, we obtain the same welfare effect at the rate of SP of 0.63 m.w.y.s. as in the baseline experiment when the rate of SP is set to 1. This is not unexpected, since a tenure-independent SP weighs more heavily on the wages of young workers at a given rate of SP. Cozzi and Fella [2016] also find that making SP increase with job tenure should be preferred over tenure-independent SP.

4.3 Discussion

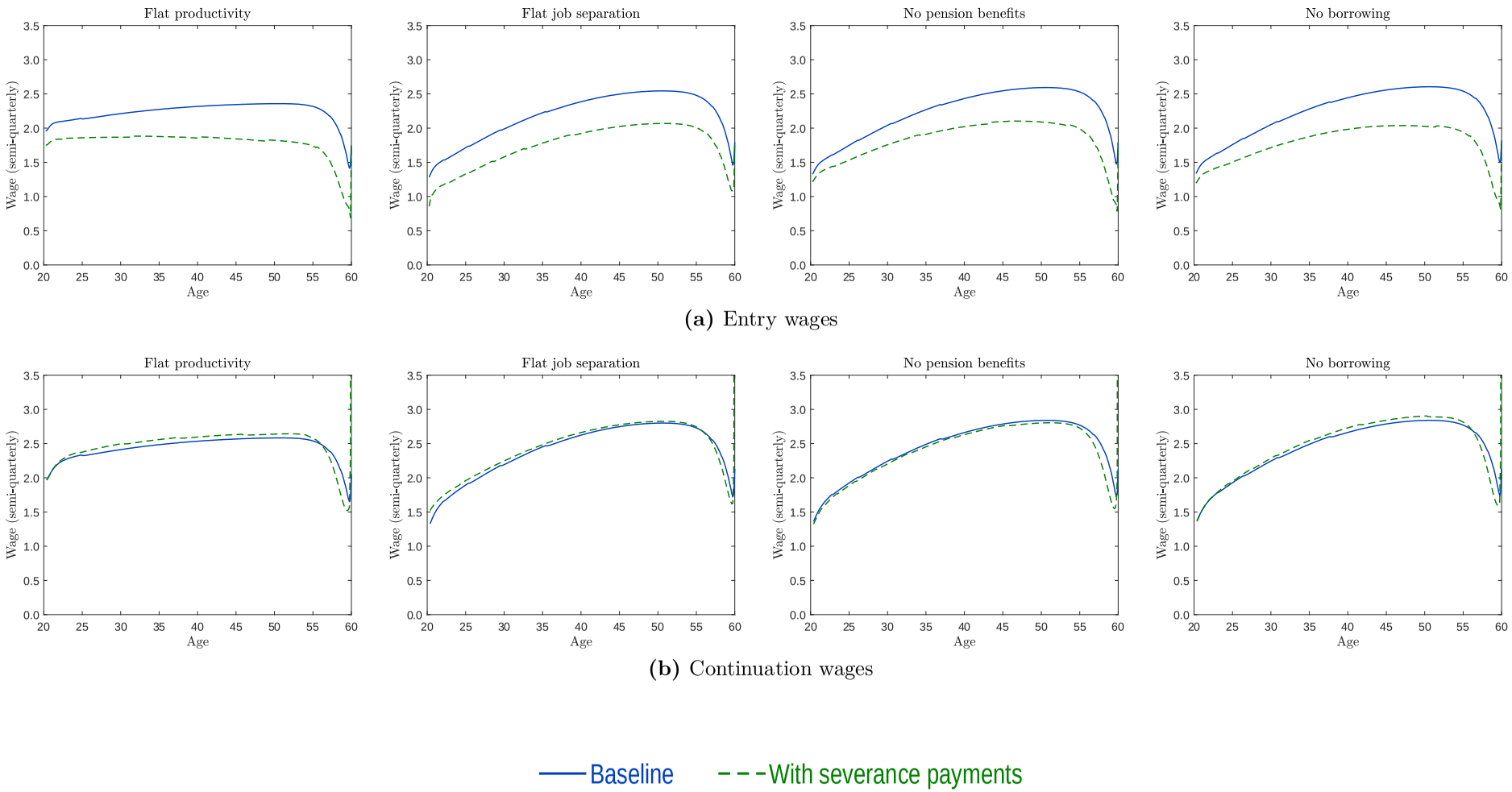
We find that SP deteriorate welfare directly through their impact on wages, and indirectly through general equilibrium effects such as lower pension benefits, higher taxes and reduced job creation. The latter arises in part because SP are not fully internalized by wages. Do these results 'ring true' in light of the empirical evidence?

In an early investigation, Friesen [1996] exploits provincial differences in Canada to estimate the wage effect of mandatory notice and severance pay laws. She finds that starting wages decrease in response to costs that will be incurred once the worker becomes protected by severance pay laws.[24] Kugler [2005] uses household survey data to examine a reform of severance payments savings accounts that took place in Colombia in 1990. She estimates that firms manage to shift up to 80 percent of their contributions into SP accounts towards workers through lower wages. Martins [2009] studies a reform that occurred in Portugal in 1989, whereby

[22] The pension system in our economy is modeled crudely for reasons of computational feasibility. For instance, it does not keep track of the individual contributions to the pension system. This feature could be key in making pension benefits have a larger impact on welfare.

[23] Average job tenure is 7.5 years in the base economy. To calculate this figure, we use $\omega_0 + \omega_1 \tau$ and the cross-sectional distribution of employment with respect to age. Notice that, according to Figure B1c in the appendix, job tenure at age 40 is 7 years. But since the employment distribution is slightly skewed towards older workers (newborn agents are unemployed initially, and younger workers have high job separation rates), average job tenure is a little higher than job tenure at age 40.

[24] Friesen [1996] also tabulates that the overall effect on the expected value of discounted lifetime earnings is negative for most workers.



(a) Entry wages

(b) Continuation wages

Figure 4: Wage effects of severance payments over the life cycle under different model specifications

Notes: In each plot, the solid line denotes the baseline model with no severance pay while the dashed line denotes the model with the rate of severance pay set at one month's wage per years of service.

firing procedures were made easier (reduction in firing costs), but more so for smaller firms (those employing 20 or fewer workers) than for larger firms. He finds that the wage growth rate fell relatively more in small firms, which suggests that employers in those firms gained more bargaining power. Leonardi and Pica [2013] study the wage effects of a 1990 reform that increased firing costs for firms below 15 employees in Italy. They uncover a significant reduction of wages in smaller firms, and find that it is concentrated on newly-hired workers as opposed to incumbent workers. Cervini-Plá et al. [2014] analyze a reduction of firing costs and payroll taxes targeted at temporary workers in Spain in 1997. They find that the reform increased the wages of workers, especially those of new entrants. They estimate that for incumbent workers only 10% of the wage change can be attributed to the reform, whereas 50% of the wage increase for newly-hired workers comes from lower dismissal costs.

There is an empirical literature, complementary to the studies cited here, that analyzes the effects of SP on employment flows. In work subsequent to her 1996 paper, Friesen [2005] reports that severance pay laws have little impact on the flows into and out of employment in Canada. In his study, Martins [2009] also assesses the impact of the reform on worker turnover rates, and finds that the effects are not statistically significant. Bauer et al. [2007] use German data on small establishments and document that dismissal costs have no discernible impact on employment turnover. Focusing on the 1990 reform of the Italian labor market previously mentioned, Kugler and Pica [2008] find that higher dismissal costs reduce worker turnover rates in small vs. large firms, but the estimated impact appears to be quantitatively small. The fact that the results in this literature often turn out insignificant suggests that most of the adjustments to SP occur through changes in wages.[25]

In summary, although the empirical literature does not provide straight estimates of the 'pass-through' effect from SP to wages, it supports the conclusion that this effect is present in the data. The lack of significant estimates when looking at employment flows similarly points into the same direction. While we cannot ascertain whether the model overstates the wage effect, our analysis shows that its welfare implications cannot be ignored when discussing the desirability of severance payments.

5 Robustness checks

In this section, we examine alternative calibrations and assumption of the model. The purpose is not only to check the robustness of the results, but also to shed light on the role of certain variables. In each calibration, we follow the procedure described in Subsection 3.2 to obtain the parameter values of the model, which are reported in Table C1 of the appendix. The results of the experiments studying the effects of SP are collected in Table 3.

Workers' bargaining power. In Panel A of Table 3, we study the role of the bargaining power of workers by setting the value of ϕ either to 0.25 or 0.75 (vs. 0.50 in the baseline

[25] We should note that the studies in this literature typically provide estimates based on a treatment group of small firms. Thus, not much is known about the effects of SP on worker flows in larger firms. It is conceivable that firm size plays a role in whether the adjustment to SP occurs through wages or through employment flows.

Table 3: Quantitative effects of severance payments: Robustness checks

	Base	Rate of SP (in m.w.y.s.) 0.25	0.50	0.75	1.00	Base	Rate of SP (in m.w.y.s.) 0.25	0.50	0.75	1.00
	A1. Low bargaining power					**A2. High bargaining power**				
Pension benefits	100	102.7	101.8	100.4	99.1	100	98.4	96.1	94.0	92.3
UI benefits tax	2.10	2.21	2.30	2.37	2.46	2.78	2.99	3.17	3.34	3.53
Unemployment rate	8.65	9.28	9.50	9.64	9.84	8.71	9.34	9.76	10.0	10.4
Separation rate	3.50	3.57	3.58	3.56	3.57	3.50	3.55	3.50	3.44	3.40
Job finding rate	45.0	41.7	40.5	39.4	38.4	45.0	40.3	37.9	35.7	33.5
Average wage	100	103.2	102.4	101.0	99.8	100	99.0	96.9	95.0	93.5
Vacancies	100	96.7	93.3	91.2	90.0	100	92.9	85.4	80.5	77.2
Output per worker	100	100.8	100.7	100.0	99.8	100	100.1	99.2	98.1	97.2
Assets	100	101.2	101.4	100.7	100.6	100	100.6	99.5	98.2	97.2
Welfare	0.00	0.63	0.78	0.74	0.69	0.00	-0.56	-1.01	-1.50	-2.01
	B1. Few endogenous separations					**B2. Many endogenous separations**				
Pension benefits	100	100.8	99.7	98.5	97.4	100	99.3	97.0	94.8	92.5
UI benefits tax	2.94	3.05	3.14	3.24	3.33	1.91	1.99	2.10	2.23	2.34
Unemployment rate	8.57	9.16	9.45	9.63	9.77	8.58	9.39	9.85	10.2	10.4
Separation rate	3.50	3.53	3.52	3.50	3.48	3.50	3.61	3.55	3.52	3.45
Job finding rate	45.0	41.2	39.8	38.7	37.7	45.0	40.4	38.2	36.3	34.2
Average wage	100	101.5	100.5	99.4	98.3	100	99.9	97.6	95.5	93.3
Vacancies	100	94.4	89.3	86.7	84.2	100	95.6	89.5	86.7	83.7
Output per worker	100	100.2	99.4	98.6	97.7	100	100.6	99.8	99.2	98.3
Assets	100	100.5	99.8	99.2	98.4	100	101.6	100.5	99.8	98.5
Welfare	0.00	-0.20	-0.40	-0.65	-0.95	0.00	-0.30	-0.54	-0.97	-1.18

Notes: Panel A: low (high) bargaining power indicates that the bargaining power of the worker, ϕ, is set to 0.25 (0.75). Panel B: few (many) endogenous separations indicates that the targeted share of endogenous job separation is $1/4$ ($3/4$). Parameter values for the models used in Panels A and B are reported in Appendix C. The rate of severance payments (SP) is expressed in months of wages per years of service (m.w.y.s.). The unemployment insurance (UI) benefit tax, unemployment rate, separation rate and job finding rate are all expressed in percentage points. The separation rate and the job finding rate are converted to monthly values. Welfare figures are percentage-point changes in lifetime consumption. Statistics without meaningful units of measurement are normalized to 100.0 in the base column.

calibration). As can be seen, with a lower bargaining power we find that SP could benefit workers, although the welfare figures eventually decrease as we keep increasing the rate of SP. Conversely, a larger value for workers' bargaining power amplifies the welfare losses of SP. These results confirm that the wage-shifting effect is key in making SP improve or deteriorate welfare. For instance, as can be seen by looking at the behavior of the average wage, the impact of SP on wages is substantially mitigated when the bargaining power of workers is lower. To rationalize these findings, observe that stricter employment protection creates the classical hold-up problem between firms and workers, and that increasing workers' bargaining power exacerbates this issue. This leads to larger reductions in entry wages when workers' bargaining power is high, and hence more negative welfare consequences.

Exogenous vs. endogenous separation. We check the importance of the 'scope' of SP, by changing the relative importance of endogenous job separations. Specifically, the calibration in Panel B1 of Table 3 implies that endogenous separations make up 25 percent of all job separations, while in Panel B2 the corresponding figure is 75 percent (vs. 50 percent in the baseline calibration). The results turn out to be remarkably robust to those changes. To understand this, notice that when we change the scope of SP, we must also change the exogenous risk of unemployment, $\bar{\lambda}$, to match the target for job separation. According to Panel B of Table 3, these forces – a larger impact of SP on wages vs. a higher exogenous risk of unemployment – roughly balance each other out. Thus, the uncertainty with respect to the share of job separations that might be impacted by SP (see Footnote 14) does not seem to drive our results.

Other robustness checks. In Subsection 4.2, we discussed the welfare implications of SP in several variants of the model that focused on aspects related to the life cycle or to precautionary savings. The effects of SP on equilibrium allocations and wages (in addition to the welfare effects) in these experiments are reported in Table C2 of the appendix. They are consistent with the results of the baseline experiment. We also studied how these four variants perform when workers' bargaining power ϕ is switched to lower or higher values, or when we change $\bar{\lambda}$ to target a different share of endogenous job separations. The results were broadly in line with those analyzed in Subsection 4.2. Last, we investigated the effects of making SP apply to exogenous job separations (in addition to endogenous separations). The results were not substantially different under this alternative assumption.

6 Conclusion

We provide a novel assessment of the effects of government-mandated severance payments, using a rich life-cycle model with search-matching frictions in the labor market, risk-averse agents and imperfect insurance against idiosyncratic shocks. In the model, entry wages fall off when severance payments are introduced. This response does not fully prevent severance payments from affecting equilibrium allocations, and it has a first-order negative impact on workers' welfare. These findings confirm and substantiate quantitatively Lazear's observation: "So long as there are no constraints on borrowing and lending, all is well. But any inability or apprehension by workers on this score causes some serious problems" (Lazear [1990, p.702]). Further, the results complement the works of Alvarez and Veracierto [2001] and Cozzi and Fella [2016]. In these two papers, the provision of severance payments enhances welfare through its firing penalty role or through its insurance role. Instead, we highlight some adverse consequences of severance payments, by using a model with wage bargains between workers and firms, and where both parties have strictly positive bargaining power and choose whether to sever the employment relationship.

The model that we develop in this paper is very rich and, as such, it opens up many possibilities for future work. In our view, the more promising avenue is to use the model to discuss specific issues regarding the design of unemployment insurance benefits and severance payments.

In particular, a key question is whether and how these programs should depend on workers' age. Hairault et al. [2012] show that the replacement ratio of unemployment benefits should decrease for the soon-to-be-retired unemployed workers because of moral hazard. Michelacci and Ruffo [2015] also find that unemployment benefits should decrease with age, arguing that these benefits are more valuable to young workers who have little savings. Chéron et al. [2011] analyze that employment protection should be hump-shaped with respect to workers' age to satisfy an efficient job creation condition. It would be very interesting to revisit these questions – in isolation, and also by addressing the issue of the joint design of unemployment benefits and severance payments – through the lens of our model.

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Appendices

A Model appendix

This appendix contains two subsections. Subsection A.1 lays out our numerical methodology to compute a stationary equilibrium of the model. Subsection A.2 explains how we proceed in order to calibrate the interest rate.

A.1 Numerical algorithm[26]

We discretize the asset space and the interval for idiosyncratic match productivity as follows:

- We work with two sets of grid points for assets. The first grid is used for value functions; this grid has 65 points and is more dense in the lower part of the asset space where there is more curvature in the policy functions. The other grid is for the population distribution; it covers the asset space with 751 evenly-spaced points.

- For match productivity, we also use a smaller grid (25 points) for value functions and a larger grid (51 points) for the population distribution. Both grids are evenly spaced over the interval $[\varphi - {}^{2\sigma}/\sqrt{1-\rho^2}, \varphi + {}^{2\sigma}/\sqrt{1-\rho^2}]$.

We approximate the transition function for match productivity using Tauchen [1986]'s method.

The steps of the solution algorithm are as follows:

1. Guess pension benefits s^0.

2. Solve for $R(a,\tau)$ and $\overline{a}^R(a,\tau)$ recursively starting from $\tau = N_w + N_r$.

3. Guess the tax rate κ_b^0.

4. Guess labor-market tightness θ^0.

5. Solve for $U_0(a,\tau)$, $U_1(a,\tau)$, $W_0(y,a,\tau)$, $W_1(y,a,\tau)$, $J_0(y,a,\tau)$, $J_1(y,a,\tau)$, for $\overline{a}_0^U(a,\tau)$, $\overline{a}_1^U(a,\tau)$, $\overline{a}_0^W(y,a,\tau)$, $\overline{a}_1^W(y,a,\tau)$, for $w_0(y,a,\tau)$, $w_1(y,a,\tau)$, and for $y_0(a,\tau)$, $y_1(a,\tau)$ recursively from $\tau = N_w$. The solution is as follows:

   (a) Given θ^0, compute $U_0(a,\tau)$, $U_1(a,\tau)$, and $\overline{a}_0^U(a,\tau)$, $\overline{a}_1^U(a,\tau)$.

   (b) Given the values $J_0(y,a,\tau+1)$, $J_1(y,a,\tau+1)$, compute the reservation wage of the firm for every (y,a) and $i_e \in \{0,1\}$. Call it $\overline{w}_{i_e}(y,a,\tau)$. Given the values $U_0(a,\tau+1)$, $U_1(a,\tau+1)$, $W_0(y,a,\tau+1)$, $W_1(y,a,\tau+1)$, and the outside option

[26] The reason we provide an algorithm is that the solution method is actually different from Krusell et al. [2010] and Bils et al. [2011]. In these two papers, the wage schedule is the solution to a functional fixed-point problem because the wage is included in the continuation values of the firm and of the worker. The deterministic life cycle in our model removes this feature. Instead, when we solve for the wage in step 5 of the algorithm, the solution requires the reservation wages of the two agents. Reservation wages are in closed-form solution when $\tau = N_w$, and are obtained by solving fixed-point problems when $\tau < N_w$.

$U_1(a,\tau)$, compute the reservation wage of the worker. Call it $\underline{w}_{i_e}(y,a,\tau)$. Both $\overline{w}_{i_e}(y,a,\tau)$ and $\underline{w}_{i_e}(y,a,\tau)$ are the solution to fixed-point problems: a guess on the reservation wage yields an asset-holding decision that affects the continuation value and, thereby, changes the reservation wage. These problems can be solved by iterations.

(c) If $\overline{w}_{i_e}(y,a,\tau) < \underline{w}_{i_e}(y,a,\tau)$, then set $w_{i_e}(y,a,\tau) = \frac{1}{2}\left(\overline{w}_{i_e}(y,a,\tau) + \underline{w}_{i_e}(y,a,\tau)\right)$. Otherwise, solve for the Nash-bargained wage $w_{i_e}(y,a,\tau)$ using the first order condition:

$$\phi\left(1-\kappa_s-\kappa_b^0\right)\frac{u'\left((1+r)a+(1-\kappa_s-\kappa_b^0)w-\overline{a}_{i_e}^W(y,a,\tau;w)\right)}{W_{i_e}(y,a,\tau;w)-U_1(a+T_{\tau,i_e},\tau)} - (1-\phi)\frac{1}{J_{i_e}(y,a,\tau;w)+T_{\tau,i_e}} = 0$$

where $T_{\tau,i_e} \equiv T_\tau \times \mathbb{1}\{i_e=1\}$. We use a bisection method to solve this equation. For $\overline{a}_0^W(y,a,\tau)$, $\overline{a}_1^W(y,a,\tau)$ (and $\overline{a}_0^U(a,\tau)$, $\overline{a}_1^U(a,\tau)$ above), we use interpolation and a golden-section search method. Notice that at this stage, we have obtained $W_0(y,a,\tau)$, $W_1(y,a,\tau)$, $J_0(y,a,\tau)$, $J_1(y,a,\tau)$ and $\overline{a}_0^W(y,a,\tau)$, $\overline{a}_1^W(y,a,\tau)$.

(d) Use $J_0(y,a,\tau)$, $J_1(y,a,\tau)$ to compute $\bar{y}_0(a,\tau)$, $\bar{y}_1(a,\tau)$.

6. Recover the location of asset decisions $\overline{a}_0^U(a,\tau)$, $\overline{a}_1^U(a,\tau)$, $\overline{a}_0^W(y,a,\tau)$, $\overline{a}_1^W(y,a,\tau)$ and decision thresholds $\bar{y}_0(a,\tau)$, $\bar{y}_1(a,\tau)$ over the large assets grid and match productivity grid. Then compute the distribution $\left(\mu^R(a,\tau),\ \mu_0^U(a,\tau),\ \mu_1^U(a,\tau),\ \mu_0^W(y,a,\tau),\ \mu_1^W(y,a,\tau)\right)$ forward starting from $\tau=1$.

7. Check whether the initial θ^0 is consistent with the free-entry condition, by computing

$$\theta^1 = \left(\frac{M}{\eta}\frac{1}{1+r}\sum_{\tau=1}^{N_w-1}\sum_{i_e=0,1}\int_{\mathcal{Y},\mathcal{A}}\max\left\{J_0\left(y',\overline{a}_{i_e}^U(a),\tau'\right),0\right\}dG_0(y')\frac{\mu_{i_e}^U(a,\tau)}{u_{N_w-1}}da\right)^{\frac{1}{\chi}}.$$

If necessary, update θ^0 using θ^1 and go back to step 4.

8. Check whether the tax rate κ_b^0 balances the government budget, by computing

$$\kappa_b^1 = \left(\sum_{\tau=1}^{N_w}\sum_{i_u=0,1} b_{i_u}\int_{\mathcal{A}} d\mu_{i_u}^U(a,\tau)\right)\times\left(\sum_{\tau=1}^{N_w}\sum_{i_e=0,1}\int_{\mathcal{Y},\mathcal{A}} w_{i_e}(y,a,\tau)\,d\mu_{i_e}^W(y,a,\tau)\right)^{-1}.$$

If necessary, update κ_b^0 using κ_b^1 and go back to step 3.

9. Check whether pension benefits s^0 balances the government budget, by computing

$$s^1 = \frac{N_w+N_r}{N_r}\kappa_s\sum_{\tau=1}^{N_w}\left(\sum_{i_e=0,1}\int_{\mathcal{Y},\mathcal{A}} w_{i_e}(y,a,\tau)\,d\mu_{i_e}^W(y,a,\tau)+\sum_{i_u=0,1} b_{i_u}\int_{\mathcal{A}} d\mu_{i_u}^U(a,\tau)\right).$$

If necessary, update s^0 using s^1 and go back to step 1. Otherwise, we are done.

In step 5 when $T_\tau > 0$, knowledge of $U_1(a,\tau)$ above the upper limit of the asset grid is required. In practice, we find that regressing $U_1(.,\tau)$ against a second-order polynomial of a based on the last upper grid points yields a R-square indistinguishable from 1 to at least 4 decimal places. Thus, the OLS coefficients deliver an accurate approximation of $U_1(a+T_\tau,\tau)$.

A.2 The interest rate

To endogenize the interest rate, we nest the model presented in Section 2 into a more general model with a rental market for capital. Specifically, we assume that firms use both capital and labor inputs to produce, and the production function is $k^\alpha \ell^{1-\alpha}$ with $\alpha \in (0,1)$. Capital depreciates at rate δ. The Bellman equation for firms' asset values in this setting becomes:

$$J_{i_e}(y,a,\tau) = \max_k \left\{k^\alpha f(y,\tau)^{1-\alpha} - (r+\delta)k - w_{i_e}(y,a,\tau)\right\} + \frac{1-\lambda_{\tau'}}{1+r}\sum_{j_e=0,1} p_{i_e,j_e}\int \max\left\{J_{j_e}(y',a',\tau'), -T_{\tau,j_e}\right\} dG(y'|y) \quad (12)$$

The first order condition for capital is

$$k^*(y,\tau) = \left(\frac{\alpha}{r+\delta}\right)^{\frac{1}{1-\alpha}} f(y,\tau) \quad (13)$$

Notice that the ratio between capital and labor efficiency units, $k^*(y,\tau)/f(y,\tau)$, is constant across firms. Plugging $k^*(y,\tau)$ back into equation (12), the flow profits are $zf(y,\tau) - w_{i_e}(y,a,\tau)$ with

$$z \equiv \frac{1-\alpha}{\alpha}(r+\delta)\left(\frac{\alpha}{r+\delta}\right)^{\frac{1}{1-\alpha}}. \quad (14)$$

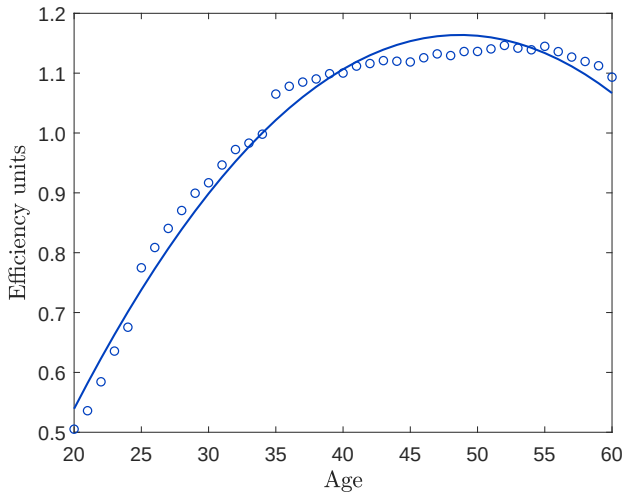
Equation (12) therefore boils down to equation (4) of the model. Assuming that the rental market for capital is perfectly competitive, we can solve for the equilibrium interest rate, r^*. To do so, denote by $\overline{k}$ the aggregate capital stock and by $\overline{a}$ the aggregate stock of assets. Let d denote equilibrium dividends, which are given by

$$d = \sum_{\tau=1}^{N_w}\sum_{i_e=0,1}\int_{\mathcal{Y},\mathcal{A}} \left(zf(y,\tau) - w_{i_e}(y,a,\tau)\right) d\mu_{i_e}^W(y,a,\tau) - \eta v. \quad (15)$$

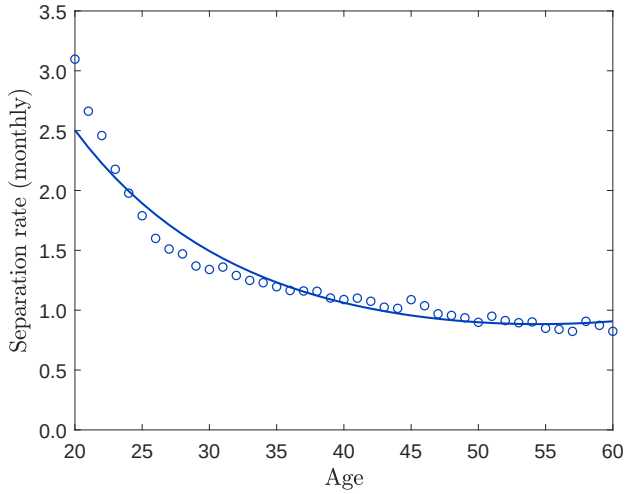
The equilibrium interest rate solves: $\overline{k} + \frac{d}{r^*} = \overline{a}$. In the computations, we set the curvature parameter α to 0.3334. We use $\delta = 0.0125$ for the semi-quarterly depreciation rate, which gives roughly an investment-to-output ratio of 0.20.

B Data appendix

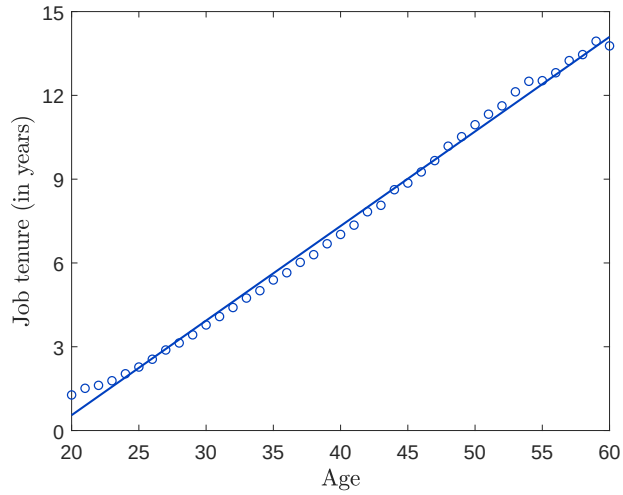
We use micro-data files from the Current Population Survey (CPS) to construct the life-cycle profiles that we then feed into the model. The data come from different extracts of the CPS and cover the past 20 years:



(a) Worker productivity



(b) Job separation



(c) Job tenure

Age dummies — Smoothed

Figure B1: Empirical life-cycle profiles of worker productivity, job separation and job tenure

Notes: Own calculations based on data from the Current Population Survey; see the text in Appendix B for details. In each plot, the dots denote the non-parametric profile estimated on data while the solid line denotes the smoothed, parametric profile used to inform the model.

- To measure worker productivity, we pool data from the 1995-2015 Outgoing Rotation Group samples of the CPS. As in Hansen [1993], we define labor efficiency units as the ratio between the hourly wage of the worker and the sample average of the hourly wage. The wage variable we use includes overtime, tips, commissions, and bonuses, is adjusted for top coding, and is measured in constant 2014 U.S. dollars.[27]

- We use the basic monthly CPS files from January 1995 to December 2015 to compute job separation rates. By linking respondents longitudinally over time, we observe transitions across different labor market statuses, which enable us to estimate transition probabilities conditional on age and time. We define the job separation rate as the probability to move from employment to unemployment.

- The data used to study job tenure come from the CPS supplements on Occupational Mobility and Job Tenure. These data are available in February for the years 1996, 1998 and 2000, and in January for every two years from 2002 to 2016.[28] As the name suggests, the supplements contain information on an individual's tenure at his/her current job.

Our approach to construct life-cycle profiles using these data is as follows. Let $q_{a,t}$ denote, for individuals of age a observed during period t, a variable that interests us, e.g. worker productivity, the separation rate or job tenure. We estimate the following regression model:

$$q_{a,t} = \psi_a \mathbf{D_a} + \psi_t \mathbf{D_t} + \upsilon_{a,t}, \tag{16}$$

where $\mathbf{D_a}$ (resp. $\mathbf{D_t}$) is a full set of age (resp. time) dummies and $\upsilon_{a,t}$ is the residual of the regression. The life-cycle profile of q refers to the coefficients ψ_a on the age dummies.

Figure B1 shows the life-cycle profile of worker productivity, job separation and job tenure. In each plot, the dots denote the value of the coefficients ψ_a. While these profiles are already quite smooth, we find it useful to approximate them by means of parametric profiles before feeding them into the model. The parametric life-cycle profiles (denoted by a solid line in each plot of Figure B1) are described in Subsections 3.2 and 4.1 of the main text.

C Additional results

Figure C1 shows the present value of expected severance payments, divided by the expected number of periods in which workers receive entry wages.

Panel A of Table C1 reports the calibrated parameter values used in eight variants of the baseline model. To gauge differences in equilibrium allocations between these variants and the baseline model, Panel B of Table C1 shows the value of several aggregate variables.

Table C2 presents the full results (summarized in Section 4 of the main text) from changing SP in four variants of the baseline model. This table provides additional evidence demonstrating the robustness of the main results.

[27] We use the wage variable constructed by the Center for Economic and Policy Research; see http://ceprdata.org/cps-uniform-data-extracts/cps-outgoing-rotation-group/cps-org-faq/.

[28] See http://www.nber.org/data/current-population-survey-data.html. For the monthly CPS, we also use files provided on the webpage of the National Bureau for Economic Research.

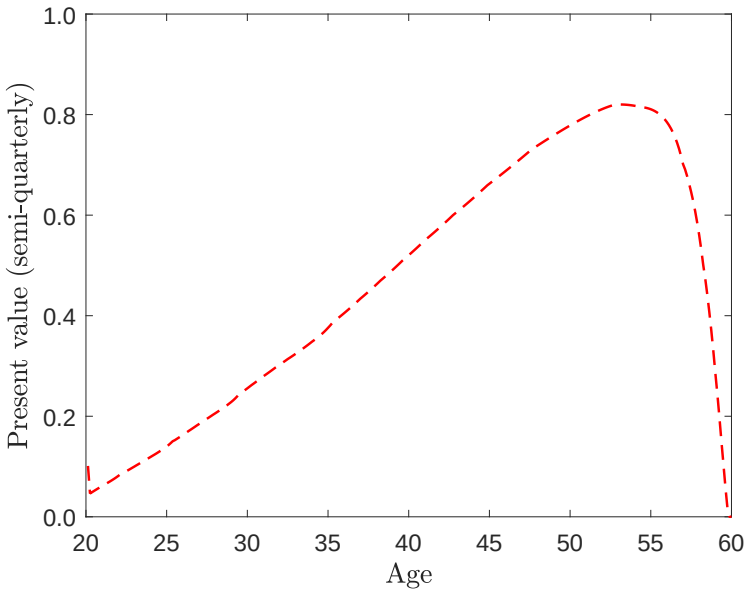


Figure C1: Present value of expected severance payments

Notes: The line shows the present value of expected severance payments at each age in the baseline experiments (with the rate of severance pay set at one month's wage per years of service). The figures are divided by the average number of model periods in which workers receive entry wages (8), so that they measure the value which is expected to be passed into entry wages; see the text in Subsection 4.2 for details.

Table C1: Parameter values and aggregate variables

Parameter	Baseline	Flat productivity	Flat job separation	No pension benefits	No borrowing	Bargaining ϕ		Job separation	
						$1/4$	$3/4$	$1/4$	$3/4$
A. Calibrated parameters									
r ($\times 10^2$)	0.4725	0.4849	0.4703	0.4689	0.4695	0.4698	0.4879	0.4790	0.4716
$\underline{a}$	4.5936	9.9764	4.9366	6.9036	0.0	8.0934	5.0789	3.8184	7.0434
σ	0.1916	0.1967	0.1884	0.1942	0.1919	0.3403	0.1274	0.1171	0.2753
M	0.2747	0.2588	0.2657	0.2631	0.2660	0.1753	0.4434	0.2636	0.2667
$\bar{\lambda}$	1.4331	1.4102	0.0264	1.4265	1.4166	1.2025	1.5861	2.5230	0.5395
η	1.2259	1.2387	1.2033	1.2305	1.2316	1.5078	1.1014	0.9727	1.5831
b_0	0.1191	0.1187	0.1161	0.1189	0.1195	0.1059	0.1251	0.0905	0.1602
b_1	1.0725	1.0686	1.0450	1.0707	1.0754	0.9535	1.1257	0.8146	1.4424
B. Aggregate variables									
s	1.2492	1.2619	1.2201	0.0	1.2699	1.1376	1.3191	0.9527	1.7273
κ_b ($\times 10^2$)	2.6023	2.4733	2.5131	2.4854	2.4786	2.0966	2.7802	2.9406	1.9061
$\widetilde{w}$	1.5721	1.5868	1.5334	1.5921	1.5972	1.4201	1.6684	1.2089	2.1479
θ	5.7372	4.2993	6.0925	5.1215	5.0193	9.7463	1.8237	5.1105	3.9522

Notes: Panel A: r: net real interest rate; $\underline{a}$: borrowing limit; σ: volatility of match productivity; M: matching efficiency; $\bar{\lambda}$: job separation scale parameter; η: vacancy posting cost; b_0: social assistance benefits; b_1: UI benefits. Panel B: s: pension benefits; κ_b: UI benefits tax; $\widetilde{w}$: average monthly wage; θ: labor-market tightness. The columns titled 'bargaining ϕ' indicate that the bargaining power of the worker, ϕ, is set to either 0.25 or 0.75 (vs. 0.50 in the baseline model). The columns titled 'Job separation' indicate that the targeted share of endogenous job separation is either $1/4$ or $3/4$ (vs. $1/2$ in the baseline model).

Table C2: Quantitative effects of severance payments: Other robustness checks

	Base	Rate of SP (in m.w.y.s.)				Base	Rate of SP (in m.w.y.s.)			
		0.25	0.50	0.75	1.00		0.25	0.50	0.75	1.00
	A. Flat productivity					**B. Flat job separation**				
Pension benefits	100	99.8	98.0	96.1	94.3	100	99.9	98.2	96.4	94.7
UI benefits tax	2.47	2.67	2.79	2.92	3.05	2.51	2.62	2.72	2.85	2.96
Unemployment rate	8.56	9.30	9.54	9.78	10.0	8.30	9.07	9.31	9.55	9.80
Separation rate	3.50	3.57	3.55	3.53	3.50	3.50	3.57	3.52	3.51	3.46
Job finding rate	45.0	41.0	39.2	37.6	36.0	45.0	40.8	39.1	37.5	36.0
Average wage	100	100.4	98.7	96.9	95.2	100	100.5	98.8	97.2	95.5
Vacancies	100	95.4	90.2	87.6	85.4	100	94.7	88.9	86.0	83.1
Output per worker	100	100.4	99.7	99.0	98.2	100	100.4	99.5	98.8	97.9
Assets	100	101.1	100.4	99.7	98.9	100	101.1	100.0	99.4	98.2
Welfare	0.00	0.01	-0.12	-0.35	-0.63	0.00	-0.15	-0.37	-0.69	-1.10
	C. No pension benefits					**D. No borrowing**				
Pension benefits	–					100	100.0	98.3	96.3	94.5
UI benefits tax	2.49	2.58	2.65	2.73	2.81	2.48	2.62	2.75	2.86	2.99
Unemployment rate	8.61	8.93	9.10	9.25	9.44	8.58	9.43	9.69	9.90	10.2
Separation rate	3.50	3.48	3.43	3.38	3.35	3.50	3.57	3.56	3.52	3.50
Job finding rate	45.0	42.6	41.0	39.5	38.0	45.0	40.9	39.2	37.7	36.2
Average wage	100	99.3	98.0	96.8	95.6	100	100.6	99.0	97.1	95.4
Vacancies	100	96.4	90.6	87.2	84.3	100	95.0	89.8	86.6	84.3
Output per worker	100	99.8	99.1	98.4	97.7	100	100.5	99.9	99.0	98.2
Assets	100	99.7	98.6	97.7	96.8	100	101.1	100.7	99.7	99.0
Welfare	0.00	-0.45	-0.72	-1.05	-1.45	0.00	-0.29	-0.56	-0.84	-1.15

Notes: Panels A, B, C and D report results in models with, respectively, a flat profile for worker productivity ($\xi_0 = 1$, $\xi_1 = \xi_2 = 0$), a flat profile for job separation ($\varsigma_0 = \varsigma_1 = \varsigma_2 = 0$), no pension benefits ($\kappa_s = 0$) and no borrowing ($\underline{a} = 0$). Parameter values for these models are reported in Table C1. The rate of severance payments (SP) is expressed in months of wages per years of service (m.w.y.s.). The unemployment insurance (UI) benefit tax, unemployment rate, separation rate and job finding rate are all expressed in percentage points. The separation rate and the job finding rate are converted to monthly values. Welfare figures are percentage-point changes in lifetime consumption. Statistics without meaningful units of measurement are normalized to 100.0 in the base column.