Labor-Market Frictions, Incomplete Insurance and Severance Payments

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Discussion Paper 16 / 648

16 November 2015
Revised 16 August 2016

A previous version was circulated with the title:
Penalty vs. Insurance: A Reassessment of the Role
of Severance Payments in an Economy with Frictions

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August 2016

Abstract

We analyze the effects of mandated severance payments in an economy with search and matching in the labor market, risk-averse individuals and imperfect insurance against shocks. Our model emphasizes a tension between efficient worker-firm bargains and consumption smoothing: a well-designed contract dictates a downward shift in entry wages to offset expected severance payments, and thus goes against having a smooth consumption path. As a result, we find that severance payments produce mostly negative welfare effects. There are large allocation and welfare effects in the absence of savings which limits the response of wages to severance payments. With savings, the impact on equilibrium allocations is considerably dampened, but the welfare losses remain substantial.

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

JEL codes: E21; I38, J63, J65

*This article is a substantially revised version of a paper previously circulated under the title: "Matching Frictions, Self-Insurance and Severance Payments". I am grateful to Régis Barnichon, Pierre Cahuc, Christian Haefke, Grégory Jolivet, Iourii Manovskii, Ander Perez, Jean-Marc Robin, Eric Smith, Hélène Turon and Etienne Wasmer for helpful discussions. I also thank seminar participants at the Macro lunch seminar at the University of Pennsylvania, the 27th Congress of the EEA, University of Bristol, Universitat Pompeu Fabra, the ADRES doctoral conference, University of St Gallen, the SaM annual conference and the African SaM workshop for their comments and suggestions. All errors are my own.

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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. The first one proceeds under the assumption of risk neutrality. This opens an important role for Lazear [1988, 1990]'s bonding critique, that severance payments can be undone by efficient worker-firm bargains if, in addition, utility is transferable between agents.[2] Hence this approach is useful to analyze conditions under which mandated severance payments can affect equilibrium allocations even in the presence of decentralized bargaining, such as, e.g., exogenous or endogenous wage rigidities (Garibaldi and Violante [2005], Fella [2012]). The other approach emphasizes risk-averse preferences to study the welfare implications of severance payments. A strand of the literature following this approach, and which we discuss below, operates using incomplete market models. However, due to the complexity of this class of model, this research typically rules out bargaining at the worker-firm level. As a result, not much is known about the equilibrium and welfare effects of severance payments when workers value consumption smoothing and bargain with their employers.

This paper contributes to filling this gap in the literature. We provide a novel assessment of the effects of severance payments based on an environment that combines search and matching with the incomplete market setting. Specifically, we build on recent advances by Krusell et al. [2010], who show how to maintain bargaining at the worker-firm level while allowing for asset accumulation, and Bils et al. [2011] who further develop a model with endogenous separations. We extend this framework in several directions. The first feature we add are two-tiered employment relationships, consistent with the view that severance payments affect new hires and incumbent workers differently. Second, we include a realistically-calibrated unemployment insurance system to allow for an alternative insurance vehicle. Finally, we cast the model in a life-cycle setting to obtain realistic savings behavior. Using this rich economic environment, we proceed with a calibration and a quantitative analysis.

The first set of results concerns the neutrality of mandated severance payments in the environment considered. We find that, in an incomplete market setting, worker-firm bargains can undo a large part of the effects of severance payments on equilibrium allocations. So doing entails a shift in the wage profile: there is a cut in entry wages to neutralize the future transfer from the firm to the worker. Thus, while employment decisions remain almost unchanged, the new wage contract is detrimental to consumption smoothing. We find, consequently, that severance payments produce negative welfare effects. In a host of numerical experiments, severance payments worth six months of a worker's wage decrease welfare by more than 1 percent of lifetime consumption. It is useful to contrast this result with the effect of a pure

[1]Government-mandated severance payments are widespread in OECD countries (OECD [2013]). This policy instrument has two facets: a firing tax paid by the employer and a compensation transferred to the dismissed employee. The penalty incurred by the employer is often higher than the transfer to the worker due to various costs involved in the dismissal procedure.

[2]Lazear [1988, 1990]'s insightful result is that the worker-firm pair can implement a different timing of wage payments: there is an entry fee so that the wage is initially lower to compensate for the expected present value of the future transfer to the worker. The name 'bonding critique' refers to the fact that the entry fee is akin to a bond issued by the newly hired worker.

firing tax. A firing tax is a distortion of job separation decisions that does not improve the bargaining position of the worker. As a result, its negative effect on wages is weaker, and it may even enhance workers' welfare if the decrease in the firing rate is sufficiently large. Severance pay which is a transfer to the worker, on the other hand, strengthens the bargaining position of incumbent employees, and therefore new hires need to 'bite the bullet' to get into employment.

The second set of results pertains to the role of savings. We consider a version of the model without asset accumulation to examine this role. The decrease in entry wages is considerably dampened in this environment, which results in a larger impact of severance payments on equilibrium allocations. Foremost, since the expected sum of payments to workers does not stay constant, firms reduce the number of vacancies posted in equilibrium. The welfare losses of severance payments are twice as large in the absence of savings as per the high marginal utility of consumption of workers. These results echo Lazear [1990]'s discussion in his seminal study: the author notes that in practice there may be several obstacles to the bonding critique, most notably "Imperfections in capital markets that prevent complete smoothing of consumption" (Lazear [1990, p.704]). Our study is the first to analyze this issue through the lens of a quantitative model and draw the implications for welfare.

Before discussing the related literature, it is worth highlighting three features of the analysis. First, we use a life-cycle economy wherein agents start off their life with no assets. It provides us with a relatively simple welfare measure, namely the lifetime utility of a new labor market entrant. In particular, we can carry out welfare comparisons without calculating individual welfare effects and aggregating them using a cross-sectional distribution. Second, we consider an exogenous interest rate and hold it constant across experiments. As such, it allows to measure how an individual fares in economies that pay the same return to the risk-free asset while implying different earnings and labor market trajectories.[3] Last, to fix the real interest rate, we equate it to the subjective discount rate of workers. One implication is that in the same economy but with risk-neutral agents, a transfer from the firm to the worker would have no effects on equilibrium allocations. Thus, as in a 'difference-in-differences' exercise, the model pins down how the effects of severance payments change as we move away from the risk neutral framework, by introducing respectively risk aversion and savings.

As already mentioned, there is a strand of literature that studies the effects of mandated severance payments in an incomplete market setting. Alvarez and Veracierto [2001] provided an early assessment based on an economy with firm-level dynamics, endogenous job separations and an inefficiently high number of layoffs. For tractability, and also for the lack of an alternative wage-setting rule, their analysis assumes rigid wage contracts.[4] Recently, Cozzi and Fella [2016] constructed an incomplete market model with severance payments, a one worker - one firm setup and flexible wages. They give all the bargaining power to workers, they set the vacancy posting cost to zero and they posit exogenous job separations. These assumptions allow the

[3]By holding the interest rate constant, we measure the insurance effects of the policy, and we abstract from a potential general equilibrium effect that would run through capital markets. One interpretation of the model is that it is a small open economy.

[4]They write, "The extreme form of rigid labor contracts we assume not only precludes insurance arrangements and makes the analysis tractable, but it also serves as a natural benchmark in the absence of an obvious intermediate case" (Alvarez and Veracierto [2001, p.482]). We explore the other extreme, in which in each period employers and workers can bargain bilaterally over the match surplus.

authors to specify a rich age-tenure dynamics of productivity to study the earnings losses suffered by displaced workers. Our work is complementary to the research in these papers. We consider the effects of severance payments under flexible wage bargaining, when firms enjoy a positive bargaining power and face costly vacancy posting, and job separations are endogenous. Although there are obviously differences due to the underlying models, we find it worth noting that these two studies report positive welfare effects of severance payments.[5] In Alvarez and Veracierto [2001], the firing penalty role of severance payments improves welfare by preventing workers from being made unemployed too often. In Cozzi and Fella [2016], there is a positive insurance role driven by the permanent earnings losses of job displacement.

There are a few other contributions in the literature that analyze severance payments in models with risk-averse workers. Bertola [2004] studies 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] uses a partial-equilibrium framework to establish that severance payments should be part of an optimal contract to help workers smooth consumption. Fella and Tyson [2013] provide micro-foundations for severance payments that are privately negotiated, in the presence of government-mandated ones. Their model features risk-averse workers and incomplete asset markets, but they rule out wealth effects to obtain tractability (they use a constant absolute risk-aversion utility function). Last, Dolado et al. [2016] study the tenure profile of severance payments. They focus on the political economy problem of reforming 'dual' labor markets. In contrast, the present paper offers a quantitative study of severance payments in a calibrated incomplete market economy.

This paper also contributes to the vast literature on the employment effects of severance payments in the search-matching framework.[6] Burda [1992], Millard and Mortensen [1997] and Mortensen and Pissarides [1999] study the general equilibrium implications of costs that distort hiring and firing decisions. More recently, the literature has analyzed the relationships between severance payments, wage-setting mechanisms and labor-market institutions. Garibaldi and Violante [2005] provide an insightful analysis of the effects of endogenous wage rigidities coming from a coalition of insider workers. Postel-Vinay and Turon [2014] consider the effects of severance payments in a search-matching model with an alternative bargaining protocol between workers and firms. In this paper, we abstract from coalition problems and use the Nash bargaining solution. We measure the employment effects that emerge in the search-matching model when workers are risk-averse, finitely-lived and accumulate assets.

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 discusses the effects of severance payments under the baseline calibration; Section 5 analyzes several alternative calibrations; Section 6 concludes. The paper has two appendices: Appendix A provides computational details on the model; Appendix B contains additional results.

[5] Ljungqvist [2002] shows that firm-level dynamics as in Alvarez and Veracierto [2001] or a one worker - one firm setup are not essential to the employment effects of mandatory layoff payments. It seems likely that rigid wage contracts in their analysis explain much of the differences with the present paper, which assumes bilateral bargaining and privately-efficient separations.

[6] Many of the insights in the literature can be gleaned from the employment adjustment cost model of a monopolistic firm studied by Bentolila and Bertola [1990]. Hopenhayn and Rogerson [1993] extend this model to a general equilibrium environment with firm entry and exit.

2 The economy

The model combines search and matching in the labor market with an incomplete market setting. The main features to capture the employment effects of severance payments are endogenous job separations and two-tiered employment relationships. The features we include for the quantitative exercise are a realistic unemployment insurance system and the life cycle.

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. Newborns are homogeneous and agents are indifferent to their offspring. In every period, agents derive utility from consumption $c_t > 0$ according to a constant relative risk-aversion function:

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

$\gamma > 0$ is the coefficient of relative risk-aversion. We let β denote the discount factor of workers. On the other side of the market, there is a continuum of risk-neutral, infinitely-lived entrepreneurs who maximize the expected value of the sum of profit streams. They discount the future using the real interest rate r, which is assumed to be exogenous and fixed.

Incomplete insurance markets. Risk-averse agents face incomplete insurance markets. Hence they are subjected to a sequence of intertemporal budget constraints:

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

a is a risk-free asset that agents can save but that they cannot borrow; i.e. $a_t \geq 0$. x_t^d denotes disposable income at time t, which is determined below for individuals in the labor force. Retired agents do not have access to retirement plans, so that $x_t^d = 0$ after retirement.

Production technology. The unit of production is a matched worker-firm pair. Labor is the only input and the flow of output that the worker-firm pair produces is y, which we refer to as match productivity. y is idiosyncratic to the worker-firm pair and evolves according to a first-order autoregressive process:

$$y_{t+1} = (1-\rho)\,\mu_y + \rho y_t + \varepsilon_{t+1}.$$

μ_y is the unconditional mean of the process, $\rho \in (0,1)$ is the persistence and $\varepsilon \sim N\left(0, \sigma_\varepsilon^2\right)$ is the innovation term. Hereafter $G\left(.|y\right)$ denotes the transition function for y, i.e. $G\left(y'|y\right) = \Pr\left\{y_{t+1} < y' | y_t = y\right\}$. Finally, we assume that a worker-firm pair can be exogenously destroyed with per-period probability δ. This assumption is inessential but it is useful to discipline the model's calibration.

Timing. The timing of meeting and production is as follows:

1. Unmatched workers search for an employer with a vacant job and vice versa. An employer pays a cost $\eta > 0$ per period to keep a vacant job open. 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 employer, and $\theta_t q(\theta_t)$ for a prospective worker.

2. On meeting, the potential worker-firm pair draws a productivity level y from the distribution $G^0(.) \equiv G(.|\mu_y)$. The worker and the employer observe y and decide whether to stay together or walk away.

3. If they choose to stay together, the worker-firm pair starts producing subject to the technology described in a previous paragraph. We introduce below mandated severance payments for incumbent workers, and thus we must keep track of a worker's tenure.[7] For parsimony, we use two levels of tenure: $i = 0$ indicates a short tenure and $i = 1$ an incumbent worker (longer tenure). Index i evolves stochastically according to:

$$p_{i,j}^e = \begin{bmatrix} 1-p^e & p^e \\ 0 & 1 \end{bmatrix}$$

   with $i, j \in \{0, 1\}$. Therefore ${1}/{p^e}$ is the expected duration before switching from a short to a longer tenure.

We remark on some implications of this timing. First, since on meeting the worker and the employer can discard the option of beginning production, the timing ensures that a firm is not subjected to any severance cost if there is never an employment relationship. The same assumption is made, for instance, in Mortensen and Pissarides [1999] and Ljungqvist and Sargent [2007].[8] Second, the decision to dissolve the match will depend on tenure. Hereafter we refer to the rule at $i = 0$ as the *entry-level* decision and the rule at $i = 1$ as the *continuation* decision. The match continuation decision will differ from the entry-level decision if, for instance, mandatory severance payments change the outside option of incumbent workers and employers.

Government-mandated policies. The government runs two labor-market programs. The first program is mandatory severance payments: there is a firing tax F paid by employers for each job that is terminated (the penalty component), and a lump-sum transfer T to the dismissed worker (the insurance component). This policy is said to be self-financed when

[7] In the majority of countries with government-mandated severance payments, the compensation to the dismissed worker increases with tenure; see, for instance, OECD [2004, 2013] and Figure 1 in Boeri et al. [2014].

[8] Ljungqvist [2002] discusses the assumption that the firm does not incur a severance cost if the worker and the employer do not agree on a wage on meeting. Like Ljungqvist and Sargent [2007], but unlike Mortensen and Pissarides [1999] who assume the initial value of employment always dominates the value of continued search, we allow for some heterogeneity in productivity at the time of meeting, i.e. the distribution $G^0(.)$ is nondegenerate. Another difference with the textbook model of Mortensen and Pissarides [1999] is that they assume independent draws conditional on resampling y. We use a first-order autoregressive process for y which we can connect to micro evidence based on wage data.

$F = T$. In that case, it cannot be distinguished whether T is paid directly by the employer to the worker or whether it is transferred by the government on collecting F from the employer. Government-mandated severance payments apply only to incumbent workers. Finally, we also assume that severance payments are waived when the worker retires from the labor force or when the job is destroyed exogenously by the δ shock.[9] Since the focus is on bargaining, we are only interested in the interaction between severance payments and those shocks that can be contracted on.

The second program is an unemployment insurance system that we specialize to replicate the current U.S. system. It pays a constant amount of benefits b_1 for a definite period; after unemployment benefits have expired, individuals move on to social assistance, which provides a significantly lower benefit b_0 for an indefinite period. Just like tenure accumulation, the exhaustion of unemployment benefits is governed by a two-state Markov process:

$$p_{i,j}^u = \begin{bmatrix} 1 & 0 \\ p^u & 1 - p^u \end{bmatrix}$$

with $i, j \in \{0, 1\}$. p^u is the per-period probability of exhausting benefits b_1. Individuals who have exhausted their unemployment benefits remain ineligible for b_1 as long as they do not return to work. The government finances the provision of unemployment insurance and social assistance by means of a payroll contribution tax κ.

2.2 Bellman equations

To formulate workers' decision problems, denote by R, U, W the value of retirement, unemployment and employment, respectively. For employers, denote by J the value of having a filled job. We formulate these decision problems in recursive form, and therefore we omit the time subscript in the remainder of this section. Hereafter, τ denotes the age of a worker and a prime ($'$) indicates the one-period-ahead value of a variable. 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

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

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 for unem-

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

ployment benefits $i \in \{0,1\}$. These asset values are the solution to:

$$U_i(a,\tau) = \max_{c,a'} \Bigg\{ u(c) + \beta \sum_{j=0,1} p^u_{i,j} \Big((1-\theta q(\theta)) U_j(a',\tau') + \theta q(\theta) \int \max\{W_0(y',a',\tau'), U_j(a',\tau')\} dG^0(y') \Big) \Bigg\} \quad (2)$$

subject to

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

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

For employed workers, the asset values depend on a and τ, and also on tenure at the current employer $i \in \{0,1\}$ and match productivity y. These asset values solve:

$$W_i(y,a,\tau) = \max_{c,a'} \Bigg\{ u(c) + \beta \Big(\delta U_1(a',\tau') + (1-\delta) \sum_{j=0,1} p^e_{i,j} \int \max\{W_j(y',a',\tau'), U_1(a'+T_{\tau,j},\tau')\} dG(y'|y) \Big) \Bigg\} \quad (3)$$

subject to

$$\begin{aligned} c + a' &\leq (1+r)a + w_i(y,a,\tau) \\ a' &\geq 0 \end{aligned}$$

for every $1 \leq \tau \leq N_w$, and where $W_i(y,a,N_w+1) = R(a,N_w+1)$ for every i, y and a. In equation (3) we use $T_{\tau,j}$ as a short notation for $T \times \mathbb{1}\{\tau < N_w, j=1\}$, i.e. T depends on the worker's tenure. In the budget constraint, $w_i(y,a,\tau)$ denotes the wage of the worker, which is determined endogenously below.

Associated with equation (1) is a decision rule for asset holdings $\overline{a}^R(a,\tau)$. Similarly, associated with equations (2) and (3) is a set of decisions rules for asset holdings $\overline{a}^U_0(a,\tau)$, $\overline{a}^U_1(a,\tau)$, and $\overline{a}^W_0(y,a,\tau)$, $\overline{a}^W_1(y,a,\tau)$, respectively.

We assume employers operate under free entry, which dictates that the value of a vacant job is always zero. As in equation (3), if we use $F_{\tau,j}$ as a short notation for $F \times \mathbb{1}\{\tau < N_w, j=1\}$, then the asset values indexed by $i \in \{0,1\}$ for matched employers solve:

$$J_i(y,a,\tau) = y - (1+\kappa) w_i(y,a,\tau) + \frac{1-\delta}{1+r} \sum_{j=0,1} p^e_{i,j} \int \max\{J_j(y',a',\tau'), -F_{\tau,j}\} dG(y'|y) \quad (4)$$

for every $1 \leq \tau \leq N_w$, and where $J_i(y,a,N_w+1) = 0$ for every i, y and a. In equation (4), $a' = \overline{a}^W_i(y,a,\tau)$: the employer recognizes that the worker's next period asset decision is given by the policy function $\overline{a}^W_i(y,a,\tau)$.

2.3 Wage setting

Wages are set via Nash bargaining. Here, we make an additional assumption: we posit that the outside option of the worker is given by the value of insured unemployment, $U_1(.)$. The rationale behind this assumption is as follows. First, for workers who have been employed at least one period, it is standard in search-matching models to assume that unemployment benefits affect the wage, and hence that $U_1(.)$ is the relevant threat point during the wage bargain. An important reason 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.[10] Next, consider an uninsured worker. On meeting an employer, her outside option could in principle be given by $U_0(.)$. After just one period of employment, however, it switches to $U_1(.)$.[11] Thus, using $U_0(.)$ as the outside option in the first employment period would complicate the model with little gain in insight, at least for our purposes. We will study in Section 5 the sensitivity of the results to changes in the value of benefits b_1.

Under these assumptions, the wage schedule $w_i(.)$ indexed by $i \in \{0, 1\}$ is given by

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

for short tenures, and

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

at longer tenures for all (y, a, τ). In equations (5) and (6), $\phi \in (0, 1)$ is the bargaining power of the worker.

2.4 Match decision rules

The entry-level decisions are based on the comparison between the value of being matched and the value of continued search. Similarly, the match-continuation decisions follow from comparing the value of continuing the match with that of dissolving the match. Therefore there are two threshold functions $\overline{y}_0(a, \tau)$ and $\overline{y}_1(a, \tau)$ which satisfy:

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

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

for all (a, τ).

[10] See Hagedorn et al. [2015] and the discussion therein. The authors provide a case study of unemployment insurance law in the State of California. They argue that in general a worker can bargain for a higher wage by threatening the employer to induce a firing. A worker fired for misconduct is not eligible for unemployment benefits, but proving misconduct is costly for the employer. In other words, the worker can effectively use insured unemployment as her outside option.

[11] Notice that in this discussion we abstract from unemployment benefits eligibility. In our view, eligibility requirements are of separate interest, and they are too costly to introduce in such a rich economic environment. For example, a common rule in many U.S. states is 'monetary eligibility': it dictates that 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.

2.5 Aggregate conditions

To write the aggregate equilibrium conditions that pin down labor-market tightness θ and the payroll tax κ, let $\mu_i^U(a,\tau)$, $\mu_i^W(y,a,\tau)$ with $i \in \{0,1\}$ denote the population distribution of workers in unemployment and employment, respectively.

Free entry. The model assumes free entry for firms: employers exhaust the present discounted value of job creation net of the vacancy-posting cost. Since vacancies and unemployed workers meet by the end of a model period, the free-entry condition yields:

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

That is, the conditional distribution used to form expectations is obtained by scaling $\mu_i^U(.)$ with the size of the unemployment pool u_{N_w-1}, and the subscript indicates agents of age less than $N_w - 1$ periods. Notice that in the asset values of employers (equation (4)) and in the wage bargain (equations (5) and (6)), we have used the fact that the value of a vacancy is zero under free entry of firms.

Balanced budget. Finally, government expenditures are financed by the payroll tax:

$$\kappa \sum_{\tau=1}^{N_w} \sum_{i=0,1} \int_{Y,A} w_i(y,a,\tau)\, d\mu_i^W(y,a,\tau) = \sum_{\tau=1}^{N_w} \sum_{i=0,1} b_i \int_A d\mu_i^U(a,\tau). \tag{10}$$

In a numerical experiment below, we study the effects of the firing tax F when the transfer component T remains equal to zero. The proceeds from F in that experiment are used to finance government expenditures, which will add a term to the left-hand side of equation (10).

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 $\left(\overline{a}^R(a,\tau), \overline{a}_0^U(a,\tau), \overline{a}_1^U(a,\tau), \overline{a}_0^W(y,a,\tau),\right.$ $\left.\overline{a}_1^W(y,a,\tau)\right)$, 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 and a payroll tax rate κ such that:

1. Optimal asset-holding decisions: the asset-holding decision $\overline{a}^R(a,\tau)$ solves the inner maximization problem in equation (1). Given tightness θ 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 payroll tax κ, the wage schedules $w_0(y,a,\tau)$, $w_1(y,a,\tau)$ and the asset-holding decisions $\overline{a}_0^W(y,a,\tau)$, $\overline{a}_1^W(y,a,\tau)$, 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 the asset values $J_0(y,a,\tau)$ and $J_1(y,a,\tau)$, the match-entry and match-continuation rules $\overline{y}_0(a,\tau)$, $\overline{y}_1(a,\tau)$ are the solution to equations (7) and (8).

4. Two-tier Nash bargaining: given the asset values $U_0(a,\tau)$, $U_1(a,\tau)$, $W_0(y,a,\tau)$, $W_1(y,a,\tau)$, $J_0(y,a,\tau)$, $J_1(y,a,\tau)$, the wage functions $w_0(y,a,\tau)$, $w_1(y,a,\tau)$ are the solution to equations (5) and (6).

5. Free-entry condition: given the asset value $J_0(y,a,\tau)$, the 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 condition: given the wage schedules $w_0(y,a,\tau)$, $w_1(y,a,\tau)$ and the population distributions $\mu_0^U(a,\tau)$, $\mu_1^U(a,\tau)$, $\mu_0^W(y,a,\tau)$, $\mu_1^W(y,a,\tau)$, the payroll tax rate κ satisfies equation (10).

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 set of decision rules $\left(\overline{a}^R(a,\tau),\right.$ $\left.\overline{a}_0^U(a,\tau), \overline{a}_1^U(a,\tau), \overline{a}_0^W(y,a,\tau), \overline{a}_1^W(y,a,\tau)\right)$ and $(\overline{y}_0(a,\tau),\, \overline{y}_1(a,\tau))$, and by equilibrium 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 and from the Bellman equations (1), (2), (3). To write the system of stock-flow equations, we assume furthermore that newborns are initially unemployed with no unemployment insurance benefits ($i = 0$), and they have no assets ($a = 0$). Appendix A.1 presents the computational algorithm we use to solve for a stationary equilibrium.

3 Calibration and steady-state properties

This section proceeds with the calibration of the model with no severance payments ($F = T = 0$). We use U.S. data for this purpose because government-mandated severance payments are virtually non-existent in most U.S. states. This suggests that the observed dynamics of the U.S. labor market is directly informative for the model, in that we need not control for a part of this dynamics that would be driven by mandated severance payments. Moreover, the unemployment insurance system of the model stands similar to the current U.S. system.

The calibration is in two steps: we choose the value of several parameters using *a priori* information, and we calibrate jointly the remaining parameters. Before we move on to the numerical results, we discuss some properties of the steady-state equilibrium.

3.1 Parameters set externally

The model period is chosen to be one quarter, which is a compromise between computational costs and the fast dynamics of the U.S. labor market that informs the model. We interpret the working life as a 40-year period and the retirement phase as 15 years; hence, $N_w = 160$ and $N_r = 60$. We choose the interest rate r to be 4 percent a year. Furthermore, we assume that $\beta = (1+r)^{-1}$, and thus $\beta = 0.990$. As noted in the introduction, this assumption is more than just a mere way to pin down β: in the same model but with risk-neutral workers, severance payments would have no effects on equilibrium allocations. We set the coefficient of relative risk aversion γ to 2.0, a standard value in the literature.

The stochastic process for match productivity y is governed by three parameters: μ_y, ρ and σ_ε. The unconditional mean of match productivity, μ_y, is normalized to 1.0. For the persistence ρ, we use the estimates reported in Table 1 of Chang and Kim [2006]: the authors find that the annual persistence of match productivity is 0.781 for men and 0.724 for women.[12] We therefore choose $\rho = 0.931$, which yields a persistence of 0.751 ($= 0.931^4$) at the annual frequency. We calibrate the volatility of productivity shocks σ_ε in the next subsection.

The remaining parameters that we choose *a priori* are ϕ, p^e, p^u. Following much of the literature on search-matching models, the bargaining power of workers is: $\phi = 0.5$. We interpret a short tenure as a period of less than 2 years, and thus we set $p^e = 0.125$.[13] Last, we use $p^u = 0.50$ to make unemployment benefits expire after two quarters.

3.2 Calibrated parameters

We must specify the matching function to complete the specification of the model. We adopt the matching function proposed by den Haan et al. [2000], namely:

$$m(u,v) = \frac{uv}{(u^\alpha + v^\alpha)^{\frac{1}{\alpha}}}, \quad \alpha > 0,$$

to ensure that the probabilities of job-filling and job-finding lie between 0 and 1. Hence the parameters to be calibrated are: α, b_0, b_1, η, σ_ε and δ.

We target the following data moments: (i) a monthly job-finding rate of 45 percent;[14] (ii) a 5 percent replacement ratio for social assistance; (iii) a 45 percent replacement ratio for unemployment insurance benefits; (iv) a job creation cost worth 57.7 percent of the average monthly labor productivity; (v) a monthly separation rate of 3.5 percent; (vi) a ratio of 50 percent between the number of endogenous job separation and the total number of job separations. (i) is the monthly target for the job-finding rate used by Shimer [2005] and Krusell et al. [2010].[15] (ii) and (iii) are based on institutional features of the U.S. labor market (OECD [2010]). In the model, we measure the replacement ratio as the value of benefits divided by the average wage in equilibrium. Target (iv) is the unit cost of a vacancy computed by Hagedorn and Manovskii

[12] Chang and Kim [2006] use wage data from the Panel Study of Income Dynamics to obtain the parameters of a first-order autoregressive productivity process, which they estimate controlling for selection into employment.

[13] p^e matters only when severance payments are introduced later on in the analysis. The value chosen for p^e is motivated by the fact that, in labor markets with high levels of employment protection for high-tenure workers, there is often an entry period (a temporary contract, a probationary period, etc.) during which the firm incurs little to no cost in case of dismissal. These entry periods typically last for no more than 2 years.

[14] Although the model period is one quarter, we convert the targets to a monthly frequency which is more common when analyzing the U.S. labor market. We follow this convention throughout the analysis.

[15] In the model, the job-finding rate and the separation rate are computed among workers aged strictly less than N_w periods; that is, we report the transition rates conditional on staying in the labor force.

[2011]. The value of the monthly separation rate in (v) is also standard for the U.S. labor market; for example, Shimer [2005] sets this target to 3.4 percent. Finally, our rationale for the additional moment condition (vi) is as follows. In the data, layoffs account for only a share of job separations, so that some separations must be caused by exogenous reasons that cannot be impacted by severance payments. Without any clear guidance from the data, we choose a 50:50 split for the share of worker-firm separations that are endogenous. In Section 5, we consider the effects of deviating below and above this moment.

Our calibration procedure allows us to match the six data moments very precisely. First, we guess a set of parameter values for b_0, b_1, η, σ_ε, δ. We calibrate α to replicate the targeted job-finding rate using the procedure described in Appendix A.2.[16] Finally, we update b_0, b_1, η, σ_ε, δ with the resulting model-generated moments for (ii)–(vi), and repeat the procedure until convergence.

3.3 Model outcomes

The parameter values of the baseline calibration are collected in Table 1. In this subsection, we highlight some properties of the model that emerge from this calibration.

Table 1: Parameter values (one model period is one quarter)

Parameters set externally		
Subjective discount factor	β	0.990
Risk aversion	γ	2.0
Periods in the labor force	N_w	160
Periods in retirement	N_r	60
Mean of match productivity	μ_y	1.0
Persistence of match productivity	ρ	0.931
Bargaining power of workers	ϕ	0.5
Probability of switching to long tenure	p^e	0.125
Probability of exhausting benefits	p^u	0.500
Calibrated parameters		
Matching function parameter	α	1.359
Social assistance benefits	b_0	0.050
Unemployment insurance benefits	b_1	0.445
Vacancy posting cost	η	0.224
Volatility of match productivity	σ_ε	0.174
Probability of exogenous destruction	δ	0.052

First, in Figure 1, we report the model-generated life-cycle profile of asset holdings. It inherits a property of life-cycle models with savings: agents accumulate assets during the working life period and then run down these assets until they leave the economy at age $N_w + N_r$. On the vertical axis, assets are expressed in years of annual labor earnings. Workers have no assets when they enter the labor force, and they hold about 10 years of annual earnings 40

[16] Notice that the job-finding rate is different from $\theta q(\theta)$: there is a non-zero probability that the worker and the employer walk away after observing the initial productivity draw.

years later. These patterns are similar to those in several analyzes based on heterogeneous-agent life-cycle models; see, for example, Figure 4 in Kitao et al. [2016].

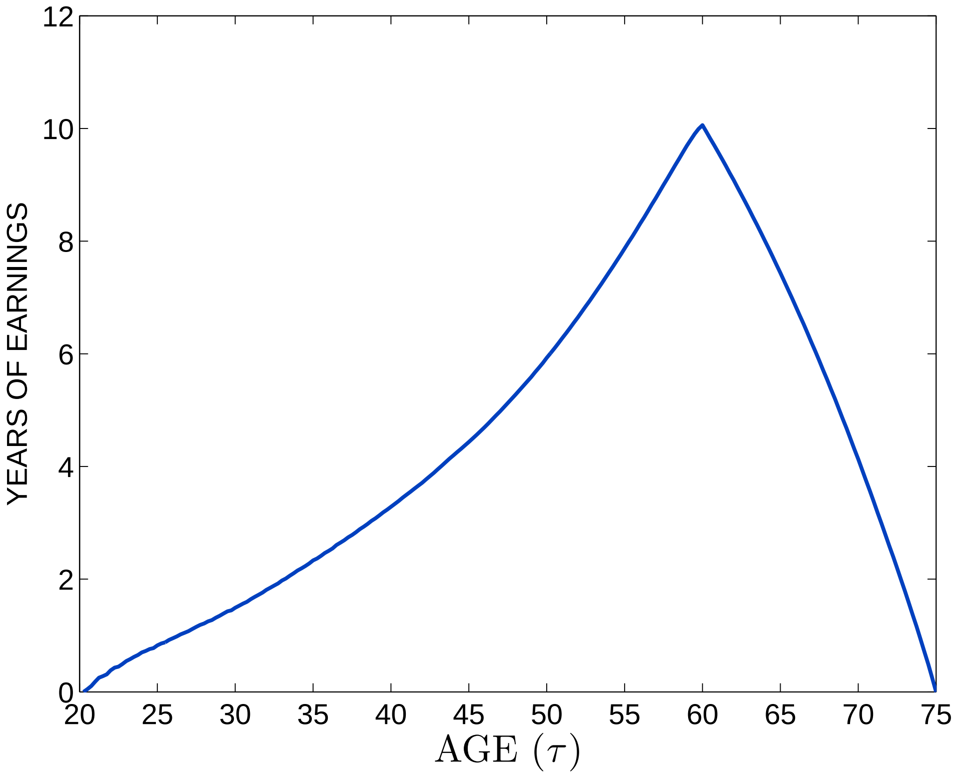

Figure 1: Average savings over the life cycle

NOTE: This plot shows average savings in each age group in the steady-state equilibrium, where savings are expressed as a function of average annual earnings.

Another property of the model is that workers would benefit from a lower unemployment compensation relative to the baseline. Indeed, in Appendix B.1, we show that welfare would be higher if the benefit b_1 delivered a replacement ratio of 35 percent. This is in tune with many studies on tax-financed unemployment insurance in incomplete market economies. The study that is closest with respect to the modeling framework is Krusell et al. [2010]; they find that a replacement ratio around 12 percent maximizes welfare. We find a higher optimal replacement ratio because unemployment benefits in our model have finite duration and agents need to accumulate savings for retirement. In any case, the main message is that the framework is consistent with previous findings about unemployment insurance based on incomplete market models calibrated to U.S. data.

4 Numerical experiments

This section contains the main discussion of the effects of severance payments on equilibrium allocations and welfare. We consider two polar cases: (i) a pure transfer from the firm to the worker and (ii) a pure tax on the worker-firm pair, which we refer to as severance payments and layoff taxes, respectively. The latter is typically the focus of the 'standard view of firing costs' (Bertola and Rogerson [1997]), i.e. it is the sunk portion of severance payments.

In the discussion that follows, in order to better isolate the main mechanisms, we will sometimes use the results based on a variant of the model that shares the same economic environment but without savings. Appendix A.3 describes this model.

Welfare metric. Throughout the analysis, we draw a comparison between welfare in the steady state equilibrium without severance payments and welfare in other equilibria. This comparison is based on a standard compensated variation measure. Let $\overline{U}_0(0,1)$ be the lifetime utility of a newborn in the base economy, and denote with an upper tilde ($\sim$) her lifetime utility in an environment with severance payments. The value ϑ given by

$$\vartheta = \left(\frac{\widetilde{U}_0(0,1) + B}{\overline{U}_0(0,1) + B}\right)^{\frac{1}{1-\gamma}} - 1,$$

with $B = \frac{1}{1-\gamma}\frac{1-\beta^{Nw+N_r}}{1-\beta}$, measures the change in lifetime consumption relative to the base economy. Hereafter, the number we report for ϑ is expressed in percentage points.

Some remarks are in order. First, while workers populate one side of the economy, the model also features a positive measure of firms. Thus, one can interpret the welfare function as having a zero weight on the utility of firms; in this environment, firms are essentially a modeling device used to endogenize wages and job creation. Moreover, we note that a welfare criterion that would account for both workers and firms would raise a number of further issues since: (i) firms are risk neutral and workers are risk averse and (ii) firms are infinitely lived and the number of firms is endogenous. In other words, a synthetic welfare criterion would be difficult to apprehend because it would aggregate heterogeneous preferences and compare economies with different population measures of firms. Finally, the welfare criterion we use is consistent with the steady-state comparisons derived from the experiments.[17]

4.1 A transfer from the firm to the worker

Table 2 reports the effects of severance payments on equilibrium allocations and welfare. The first column ('base') is the baseline economy with no severance payments. The other columns characterize steady-state equilibria with increasing levels of severance payments. The subsequent tables of the paper follow this practice.

Equilibrium allocations. The first remarks concern the effects of severance payments on employment inflows and outflows. There are two forces shaping the effects on the separation rate: the penalty component F deters employers from dissolving the match, while receiving the transfer T gives workers incentives to separate. We find that these effects roughly compensate each other. More importantly, severance payments have a limited impact on the hiring margin, for reasons that we discuss momentarily. Therefore the effect of severance payments on unemployment is quantitatively small. We find, in particular, that it is an order of magnitude lower

[17] Our focus on newborn workers would be less justified in a study of the transition dynamics. The transition dynamics is a complicated problem in this setting because the payroll tax is a sluggish variable, which in turn implies that tightness cannot 'jump' to its new steady-state value after a policy change. Dolado et al. [2016] tackle this issue; they rule out savings to keep the computational task manageable.

than what previous studies tabulated: Alvarez and Veracierto [2001], for example, report that severance payments worth 6 months of wages change unemployment by 1.4 percentage points, whereas Table 2 indicates a change by 0.1–0.2 percentage points.

The second part of the table sheds light on these results. A mandatory transfer to the worker lowers the average wage through bargaining at the worker-firm level. The insights of Lazear [1988, 1990]'s bonding critique help understand the mechanism at work. At the entry level, workers must accept lower wages in order to remain employed until they become eligible for severance payments. The wages of incumbent workers (not reported) actually increase because severance payments strengthen their bargaining position, but the decrease in entry wages is much larger and drives the average wage downward. In the sequel, we refer to this wage profile as a two-step wage contract, as in the literature on wage-tenure contracts (e.g., Burdett and Coles [2003], Stevens [2004]).[18] Finally, due to the decrease in the average wage, the payroll tax rate increases in the columns on the right of the table.

Table 2: Quantitative effects of severance payments: Baseline results

	Base	$F = T > 0$ (in months of average wage)					
		1.0	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**
Tax rate	5.13	5.20	5.25	5.30	5.34	5.37	5.39
Separation rate	3.50	3.51	3.52	3.53	3.53	3.54	3.54
Job-finding rate	45.0	45.0	45.0	44.9	44.9	44.8	44.7
Average wage, overall	100.0	99.3	98.6	98.0	97.5	97.1	96.7
Average wage, entry level	100.0	96.3	92.6	89.1	85.6	82.1	78.7
Vacancies	100.0	100.1	100.1	100.0	99.8	99.7	99.6
Assets	100.0	101.7	102.9	103.5	103.6	103.1	102.1
Welfare	0.00	-0.01	-0.05	-0.20	-0.43	-0.74	-1.12

NOTE: The numbers in bold refer to the value of F and T in months of the average wage in the steady state of the corresponding column. Rates are expressed in percentage points. The separation and the job-finding rates are converted to monthly values. Statistics without meaningful units of measurement are normalized to 100.0 in the base column. Welfare effects are percentage-point changes in lifetime consumption.

The results obtained thus far show that the impact of severance payments on equilibrium allocations can be largely undone in a standard incomplete market setting. As can be inferred from the behavior of the separation rate and the job-finding rate, productivity per workers remains almost constant, and so does gross output.[19] Vacancies decrease only slightly when severance payments amounts to 4, 5 or 6 months of wages. To better understand the results, we conducted the same numerical experiment in the model without savings (Appendix B.3). We find that the absence of savings goes against the decrease in entry wages. As a result, the effects on job separations, job finding, output and vacancies are substantially larger without savings. For instance, vacancies decrease by more than 10 percent when severance payments amount to

[18] Of course, there are very different forces at work behind those two-step wage contracts. The key element in that literature is that employed workers search for jobs as well as unemployed workers.

[19] Thus, the decrease in wages is not driven by a change in the cross-sectional distribution of worker-firm pairs across the values of match productivity.

6 months of wages. This finding underscores the importance of asset market incompleteness as an impediment to the neutrality of severance payments.

Welfare. The last row of Table 2 shows that severance payments produce negative welfare effects. This follows from the previous discussion: mandatory transfers have a limited impact on equilibrium allocations because they can be undone by a two-step wage contract which, in turn, is detrimental to workers as they value consumption smoothing. The accumulation of assets over the life cycle implies that these wage-shifting effects are less costly at older ages. The economy without savings illustrates this point well: the welfare losses are larger therein because workers cannot avoid having high marginal utilities from consumption. This said, even with savings the welfare losses that we tabulate are substantial. They stand in contrast with the results of Alvarez and Veracierto [2001] and Cozzi and Fella [2016] who report welfare improvements by 1.6 percent and 0.8 percent, respectively.[20] Severance payments worth 6 months of wages entail a decrease in lifetime consumption by 1.1 percent.

4.2 A tax on the worker-firm pair

Next, we remove the transfer component, i.e. we set $T = 0$. We study the effects of varying the level of $F > 0$ and use the proceeds from the firing tax to finance unemployment insurance.[21] That is, F plays an overtly negative role because it creates a deadweight loss for the worker-firm pair, but the distortion can be mitigated by lowering the payroll tax κ.

Equilibrium allocations. As shown in Table 3, firing taxes have a large negative impact on the separation rate: this is the so-called firing penalty role of severance payments. They also reduce the surplus of every job, which has a negative impact on job creation, but in all calibrations (e.g., Table 5) we find that the effect on worker flows into unemployment dominates the effect on the outflows.[22] The unemployment rate decreases by about 0.7 percentage points under the baseline calibration. One factor that mitigates the negative effects of firing taxes on profits, and thereby job creation, is the reduction of the payroll tax κ. First, there are fewer unemployed workers and thus fewer unemployment benefits claims to finance. Second, the payroll tax revenue increases because of a larger tax base. In some instances in Table 5, we find that the effect is so large that the proceeds of the tax are actually rebated as a wage subsidy.

[20]As we noted in the introduction, the model used by these authors differ from our model along several dimensions. For the study by Alvarez and Veracierto [2001], the welfare figures we report are based on Table 1 of their paper. For the study by Cozzi and Fella [2016], we use the results from Table 7 of their paper where severance payments are measured in months of wages.

[21]The budget constraint (equation (10)) becomes

$$\Omega F + \kappa \sum_{\tau=1}^{N_w} \sum_{i=0,1} \int_{Y,A} w_i\left(y,a,\tau\right) d\mu_i^W\left(y,a,\tau\right) = \sum_{\tau=1}^{N_w} \sum_{i=0,1} b_i \int_A d\mu_i^U\left(a,\tau\right),$$

where Ω is the number of endogenous job separations.

[22]In principle, the effect of firing taxes on the unemployment rate is ambiguously signed. It seems that, in practice, many calibrated versions of the search-matching model predicts a negative effect (unemployment decreases). This point is illustrated by Ljungqvist [2002]'s examination of various calibrations of the model.

The second part of Table 3 shows the effects of firing taxes on wages. The average wage decreases, but the underlying mechanism is different from the wage-shifting effect analyzed in the previous section: wages decrease among both new hires and incumbent workers. It is worth distinguishing two effects. First, there is a reduction of the size of the job surplus, *ceteris paribus*. Second, layoff taxes make employers retain their workers more often when match quality deteriorates, which entails a less efficient allocation of labor. In fact, for incumbent workers ($i = 1$) we find that output per worker decreases by 6.2 percent when firing taxes amount to 6 months of the average wage.

Table 3: Quantitative effects of firing taxes: Baseline results

	Base	$T = 0,\ F > 0$ (in months of average wage)					
		1.0	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**
Tax rate	5.13	4.04	3.10	2.28	1.57	0.98	0.50
Separation rate	3.50	3.36	3.24	3.15	3.08	3.04	3.01
Job-finding rate	45.0	45.0	44.9	44.6	44.3	43.9	43.3
Average wage, overall	100.0	99.4	98.8	98.1	97.3	96.5	95.7
Average wage, entry level	100.0	99.0	97.8	96.5	95.1	93.5	91.9
Net output	100.0	100.0	99.9	99.8	99.6	99.4	99.1
Assets	100.0	99.9	99.2	98.0	96.2	93.9	91.1
Welfare	0.00	0.36	0.60	0.72	0.74	0.65	0.46

NOTE: The numbers in bold refer to the value of F in months of the average wage in the steady state of the corresponding column (note: $T = 0$). Rates are expressed in percentage points. The separation and the job-finding rates are converted to monthly values. Statistics without meaningful units of measurement are normalized to 100.0 in the base column. Welfare effects are percentage-point changes in lifetime consumption.

In this experiment, instead of the change in vacancies, we report the impact of the policy on net output. Notice first that layoff taxes have two countervailing effects on gross output. On the one hand, as just noted, they deteriorate average output per worker. On the other hand, there are more employed workers because the separation rate decreases. We find that the first effect always dominates, so that gross output decreases with the amount of layoff taxes. Next, in the economy there are less congestion on the worker side and, consequently, there are fewer vacant positions. Since firms incur a per-period cost of keeping a job vacant, this effect increases net output. We find, however, that it is quantitatively limited, so that under the baseline calibration net output decreases with firing taxes. This finding turns out to hold true in most calibrations. In the absence of savings, the decrease in vacancies is magnified, and therefore the increase in output through this channel is larger (see Appendix B.3). The overall change of net output remains plausibly small.

Welfare. The penalty component of severance payments increases welfare under the baseline calibration.[23] It is noteworthy that this result is *not* a robust prediction of the model.

[23]Firing taxes have a large impact on savings, in contrast to the transfer component of severance payments. A change in the real interest rate could change the welfare impact of firing taxes. Hence we think that the welfare implications (the sign of which is not constant across different calibrations) should be interpreted with caution.

That is, the effects on welfare depends on the relative importance of two effects: layoff taxes deteriorate welfare by lowering wages and they improve it by increasing the duration of employment. We think these findings share certain features of the positive welfare effects of firing taxes in Alvarez and Veracierto [2001], and more generally with an important rationale for employment protection (Pissarides [2001]): the penalty component of severance payments can be beneficial to the extent that it improves job stability. In Alvarez and Veracierto [2001], this effect is much more pronounced because workers suffer a large disutility from search effort during unemployment. In our model the costs of job creation accrue to the firms and welfare is measured from a worker's perspective. These features mitigate the adverse welfare consequences of firing taxes.

5 Sensitivity analysis

In this section, we examine a host of alternative calibrations. The purpose is not only to check the robustness of the results, but also to highlight the role of some key variables. In each calibration, we follow the procedure described in Subsection 3.2. The recalibrated parameters are reported in Appendix B.2. The results of the experiments studying the effects of severance payments (resp. firing taxes) are collected in Table 4 (resp. Table 5).

Volatility of productivity shocks σ_ε. To understand the effects of endogenous separations (which are subjected to severance payments) we shift the volatility of productivity shocks σ_ε. We set σ_ε below (resp. above) the base value so that these shocks explain 25 percent (resp. 75 percent) of all separations. As shown in Panel 1 of Table 4, the effects of severance payments are robust to changing this feature of the calibrated model. The more interesting result pertains to the effects of the firing tax component. We see that, in Table 5 together with Table 3, the welfare implications range from very negative to very positive, depending on the share of endogenous separations. For instance, at a lower value of σ_ε, the decrease in wages is similar to the baseline results but the change in welfare is negative. This could be driven by the fact that the decrease in the motive for savings is less than in the baseline results.[24] On the other hand, at a higher value of σ_ε, we find a smaller decrease in wages and a more pronounced increase in job security as measured by the separation rate. As a result, in this scenario welfare increases by 2.7 percent. It should be noted, again, that these experiments measure the pure insurance value of the policy.

Unemployment insurance benefits b_1. We analyze the effects of changing the generosity of unemployment benefits b_1: in the low b_1 scenario, the replacement ratio is 30 percent while in the high b_1 scenario this ratio is 60 percent.[25] The effects of layoff taxes are qualitatively similar to the baseline results, and hence we focus on the effects of severance payments

[24] To rationalize the exogenous interest rate, we have invoked the assumption of a small open economy (Footnote 3). In a closed economy, since workers should hold a small share of the capital stock, it seems unclear whether the impact of severance payments on their saving decisions should matter for the aggregate asset market.

[25] As shown in Appendix B.2, in the recalibration the value of the parameter b_0 changes so that the replacement ratio of social assistance remains constant at 5 percent of the average wage.

Table 4: Quantitative effects of severance payments: Sensitivity analysis

	Base	$F = T > 0$				Base	$F = T > 0$			
		1.5	**3.0**	**4.5**	**6.0**		**1.5**	**3.0**	**4.5**	**6.0**
		1a. Low σ_ε					**1b. High** σ_ε			
Tax rate	5.07	5.13	5.16	5.18	5.20	5.20	5.34	5.45	5.51	5.53
Separation rate	3.50	3.51	3.52	3.53	3.54	3.50	3.51	3.51	3.50	3.47
Job-finding rate	45.00	45.1	45.1	45.0	44.9	45.00	44.9	44.7	44.6	44.4
Average wage, overall	100.0	99.7	99.5	99.3	99.2	100.0	97.3	95.3	94.1	93.4
Average wage, entry level	100.0	94.9	89.8	84.6	79.3	100.0	93.7	87.9	82.6	77.5
Vacancies	100.0	100.6	100.9	101.0	100.8	100.0	100.0	99.6	98.8	97.7
Assets	100.0	100.6	101.2	101.9	102.6	100.0	100.4	100.3	99.8	98.7
Welfare	0.00	-0.03	-0.18	-0.59	-1.19	0.00	-0.01	-0.20	-0.62	-1.21
		2a. Low b_1					**2b. High** b_1			
Tax rate	3.35	3.43	3.49	3.55	3.60	6.67	6.75	6.84	7.00	7.20
Separation rate	3.50	3.52	3.55	3.56	3.58	3.50	3.50	3.51	3.53	3.57
Job-finding rate	45.00	44.9	44.8	44.7	44.6	45.00	45.1	45.0	44.7	44.3
Average wage, overall	100.0	98.6	97.4	96.4	95.5	100.0	99.3	98.3	96.9	95.2
Average wage, entry level	100.0	94.2	88.6	83.3	78.3	100.0	94.5	89.1	83.6	78.3
Vacancies	100.0	100.3	100.4	100.5	100.4	100.0	100.2	100.1	99.8	99.3
Assets	100.0	98.8	98.4	99.0	100.3	100.0	99.4	99.0	99.1	99.4
Welfare	0.00	-0.32	-0.80	-1.46	-2.26	0.00	-0.06	-0.31	-0.77	-1.39
		3a. Low γ					**3b. High** γ			
Tax rate	5.08	5.19	5.25	5.32	5.39	5.00	5.13	5.25	5.33	5.40
Separation rate	3.50	3.51	3.51	3.51	3.51	3.50	3.53	3.56	3.58	3.59
Job-finding rate	45.00	45.1	45.1	45.0	44.8	45.00	44.9	44.7	44.4	44.0
Average wage, overall	100.0	98.9	97.8	96.7	95.5	100.0	98.3	96.9	96.0	95.4
Average wage, entry level	100.0	94.3	88.7	83.1	77.7	100.0	93.9	88.2	83.1	78.2
Vacancies	100.0	100.2	100.2	99.9	99.4	100.0	100.1	99.8	99.0	97.9
Assets	100.0	100.2	100.5	100.9	101.4	100.0	100.3	101.0	101.9	103.2
Welfare	0.00	-0.02	-0.10	-0.26	-0.48	0.00	-0.34	-0.76	-1.27	-1.87

NOTE: The numbers in bold at the top refer to the value of F and T in months of the average wage in the corresponding steady state equilibrium. Rates are expressed in percentage points. The separation and the job-finding rates are converted to monthly values. Statistics without meaningful units of measurement are normalized to 100.0 in the base column. Welfare effects are percentage-point changes in lifetime consumption.

(Panel 2 of Table 4). Interestingly, we find that in these experiments the welfare losses are larger when b_1 is either low or high. Consider first a high unemployment benefit. As reported in Subsection 3.3, a replacement ratio of 45 percent is actually above the level of optimal unemployment benefits. Therefore at higher values of b_1 the insurance role of severance payments tends to be more negative. A replacement ratio of 30 percent (low b_1), conversely, is below the level of optimal unemployment benefits. However, the two-step wage contract that emerges under severance payments is more detrimental to workers when their marginal utility from consumption is higher. The latter feature is typically reinforced by having a low outside option, as is the case with a low b_1. This result illustrates well the importance of worker-firm bargains to correctly assess the welfare effects of severance payments. Perhaps more importantly, it

Table 5: Quantitative effects of firing taxes: Sensitivity analysis

	Base	$T=0,\ F>0$ **1.5**	**3.0**	**4.5**	**6.0**	Base	$T=0,\ F>0$ **1.5**	**3.0**	**4.5**	**6.0**
			1a. Low σ_ε					**1b. High** σ_ε		
Tax rate	5.07	4.36	3.85	3.54	3.39	5.20	3.35	1.62	0.03	-1.43
Separation rate	3.50	3.34	3.21	3.13	3.07	3.50	3.32	3.18	3.09	2.96
Job-finding rate	45.0	45.0	45.0	44.9	44.8	45.0	45.1	44.6	43.5	41.9
Average wage, overall	100.0	99.1	98.0	96.9	95.7	100.0	98.5	97.5	96.9	96.7
Average wage, entry level	100.0	97.9	95.7	93.4	91.1	100.0	98.5	97.1	95.9	94.7
Net output	100.0	99.9	99.8	99.6	99.4	100.0	100.1	100.0	99.8	99.4
Assets	100.0	99.1	97.9	96.3	94.5	100.0	99.3	98.1	97.2	96.3
Welfare	0.00	-0.08	-0.29	-0.67	-1.17	0.00	0.83	1.55	2.17	2.71
			2a. Low b_1					**2b. High** b_1		
Tax rate	3.35	1.91	0.70	-0.21	-0.89	6.67	4.92	3.56	2.62	1.99
Separation rate	3.50	3.34	3.20	3.08	2.98	3.50	3.22	3.02	2.90	2.84
Job-finding rate	45.0	44.7	44.5	44.4	44.3	45.0	45.0	44.8	44.3	43.7
Average wage, overall	100.0	99.2	97.9	95.9	93.7	100.0	99.5	98.6	97.3	95.6
Average wage, entry level	100.0	98.2	96.2	93.8	91.3	100.0	98.4	96.5	94.1	91.6
Net output	100.0	99.9	99.8	99.5	99.1	100.0	100.1	100.1	99.8	99.4
Assets	100.0	99.5	98.7	97.8	96.7	100.0	99.0	96.9	93.3	88.7
Welfare	0.00	0.29	0.23	-0.21	-0.89	0.00	0.30	0.45	0.42	0.26
			3a. Low γ					**3b. High** γ		
Tax rate	5.08	3.44	2.05	0.93	0.04	5.00	3.44	2.19	1.32	0.71
Separation rate	3.50	3.27	3.10	3.02	2.99	3.50	3.28	3.12	3.02	2.96
Job-finding rate	45.0	44.9	44.6	44.1	43.5	45.00	45.0	44.8	44.4	44.0
Average wage, overall	100.0	99.5	98.9	98.4	97.8	100.0	99.6	98.3	95.8	92.8
Average wage, entry level	100.0	98.2	96.4	94.6	92.7	100.0	98.3	96.1	93.7	91.1
Net output	100.0	100.0	99.8	99.5	99.0	100.0	100.0	99.8	99.6	99.3
Assets	100.0	100.2	99.3	97.1	93.7	100.0	100.2	98.9	96.0	91.9
Welfare	0.00	0.38	0.72	1.01	1.26	0.00	0.04	-0.07	-0.37	-0.76

NOTE: The numbers in bold at the top refer to the value of F in months of the average wage in the corresponding steady state equilibrium (note: $T=0$). Rates are expressed in percentage points. The separation and the job-finding rates are converted to monthly values. Statistics without meaningful units of measurement are normalized to 100.0 in the base column. Welfare effects are percentage-point changes in lifetime consumption.

suggests that severance payments may not be a good substitute for unemployment benefits to provide insurance to workers.

Coefficient of risk aversion γ. The third sensitivity checks considers the effects of γ, the coefficient of risk aversion, which we vary from 1.0 to 3.0.[26] Beginning with firing taxes (Panel 3a of Table 5), the experiments confirm that the sign of the welfare effects depend on the relative impact on wages and the separation rate. For example, firing taxes reduce

[26] When $\gamma = 1.0$, utility is logarithmic. Thus, the welfare criterion becomes:

$$\vartheta = \exp\left(\left(\widetilde{U}_0\,(0,1) - \overline{U}_0\,(0,1)\right)\frac{1-\beta}{1-\beta^{Nw+N_r}}\right) - 1.$$

welfare by 0.76 percent when $\gamma = 3.0$ because of the large decrease in wages. As for the effects of severance payments (Table 4), it is useful to view γ as the inverse of the intertemporal elasticity of substitution. A lower elasticity increases the impact of severance payments on the separation rate: workers separate more often to consume T which is available on leaving the job. The change in equilibrium allocations, however, remains modest: vacancies decrease by 'only' 2.1 percent when severance payments amount to 6 months of the average wage. Since γ governs the curvature of the utility function, we observe that the size of welfare losses increases with γ. Overall, the results obtained with a different coefficient of risk aversion are consistent with the welfare figures from the baseline experiments.

6 Conclusion

We provided a novel assessment of the effects of mandated severance payments in an economy with search and matching in the labor market and incomplete insurance markets. In contrast to previous studies, our model emphasizes efficient bargains, when both firms and workers have positive bargaining power and job separations are endogenous. When mandated severance payments are introduced, employers and workers settle on a two-step wage contract that undoes most of the effects of the policy on equilibrium allocations. Thereby we confirmed the presumption, implicit in previous studies, that severance payments should be almost neutral under flexible wage contracts even if the economy suffers from incompleteness along other dimensions. Due to the conjunction of this two-step wage contract and workers' preference for smooth consumption, we found the welfare implications of severance payments to be consistently negative across calibrations.

The main purpose of this study was to evaluate the effects of severance payments in a search-matching model with nontrivial welfare implications. We think that at least two policy implications emerge from the analysis.

First, the wage-shifting effects that arise in the model seem to dovetail with several empirical observations. In a study of severance payments savings accounts, Kugler [2005] finds that firms manage to shift up to 80 percent of their contributions into the accounts towards workers through lower wages. Leonardi and Pica [2013] analyze how an increase in employment protection affects the wages of incumbent workers and newly-hired workers. They find that the effects are concentrated on the latter who suffer a substantial decrease in entry wages. Given the welfare losses we report, these wage-shifting effects should not be ignored when evaluating the effects of government-mandated severance payments.

Second, we studied severance payments when unemployment insurance benefits are lower and found larger welfare losses from these wage-shifting effects. However, in current debates on the optimal public provision of job security (e.g., the European debate on 'flex-security'), severance payments and unemployment benefits are typically viewed as substitutes in providing insurance to workers. Our results caution against this view. The additional losses arise in our analysis because workers at a weaker bargaining position have a higher marginal utility of consumption. In this respect, it seems that unemployment insurance benefits should be more valuable for younger workers with little savings (Michelacci and Ruffo [2015]). Severance payments, on the other hand, could be useful at older ages to help workers bridge the gap to retirement (Dolado et al. [2016]).

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A Model appendix

This appendix has three sections: our numerical methodology is presented in A.1, the calibration of the matching parameter α in A.2, and the model without savings in A.3.

A.1 Numerical methodology

The numerical algorithm to compute an equilibrium of the model is provided below.[27] We discretize the asset space and the interval for idiosyncratic match productivity as follows:

- For assets, we use one grid for the wage schedules and the value functions and another grid for the population distribution. The first grid is more dense in the lower part of the asset space where there is more curvature in the policy functions. The other grid has many more nodes and covers the asset space with evenly-spaced points.
- For match productivity, we also use two grids: one with a small number of nodes for wages and value functions and a large grid for the population distribution. Both are evenly spaced over the interval $\left[\mu_y - \frac{2\sigma_\varepsilon}{\sqrt{1-\rho^2}}, \mu_y + \frac{2\sigma_\varepsilon}{\sqrt{1-\rho^2}}\right]$.

We use standard methods to approximate the transition function G. Then, the solution method includes the following steps:

1. Solve for $R(a,\tau)$ and $\overline{a}^R(a,\tau)$ recursively starting from $\tau = N_w + N_r$.
2. Guess a tax rate κ^0.
3. Guess tightness θ^0.
4. 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 $U_0(a,\tau+1)$, $U_1(a,\tau+1)$, $W_0(y,a,\tau+1)$, $W_1(y,a,\tau+1)$, and the outside option $U_1(a,\tau)$, we can compute the reservation wage of the worker in age τ, for every (y,a) and $i \in \{0,1\}$. Call it $\underline{w}_i(y,a,\tau)$.
   (c) Compute the reservation wage of the firm. Call it $\overline{w}_i(y,a,\tau)$.[28]

[27] The reason we provide an algorithm is that the solution 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 employer and the worker. The life cycle in our model removes this feature. Instead, when we solve for the wage in step 4 of the algorithm, the solution requires the reservation wages of the worker and the employer, both of which are the solutions to fixed-point problems.

[28] Observe that, in the computation of the reservation wage of the worker and the firm, a guess on the reservation wage yields an asset-holding decision that affects the continuation value, and thereby this changes the value of the reservation wage. Thus, both $\underline{w}_i(y,a,\tau)$ and $\overline{w}_i(y,a,\tau)$ are the solution to a fixed-point problem, which can be solved iteratively.

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

$$\phi \frac{u'\left((1+r)\,a + w - \overline{a}_i^W(y,a,\tau;w)\right)}{W_i(y,a,\tau;w) - U_1(a+T_i,\tau)} = (1-\phi)\frac{1+\kappa^0}{J_i(y,a,\tau;w)+F_i}$$

(with $T_i = T \times \mathbb{1}\{i=1\}$ and $F_i = F \times \mathbb{1}\{i=1\}$). 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. Note 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 $\overline{a}_0^W(y,a,\tau)$, $\overline{a}_1^W(y,a,\tau)$.

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

5. 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 separation thresholds $\bar{y}_0(a,\tau)$, $\bar{y}_1(a,\tau)$ over the large grids for assets and match productivity. 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 $\tau = 1$.

6. Check whether the initial θ^0 is consistent with the free-entry condition; compute:

$$\theta^1 = \left(\left(\frac{1}{\eta}\frac{1}{1+r}\sum_{\tau=1}^{N_w-1}\sum_{i=0,1}\int_{Y,A}\max\left\{J_0\left(y',\overline{a}_i^U(a),\tau'\right),0\right\}dG^0(y')\,\frac{\mu_i^U(a,\tau)}{u_{N_w-1}}da\right)^{\alpha} - 1\right)^{\frac{1}{\alpha}}.$$

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

7. Check whether the tax rate κ^0 balances the government budget; compute:

$$\kappa^1 = \left(\sum_{\tau=1}^{N_w}\sum_{i=0,1} b_i \int_A d\mu_i^U(a,\tau)\right) \times \left(\sum_{\tau=1}^{N_w}\sum_{i=0,1}\int_{Y,A} w_i(y,a,\tau)\,d\mu_i^W(y,a,\tau)\right)^{-1}.$$

If necessary, update κ^0 using κ^1 and go back to step 2. Otherwise, the computation is over.

In step 4, when we use $T > 0$, knowledge of $U_1(a,\tau)$ above the upper limit of the asset grid is required. In practice, we find that regressing $U_1(.)$ against a second-order polynomial of assets based on the last upper grid points yields a R-square indistinguishable from 1 to at least 4 decimal places. Thus, a highly accurate prediction can be obtained using the OLS coefficients.

A.2 Calibration of α

To calibrate the parameter α, we must proceed as follows. Let **X** denote the *targeted* job-finding rate, and let **P** denote the probability that a match is formed conditional on meeting. Notice that in order to hit the calibration target, we must have: $\mathbf{X} = \theta q(\theta)\,\mathbf{P}$. **P** is an equilibrium object that needs to be solved for. We can initialize **P** to 1 and proceed using these steps:

1. Guess α^0.

2. Calculate θ^0 such that $\mathbf{X} = \theta^0 q(\theta^0)\mathbf{P}$. The closed-form solution gives:

$$\theta^0 = \left(\left(\frac{\mathbf{X}}{\mathbf{P}}\right)^{-\alpha^0} - 1\right)^{-\frac{1}{\alpha^0}}.$$

3. Perform the steps 4 and 5 of the algorithm presented in Appendix A.1.

4. Calculate the expected present discounted value of filling a vacancy, denoted as $\mathbf{J}$. Namely,

$$\mathbf{J} = \frac{1}{1+r}\sum_{\tau=1}^{N_w-1}\sum_{i=0,1}\int_{Y,A}\max\left\{J_0\left(y', \overline{a}_i^U(a), \tau'\right), 0\right\} dG^0(y')\frac{\mu_i^U(a,\tau)}{u_{N_w-1}}da.$$

As per the free entry condition, we obtain the following value for labor-market tightness:

$$\theta^1 = \frac{\mathbf{J}}{\eta} \times \frac{\mathbf{X}}{\mathbf{P}}.$$

5. We must also have: $q(\theta^1) = \frac{\eta}{\mathbf{J}}$. Thus, solve for α^1 numerically in the equation:

$$\left(1 + \left(\theta^1\right)^{\alpha^1}\right)^{-\frac{1}{\alpha^1}} = \frac{\eta}{\mathbf{J}}.$$

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

Using this algorithm, we obtain α that matches the targeted job-finding rate while simultaneously solving for equilibrium tightness θ. The exercise must be repeated until the balanced budget condition is satisfied (i.e., there is an outer loop for κ).

A.3 The economy without savings

This appendix contains a succinct description of the theoretical model in the absence of savings, followed by information about the calibration.

The model. We use the same notations as in Section 2. In the economy without savings, an individual consumes her disposable income in each period. Thus, the asset values of being unemployed with $i \in \{0, 1\}$ solve:

$$U_i(\tau) = u(b_i) + \beta\sum_{j=0,1} p_{i,j}^u \Big((1 - \theta q(\theta)) U_j(\tau') + \theta q(\theta)\int \max\left\{W_0(y', \tau'), U_j(\tau')\right\} dG^0(y')\Big) \quad (11)$$

for every $1 \leq \tau \leq N_w$, and where $U_i(N_w + 1) = R(N_w + 1)$. We explain in the paragraph called 'Calibration' below how $R(N_w + 1)$ is computed. For employed workers, the asset values associated with $i \in \{0,1\}$ are the solution to:

$$W_i(y,\tau) = u(w_i(y,\tau)) + \beta \Bigg(\delta U_1(\tau') + (1-\delta) \sum_{j=0,1} p^e_{i,j} \int \max\{W_j(y',\tau'), u(T_{\tau,j}+b_1) - u(b_1) + U_1(\tau')\} \, dG(y'|y) \Bigg) \quad (12)$$

for every $1 \le \tau \le N_w$, and where $W_i(y, N_w+1) = R(N_w+1)$ for every y. Again, we use $T_{\tau,j}$ as a short notation for $T \times \mathbb{1}\{\tau < N_w, j=1\}$. Notice that since agents cannot save, they consume $T_{\tau,j}$ immediately on being separated from their jobs. Hence the gain in utility $u(T+b_1) - u(b_1)$ for incumbent workers. For employers, the asset values of a filled job solve:

$$J_i(y,\tau) = y - (1+\kappa) w_i(y,\tau) + \frac{1-\delta}{1+r} \sum_{j=0,1} p^e_{i,j} \int \max\{J_j(y',\tau'), -F_{\tau,j}\} \, dG(y'|y). \quad (13)$$

In this setting, the two-tier Nash-bargained wage is given by:

$$w_0(y,\tau) = \arg\max \left\{ (W_0(y,\tau) - U_1(\tau))^{\phi} J_0(y,\tau)^{1-\phi} \right\} \quad (14)$$

$$w_1(y,\tau) = \arg\max \left\{ (W_1(y,\tau) - (u(T+b_1) - u(b_1) + U_1(\tau)))^{\phi} (J_1(y,\tau)+F)^{1-\phi} \right\}. \quad (15)$$

The transfer component of severance payment improves the bargaining position of incumbent workers through the gain in utility $u(T+b_1) - u(b_1)$. Efficient bargaining yields match-entry and match-continuation rules. These are pinned down by:

$$J_0(\overline{y}_0(\tau), \tau) = 0 \quad (16)$$

$$J_1(\overline{y}_1(\tau), \tau) = -F. \quad (17)$$

Finally, the aggregate conditions are given by

$$\frac{\eta}{q(\theta)} = \frac{1}{1+r} \sum_{\tau=1}^{N_w-1} \sum_{i=0,1} \int \max\{J_0(y',\tau'), 0\} \frac{\mu^U_i(\tau)}{u_{N_w-1}} dG^0(y') \quad (18)$$

for the free-entry condition, and

$$\kappa \sum_{\tau=1}^{N_w} \sum_{i=0,1} w_i(y,\tau) \, d\mu^W_i(y,\tau) = \sum_{\tau=1}^{N_w} \sum_{i=0,1} b_i \mu^U_i(\tau) \quad (19)$$

for the balanced budget condition.

Calibration. In the calibration, we use the external parameter values of the main model displayed in the top panel of Table 1. We use the same data moments and procedure to calibrate α, b_0, b_1, η, σ_ε, δ. In addition, we must determine the asset value of retirement, $R(N_w+1)$. We assume that in the economy without savings, agents consume a home-produced good h during retirement. As a result, we have:

$$R(N_w + 1) = \frac{1 - \beta^{N_r}}{1 - \beta} u(h). \quad (20)$$

We calibrate h so that its value is 92.5 percent of average labor earnings in the economy. This moment is based on the calibrated model with savings: it is the ratio between average consumption among retired agents and average labor earnings. So doing, our objective is to make the welfare figures with and without savings as comparable as possible. We find that in practice the value of h has little impact on the results.

B Additional tables

B.1 Unemployment benefits

Table B1 reports the effects of reducing unemployment insurance benefits under the baseline calibration. As can be seen, a replacement ratio around 35 percent maximizes the steady-state lifetime utility of new labor market entrants. On the other hand when unemployment benefits are lowered further, there are substantial welfare losses. For instance, removing the gap between unemployment benefits and social assistance (the replacement ratio of which is 5 percent) decreases welfare by 3.5 percent of lifetime consumption.

Table B1: Quantitative effects of unemployment benefits

	b_1 (as replacement ratio of the average wage)								
	0.45	**0.40**	**0.35**	**0.30**	**0.25**	**0.20**	**0.15**	**0.10**	**0.05**
Tax rate	5.13	4.44	3.77	3.14	2.54	1.98	1.46	0.98	0.55
Unemployment rate	7.22	6.86	6.53	6.22	5.94	5.68	5.44	5.23	5.04
Job-finding rate	45.0	46.2	47.5	48.7	49.9	51.1	52.2	53.3	54.4
Assets	100.0	102.1	103.6	104.6	105.0	104.7	103.9	102.5	100.4
Welfare	0.00	0.18	0.19	0.02	-0.34	-0.88	-1.59	-2.45	-3.46

NOTE: The numbers in bold give the value of b_1 as a replacement ratio of the average wage of the corresponding column. Rates are expressed in percentage points. Assets are normalized to 100.0 in the base column. Welfare effects are percentage-point changes in lifetime consumption.

It should be noted that even when unemployment benefits are set to their optimal value, there may still be some welfare gains from introducing a public insurance program. Indeed, the reason why unemployment benefits should not be increased is that they result in a lower job-finding rate. A different program that could provide insurance without generating such distortion could be beneficial to workers.

B.2 Alternative calibrations

Table B2 shows the parameter values in six alternative calibrations analyzed in Section 5. To facilitate comparisons, in the first column we report the values under the baseline calibration.

Table B2: Parameter values in alternative calibrations

		Benchmark	Low σ_ε	High σ_ε	Low b_1	High b_1	Low γ	High γ
Matching function parameter	α	1.3590	1.3360	1.6310	1.2540	1.5753	1.3850	1.3115
Social assistance benefits	b_0	0.0496	0.0455	0.0588	0.0499	0.0484	0.0500	0.0495
Unemployment insurance benefits	b_1	0.4451	0.4085	0.5298	0.2997	0.5807	0.4502	0.4446
Vacancy posting cost	η	0.2237	0.2014	0.2755	0.2276	0.2170	0.2241	0.2237
Volatility of match productivity	σ_ε	0.1741	0.0952	0.3203	0.1980	0.1281	0.1702	0.1721
Probability of exogenous destruction	δ	0.0524	0.0785	0.0294	0.0529	0.0510	0.0517	0.0524

B.3 The economy without savings: Results

Panel 1 (resp. Panel 2) of Table B3 reports the effects of severance payments (resp. firing taxes) in the model without savings presented in Appendix A.3. The results are discussed in Section 4 of the paper.

Table B3: Quantitative effects of severance payments and firing taxes, without savings

1. Severance payments	Base	$F = T > 0$ (in months of average wage)					
		1.0	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**
Tax rate	5.07	5.10	5.12	5.13	5.13	5.12	5.11
Separation rate	3.50	3.52	3.52	3.52	3.50	3.47	3.43
Job-finding rate	45.0	44.4	43.8	43.3	42.8	42.4	42.1
Average wage, overall	100.0	100.3	100.5	100.4	100.2	99.9	99.4
Average wage, entry level	100.0	97.4	95.3	93.7	92.5	91.8	91.5
Vacancies	100.0	97.7	95.6	93.7	91.9	90.4	89.1
Welfare	0.00	0.13	0.07	-0.19	-0.64	-1.27	-2.05
2. Firing taxes	Base	$T = 0,\ F > 0$ (in months of average wage)					
		1.0	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**
Tax rate	5.07	4.95	4.85	4.77	4.69	4.63	4.59
Separation rate	3.50	3.45	3.41	3.38	3.35	3.34	3.34
Job-finding rate	45.0	44.6	44.3	44.0	43.6	43.3	43.0
Average wage, overall	100.0	99.6	99.3	99.1	98.9	98.7	98.6
Average wage, entry level	100.0	99.1	98.2	97.4	96.6	95.8	95.1
Net output	100.0	100.3	100.6	100.8	100.9	101.1	101.1
Welfare	0.00	-0.32	-0.64	-0.95	-1.25	-1.56	-1.86

NOTE: In Panel 1, the numbers in bold refer to the value of F and T in months of the average wage in the steady state of the corresponding column. In Panel 2, the numbers in bold refer to the value of F in months of the average wage in the steady state of the corresponding column (note: $T = 0$ in Panel 2). Rates are expressed in percentage points. The separation and the job-finding rates are converted to monthly values. Statistics without meaningful units of measurement are normalized to 100.0 in the base column. Welfare effects are percentage-point changes in lifetime consumption.