Job Displacement Risk and Severance Pay

Marco Cozzi[1]

Giulio Fella[2]

Abstract

This paper is a quantitative, equilibrium study of the insurance role of severance pay when workers face displacement risk and markets are incomplete. A key feature of our model is that, in line with an established empirical literature, job displacement entails a persistent fall in earnings upon re-employment due to the loss of tenure. The model is solved numerically and calibrated to the US economy. In contrast to previous studies that have analyzed severance payments in the absence of persistent earning losses, we find that the welfare gains from the insurance against job displacement afforded by severance pay are sizable.

Keywords: Severance Payments, Incomplete Markets, Welfare.

JEL classification: E24, D52, D58, J65.

[☆]We thank the editor, Urban Jermann, and an anonymous referee for helpful and constructive comments, as well as Gianluca Violante for his help on this project. We are also grateful to the George Alessandria, Marco Bassetto, Rui Castro, Henry Farber, Dirk Krueger, Igor Livshits, Claudio Michelacci, Makoto Nakajima, Fabien Postel-Vinay, Víctor Ríos-Rull, Richard Rogerson, Andrew Scott, Ludo Visschers and seminar participants at several conferences and institutions for useful comments and suggestions.

[1]University of Victoria, Department of Economics, Victoria BC V8P 5C2, Canada. E-mail: `mcozzi@uvic.ca`

[2]School of Economics and Finance, Queen Mary University of London, Mile End Road, London E1 4NS, UK. E-mail: `g.fella@qmul.ac.uk`

1. Introduction

Employment contracts often contain explicit severance-pay provisions.[1] Many countries also mandate minimum levels of severance pay and other forms of employment protection. Both privately-contracted and legislated severance pay provisions are commonly increasing, approximately linear, functions of job tenure (see, e.g., OECD 2013 and Parsons 2013). The existence of these measures is difficult to understand in the context of standard, complete-markets models in which workers maximize expected labor income and wages are perfectly flexible. As observed by Lazear (1990), employment protection measures have no useful role in such a setting. This has lead some authors (e.g., Pissarides, 2001) to conclude that the debate about employment protection has been mostly conducted within a framework that is not appropriate for a proper evaluation of its role.

There is robust evidence documenting both the failure of complete risk sharing[2] and the substantial costs associated with job loss.[3] For example, Couch and Placzek (2010) estimate earnings reductions for workers affected by mass layoffs of more than 30 percent in the post-displacement year and as much as 15 percent six years later. The extent and persistence of displacement losses has prompted calls (e.g., LaLonde, 2007) for the introduction of long-term insurance for displaced workers by means of earnings supplements upon re-employment. Yet, loss-based, earnings-replacement insurance is subject to moral hazard issues due to its conditionality on wages being lower in the new job. In fact, the lack of, even public, provision of earnings-replacement insurance suggests that this kind of issues are even more relevant than in the case of unemployment insurance.

These considerations suggest that a candidate explanation for the existence of severance pay is as a means of (imperfectly) insuring displaced workers against labor market risk and,

---

[1] Parsons (2013) reports that 36 percent of US workers in firms with more than 100 employees and 16 percent in smaller businesses, were covered by severance-payment clauses over the period 1980-2001. For the UK, the 1990 *Workplace Industrial Relations Survey* reveals that 51 percent of union companies bargained over the size of (non-statutory) severance pay for non-manual workers and 42 percent for manual workers (see Millward, Neil et al., 1992).

[2] See, e.g., Attanasio and Davis (1996) and Hayashi et al. (1996).

[3] Examples include Jacobson et al. (1993), Farber (2005), Couch and Placzek (2010) and Davis and von Wachter (2011).

in particular, against the persistence of earnings losses upon re-employment.

The objective of this paper is to provide a quantitative, equilibrium framework to assess the role of severance pay as an insurance device. The crucial features of our analysis that distinguish it from existing contributions are: a detailed modeling of the sources of labor market risk, and imperfect insurance. In particular, in addition to labor market search frictions, we allow workers' productivity and job duration to be functions of both age and on-the-job tenure. Namely, job displacement risk has two components: the—temporary—loss of earnings associated with transition through unemployment and the—persistent—loss of earnings upon re-employment due to the loss of tenure. To isolate the pure insurance role of severance pay, we assume, following Lazear (1990) and most of the matching literature, that wages are flexible (full bonding). Given the significance that life-cycle factors—namely, asset accumulation and the positive correlation between age and job-tenure—play for agents' ability to insure against job-loss, we cast our analysis in a life-cycle setting.

A calibrated version of our model implies the following results. First, the average welfare gains of realistic severance pay schemes are positive and quantitatively important, ranging between 0.5 and 1 percentage points. Second, a large fraction of these gains stem from the fact that severance pay provide insurance against the—persistent—loss of tenure associated with job displacement. In fact, in line with the findings in Alvarez and Veracierto (2001), severance pay would actually *reduce* average welfare in the absence of tenure effects on wages, as the insurance gains would be more than offset by the fall in precautionary savings and the equilibrium capital stock. Finally, the model can explain why severance pay is generally an increasing function of on-the-job tenure. Keeping constant the average severance transfer, the average welfare gains are between 15 and 20 per cent higher if the transfer is (linearly) increasing in tenure. A tenure-independent transfer over-insures workers with low tenure.

The paper is related to a large literature that can be divided into two main strands. The first strand studies the role of employment protection measures in environments with risk-neutral agents. Its main result (Lazear, 1990) is that, if wage bargaining is efficient, employment protection is non-neutral only if it entails a *tax* component that is lost to the firm-worker pair. This "firing tax" is always welfare-reducing and has ambiguous, and model-specific, employment effects.[4] Conversely, severance pay—the pure transfer component of employment protection measures[5]—is neutral unless efficient wage bargaining is constrained. If downward-rigid wages in ongoing matches results in inefficient separation, severance pay reduces job destruction and increase job creation and efficiency as long as entry-wage flexibility allows workers to pre-pay for future transfers (Saint-Paul, 1995; Fella, 2000, 2012). Entry-wage rigidity constrains such pre-payment and implies that severance pay reduces job creation and, possibly, employment and efficiency (Garibaldi and Violante, 2005).

This paper is closer to the second, and more recent, strand of the literature that develops microfoundations for the (potential) relevance of legislated employment protection measures based on risk-averse workers and incomplete markets. Fella and Tyson (2013) build an incomplete-market version of Mortensen and Pissarides (1994) and use it to characterize the privately-optimal size of severance pay and show that Lazear's (1990) neutrality result (approximately) holds despite asset market incompleteness. Alvarez and Veracierto (2001) were the first to study the welfare effects of severance payments in an incomplete market setting. Our findings are complementary to theirs. Differently from us, they assume that a unique wage applies to all jobs and, therefore, that job destruction is inefficiently high in the absence of severance pay. As pointed out by Ljungqvist (2002), it is this assumption of wage rigidity, rather than market incompleteness, that accounts for the large welfare gains they find. Indeed, Alvarez and Veracierto (2001) find that the pure insurance benefit of severance pay is negligible and even *negative* in their environment, given the short duration of a typical unemployment spell and the absence of tenure effect on wages, which implies that the earnings of displaced workers fully recover upon re-employment.

Rogerson and Schindler (2002) is the first quantitative equilibrium study of the welfare costs of the risk of persistent earnings losses. They evaluate the welfare costs of a one-off, mid-

[4]Firing taxes depress employment in environments with employment lotteries (Hopenhayn and Rogerson, 1993), and in matching models if they increase workers' threat point in new matches. The latter is the case only if firms, counter-factually, incur the firing tax even if an encounter with an unemployed worker is not turned into an employment relationship, as in Millard and Mortensen (1997) (see Ljungqvist 2002 and reference therein for a comprehensive discussion).

[5]Garibaldi and Violante (2005) and Fella (2007) argue that firing taxes are unlikely to be quantitatively important.

career, permanent earnings loss in an incomplete-market setting, but with no unemployment. They find that the welfare cost of a permanent 30% earnings loss at age 45 is around half a percentage point of permanent consumption. Since the shock is one-off, permanent and common to all workers it can be perfectly insured by a common, one-off transfer equal to about four years of wages. Unlike them, the combination of returns to tenure and positive job loss hazard in each period implies heterogeneity of displacement costs in our environment. We find that the welfare gains from severance pay are significantly larger in our set up, despite the fact that our parameterization implies more conservative and non-permanent displacement costs, and that we restrict attention to a (linear) severance-pay schedule in line with observed measures.

Krebs (2007) evaluates the welfare gains from eliminating the *cyclical variation* in idiosyncratic job displacement risk, while we study the welfare gains from using severance pay to provide insurance against the average job displacement risk.

Michelacci and Ruffo (2015) study the optimal age profile of unemployment benefit replacement rates in a life cycle model with unemployment risk and on-the-job accumulation of (general) human capital. They show that the trade-off between moral hazard and insurance/liquidity provision associated with unemployment benefits is weak for young unemployed workers, who have little wealth and high returns to on-the-job human capital accumulation, and steep for older workers. As a result, optimal replacement rates are strongly decreasing in age. They find that allowing for optimal severance pay adds little to the welfare gains from the optimal policy. The main difference is that, since earnings losses depend on age but not tenure in their model, their calibration implies substantially lower losses for older (usually high-tenure) workers compared to both our calibration and the data.

On the positive side, the paper is also related to a number of recent contributions that propose alternative mechanisms to generate realistic displacement costs. In line with the job-ladder models of Jarosch (2015) and Krolikowski (2015), it generates earnings losses as a result of both lower average match quality upon reemployment *and* a downward-sloping separation-tenure profile that slows down the rate of which workers rebuild match capital.[6] In Huckfeldt (2016) there is effectively a job ladder across occupations, with better occupations

[6]The coexistence of these two forces was first documented by Stevens (1997).

having both higher productivity and higher rates of skill accumulations. Persistent earnings losses are the result of job loss being associated with a fall off the occupational ladder. Our environment captures these forces in reduced form, while maintaining sufficient tractability to study the welfare implications of earnings losses.

The rest of the paper is organized as follows. Section 2 presents the theoretical model, Section 3 discusses the calibration and Section 4 presents the main results. Finally, Section 5 discusses the sensitivity of the results to our assumptions, while Section 6 concludes. A series of Appendices documents the numerical methods used, the data and the details of the calibration, and provides some additional results.

2. The model

2.1. Environment

Demographics, preferences and endowments: The economy is populated by a measure one of agents (workers) in every period. Agents have stochastic lifetimes, transiting through working ages $i \in \mathcal{I} = \{1, 2, ..., I\}$, retirement[7] and, eventually, dying. We denote by π_i the, constant, age-transition probability and by ρ_i the retirement probability for an agent of age i. Retired agents die with constant probability π_d and are replaced by a newborn who starts life as an unemployed.

Agents are not altruistic and have time-separable preferences with time discount factor $\beta \in (0, 1)$. Their intra-period utility function is defined over consumption c and search effort ψ as

$$U(c, \psi) = u(c) - v\psi,$$

with $v > 0$ and $u(.)$ strictly increasing, strictly concave, and satisfying the Inada conditions. The search effort choice is binary (participation) and defined over the set $\Psi \equiv \{0, 1\}$.[8]

[7] We consider a retirement period because of its role in generating a realistic saving behavior. The existence of a reasonable—7 years in our calibration—retirement period is also important for the insurance value of severance pay for older workers.

[8] Note that for the same consumption level, employed workers enjoy (weakly) higher utility than unemployed workers and quitting a productive job is never optimal. This feature, together with the binary effort choice, simplifies the analysis substantially. A previous version of this paper, allowing for continuous job

Let $b \in \mathcal{B} \equiv \{0,1\}$ denote an unemployed worker's benefit entitlement status. Agents of working age can be employed, unemployed and eligible to collect unemployment benefits—$b=1$—or unemployed and ineligible to collect unemployment benefits—$b=0$. Employed workers supply labor inelastically. Newly born agents are endowed with a_0 units of the consumption good.

We index job tenure in the last job held by t,[9] with $t \in \mathcal{T} = \{1,...,T\}$. Tenure on the current job increases with constant probability $\pi_t > 0$ between successive tenure levels until $t = T$.

We assume that both tenure and age affect the productivity of a worker and denote by ε_s the productivity level of a worker of type $s \equiv (i,t)$ and by $\mathcal{S}$ the set of worker types $\mathcal{I} \times \mathcal{T}$. The component of productivity related to age i can be thought of as general human capital. Conversely, the component of productivity due to on-the-job tenure t is not transferable and lost upon job loss. Age and tenure transitions are assumed to be independent events.

Firms and technology: The population of production units (firms) is exogenous with measure greater than one.[10] Each firm uses one worker and capital to produce output according to a common, constant returns to scale technology. The output of a firm employing a worker of productivity ε_s and K_s units of capital is $Y_s = F(K_s, \varepsilon_s)$. The same production function in intensive units is $y_s = f(k_s)$, with $k_s = K_s/\varepsilon_s$. Capital depreciates at the exogenous rate δ.

Labor Market: Unemployed workers must search to find a firm with an unfilled vacancy and are successful with probability $\phi(\psi)$ with $\phi(1) > \phi(0) = 0$.

At the beginning of each period a currently-active firm and its worker of type s bargain over the wage w_s according to the generalized Nash bargaining solution. After the wage is agreed upon, capital is rented and production takes place. We consider the limit case in which the workers' bargaining weight converges to one,[11] which implies that the value of a

search effort, yielded very similar results, but also numerical instability.

[9]Namely, t denotes tenure in the current job match for employed workers (including new hires) and tenure in the last job for unemployed workers.

[10]The assumption implies that job creation by firms is exogenous.

[11]The assumption implies that wages are determined only by productivity and severance payments. If firms had positive bargaining power wages would depend on the workers' marginal utility of consumption and

firm without a worker is zero.

At the end of the period, the firm can be hit with exogenous probability $\sigma_s > 0$ by an idiosyncratic productivity shock that renders the match unproductive.[12] If hit by the shock, the firm lays its worker off, paying a severance payment—a one-off transfer—θ_s if the worker is entitled to it. The severance payment is a non-negative function $\theta_s = \gamma_t w_s$ of the last wage. Such specification allows the severance payment to depend both on productivity ε_s and on tenure length t.[13]

Other market arrangements: The final good market and the rental market for physical capital are competitive.

There are no state-contingent markets to insure against unemployment and income risk, but there is a competitive banking sector that: 1) takes deposits from and lends to consumers at the risk-free rate r; 2) holds firms and physical capital and rents the latter to firms.

Consumers' borrowing is subject to a limit, denoted by $d \geq 0$. There are perfect annuity markets where retired workers share their mortality risk.

Government: Unemployed workers are entitled to unemployment benefits upon job loss, but lose benefit entitlement with probability π_b. The unemployment benefit for a worker of type s whose benefits have not expired is given by $\varpi_s^1 = RRw_s$,[14] where RR is the benefit

wealth. This would substantially complicate the problem as one could not solve recursively for equilibrium wages independently of the equilibrium wealth distribution. Krusell et al. (2010) show that, when firms' bargaining power is positive, wealth affects only the wages of workers very close to the borrowing limit. Furthermore, the effect is small and hardly relevant for wage dispersion.

[12]There is a large body of evidence, discussed for example in Gottschalk and Moffitt (1999),showing that workers' retention probabilities are significantly affected by a set of observables, such as age and tenure. Age and tenure specific separation rates help in fitting the tenure and unemployment distributions, and the unemployment rates over the life cycle.

[13]The ratio between severance pay and wages is indeed increasing in tenure for most OECD countries.

[14]In reality, unemployment benefits are usually proportional to the last wage. Since, s may change if the worker ages over the course of an unemployment spell, our formulation makes benefits a function of the wage a worker would have received in the *current* period had her tenure been the same as at the time of job loss. In the numerical model, making the severance payment proportional to the last wage would have further increased the dimension of the state space. Given the much larger probability of unemployment-employment rather than age transitions, the number of age transitions among unemployed workers is negligible.

replacement rate. Unemployed workers of type s whose benefits have expired still receive a flow $\varpi_s^0 = g$ of the consumption good, which can be thought of as a safety net policy (e.g., food stamps). Finally, retired workers receive a pension income y_p.

The government balances the budget in every period by levying a proportional labor income tax τ on employed consumers to finance the unemployment insurance scheme, the safety net program and the pay-as-you-go pension system.

2.2. Consumers

2.2.1. Employed consumers

Let $V_e(s,a)$ denote the value function of an employed consumer of type $s=(i,t)$ with current assets a while $V_u(s,b,a)$ denotes the value function of an unemployed consumer of type s, with benefit entitlement status b and current assets a. Finally, $V_r(a)$ denotes the value function of a retired consumer.

To streamline notation, we denote by $\pi(\varsigma'|\varsigma)$ the generic transition probability from the current value ς of a state variable to some future value ς'. The recursive representation of the problem of an employed consumer can then be written as

$$\begin{aligned} V_e(s,a) = & \max_{c,a'} u(c) + \beta\rho_i V_r(a') + \beta(1-\rho_i)\times \\ & \Big[(1-\sigma_s)\sum_{s'}\pi(s'|s)V_e(s',a') + \sigma_s\sum_{i'}\pi(i'|i)V_u(s',1,a'+\theta_s)\Big] \\ & \text{s.t. } c + a' = (1+r)\,a + (1-\tau)\,w_s \quad a' \geq -d. \end{aligned} \tag{1}$$

Employed agents receive a post-tax wage $(1-\tau)w_s$, choose current consumption and face several uncertain events in the future. They retire with probability ρ_i. With probability $(1-\rho_i)(1-\sigma_s)$ they remain in employment and may undergo a stochastic age or tenure transition. With probability $(1-\rho_i)\sigma_s$ they lose their job and enter unemployment being entitled to benefits, with a severance payment θ_s, and $s'=(i',t)$; namely job losers may undergo an age but not a tenure transition. Hence the summation over i' in the last term in the square bracket.

2.2.2. Unemployed consumers

The problem of unemployed agents of type s and benefit-entitlement status b can be represented as follows

$$
\begin{aligned}
V_u\left(s,b,a\right) = &\max_{c,a',\psi} u(c) - \upsilon\psi + \beta\rho_i V_r(a') + \beta(1-\rho_i)\times \\
&\Big[\phi(\psi)\sum_{i'}\pi(i'|i)V_e(i',0,a') + (1-\phi(\psi))\sum_{i',b'}\pi(i',b'|i,b)V_u(s',b',a')\Big] \\
&\text{s.t. } c + a' = (1+r)\,a + \varpi_s^b, \quad a' \geq -d.
\end{aligned} \tag{2}
$$

Unemployed agents choose optimally both their consumption/savings plans and whether to participate in the labor market in the current period. They may retire with probability ρ_i. Alternatively, if they participate—$\psi = 1$—they find a job with probability $\phi(1)$ and become employed at the lowest tenure level. Workers who are entitled to benefits—$\varpi_s^1 = RRw_s$—may also experience a change in the level of benefits either because of an age transition or because of benefit expiration.

2.2.3. Retired consumers

The problem of retired agents can be represented as follows

$$
\begin{aligned}
V_r\left(a\right) = &\max_{c,a'} u(c) + \beta(1-\pi_d)V_r(a') \\
&\text{s.t. } c + a' = \left(\frac{1+r}{1-\pi_d}\right)a + y_p, \quad a' \geq -d.
\end{aligned} \tag{3}
$$

Agents receive pension income y_p, and the rate of return on their saving reflects the actuarially fair insurance against their survival risk.

2.2.4. Firms

Firms maximize the present discounted value of profits. In every period, after wages have been set, the value of a firm matched to a worker of type s satisfies

$$
J\left(s\right) = \max_{k_s} f(k_s)\varepsilon_s - w_s - (r+\delta)\,k_s\varepsilon_s + \frac{1-\rho_i}{1+r}\Big[(1-\sigma_s)\sum_{s'}\pi(s'|s)J(s') - \sigma_s\theta_s\Big]. \tag{4}
$$

Similarly to equation (1), the firm's Bellman equation takes into account all possible transitions the currently employed worker can go through. The firm's payoff equals zero if the match is destroyed due to the worker's retirement, as retiring workers are not entitled to severance pay and vacancies have zero value.

Constant returns to scale imply all firms use the same stock of capital k per efficiency unit of labor satisfying the first order condition

$$f'(k) = r + \delta. \tag{5}$$

2.2.5. Wage determination

In each period, the wage solves the Nash bargaining problem

$$\max_{w_s} \left(V_e(s,a) - V_u(s,b,a)\right)^{\zeta} J(s)^{1-\zeta}.$$

This is the same bargaining solution used in Krusell et al. (2010). Contrary to Alvarez and Veracierto (2001), but in line with the standard matching literature, it implies that wages are privately efficient, subject to the constraint that bargaining is over spot wages rather than contracts.[15] It also assumes that severance pay does not affect the parties' bargaining threat points.[16]

It is straightforward to verify that in the limit when the worker's bargaining weight ζ converges to one, the equilibrium value of a productive match $J(s)$ goes to zero. Hence, it follows from equation (4) that w_s satisfies

$$w_s = f(k)\varepsilon_s - (r+\delta)\, k\varepsilon_s - \frac{1-\rho_i}{1+r}\sigma_s\theta_s. \tag{6}$$

The wage falls by the actuarially-fair value of the expected layoff transfer (full-bonding).[17]

3. Parameterization

We calibrate the model to data for male workers in the US economy, where there are no mandated severance packages. In order to properly capture the labor market dynamics, we work with a short time period; namely, one model period corresponds to two months.

[15] With risk-averse workers and risk-neutral firms, bargaining over spot wages is only constrained-efficient as it is Pareto dominated by bargaining over contracts. The assumption keeps separate the insurance role of, exogenously-given, severance pay from that of more general, optimal contracting.

[16] This is the natural assumption for bargaining with new hires ('outsiders'), as severance pay is not due if a contact between a firm and a worker is not turned into a match. Section 5 discusses why, in our environment, it is the more reasonable assumption even for ongoing matches.

[17] It follows that, at constant interest rate, severance pay does not affect the shadow cost of labor. Section 5 discusses how wage flexibility is sufficient for severance pay to have negligible effects on the allocation of labor even with endogenous contact and destruction rates.

In what follows, we first comment upon the choice of parameters set outside the model and then discuss those whose calibration requires solving for the equilibrium. All parameters are reported in Table 1. We assume that newborns enter the economy without any asset endowment, or $a_0 = 0$. The CRRA coefficient η is set to 2.0, a common value in the literature (see, e.g. Attanasio, 1999)

[Table 1 about here]

The age grid has 10 points each corresponding to a five-year age bracket. Workers enter the economy at age 18-22 and reach at most age 63-67. It follows that $\pi_i = 0.033$ for all $i < I$. We specify the retirement probability as $\rho_i = 0$ for all ages between 18 and 47, and $\rho_i = 0.02$ for the remaining ages. This parameter is calibrated for the model to match the median age observed in the US labor force (39 years). The pensioners' death probability is set to $\pi_d = 0.0238$, which matches the US Census share of (male) retirees of 15.6%.

The tenure grid goes has 11, equally-spaced, points each corresponding to a two-year interval between 0-2 and 20+. On average workers in continuous employment experience an increase in tenure every 2 years. It follows that $\pi_t = 0.083$.

The unemployment benefit replacement rate is set to $RR = 0.5$, and the probability of losing benefit eligibility is set to $\pi_b = 0.333$ which implies an average benefit duration of six months. These values capture unemployment benefit rules in place in several US states. Transfers to unemployed workers who have lost eligibility are set to a $\varpi_s^0 = 0.077$, which corresponds to a monthly payment of approximately \$140. This value matches the average transfer observed for households receiving food stamps in the US in 1996, according to USDA (2014).

Pension income y_p is set so as to imply a pension replacement rate equal to 0.394 of average earnings, which is the value found in OECD (2011). The borrowing constraint $\underline{d}$ is the natural one–the value of food stamps capitalized at the market interest rate—and equals around 12 times average post-tax wages. Finally, $\gamma_t = 0$ in the benchmark economy consistent with the absence of mandated severance pay in the US.

The capital depreciation rate is set to $\delta = 0.017$ which implies an investment/output share of about 20%, on an annual basis. We assume a Cobb-Douglas production function, with capital share equal to $\alpha = 0.3$.

The labor market statistics rely on CPS data for the period 1996-2006 and, in order to be consistent with the model, we restrict our analysis to workers between the ages of 18 and 67.

The job finding probability for searching workers is set to $\phi(1) = 0.524$ to match an average unemployment duration of about 16 weeks in our target population.

The profile of efficiency units ε_s for $s = (i, t)$ is estimated using CPS data.[18] We start by estimating a simple linear regression by OLS, where the dependent variable is the natural logarithm of earnings and the set of explanatory variables are a second-degree polynomial in age and tenure and year dummies. Notice that, in order to preserve consistency between the theoretical model and the data, we transformed the dependent variable and the explanatory ones to the same time period of the model, that is we estimated log-wages on a bimonthly basis. Table 2 reports the results of both an OLS and a Tobit regression. The Tobit specification, taking into consideration the right censoring in the data due to top-coding, gives virtually the same estimates. With the estimated parameters, we retrieve the $\{\varepsilon_s\}$ as the fitted values of the econometric model at all the pairs of the respective mid-points of our tenure and age bins.

Although our estimation procedure does not deal with the likely pervasive selection and endogeneity problems, it implies an estimated average return to tenure of approximately 2% on a yearly basis. This value is in the middle of existing estimates of returns to tenure. At the low end of the spectrum, Altonji and Williams (2005) reconcile the large discrepancies in the seminal studies of returns to tenure by Abraham and Farber (1987), Altonji and Shakotko (1987) and Topel (1991) and report a return of 1.1-1.4% per year as their preferred estimate for the PSID. Yamaguchi (2010) estimates a similar value for the rate of job-specific wage growth associated with employers matching of outside offers in the NLSY79. At the upper end of the spectrum, Buchinsky et al. (2010) find a yearly average return of approximately 5% for the first ten years in the PSID. Dustmann and Meghir (2005) estimate a yearly return

[18] In the US also the NLSY and the PSID contain information on age and job tenure. The advantage of the CPS is that it is a random sample of the whole US labor force, unlike the NLSY that contains information on only one cohort and the PSID that provides a tenure measure contaminated by measurement error, as discussed for example in Altonji and Williams (2005).

of 4% for unskilled and 2.4% for skilled workers in the first five year of tenure and respectively 1.1 and 1.7% thereafter, using German administrative data.

[Table 2 about here]

The remaining parameters are chosen to minimize the sum of squared deviations of a set of simulated moments from their data counterparts. The job destruction probability is assumed to depend on age and tenure according to $\sigma_s = \overline{\sigma} \cdot \exp\{-\overline{\sigma}_i \cdot (i-1) - (\overline{\sigma}_t^0 + \overline{\sigma}_t^1 \mathbb{I}_{t>2}) \cdot (t-1)\}$, where $\overline{\sigma}, \overline{\sigma}_i, \overline{\sigma}_t^0$ and $\overline{\sigma}_t^1$ are parameters to be calibrated. $\overline{\sigma}$ represents the common starting value for the job separation probability (for the young and untenured workers), while the other three parameters allow for increasing job retention probabilities for workers that are older and/or with higher seniority.

The four parameters ($\overline{\sigma}, \overline{\sigma}_i, \overline{\sigma}_t^0$ and $\overline{\sigma}_t^1$), together with the disutility of search effort v and the rate of time preference β are calibrated with an over-identified moment-matching procedure. It is implemented with more moments (33) than unknown parameters (6). The moments we match are an annual interest rate of 4% and 32 moments from the CPS; namely, the tenure distribution of the employed, the age distribution of the labor force, the profile of unemployment rates over the life cycle, and the ratio of the number non-participants—$\psi = 0$—to that of searching unemployed workers—$\psi = 1$. The target for this last moment is 0.06. This is the share, relative to the unemployed population, of the number of workers that report having looked for work in the previous year—but not in the previous four weeks—*and* and that do not report being discouraged.[19] This target effectively identifies the search cost. Since, for tractability, the model lacks an intensive search margin, targeting a category of workers that are marginally attached—as opposed unambiguously out the labor force—has the aim of ensuring a meaningful, extensive-margin response of the number of active searchers to changes in policy.

The calibrated parameter values are $\overline{\sigma} = 0.042$, $\overline{\sigma}_i = 0.035$, $\overline{\sigma}_t^0 = 0.094$,$\overline{\sigma}_t^1 = 0.009$, $\beta = 0.998$ and $v = 3.735$.[20] The job separation profiles imply a monthly mean separation

[19]The formal CPS category is marginally attached workers who are not discouraged.

[20]The complete list of targets and moments generated by the model, are reported in Table E.9 in Appendix Appendix E.

rate of 0.015. This is the same value used in Alvarez and Veracierto (2001) and is line with Fallick and Fleischman's (2004) estimates from the CPS over our sample 1996-2006 period.

4. Numerical analysis

4.1. Further properties of the calibrated economy

Although the parameterization is quite parsimonious, the calibration achieves a very good fit. The four panels in Figure 1 plot the data (the solid black line) against the model (the dashed blue line) statistics for the target marginal distributions of workers by age, employment status and tenure.

[Figure 1 about here]

As for the age distribution of the labor force, plotted in panel 1, the model captures well the decline in the shares of older workers, while it misses the non-monotonic behavior for younger ones. The errors, though, are relatively small.

Panel 2 plots the distribution of current tenure for employed workers. The model captures well the main patterns, both qualitatively and quantitatively. In particular, three important features of the data are accounted for: the high share of jobs with less than two years of tenure, the smoothly decreasing share of workers employed at increasing levels of tenure, and the high share of jobs lasting for at least 20 years.[21] The model somewhat misses, though, the sharp decline moving from less than two to less than four years of tenure.

Panel 3 plots the age distribution of the unemployed distributions, while panel 4 the unemployment rates over the life-cycle. The model overestimates the share of young unemployed, while it matches almost perfectly the unemployment rates until age 50. As for Panel 4, also in this case age and tenure dependent separation rates are instrumental to achieve a good fit.

Finally, a crucial—and untargeted—ingredient of our quantitative analysis is the size of earnings losses associated with displacement. Following the seminal contribution of Jacobson et al. (1993), a growing body of research has exploited program evaluation techniques applied

[21] With a constant separation rate over age and tenure the model would miss the first and third characteristics.

to administrative data to identify the causal effect of job displacement on earnings. The study with the most comprehensive coverage is Davis and von Wachter (2011) (DV in what follows), using annual Social Security records for all U.S. states from 1974 to 2008. To compare our simulated data to their empirical estimates, we aggregate our simulated bi-monthly wage series into annual earnings and estimate the following equation which is equivalent to equation (1) in DV.

$$e_{it}^{y} = \iota_i^y + f(age_{it}) + \sum_{j=-6}^{20} \xi_j^y D_{it}^j + u_{it}^y, \tag{7}$$

where y is a separation year, the outcome variable e_{it}^y denotes yearly earnings for individual i in year t, ι_i^y is an individual fixed effect, $f(age_{it})$ is a quartic polynomial in age and D_{it}^j are dummies equal to one in the j-th year before or after displacement for the treatment group of workers displaced in year y and zero otherwise. We follow DV and restrict attention to workers aged less than 50 with at least 3 years of tenure in the current job.[22] The sequence of coefficients ξ_j^y then captures the (absolute) change in earnings j years after the displacement year relative to the control group of non-separators. Similarly, estimating equation (7) using average wages (i.e., average earnings conditional on employment) rather than earnings as the dependent variable returns a measure of post-displacement wage losses. Wages losses capture the contribution to earnings losses of the loss of human capital. The difference between earnings and wage losses is accounted for by the post-displacement fall in employment, the result of post-displacement unemployment incidence and average unemployment duration. Unemployment incidence is initially higher after a displacement event, as separation rates are decreasing in tenure both in the model and in the data.

The solid line in Panel 1 in Figure 2 plots the earnings losses in the model against the losses estimated by DV for workers displaced as part of a mass layoff, respectively, in expansions and recessions. Qualitatively, the model captures rather well the time profile of losses,[23] but implies a much faster recovery in the second post-displacement year, and lower

[22]DV consider workers displaced as part of a mass layoff (defined as a lasting decline in firm-level employment of at least 30%) to control for selection.

[23]The difference between the model and the data in year zero, the displacement year, is due to the fact that DV average over three adjacent years (see their fn. 12) to smooth the timing issues highlighted in

afterwards. Therefore, our estimated tenure profile of productivity implies substantially conservative earnings losses compared to the estimates in DV. The dashed line plots wages losses in the model. Wages fall very little in the separation year, because most employment in that year is pre-displacement. Instead, wages in the first post-displacement year are associated with re-employment and are roughly 15% lower than counterfactual wages. The 10 percentage points difference between the earnings loss and the wage loss reflects both the incidence of subsequent separations from post-displacement jobs and the average duration of unemployment. Two years after displacement, though, earnings losses are due to the persistent reduction in wages rather than in hours. These findings are consistent with Stevens (1997)and Huckfeldt (2016) who also find a similar fast convergence of earnings and wages for the PSID. Intuitively, though unemployment incidence increases with the loss of pre-displacement tenure, given an average unemployment duration of one quarter in the US, the contribution of higher post-displacement separation rates declines very quickly.[24]

Just looking at earnings losses, though, overestimates the income loss from job displacement—which is the relevant loss from a welfare perspective—since it does not take into account the income flow associated with unemployment benefits. For this reason, we also compute the present value of the income loss for the *average* job loser in the model as the difference in the present value of income (including unemployment benefits) between a random sample of workers displaced in period t_0 and the same sample in the counterfactual when we turn off the separation at t_0. For comparability with Davis and von Wachter (2011) we compute the present value over twenty years and report two measures. The first one is the present value income loss as a percentage of the present value of income in the counterfactual and equals 5 per cent. The second one is the present value loss as a share of the pre-displacement wage and equals 9.2 months of wages.[25] As argued in Fella and Tyson (2013), this latter measure is the natural benchmark for the size of the optimal severance pay and

Stevens (1997).

[24]This findings contrasts with Jarosch (2015), who finds a much slower convergence of wages and earnings using German data. The difference can easily be reconciled once one notes that the the unemployment exit rate in the German economy is nearly one third of the US one (0.09 per month instead of 0.26).

[25]The corresponding numbers, though for *earnings* rather than *income* losses, in Davis and von Wachter (2011) are respectively 11.9 per cent and 20.5 months for the workers satisfying their selection criterion.

we will refer to it in what follows.

4.2. Quantitative effects of severance pay

4.2.1. Benchmark economy

This section discusses the allocational and welfare effects of introducing severance pay in the benchmark economy.

In assessing the welfare consequences of any policy change one should ideally take into account the transition path to the new steady state. This is a very costly computational task in our environment, as it requires tracing the equilibrium sequence of the rate of return on capital, average wage and labor income tax along the transition. For this reason, we restrict attention to a comparison of steady states. We report welfare effects according to two different welfare criteria in order to facilitate relating our results to the existing literature. The first is the one used in Hansen and İmrohoroğlu (1992) and Rogerson and Schindler (2002). It measures welfare changes as the fraction—constant across time and contingencies—by which consumption in the benchmark economy would have to be scaled to equalize the lifetime utility of a newborn in the benchmark economy to the utility of a newborn in the counterfactual economy.[26] The second welfare criterion averages the heterogeneous individual gains in lifetime utility associated with switching from the benchmark to the counterfactual economy (keeping constant each individual's state) where the weights are given by the steady-state, cross-sectional distribution in the benchmark economy. The welfare gain is the fraction—constant across time, contingencies *and* individuals—by which consumption in the benchmark economy would have to be scaled for the average gain to be zero.[27] This average welfare criterion is used, for example, in Chatterjee et al. (2007) and is comparable to the one employed by Alvarez and Veracierto (2001).[28]

[26]Since newborns have zero assets, this welfare measure is in general very sensitive to agents' borrowing ability early in life. We have assumed a natural borrowing limit exactly to minimize this effect.

[27]This average welfare criterion can be seen as either trading off (according to a utilitarian social welfare function) distributional effects across ex post heterogeneous individuals or as evaluating expected lifetime utility under the veil of ignorance of not knowing when in the cross-sectional distribution one would be placed.

[28]To the best of our understanding Alvarez and Veracierto (2001) weigh allocations in the counterfactual

In most countries, levels of both privately-negotiated and mandated severance pay increase linearly with job tenure, subject possibly to a maximum limit (see, e.g., OECD, 2013; Parsons, 2013). Table E.10 in Appendix E reports levels of statutory severance pay for three different levels of tenure for a number of OECD countries. Since our aim is to quantify the effect of realistic measures, we study the effect of severance payments that are linear in tenure. In particular, we consider severance payments equal to 0.3, 0.6, 0.9 and 1.2 months of the last wage per each year of tenure.[29] These values span most of the spectrum from the least (UK) to the most restrictive (Spain) country. To get an idea of the average payment involved, average completed job tenure in our benchmark economy is 6 years.

[**Table 3 about here**]

Table 3 reports the allocational and welfare effects of introducing severance payments—columns 3 to 6—compared to the *employment-at-will* benchmark economy in column 2.[30]

Severance pay marginally increases the number of non-participants, as job losers have higher assets compared to the baseline economy. The unemployment rate also marginally increases as the reduction in the number of searchers is concentrated among relatively older, wealthier workers. Since the probability of losing one's job is decreasing in age, the fall in the average age of (searching) unemployed, and therefore also of employed, workers marginally increases the average job destruction and unemployment rates.

Severance pay also reduces precautionary savings and therefore the supply of assets. It follows that the equilibrium capital stock[31] and output fall. Consumption follows a pattern similar to output, but its variability is substantially reduced. As in Alvarez and Veracierto

economy by the steady-state distribution in the counterfactual, rather than the benchmark, economy. We have verified that there is little difference in using their rather than our ex post measure.

[29]We evaluate the severance payment for a job losers at the mid-point of her tenure bin.

[30]Output, consumption and welfare changes are reported as a percentage of their values in the benchmark economy.

[31]The difference between the capital stock and the aggregate supply of assets in tables 3-6 is the aggregate value of firms—the second addendum in the square bracket in equation (D.2)—which is negative in the economy with severance pay. A negative aggregate value of firms is consistent with a competitive banking sector, since wages ensure that the internal rate of return on *new* firms coincides with the market interest rate.

(2001) (cf. their tables 4 and 5), the fall in the asset supply, and therefore, in output and consumption is not monotonic though. As severance pay increases from 0.9 to 1.2 months per year of tenure, job losers are overinsured and save to finance consumption during employment. The increase in savings is so significant that the stock of capital increases. The fall in consumption variability, though, is substantial and monotonic, more than compensating for the fall in aggregate consumption relative to *laissez-faire*. As a result welfare increases and the increase is significant, ranging from 0.3 to 1 percentage point with minor differences between the two welfare metrics.

In order to understand what drives the welfare gains it is useful to decompose them into a pure insurance—at constant interest rate—effect and the effect associated with the general equilibrium response of the interest rate and the capital stock. The general equilibrium increase in the interest rate has two implications. On the one hand, it increases the cost of capital to firms and reduces output and wages, reducing workers' welfare. On the other hand, it increases the return to saving which is welfare-increasing for savers but welfare-reducing for, the mostly young, borrowers. Table 4 reports the results for the same policy change, but at constant interest rate. Comparing the welfare changes with their counterparts in Table 3 reveals that the general equilibrium increase in the interest rate offsets roughly one third of the pure insurance, partial equilibrium, welfare gains.

[**Table 4 about here**]

In a related paper, Rogerson and Schindler (2002) compute the welfare costs of displacement risk; namely the risk of persistent wage loss. They consider an economy without unemployment and model displacement as a one-off, permanent fall in workers' productivity. On the basis of the estimates in Jacobson et al. (1993), they parameterize displacement risk as a 0.25 probability of a permanent 30 per cent fall in the intercept of the labor income process at age 45. They compute the benefits of completely eliminating such risk and argue that this can be achieved by a one-off payment (severance pay) to displaced workers equal to about four years of pre-displacement wages. For our chosen value of the CRRA coefficient—$\eta = 2$—their results imply a welfare gain, measured from the perspective of a newborn, of about 0.5 percentage points at constant interest rate and 0.3 in general equilibrium.[32]

In our framework a severance payment of 1.2 months per year of tenure—i.e., on average 7.2 months of wages, against their four years—implies substantially larger gains. The main difference is due to the fact that, although our model features a lower displacement risk at age 46 and earnings losses that are persistent but not permanent, it features ongoing risk in every period. This cumulates to a larger overall risk and implies welfare gains that are three times as large as those computed by Rogerson and Schindler (2002).

While tables 3 and 4 report welfare gains over a range of severance payments covering most OECD countries, it is instructive to explore the welfare implications over a broader range of values. To this effect, Figure 3 plots gains/losses according to our two welfare metrics, both in general equilibrium and at constant interest rate, as a function of the average severance pay.[33] For comparison, the average lifetime income loss associated with displacement is 9.2 months in our benchmark economy as discussed in Section 4.1.

At constant interest rate, the average severance pay maximizing either of our two welfare metrics is around 11 months, roughly 20% larger than the lifetime income loss.[34] In general equilibrium, the severance payment maximizing our average welfare criterion is only about 7 months, corresponding exactly to the value in the last column of tables 3 and 4. As discussed above, the general equilibrium fall in the interest rate reduces welfare for the average agent. Finally, in general equilibrium the welfare of newborns is maximized for an average severance pay equal to 27 months. The intuition behind this, apparently surprising, result is that, as discussed above, an average severance pay in excess of 7 months increases aggregate saving, as overinsured job losers save to finance consumption during employment. The fall in the

[32]These numbers are obtained by linearly interpolating the welfare gains when $\eta = 1.5$ and $\eta = 3$ in Rogerson and Schindler (2002). Their partial equilibrium welfare gains are indeed linear in the CRRA coefficient, but the general equilibrium gains are less than linear. In this sense, 0.3 is an overestimate of the general equilibrium gains in their model for $\eta = 2$.

[33]As in tables 3 and 4, our computations assume that severance is proportional to tenure. The coefficient of proportionality can be obtained by dividing the average payment in Figure 3 by the average job duration of 6 years.

[34]This is consistent with Fella and Tyson's (2013) result that, at constant interest rate, the optimal payment is bounded below by the lifetime income loss.

equilibrium interest[35] rate associated with the increase in the capital stock, benefits young agents, who are net borrowers, but reduces capital income and welfare for the middle-aged net savers. Unlike the average welfare measure, which gives equal weight to all agents independently of age, considering welfare from the viewpoint of newborns discounts the backloaded losses associated with the lower return to positive wealth accumulation later in life thus failing to capture the conflict of interest among different, contemporaneous cohorts.[36]

[Figure 3 about here]

4.2.2. No tenure effects

The purpose of our model has been to isolate the welfare gains from the pure insurance role of severance pay. In this sense, the gains we find are additional to the gains associated with the firing tax component of severance pay in the presence of downward rigid wages identified in Alvarez and Veracierto (2001).[37] Yet, the welfare gains we compute may, at first, appear surprising in the light of Alvarez and Veracierto's (2001) findings that the welfare gains from the pure-transfer (what they call the "unemployment-insurance") component of severance pay are negligible in general, and *negative* for values of severance pay exceeding three months of wages (see their Section 5.2, in particular tables 4 and 5).

Our model is indeed close to Alvarez and Veracierto (2001). The main difference is that in their model there are no returns to job tenure; the only risk associated with job loss is that of transiting temporarily through unemployment. To understand the quantitative importance of the loss of tenure we simulate our model by shutting down the tenure-related component of productivity. The results are reported in Table 5 and are very much in line

[35]This effect is absent from Alvarez and Veracierto (2001) and Rogerson and Schindler (2002), who rule out borrowing altogether.

[36]Furthermore, our maintained assumption of flexible wages (full bonding) is likely to be violated, and therefore both welfare measures are likely to be upward-biased, at high levels of the average severance pay.

[37]As pointed out by Ljungqvist (2002), the sizable welfare gains from the introduction of severance pay in Alvarez and Veracierto (2001) do not stem from market incompleteness, but from the assumption that job loss is involuntary due to downward wage rigidity. As shown by Fella (2000), in such an environment, severance pay increase welfare and efficiency by making firms internalize workers' cost of involuntary job loss.

with those in Table 5 in Alvarez and Veracierto (2001), featuring endogenous search effort. Small values of severance pay marginally reduce consumption variability and saving. For larger values, consumption variability and saving eventually increase as unemployed workers are overinsured and unemployed agents save to finance consumption during employment. According to the average welfare metric, which is the counterpart of that used in Alvarez and Veracierto (2001), the welfare gains are zero or negative and very similar in magnitude to those they find.

[Table 5 about here]

In fact the comparison of the average post welfare gains in our Table 3 and Table 5 reveals that the *differential* gains from providing insurance against persistent earnings losses are even larger than the net gains in Table 3. Intuitively, in the absence of persistent earnings losses, the job loss risk faced by the *average* individual is easily insured given the duration of the average unemployment spell. On the other hand, the loss of tenure associated with displacement is persistent for two reasons. First, the higher the tenure in the previous job the longer it takes to rebuild it in the new match, even conditionally on the match surviving. Second, the probability of job loss is decreasing in tenure. Therefore, the average welfare gains from insuring against displacement risk are sizable.

From the perspective of a newborn, though, the gains from severance pay are half as large relative to the case in which wages increase with tenure, but still positive. For a newborn the insurance provided by severance pay is more valuable than for the average individual, as young individuals hold less assets and have a higher desire to bring consumption forward, given that wages increase with age.

The important message from these results is that, to the extent that it generates counterfactually small and transitory earnings losses from displacement, the standard search literature substantially underestimates the potential benefits of insurance against job loss.

4.2.3. Tenure-independent severance pay

The previous section has made clear how the gains from severance pay revolve around the persistence of displacement losses. Both these losses and their persistence are higher for workers with higher tenure. This seems to call for insurance against job loss to be increasing in tenure. To verify this hypothesis we simulate the model under the assumption that severance pay is independent of tenure. For comparability we impose that the average severance pay is the same as in the counterpart economy with linear severance pay considered in Section 4.2.1. Given an average completed job tenure of 6 years, this implies a severance pay of 1.8, 3.6, 5.4 and 7.2 months, respectively.

Table 6 reports the results. Comparing them to those in Table 3 suggests that, from the perspective of a newborn, these effects are negligible as they accrue into the future. Yet, measured from the perspective of the average individual, welfare gains are between 15 and 20 per cent larger in the economy in which severance pay increases linearly with tenure.

[**Table 6 about here**]

This result may provide a rationale for the stylized fact that both privately negotiated and mandated severance pay is indeed increasing in tenure in most countries (Parsons 2013).

5. Discussion

This paper focuses on measuring the insurance benefits of severance pay when job displacement implies persistent earnings losses and markets are incomplete. To this effect we have concentrated our efforts on carefully modeling the various aspects of job loss risk, namely its evolution over tenure and age, and purposefully abstracted from other potential roles of severance pay.

In line with most of the matching literature, the assumption that wage setting is privately (constrained-) efficient, and therefore wages are flexible at the match level, distinguishes this paper from Alvarez and Veracierto (2001) who emphasize the sizable welfare gains associated with the (Pigouvian) tax role of severance pay when wages are downward-rigid in the face of idiosyncratic productivity shocks.[38] Assuming wage flexibility abstracts from this mechanism and our welfare gains are additional to those they find.

[38]In fact, if wages are downward rigid, the tax role of severance pay is welfare improving even under complete markets (see Fella, 2000).

As first pointed out by Lazear (1990), severance pay is in fact neutral if wages are flexible and asset markets complete. Complete asset markets are not crucial for this result as long as bargaining is efficient, as shown by Fella and Tyson (2013).[39]

The assumption that workers have all the bargaining power in wage negotiations still implies efficient bargaining, but substantially simplifies the model computation. If firms had positive bargaining power, the distribution of wages would depend on the workers' asset distribution, as shown in Krusell et al.'s (2010) version of Mortensen and Pissarides (1994) with CRRA preferences, period-by-period wage bargaining with symmetric weights and endogenous interest rate. Reassuringly, Krusell et al. (2010) find that the dependence of wages on workers' asset position does not have quantitatively significant effects. We have actually verified that introducing a severance payment up to 6 months of wages in the steady-state version of Krusell et al. (2010) has a negligible impact on the equilibrium allocation of labor and the interest rate.[40]

In a nutshell, privately (constrained-)efficient wage setting implies that severance pay are near-neutral, independently from whether asset markets are complete and the particular value of workers' bargaining power. Therefore, our assumption that severance pay does not affect the firm-level dynamics—namely the job destruction rate and job finding rate for searching workers— not only buys us substantial tractability, but is in fact consistent with the implications of wage flexibility.

While the assumption that severance pay does not affect threat points when bargaining with new hires ('outsiders') is a natural and common one, the literature entertains two different assumptions on how severance pay affects wages for continuing workers who have matured entitlement to it ('insiders'). The first one (see Mortensen and Pissarides, 1999) implicitly maintains that insider workers are able to unilaterally secure severance pay in case

[39]While Fella and Tyson (2013) assume that workers have CARA preferences and borrowing is unconstrained, the same result holds in an earlier version with CRRA preferences and hand-to-mouth workers.

[40]In particular, a severance payment equal to six months of wages increases the aggregate capital stock by 0.14%, and the unemployment rate by 0.02 percentage points. Results are available upon request. We were not able to obtain convergence for higher value of the severance pay. Moreover, introducing wage and tenure effects in Krusell et al.'s (2010) model would have entailed a functional fixed point problem with as many wage schedules as worker types (110 in our case), which is computationally intractable.

of disagreement. As a result, a severance payment θ reduces the firm's and increases the worker's bargaining threat point. Effectively, insider workers receive the severance pay with probability one: either as a wage premium equal to the annuity value $r\theta$ or as a transfer θ upon separation.[41] The alternative assumption (see Ljungqvist, 2002) is that severance pay affects wages only indirectly but not, directly, through the bargaining threat points. This is consistent with the point made by Binmore et al. (1986) that the appropriate threat points are the parties' expected payoffs in case of perpetual disagreement and not the payoffs that the parties would obtain by *irreversibly* breaking the match to trade outside (outside options). Applications of this insight are Hall and Milgrom (2008) and the wage renegotiation framework introduced by MacLeod and Malcomson (1993) and used in Postel-Vinay and Robin (2002) and their subsequent work. This is also the route we follow here.

If workers are risk-neutral, Ljungqvist (2002) shows that the two assumptions are equivalent, the only difference being a backloading of payments from firms to workers in the case in which severance pay are paid in case of a breakdown in bargaining. If workers are risk-averse, though, this equivalence no longer holds. As in Alvarez and Veracierto (2001), under our assumption severance pay can potentially provide insurance. In the alternative case, though, the purely deterministic backloading of payments is either fully undone—if Ricardian equivalence applies—or reduces insurance—if, as in our framework, Ricardian equivalence fails. Among the many possible bargaining protocols, the one assuming that severance pay is due in case of a breakdown in bargaining is the only one that delivers this counter-intuitive result. This lack of generality and the related argument in Binmore et al. (1986) that, whenever there is ambiguity about the appropriate threat points one should get guidance by modeling the bargaining process strategically, induced us not to pursue this alternative route in the paper.[42]

---

[41] If workers are risk neutral, this is true independently of their bargaining power (Mortensen and Pissarides, 1999). If workers are risk averse, it can be shown analytically that it is still true if workers' bargaining power is zero or one.

[42] In preliminary work, we have solved the model at constant interest rate under the alternative assumption. Perhaps counterintuitively, the welfare gains from severance pay are larger than those reported in Table 4. The backloading of transfers reduces welfare for new hires and increases it for continuing workers. Since the latter are the vast majority of agents, the policy has a large positive effect on the average welfare metric.

6. Conclusion

This paper has provided a quantitative equilibrium framework to study the insurance properties of severance payments when markets are incomplete and workers' job displacement risk includes the kind of sizable and persistent earnings documented, for example, in Couch and Placzek (2010) and the literature they survey. Our focus has been to carefully model the various aspects of job loss risk while abstracting from other potential roles of severance pay emphasized in previous literature.

We find that the introduction of severance pay entails sizable welfare gains. These gains are due to the difficulty of self-insuring against the persistent earnings loss upon displacement stemming from the loss of job-specific human. In line with existing studies, we find that severance pay reduces average welfare if the only cost of job displacement is the transitory income loss associated with transiting through unemployment. The average welfare gain we find is higher if severance pay is an increasing function of tenure, consistently with observed privately-negotiated and mandated severance packages.

Our conservative calibration of post-displacement earnings losses implies that our quantitative findings may understate the actual welfare gains from severance pay. On the other hand, our analysis likely overestimates the benefits of severance pay, to the extent that job losers have access to additional forms of insurance, such as risk sharing at the household level, beyond the single risk-free asset in the model.

References

Abraham, K., Farber, H., 1987. Job duration, seniority, and earnings. American Economic Review 77, 278–297.

Altonji, J.G., Shakotko, R.A., 1987. Do wages rise with job seniority? The Review of Economic Studies 54, 437–459.

Altonji, J.G., Williams, N., 2005. Do wages rise with job seniority? a reassessment. Industrial and Labor Relations Review 58, 370–397.

This seems an unappealing implication of the assumption.

Alvarez, F., Veracierto, M., 2001. Severance payments in an economy with frictions. Journal of Monetary Economics 47, 477–98.

Attanasio, O., 1999. Consumption, in: Taylor, J.B., Woodford, M. (Eds.), Handbook of Macroeconomics. North Holland, Amsterdam. volume 1B, pp. 741–812.

Attanasio, O., Davis, S.J., 1996. Relative wage movements and the distribution of consumption. Journal of Political Economy 104, 1227–62.

Binmore, K.G., Rubinstein, A., Wolinsky, A., 1986. The Nash bargaining solution in economic modelling. Rand Journal of Economics 17, 176–188.

Buchinsky, M., Fougère, D., Kramarz, F., Tchernis, R., 2010. Interfirm mobility, wages and the returns to seniority and experience in the United States. The Review of Economic Studies 77, 972–1001.

Chatterjee, S., Corbae, D., Nakajima, M., Ríos-Rull, J.V., 2007. A Quantitative Theory of Unsecured Consumer Credit with Risk of Default. Econometrica 75, 1525–1589.

Couch, K.A., Placzek, D.W., 2010. Earnings losses of displaced workers revisited. American Economic Review 100, 572–89.

Davis, S.J., von Wachter, T., 2011. Recessions and the Costs of Job Loss. Brookings Papers on Economic Activity 2011, 1–72.

Dustmann, C., Meghir, C., 2005. Wages, Experience and Seniority. Review of Economic Studies 72, 77–108.

Farber, H.S., 2005. What do we know about job loss in the United States? evidence from the displaced workers survey 1984-2004. Working Paper. N. 498, Princeton University Industrial Relations Section.

Fella, G., 2000. Efficiency wages and efficient redundancy pay. European Economic Review 44, 1473–1490.

Fella, G., 2007. When do firing taxes matter? Economics Letters 97, 24–31.

Fella, G., 2012. Matching, wage rigidities and efficient severance pay. The B.E. Journal of Economic Analysis and Policy 12.

Fella, G., Tyson, C.J., 2013. Privately optimal severance pay in a matching model. B.E. Journal of Macroeconomics 13.

Garibaldi, P., Violante, G.L., 2005. The employment effects of severance payments with wage rigidities. Economic Journal 115, 799–832.

Gottschalk, P., Moffitt, R., 1999. Changes in job instability and insecurity using monthly survey data. Journal of Labor Economics 17, S91–S126.

Hall, R.E., Milgrom, P.R., 2008. The limited influence of unemployment on the wage bargain. American Economic Review 98, 1653–74.

Hansen, G.D., İmrohoroğlu, A., 1992. The role of unemployment insurance in an economy with liquidity constraints and moral hazard. Journal of Political Economy 100, 118–142.

Hayashi, F., Altonji, J., Kotlikoff, L., 1996. Risk-sharing between and within families. Econometrica 64, 261–94.

Hopenhayn, H., Rogerson, R., 1993. Job turnover and policy evaluation: A general equilibrium analysis. Journal of Political Economy 101, 915–38.

Huckfeldt, C., 2016. Understanding the scarring effects of recessions. Mimeo, Cornell University.

Jacobson, L.S., LaLonde, R.J., Sullivan, D.G., 1993. Earnings losses of displaced workers. American Economic Review 83, 685–709.

Jarosch, G., 2015. Searching for job security and the consequences of job loss. Mimeo, Princeton University.

Krebs, T., 2007. Job displacement risk and the cost of business cycles. American Economic Review 97, 664–686.

Krolikowski, P., 2015. Job ladders and earnings of displaced workers. Mimeo, Federal Reserve Bank of Cleveland.

Krusell, P., Mukoyama, T., Sahin, A., 2010. Labour-market matching with precautionary savings and aggregate fluctuations. Review of Economic Studies 77, 1477–1507.

LaLonde, R.J., 2007. The Case for Wage Insurance. Technical Report. Council on Foreign Relations.

Lazear, E.P., 1990. Job security provisions and employment. The Quarterly Journal of Economics 105, 699–726.

Ljungqvist, L., 2002. How do layoff costs affect employment? Economic Journal 112, 829–853.

MacLeod, W.B., Malcomson, J.M., 1993. Investments, holdup and the form of market contracts. American Economic Review 83, 811–837.

Michelacci, C., Ruffo, H., 2015. Optimal life cycle unemployment insurance. American Economic Review 105, 816–859.

Millard, S.P., Mortensen, D.T., 1997. The unemployment and welfare effects of labour market policy: A comparison of the US and the UK, in: Snower, D., Guillermo de la Dehesa (Eds.), Unemployment Policy: Government Options for the Labour Market. Cambridge University Press, Cambridge: UK, pp. 545–572.

Millward, Neil et al., 1992. Workplace Industrial Relations in Transition. Aldershot, Dartmouth.

Mortensen, D.T., Pissarides, C.A., 1994. Job creation and job destruction in the theory of unemployment. Review of Economic Studies 61, 397–415.

Mortensen, D.T., Pissarides, C.A., 1999. New developments in models of search in the labor market, in: Ashenfelter, O.C., Card, D. (Eds.), Handbook of Labor Economics. Elsevier. volume 3, Part B, pp. 2567–2627.

OECD, 2011. Pensions at a glance 2011 http://dx.doi.org/10.1787/pension_glance-2011-en.

OECD, 2013. DETAILED DESCRIPTION OF EMPLOYMENT PROTECTION LEGISLATION, 2012-2013. Technical Report. OECD. http://www.oecd.org/els/emp/All.pdf.

Parsons, D.O., 2013. Understanding severance pay. IZA Discussion Paper No. 7641.

Pissarides, C.A., 2001. Employment protection. Labour Economics 8, 131–159.

Postel-Vinay, F., Robin, J.M., 2002. Equilibrium wage dispersion with worker and employer heterogeneity. Econometrica 70, 2295–2350.

Rogerson, R., Schindler, M., 2002. The welfare costs of worker displacement. Journal of Monetary Economics 49, 1213–34.

Saint-Paul, G., 1995. Efficiency wage, commitment and hysteresis. Annales d'Economie et de Statistique 37-38, 39–53.

Stevens, A.H., 1997. Persistent Effects of Job Displacement: The Importance of Multiple Job Losses. Journal of Labor Economics 15, 165–188.

Topel, R., 1991. Specific capital, mobility, and wages: Wages rise with job seniority. Journal of Political Economy 99, 145–76.

USDA, 2014. Supplemental Nutrition Assistance Program Participation and Costs. Technical Report. FNS–USDA. http://www.fns.usda.gov/sites/default/files/pd/SNAPsummary.pdf.

Yamaguchi, S., 2010. Job search, bargaining, and wage dynamics. Journal of Labor Economics 28, pp. 595–631.

	Value	Source/Target
Value of assigned parameters		
Newborns' asset endowment a_0	0	–
CRRA coefficient η	2.0	Attanasio (1999)
Age ($i = 1, 2, \ldots, 10$) transition π_i	0.033	A jump every 5 years
Retirement prob. ρ_i	0 ($i < 7$);	Median age of workers
	0.02 ($i \geq 7$)	
Pensioners' death prob. π_d	0.0238	% of retirees $\approx$ 16% (Census)
Tenure ($t = 1, 2, \ldots, 11$) transition π_t	0.083	A jump every 2 years
UI benefit replacement rate RR	0.5	Avg. replacement rate
UI benefit loss prob. π_b	0.333	Avg. time limit 6 months
Food stamps g	0.077	Avg. transfer ($140/m) (USDA 2014)
Pension y_p	$0.394 * \bar{w}$	OECD (2011)
Severance Payments γ_t	0	Employment at will
Capital share α	0.3	NIPA
Capital depreciation rate δ	0.017	$I/Y = 0.22$ (NIPA)
Job finding prob. $\phi(1)$	0.52	Un. duration $\approx$ 16.4w (CPS)
ε_s - Productivity values	See Table 2	Regression on CPS data
Borrowing limit d	–	Natural borrowing limit
Value of calibrated parameters		
Disutility of search effort v	3.735	0.06 - ratio of marginally-attached
		to unemployed workers (CPS)
Job losing prob. baseline $\overline{\sigma}$	0.042	Unemployment/tenure moments (CPS)
Job losing prob. tenure gradient $\overline{\sigma}_t^0$	0.094	"
Job losing prob. tenure gradient $\overline{\sigma}_t^1$	0.009	"
Job losing prob. age gradient $\overline{\sigma}_i$	0.035	Unemployment/age moments (CPS)
Discount factor β	0.998	4% - annual interest rate

Table 1: Parameter values in the benchmark economy

Parameter	*OLS (CPS)*	*Tobit (CPS)*	*OLS (Model)*
Age	.0262816	.0263248	.0257998
	(.00055)	(.0004587)	–
Age^2	$-.0000507$	$-.0000508$	$-.0000497$
	$(1.22e-06)$	$(9.92e-07)$	–
$Age{*}Tenure$	$-.0000965$	$-.0000949$	$-.0000963$
	(.0000149)	(.0000138)	–
$Age^2{*}Tenure$	$2.03e-07$	$2.00e-07$	$2.03e-07$
	$(3.27e-08)$	$(2.91e-08)$	–
$Age{*}Tenure^2$	$2.43e-08$	$2.58e-08$	$2.43e-08$
	$(3.47e-08)$	$(3.20e-08)$	–
Tenure	.0172868	.0171138	.016948
	(.0016133)	(.0015543)	–
$Tenure^2$	$-.0000339$	$-.0000347$	$-.0000339$
	(.000011)	(.0000104)	–
Constant	4.624496	4.618056	-2.907707
	(.0573555)	(.049042)	–
Year Dummies	*Yes*	*Yes*	–
N. Obs	36013	36013	158809
R^2 (*Pseudo* R^2)	0.2482	(0.1260)	1.0000

Table 2: Log Earnings Pooled OLS Regressions, t-statistics in parenthesis. For the Tobit model, the right censoring point is 9.33, and there are 831 censored observations. (Data: CPS Displaced Workers/Job Tenure Supplement, 1996-2006). The model is stationary, and the year dummies don't have to be included. The constant in the model differs from the estimated one, because the highest value of the efficiency units is normalized to one. The OLS estimates for the model do not have standard errors, because we are running only one very large simulation.

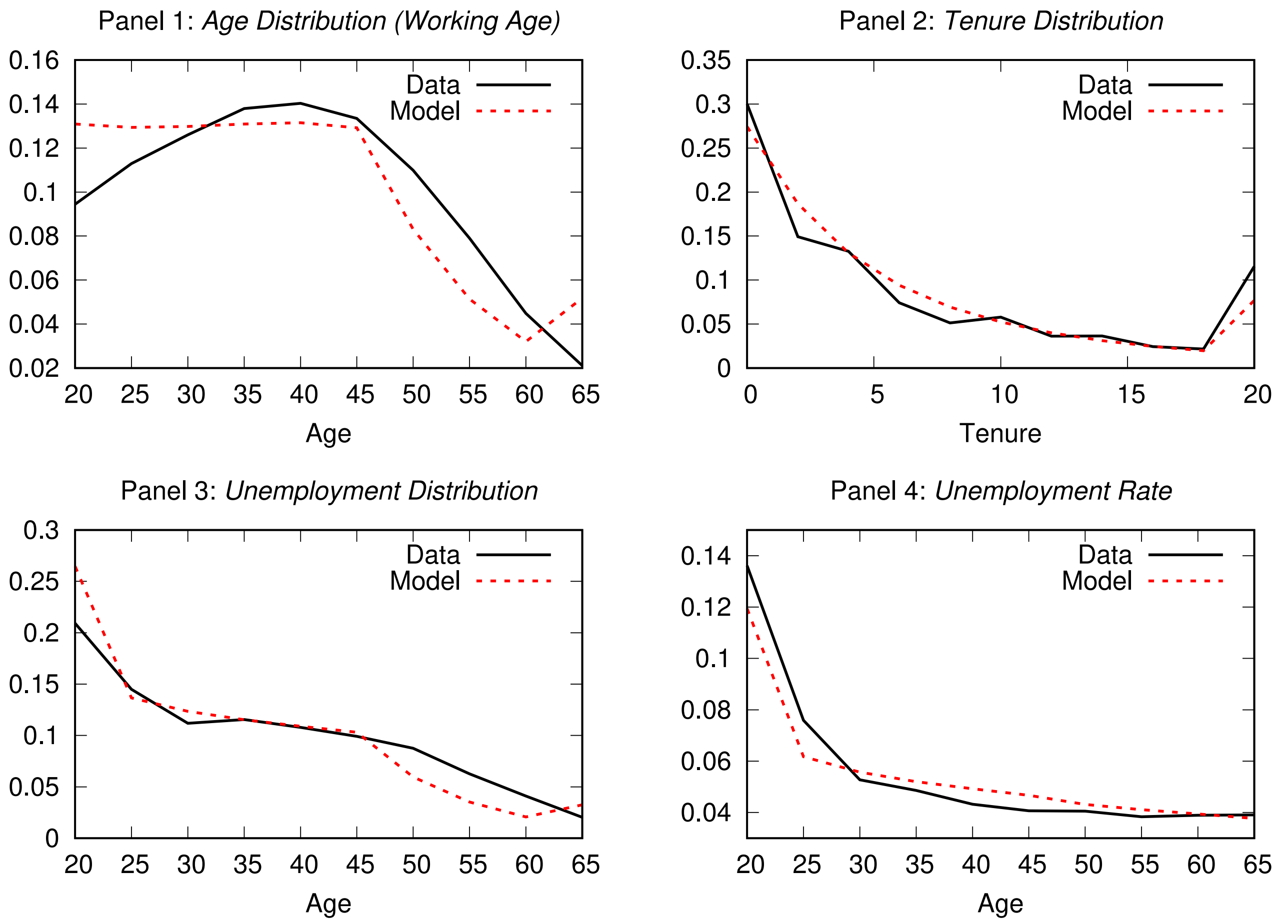

Figure 1: Calibration - Model Fit.

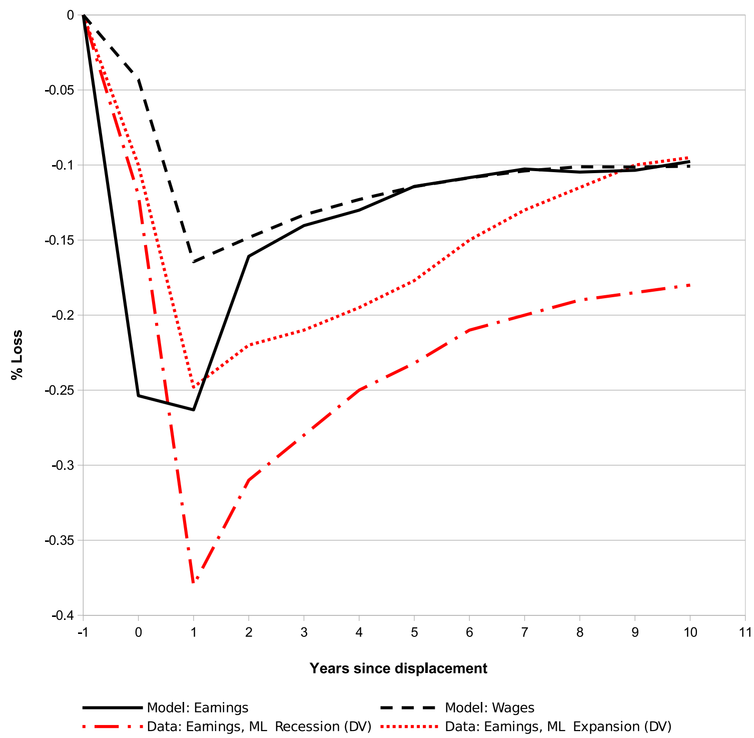

Figure 2: Earnings losses. Workers with at least 3 years of tenure: model vs estimates in Davis and von Wachter 2011 (DV).

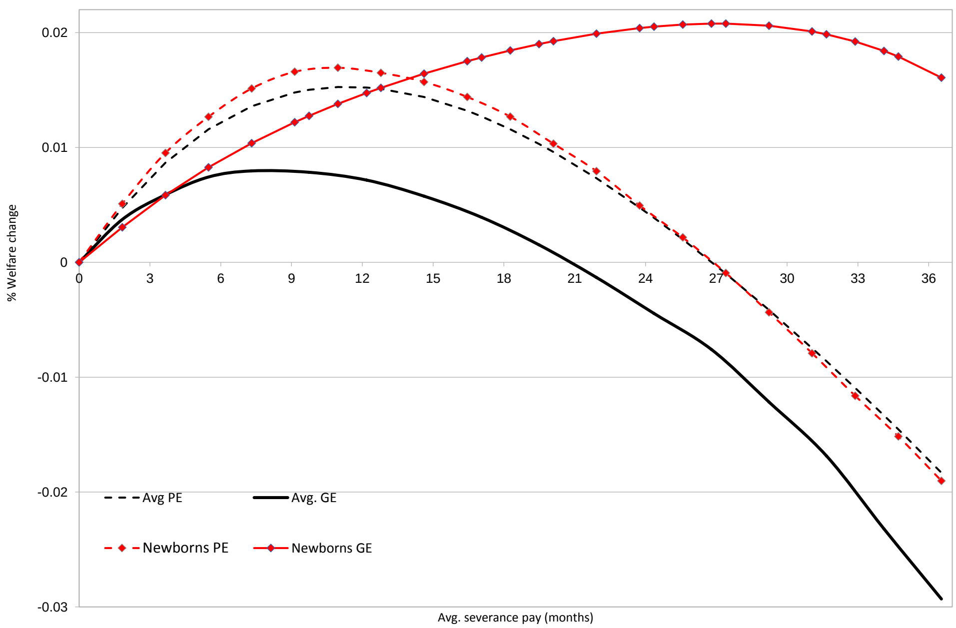

Figure 3: Welfare maximizing average severance pay.

	Severance pay				
Months of wages/year	0	0.3	0.6	0.9	1.2
Unemployment rate (%)	6.3	6.3	6.3	6.4	6.4
Non-participants/searchers (%)	6.2	7.1	7.7	8.5	9.2
Output	100.0	99.7	99.5	99.5	99.6
Capital	100.0	99.1	98.6	97.8	98.9
Assets	100.0	98.9	98.2	97.2	98.1
Consumption	100.0	99.9	99.8	99.8	99.8
S.D. consumption	100.0	97.4	95.6	94.3	93.4
Welfare (newborns)	100.0	100.3	100.6	100.8	101.0
Welfare (average)	100.0	100.4	100.6	100.7	100.8

Table 3: Allocational and welfare effects of linear severance-pay

	Severance pay				
Months of wages/year	0	0.3	0.6	0.9	1.2
Unemployment rate (%)	6.3	6.3	6.3	6.3	6.4
Non-participants/searchers (%)	6.2	6.6	7.0	7.6	8.5
Output	–	–	–	–	–
Capital	–	–	–	–	–
Assets	100.0	96.8	94.8	93.5	93.9
Consumption	100.0	99.8	99.7	99.7	99.8
S.D. consumption	100.0	95.6	92.9	91.5	91.5
Welfare (newborns)	100.0	100.5	101.0	101.3	101.5
Welfare (average)	100.0	100.4	100.8	101.1	101.4

Table 4: Allocational and welfare effects of linear severance-pay (constant interest rate)

	Severance pay				
Months of wages/year	0	0.3	0.6	0.9	1.2
Unemployment rate (%)	6.0	6.0	6.0	6.1	6.1
Non-participants/searchers (%)	1.6	1.8	2.1	2.4	2.7
Output	100.0	100.0	100.1	100.3	100.6
Capital	100.0	100.0	100.4	101.1	102.3
Assets	100.0	99.8	100.0	100.6	101.5
Consumption	100.0	100.0	100.0	100.1	100.1
S.D. consumption	100.0	99.6	99.3	99.5	99.8
Welfare (newborns)	100.0	100.2	100.3	100.4	100.5
Welfare (average)	100.0	100.1	100.0	99.9	99.7

Table 5: Allocational and welfare effects of linear severance-pay: no job-specific human capital

	Severance pay				
Months of wages	0	1.8	3.6	5.4	7.2
Unemployment rate (%)	6.3	6.3	6.3	6.3	6.3
Non-participants/searchers (%)	6.2	6.7	6.9	7.1	7.1
Output	100.0	99.7	99.6	99.6	99.6
Capital	100.0	99.1	98.6	98.6	98.9
Assets	100.0	98.9	98.2	98.0	98.2
Consumption	100.0	99.9	99.9	99.9	99.9
S.D consumption	100.0	98.5	97.4	96.0	94.8
Welfare (newborns)	100.0	100.3	100.6	100.8	101.0
Welfare (average)	100.0	100.3	100.5	100.7	100.7

Table 6: Allocational and welfare effects of (tenure-independent) severance-pay

Appendix A. Appendix for the editor and referee (not for publication)

In all the robustness analyses in this section, we recalibrate the discount factor to keep constant the wealth-income ratio in the baseline.

Appendix A.1. Ad-hoc borrowing constraint

	Severance pay				
Months of wages/year	0	0.3	0.6	0.9	1.2
Unemployment rate (%)	6.3	6.3	6.4	6.4	6.5
Non-participants/searchers (%)	6.2	7.3	7.5	8.0	9.2
Output	100.0	99.5	99.3	99.3	99.4
Capital	100.0	98.6	97.9	98.0	98.4
Assets	100.0	98.4	97.4	97.5	97.6
Consumption	100.0	99.8	99.7	99.7	99.7
S.D. consumption	100.0	97.1	95.2	93.6	92.9
Welfare (newborns)	100.0	100.5	100.9	101.4	101.7
Welfare (average)	100.0	100.5	100.8	101.0	101.0

Table A.7: Allocational and welfare effects of linear severance-pay (ad-hoc borrowing limit)

This section reports the general equilibrium effects of severance pay for the economy with an ad-hoc borrowing constraint calibrated to match a proportion of agents with non-negative wealth of 15% in the SCF. For comparison, the same proportion equals 33% in the benchmark economy with the natural borrowing limit. The model parameters are the same as in Table 1 with the exception of the borrowing limit and the discount factor that are recalibrated and equal $d = 1.276$ and $\beta = 0.996$.

Table A.7 above is the counterpart of Table 3 in the main text. The allocational effects are very similar, but the welfare gains are, as expected, larger.

Appendix A.2. Uncertain earnings losses

This section reports results from simulating a version of the model featuring uncertainty about the earnings reduction associated with a given human capital loss due to displacement.

We introduce dispersion in losses by assuming that at the time of a match workers draw a random shock that scales the productivity profile multiplicatively. The shock is i.i.d. across matches but permanent while the match lasts. We assume that the shock takes three values with equal probabilities. The middle point equals one. The other two points equal $\pm\Delta$.

By construction, the very way earnings losses are identified in the literature (see, e.g. (7) in the main text) returns only a measure of the *average* loss. For this reason, we lack a direct measure of the variance of earnings losses to inform the calibration of Δ above. In the absence of a direct measure, we have proceeded to calibrate Δ so that the residual wage inequality in the model, measured by the ratio of wages at the 50 and 10 percentiles, matches that in the data. The data moment is a log 50/10 ratio of 0.55. This is the estimate computed by Autor et a. (2008) for males, over the period 1973-2005, using the CPS (see their Figure 8). We compute residual earnings inequality in the model using the residuals from the regression of wages over a full set of age dummies. The calibrated value of Δ is 0.36 which implies that the shock-dependent profile of tenure equals the mean profile plus/minus 36%. We see this as an extreme upper bound for the variance of earnings losses since it attributes all residual wage inequality to match specific heterogeneity. Conversely, the residual wage inequality estimated by Autor et al. (2008) encompasses *all* unobserved heterogeneity since the CPS does not allow to control for unobserved workers' heterogeneity.

Table A.8 reports the results. Comparing them to those for the baseline model in Table 3 reveals that allowing for dispersion in earnings losses has a negligible effect on the results.

Appendix A.3. Wage-tenure profiles

Figure A.4 reports the profile of the average wage by tenure for the economy without severance pay (solid line), with a severance pay equal to 1.2 months per year of tenure (dashed line) and for a, tenure-independent, severance pay of 7.2 months (dashed-dotted line). The figure shows how severance pay reduces wages at all tenure levels as workers pre-pay for the expected severance pay. A tenure-independent severance pay of 7.2 months reduces the average entry wage by 12% and results in a mildly steeper wage-tenure profile. On the other hand, the linearly-increasing severance pay results in a small fall in the average entry wage and a significant flattening of the wage-tenure profile.

	Severance pay				
Months of wages/year	0	0.3	0.6	0.9	1.2
Unemployment rate (%)	6.0	6.0	6.0	6.1	6.1
Non-participants/searchers (%)	6.0	6.8	6.8	7.6	8.0
Output	100.0	99.7	99.5	99.4	99.4
Capital	100.0	99.0	98.5	98.3	98.5
Assets	100.0	98.7	98.0	97.7	97.7
Consumption	100.0	99.9	99.8	99.8	99.8
S.D. consumption	100.0	97.8	95.8	94.2	93.0
Welfare (newborns)	100.0	100.3	100.5	100.7	100.9
Welfare (average)	100.0	100.2	100.4	100.6	100.7

Table A.8: Allocational and welfare effects of linear severance-pay (uncertain earnings losses)

Appendix A.4. Profile of separation rates by tenure

Figure A.5 reports the monthly separation probabilities (age-averaged) by tenure in the model calibration targeting the set of labor market moments discussed in Section 3 and estimated from the CPS 1996-2006. It is mainly identified by the tenure distribution of uncompleted tenure among employed workers (see Figure 1).

It is to be noted that the separation probabilities are evaluated at the mid-point of each tenure bin; e.g. the separation rate for the first ([0,2] years) tenure bin is the separation rate corresponding to point 1 on the horizontal axis in Figure A.5; namely 1.8 per cent. This is, if anything, higher than the separation rate in the PSID for either workers with one year of tenure (0.015), or averaged across all workers with tenure between 0 and 2 years (see Figure 8 in Krolikowski, 2015). It is even higher than the corresponding rates in the SIPP (see Figure 9 in Menzio et al., 2016).

The main difference is that our calibrated profile is flatter than those estimated from the PSID and the SIPP. Our findings in Section 4.2.2, that results are not sensitive to the tenure profile of separation keeping constant the average separation rates, suggests that this difference is unlikely to substantially affect our findings. On the other hand, the average monthly separation rate is 0.8 per cent in the PSID and between 0.5 and 0.9 per cent

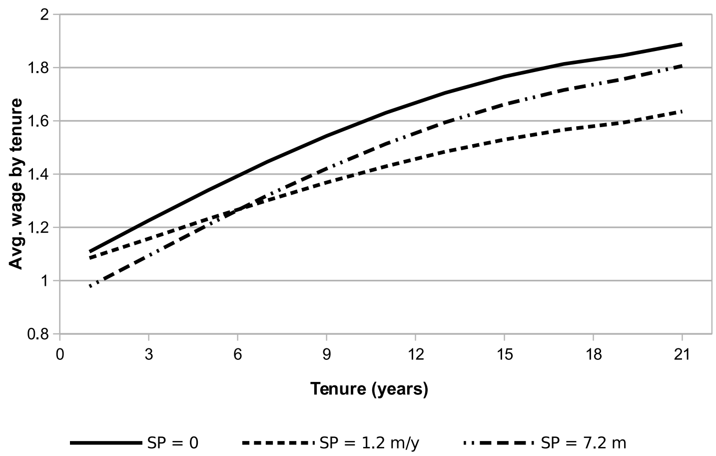

Figure A.4: Wage-tenure profile with and without severance pay

in the SIPP (see Table 5 in Krolikowski, 2015). These values are at the low end of the average separation rates people use in the macro literature and imply counterfactually low unemployment rates. Conversely, our value of 1.5 per cent coincides with the value used by Alvarez and Veracierto (2001) and is in line with the most used estimates by Fallick and Fleischman (2004, updated 2015) from the CPS. Davis and von Wachter's (2011) estimate from the CPS 1996-2006 is an even higher 6 per cent quarterly.

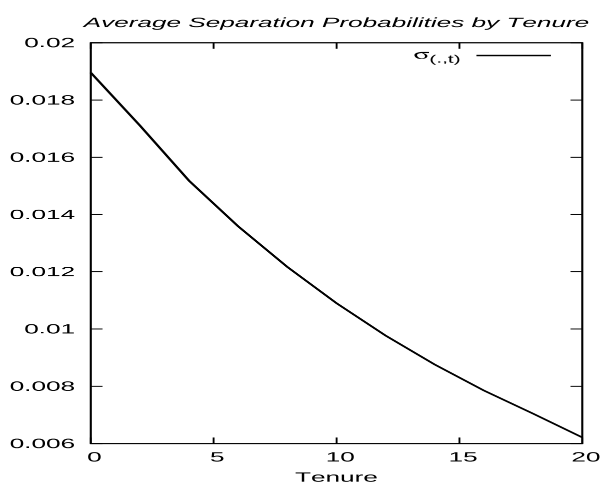

Figure A.5: Calibrated average monthly separation rates by tenure (in years)

Appendix B. Computation

- All codes were written in the FORTRAN 2003 language, relying on the Intel Fortran Compiler, build 11.1.048 (with the IMSL library). They were compiled selecting the O3 option (maximize speed), and without automatic parallelization. They were executed on a 64-bit PC platform, running Windows 7 Professional Edition, with an Intel $i7-2600k$ Quad Core processor clocked at 4.6 Ghz.

- We solve the decision problem using the generalized endogenous grid algorithm in Fella (2014).

- The stationary distributions are computed by simulating a large sample of $200,000$ individuals for $1,500$ periods, which ensures that: 1) the statistics of interest are stationary processes, 2) there are enough artificial agents for each of the many types.

- The calibration is quite parsimonious in terms of the model's parameters. It is implemented with more moments (33) than unknown parameters (6). All the moments (but the interest rate and the share of households in debt) are computed from the CPS data, and are listed in Table E.9. A Nelder-Mead algorithm is used to locate the minimum of the loss function, which is the unweighted sum of the squares of all the errors made in each moment. Note that all the variables that represent percentages are multiplied by a factor of 100, to make them comparable with the others in terms of their respective contributions to the loss function. The parameters providing the best fit achieve a minimum of 103.44.

Appendix C. Solution Algorithm

Appendix C.1. Solution Algorithm for the main model

For a given set of parameters, the computational procedure used to solve the baseline model can be represented by the following algorithm:

- Guess the proportional tax τ_0.
- Guess the measure of retirees $\overline{\mu}_{p,0}$.
- Guess the interest rate r_0.
- Compute the individual firms' capital demand K_s and wages w_s.
- Compute the individual saving functions $a'_e(s,a), a'_u(s,b,a), a'_r(a)$.
- Compute the stationary distributions $\mu_e(s,a), \mu_u(s,b,a), \mu_r(a)$.
- Compute the aggregate capital supply and demand.
- Check for asset market clearing.
- Compute r_1 from the marginal product of capital evaluated at the capital supply as well as $\tau_1, \overline{\mu}_{p,1}$.
- Update $r'_0 = \lambda_r r_0 + (1-\lambda_r)\, r_1$ (with λ_r an arbitrary weight).
- Update $\tau'_0 = \lambda_\tau \tau_0 + (1-\lambda_\tau)\, \tau_1$ (with λ_τ an arbitrary weight).
- Update $\overline{\mu}'_{p,0} = \lambda_p \overline{\mu}_{p,0} + (1-\lambda_p)\, \overline{\mu}_{p,1}$ (with λ_p an arbitrary weight).
- Iterate until market clearing and $\tau_1 \simeq \tau_0$, $\overline{\mu}_{p,1} \simeq \overline{\mu}_{p,0}$.
- Compute the consumption functions $c_e(s,a), c_u(s,b,a), c_r(a)$.
- Check the final good market clearing.
- Compute the welfare effects.

Appendix D. Stationary Equilibrium

The equilibrium concept used is the standard, recursive stationary equilibrium. The individual state variables are the employment status $l \in \mathcal{L} = \{e, u, r\}$, age-tenure pair $s \in \mathcal{S} \equiv \mathcal{T} \times \mathcal{I}$, asset holdings $a \in \mathcal{A} = [-d, \overline{a}]$ and benefit-entitlement status $b \in \mathcal{B}$. The (stationary) distribution of employed agents is denoted by $\mu_e(s, a)$, the distribution of unemployed agents is $\mu_u(s, b, a)$, whereas that of retirees is $\mu_r(a)$.

Definition 1. *For given policies $\theta_s, \varpi_s^b, y_p$ a recursive stationary equilibrium is a set of decision rules $\{c_e(s, a), c_u(s, b, a), c_r(a), a'_e(s, a), a'_u(s, b, a), a'_r(a), \psi(s, b, a), k\}$, value functions $\{V_e(s, a), V_u(s, b, a), V_r(a), J(s)\}$, prices $\{r, w_s\}$, proportional tax τ and a set of stationary distributions $\{\mu_e(s, a), \mu_u(s, b, a), \mu_r(a)\}$ such that:*

- *Given prices $\{r, w_s\}$ the individual policy functions $\{c_e(s, a), c_u(s, b, a), c_r(a), a'_e(s, a), a'_u(s, b, a), a'_r(a), \psi(s, b, a)\}$ solve the consumer problems* (1)-(3) *and $\{V_e(s, a), V_u(s, b, a), V_r(a)\}$ are the associated value functions.*

- *Given prices $\{r, w_s\}$, k and $J(s)$ satisfy* (4).

- *Wages w_s satisfy equation* (6).

- *The labor market is in flow equilibrium*

$$\int_{\mathcal{S}\times\mathcal{A}} (1-\rho_i)\sigma_s d\mu_e(s, a) + \int_{\mathcal{A}} \pi_d d\mu_r(a) = \int_{\mathcal{S}\times\mathcal{B}\times\mathcal{A}} (1-\rho_i)\phi(\psi(s, b, a)) d\mu_u(s, b, a), \tag{D.1}$$

  which requires the inflow of job losers and newborns into unemployment to equal the outflow.

- *The asset market clears*

$$\int_{\mathcal{S}\times\mathcal{A}} \left[k\varepsilon_s + \frac{f(k_s)\varepsilon_s - w_s - (r+\delta)k_s\varepsilon_s - (1-\rho_i)\sigma_s\theta_s}{r}\right] d\mu_e(s, a) = \int_{\mathcal{S}\times\mathcal{A}} a'_e(s, a) d\mu_e(s, a) + \int_{\mathcal{S}\times\mathcal{B}\times\mathcal{A}} a'_u(s, b, a) d\mu_u(s, b, a) + \int_{\mathcal{A}} a'_r(a) d\mu_r(a) \tag{D.2}$$

or the total value of assets, capital plus firms, owned by the banking sector equals the total supply of deposits.

- *The goods market clears*

$$\begin{aligned} &[f(k) - \delta k] \int_{\mathcal{S}\times\mathcal{A}} \varepsilon_s d\mu_e(s,a) = \\ &\int_{\mathcal{S}\times\mathcal{A}} c_e(s,a) d\mu_e(s,a) + \int_{\mathcal{S}\times\mathcal{B}\times\mathcal{A}} c_u(s,b,a) d\mu_u(s,b,a) + \int_{\mathcal{A}} c_r(a) d\mu_r(a) \end{aligned} \tag{D.3}$$

- *The government budget is balanced*

$$\tau \int_{\mathcal{S}\times\mathcal{A}} w_s d\mu_e(s,a) = \int_{\mathcal{S}\times\mathcal{B}\times\mathcal{A}} \varpi_s^b d\mu_u(s,b,a) + y^p \int_{\mathcal{A}} d\mu_r(a) \tag{D.4}$$

or the labor income tax revenues covers all transfers: unemployment benefits, food stamps and pensions.

- *The measures of agents in each state* $\{\mu_e(i,t,a), \mu_u(i,t,b,a), \mu_r(a)\}$ *are time invariant and satisfy*

$$\begin{aligned} \mu_e(i',t',a') = (1-\rho_i)\Bigg[&\int_{\{(i,t)\in\mathcal{S}\}\times\{a:a_e'(i,t,a)=a'\}} \pi(i'|i)\pi(t'|t)(1-\sigma_{(i,t)}) d\mu_e(i,t,a) + \\ &\mathbb{I}_{t'=1} \int_{\{(i,t)\in\mathcal{S}\}\times\mathcal{B}\times\{a:a_u'(i,t,b,a)=a'\}} \pi(i'|i)\phi(i,t,b,a) d\mu_u(i,t,b,a) \Bigg] \end{aligned} \tag{D.5}$$

$$\begin{aligned} \mu_u(i',t',b',a') = &\int_{\{i\in\mathcal{I}\}\times\mathcal{B}\times\{a:a_u'(i,t',b',a)=a'\}} (1-\rho_i)\pi(i'|i)(1-\phi(i,t',b',a)) d\mu_u(i,t',b',a) + \\ &\mathbb{I}_{b'=1}\Bigg[\int_{\{i\in\mathcal{I}\}\times\{a:a_e'(i,t',a)+\theta_{it'}=a'\}} (1-\rho_i)\sigma_{(i,t')}\pi(i'|i) d\mu_e(i,t',a) + \pi_d \mathbb{I}_{i'=1,a'=a_0} \int_{\mathcal{A}} d\mu_r(a) \Bigg] + \\ &\int_{\{i\in\mathcal{I}\}\times\{a:a_u'(i,t,b,a)=a'\}} \mathbb{I}_{b'=0}\pi_b(1-\rho_i)\pi(i'|i)(1-\phi(i,t',1,a)) d\mu_u(i,t',1,a) \end{aligned} \tag{D.6}$$

$$\mu_r(a') = (1-\pi_d)\int_{\{a:a_r'(a)=a'\}} d\mu_r(a) + \left[\int_{\{(i,t)\in\mathcal{S}\}\times\{a:a_e'(i,t,a)=a'\}\}} \rho_i d\mu_e(i,t,a) + \int_{\{(i,t)\in\mathcal{S}\}\times\mathcal{B}\times\{a:a_u'(i,t,b,a)=a'\}} \rho_i d\mu_u(i,t,b,a)\right]. \tag{D.7}$$

Appendix E. Data

Appendix E.1. Data and model fit

Moment	*Data*	*Model*	*Moment*	*Data*	*Model*
			Unemployment rates		
r	0.0400	0.0383	*Age* = *20*	0.1361	0.1194
			Age = *25*	0.0759	0.0617
Tenure distribution			*Age* = *30*	0.0528	0.0557
Tenure = *0*	0.3001	0.2744	*Age* = *35*	0.0486	0.0520
Tenure = *2*	0.1493	0.1867	*Age* = *40*	0.0432	0.0493
Tenure = *4*	0.1327	0.1308	*Age* = *45*	0.0407	0.0467
Tenure = *6*	0.0743	0.0941	*Age* = *50*	0.0405	0.0431
Tenure = *8*	0.0513	0.0694	*Age* = *55*	0.0384	0.0411
Tenure = *10*	0.0580	0.0523	*Age* = *60*	0.0389	0.0394
Tenure = *12*	0.0362	0.0400	*Age* = *65*	0.0391	0.0377
Tenure = *14*	0.0364	0.0311	*Unemployment distribution*		
Tenure = *16*	0.0244	0.0246	*Age* = *20*	0.2093	0.2646
Tenure = *18*	0.0216	0.0196	*Age* = *25*	0.1448	0.1366
Tenure = *20*	0.1156	0.0769	*Age* = *30*	0.1118	0.1235
Discouraged workers	0.0605	0.0611	*Age* = *35*	0.1155	0.1153
			Age = *40*	0.1079	0.1089
			Age = *45*	0.0992	0.1031
			Age = *50*	0.0875	0.0596
			Age = *55*	0.0626	0.0352
			Age = *60*	0.0410	0.0207
			Age = *65*	0.0203	0.0324

Table E.9: Model Fit - Empirical vs. Predicted Moments

The labor market data used in this paper come from the *Current Population Survey* (CPS): it's a monthly survey of about 50,000 households conducted by the Bureau of the Census for the Bureau of Labor Statistics. The survey has been conducted for more than 50 years. The CPS is the primary source of information on the labor force characteristics of the U.S. population. The sample is scientifically selected to represent the civilian non-institutional population. Data and codebooks can be downloaded from `http://www.bls.census.gov/cps.` Our sample selection rule is males, between the age of 18 and 67, in the labor force, and with a valid observation for the tenure variable when computing the wage regressions.

Table E.9 reports the fit of the model in terms of the set of moments targeted in the calibration.

Figure E.6 compares earnings losses in the model with estimates from another influential, recent study by Couch and Placzek (2010) (CP), using quarterly administrative data for Connecticut from 1993 to 2004. CP estimate quarterly, average earnings losses for workers with at least 6 years of pre-displacement tenure, aged between 20 and 50. We report losses for this group of workers in the model[43] (solid line) against the estimates in CP for, respectively, workers displaced as part of a mass layoff (dashed-dotted line) and all separators claiming unemployment insurance (dotted line).

Comparing earnings losses for the various groups in CP reveals that losses are substantially larger for separators who claim UI benefits. Intuitively, separations resulting in UI claims do not include voluntary quits to unemployment and job-to-job transitions—which, at least the latter, are likely to entail substantially lower average losses.[44] This also explains why the average losses estimated by CP are considerably smaller than those reported in DV even for workers displaced in expansions and with at least 3 rather than 6 years of tenure. The relevant period considered by CP features an unusually low unemployment rate (3.8% on average) and a proportion of UI claimants among job losers of 36%.[45] As a reference,

[43]Quarterly losses in the model are obtained from linear interpolation of half-yearly losses.

[44]Given that all workers in the sample have more than one year of pre-displacement tenure, the most likely reason for benefit ineligibility is that the separation does not involve an involuntary entry into unemployment.

[45]CP argue that differences in economic conditions and, in particular in the incidence of UI recipients, are "...the primary factor that underlies differences..." between their estimates and the much larger earnings

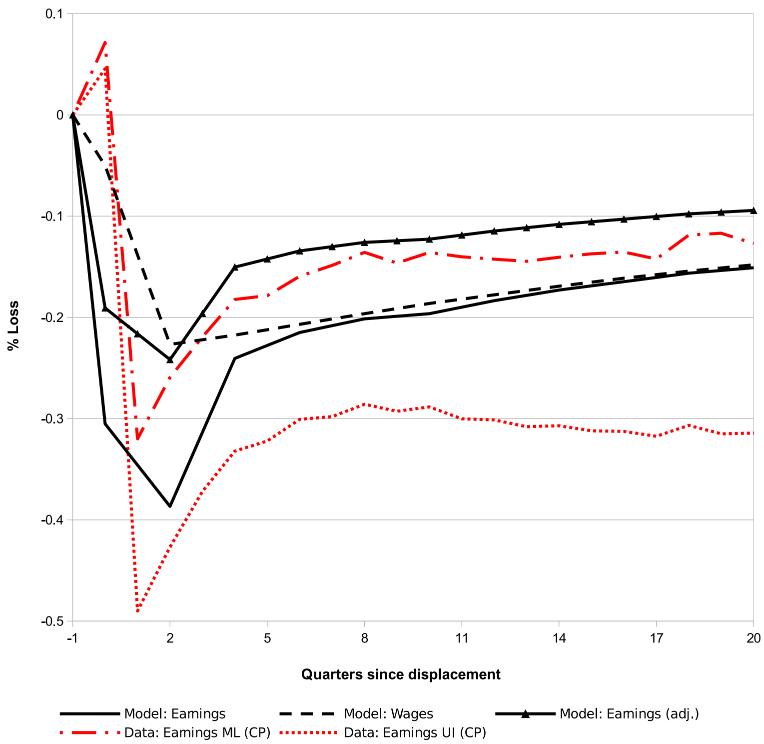

Figure E.6: Earnings losses. Workers with at least 6 years of tenure: model vs estimates in Couch and Placzek 2010 (CP).

DV document that only 23% of all years from 1980 to 2005 had an unemployment rate below 5% and the average incidence of UI claims among unemployment entrants is about 0.5 according to Figure 14 in Song and von Wachter (2014). DV's estimates (Table 1, p. 22 in their paper) imply a 1.6 ratio between the present value (over 20 years and as a fraction of pre-displacement earnings) of the average loss for workers displaced in years with an unemployment rate below 5% and the unconditional average loss. For this reason, we plot the losses in the model both unadjusted (solid black line) and scaled down by 1.6 (solid black line with triangles). Again, the model captures reasonably well the profile of the empirical estimates. The (unadjusted) losses in the model are substantially below the estimates for UI claimants, than those estimated by CP both for mass layoffs. On the other hand, the rescaled losses are below even the lowest set of estimates.[46]

losses estimated by Jacobson et al. (1993) for Pennsylvania in 74-86.

[46]The dashed line plots wage losses in the model. Even for workers with more than 6 years of tenure,

To sum up, taking into account the above discussion about the representativeness of the CP sample period, together with the fact that the population of displaced workers in the data, but not in the model, includes job-to-job quitters, it seems safe to conclude that if anything the model generates rather conservative earnings losses relative to the data.

Appendix E.2. Mandated severance pay

Table E.10 reports severance pay levels for a number of OECD countries.

earnings and wage losses converge within two years from the first displacement event.

	Tenure		
Country	9 months	4 years	20 years
Australia	0	1.9	2.8
Belgium	3	5	21
Canada	0	0	2.1
Denmark	0	0	0.9
Finland	0.5	0.9	6.1
France	0.9	2.8	7.5
Germany[a]	0.3	2	10
Ireland	0	2.1	9.6
Italy	2.6	5.8	21
Netherlands	0	6.1	20
Portugal	3	4	20
Spain	1.5	6	23
Sweden	0.9	3	6
U.K.	0.2	0.9	4.7
U.S.	0	0	0

[a.] Dependent on age and length of service; we assume employment started at age 20.

Table E.10: Severance pay and/or notice period (in months of wage)in selected OECD countries at three different tenure levels, Source: OECD (2013). For this group of economies there are different provisions for different workers' categories and type of dismissal. For each country, the largest possible payments are reported.

References for the Appendix

Autor, D.H., Katz, L.F., Kearney, M.S., 2008. Trends in U.S. wage inequality: Revising the revisionists. Review of Economics and Statistics 90, 300–323.

Fallick, B.C., Fleischman, C.A., 2004. Employer-to-employer flows in the U.S. labor market: the complete picture of gross worker flows. Finance and Economics Discussion Series 2004-34. Board of Governors of the Federal Reserve System (U.S.).

Fella, G., 2014. A generalized endogenous grid method for non-smooth and non-concave problems. Review of Economic Dynamics 17, 329–344.

Menzio, G., Telyukova, I.A., Visschers, L., 2016. Directed search over the life cycle. Review of Economic Dynamics 19, 38–62.

Song, J., von Wachter, T., 2014. Long-term nonemployment and job displacement. Prepared for the 2014 Jackson Hole Symposium.