Job Displacement Risk and Severance Pay*

Marco Cozzi†

Giulio Fella‡

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 reemployment due to the loss of job-specific human capital. 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. These gains are higher if, as in most OECD countries, severance pay increases with tenure. The result is a consequence of the higher persistence of earnings losses for workers with a larger stock of job-specific human capital at the time of displacement.

JEL classification: E24, D52, D58, J65.

Keywords: Severance Payments, Incomplete Markets, Welfare.

---

* **Acknowledgments:** We are especially indebted to Gianluca Violante for his continued help on this project. We are also grateful to George Alessandria, Rui Castro, Dirk Krueger, Igor Livshits, Claudio Michelacci, Makoto Nakajima, Victor Rios-Rull, Richard Rogerson, Andrew Scott and seminar participants at several conferences and institutions for useful comments and suggestions.

† Queen's University, Department of Economics, Dunning Hall 94 University Avenue, Kingston, ON K7L 3N6, Canada. E-mail: mcozzi@econ.queensu.ca

‡ 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. Thus, as Pissarides (2001) concludes, "much of the debate about employment protection has been conducted within a framework that is not suitable for a proper evaluation of its role in modern labor markets."

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.

[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). For Spain—a country usually thought to have high levels of state-mandated employment protection—Lorences, Fernandez and sar Rodriguez (1995) document that from 1978–91, the proportion of collective bargaining agreements establishing severance pay in excess of the legislated minimum varied between 8 and 18 percent in the metal manufacturing sector and between 22 and 100 percent in the construction sector.

[2]See, e.g., Attanasio and Davis (1996) and Hayashi, Altonji and Kotlikoff (1996).

[3]Examples include Topel (1990), Jacobson, LaLonde and Sullivan (1993), Farber (2005) and Couch and Placzek (2010). Couch and Placzek (2010) also provide a survey of existing estimates of the earning losses from job displacement.

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, 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 job-specific capital (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 this trade-off, 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, these gains stem from the fact that severance pay provide insurance against the—persistent—loss of job-specific human capital associated with job displacement. In fact, in the absence of tenure effects on wages severance pay would actually *reduce* welfare in the calibrated economy, as the insurance gains would be more than offset by the fall in precautionary saving 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 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, who have accumulated a relatively low stock of job-specific capital.

Our set-up can also be used to assess agents' willingness to trade off unemployment insurance for severance pay. In partial equilibrium, a reduction in the unemployment benefit replacement rate reduces welfare in the absence of severance pay. Yet, agents are willing to accept a reduction of the benefit replacement rate from 50% to 30% in exchange for the introduction of a severance payment equal to 1.2 months of pay per year of tenure. The benefits from this exchange are even larger (and always positive) in general equilibrium.

The paper is related to several other contributions that study labor-market risk under incomplete markets. In contrast to Lazear (1990), these papers develop microfoundations for the (potential) relevance of legislated employment protection measures based on risk-averse workers and incomplete markets, rather than wasteful firing taxes.[4]

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. Instead, 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 job-specific human capital, which implies that the earnings of displaced workers fully recover upon re-employment. Boeri, Garibaldi and Moen (2014) also study an environment with rigid wages—but risk-neutral workers—in which severance pay improves the efficiency of separation. Their model can account for the increasing tenure profile of severance pay, to the extent that workers' effort and/or investment costs increase with tenure.

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,

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

mid-career, permanent loss of human capital in an incomplete-market setting, but with no unemployment. They find that the welfare cost of a permanent 30% loss of human capital 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 human capital accumulation and positive job loss hazard in each period implies heterogeneity of displacement costs. 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 (2014) 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, but conjecture that this result may be due to the absence of job-specific human capital in their model. Our findings indeed confirm that severance pay is a valuable, complementary form of insurance/liquidity provision when earnings losses reflect loss of job-specific human capital.

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 provide some additional results.

2 The model

2.1 Environment

Demographics, preferences and endowments: The economy is populated by a continuum of agents (workers) of measure one in every period. Agents have stochastic lifetimes, transiting through working ages $i \in \mathcal{I} = \{1, 2, ..., I\}$, retirement[5] 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 an offspring who starts life as an unemployed.

Agents do not value their offsprings' welfare 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 and defined over the set $\Psi \equiv \{0, 1\}$.[6]

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,[7] with $t \in \mathcal{T} = \{0, 1, ..., T\}$. 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

[5] We consider a retirement period because of its role in generating a realistic saving behavior.

[6] Note that for the same consumption level, employed workers enjoy (weakly) higher utility that 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 search effort, yielded very similar results, but also numerical instability.

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

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.

Technology: Each production unit (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 Frictions: Unemployed workers meet a firm with an unfilled vacancy with probability $\phi(\psi)$ with $\phi(1) > \phi(0) = 0$. Keeping an open vacancy is costless and there is free entry of vacancies.

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.[8]

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.[9] If hit by the shock, the firm lays its worker off, paying a severance payment θ_s if the worker is entitled to it.

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

[8]This assumptions 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 wealth. This would substantially complicate the problem as one could not solve recursively for equilibrium wages independently of the equilibrium wealth distribution. Krusell, Mukoyama and Sahin (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.

[9]There is a large body of evidence, discussed for example in Gottschalk and Moffitt (1999) and Neumark, Polsky and Hansen (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. In a previous version of the paper, we assumed $\sigma_s = \overline{\sigma}$ obtaining a less satisfactory fit.

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: The government enforces a severance payment—a one-off transfer—from firms to laid-off workers. The severance payment is a 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.[10] We assume $\gamma_0 = 0$, or that a worker with zero tenure is not entitled to severance pay.

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 $\varpi_s^1 = RRw_s$,[11] where RR is the benefit 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

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

[11] 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.

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

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

Unemployed agents choose optimally both their consumption/savings plans and their search intensity. They may retire with probability ρ_i. Alternatively, if they search—$\psi = 1$—they find a job with probability $\phi(1)$ and become employed with zero tenure. 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

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

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

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

Similarly to equation (1), the firm's Bellman equation takes into account all possible transitions the currently employed worker can go through. Free entry implies that 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.[12]

Constant returns to scale imply all firms use that same stock 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

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

[12]This formulation of the Bellman equation already substitutes the equilibrium, free-entry condition.

This is the same bargaining solution used in Jung and Kuester (2014). Crucially it assumes that severance pay does not affect the parties' bargaining threat points. Equivalently, it implies that payments upon separation are contingent on which party takes verifiable steps to end the relationship. A separation is deemed a layoff, and the worker is entitled to the contractual severance payment, if and only the firm gives written notice that the worker's services are no longer required. On the other hand, no payment is due, if the worker gives written notice that he or she no longer intends to remain in employment (or simply stops showing up for work without obtaining leave) or if wage negotiations stall. Any claim by one party that the other has unilaterally severed the relationship must be supported by documentation. This accords with existing practices in most industrialized countries.

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 full amount of the expected layoff transfer (full-bonding).[13] Contrary to Alvarez and Veracierto (2001) but in line with the standard matching literature, wages are (privately) efficient subject to the constraint that bargaining is over spot wages rather than contracts.

2.3 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*

[13] It follows that, at constant interest rate, severance pay does not affect the shadow cost of labor. Fella and Tyson (2013) show that wage flexibility is sufficient for severance pay to have negligible effects on the allocation of labor even when markets are incomplete and the job destruction is endogenous.

$\{V_e(s,a), V_u(s,b,a), V_r(a), J(s)\}$, 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*

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

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

- *The asset market clears*

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

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

- *The goods market clears*

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

- *The government budget is balanced*

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

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

- *The measure of agents in each state is time invariant and consistent with individual decisions, as given by the three equations that can be found in Appendix C.*

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.

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. The first set of parameters is reported in Table 1 while the second set is listed in Table 3.

[Table 1 about here]

We assume that newborns enter the economy without any asset endowment, or $a_0 = 0$. The CRRA coefficient η, which is set to 2.0, a common value in the literature (see, e.g., Attanasio 1999)

The age grid had 10, equally-spaced, points: workers enter the economy at age 20 and reach at most age 65. It follows that $\pi_i = 0.033$ for all $i < I$. We specify the retirement probability as $\rho_i = 0$ for all ages between 20 and 45, and $\rho_i = 0.02$ for the remaining ages.[14] This parameter is calibrated for the model to match the median age observed in the US labor force (39 years).[15]

[14]It turns out that the results are very similar to modeling ρ_i as a two-parameter exponential function.

[15]Another possibility would be to target an average working life of 40 years. However, this would not be the right choice in our set-up, as it would significantly overstate the share of 65 year old in the population. In turn, a counterfactually high share of older agents would give them too high a weight in our utilitarian welfare function and significantly affect our computed welfare gains.

The tenure grid goes from 0 to 20 years and has 11, equally-spaced, points. On average workers in continuous employment experience an increase in tenure every 2 years. It follows that $\pi_t = 0.077$.

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 pensioners' death probability is set to $\pi_d = 0.0238$, which matches the US Census share of (male) retirees of 15.6%. 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 1996 and, in order to be consistent with the model, we restrict our analysis to workers between the ages of 20 and 65.

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

The profile of efficiency units ε_s for $s = (i, t)$ is estimated using CPS data.[16] We start by estimating a simple linear regression with 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. 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

[16] 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).

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 $s = (i, t)$ pairs in our grid. Although our estimation procedure does not deal with the likely pervasive selection and endogeneity problems, it implies an estimated return to tenure of approximately 2% on a yearly basis. This value is in line with the most recent evidence, as reported in Altonji and Williams (2005) who find a 10-year tenure effect on wages of 27.11%.[17]

[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. Their values are reported in Table 3. The job destruction probability is assumed to depend on age and tenure according to $\sigma_s = \overline{\sigma} \cdot \exp\{-\overline{\sigma}_i \cdot (i-1) - \overline{\sigma}_t \cdot t)\}$, where $\overline{\sigma}, \overline{\sigma}_i$, and $\overline{\sigma}_t$ 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 two parameters allow for increasing job retention probabilities for workers that are older and/or with higher seniority.

The three parameters ($\overline{\sigma}, \overline{\sigma}_i$, and $\overline{\sigma}_t$), together with the disutility of search effort v, the borrowing limit d, and the rate of time preference β are calibrated with an over-identified moment-matching procedure. It is implemented with more moments (34) than unknown parameters (6). The moments we match are the share of households with negative net wealth, the interest rate, the tenure distribution, the age distribution of the unemployed, the profile of unemployment rates over the life cycle, and the ratio between the number of non-employed workers that do not search to those who search. The target for this last moment is 0.06. This is the share, relative to the unemployed population, of the number of workers in the CPS 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.[18] This target effectively

[17] The value lies between the lower returns estimated, for example, by Abraham and Farber (1987) or Altonji and Shakotko (1987) and the higher ones by Topel (1991).

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

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 to 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 $\overline{\sigma} = 0.037$, $\overline{\sigma}_i = 0.0366$, $\overline{\sigma}_t = 0.0953$, $d = 1.0929$, $\beta = 0.9953$, and $v = 3.9713$.[19] A few comments are in order. The calibrated value for the borrowing limit is approximately 50% of average labor income and is strictly lower than the natural borrowing limit of every agent type. The job separation profiles imply an average separation probability which is lower than the ones reported by Shimer (2005) and others: according to their computations, on average a worker gets separated every three years. Our lower value is dictated by our sample choice. We rely on CPS data for 1996 and, in order to be consistent with the model, we restrict the analysis to male workers between the ages of 20 and 65. This leads to both a longer median duration of an employment spell and a lower unemployment rate.

[**Table 3, Figures 1 and 2 about here**]

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.

As for the age distribution of the unemployed, 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 and hard to improve upon.

Panel 2 plots the tenure distribution. 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

[19] The complete list of targets and moments generated by the model, are reported in Table 10 in Appendix D.

jobs lasting for at least 20 years.[20] The model somewhat misses, though, the sharp decline moving from less than two to less than four years of tenure.

Panel 3 plots the unemployment 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 55. Also in this case, age and tenure dependent separation rates are instrumental to achieve a good fit.

Finally, a crucial ingredient of our quantitative analysis is the size of earnings losses associated with displacement. Couch and Placzek (2010) estimate these losses to equal about 32% of counterfactual wages after one year and between 12 and 15% after six year for workers with at least six years of pre-displacement tenure, aged between 20 and 50 and part of a mass layoff.[21] In the model, the average earnings loss for workers aged 20-50 with at least six years of pre-displacement tenure is 24% after one year and 12% after six, compared to the counterfactual workers with the same characteristics that remain in employment over the comparison period. Therefore, the model performs quite well even along this non-targeted dimension. Furthermore, the fact that it generates somewhat conservative earnings losses compared to the data implies that the welfare gains from severance pay we compute constitute a lower bound.

4 Quantitative effects of severance pay

4.1 Benchmark economy

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

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,

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

[21]Couch and Placzek (2010) use administrative data for Connecticut over the period 1993-2004. They argue that compared to theirs, the significantly higher estimates in Jacobson et al. (1993) using data for Pennsylvania for 1974-85, are likely to be upward biased by the significantly higher incidence of unemployment in that sample. The mass layoff criterion is used to identify involuntary displacement, as opposed to voluntary separations, given the lack of additional information in administrative data.

Parsons 2013). Table 4 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. These values span most of the spectrum from the least (UK) to the most restrictive (Spain) country. Given an average tenure of 6.7 years in our model they imply an average severance transfer of 2, 4, 6 and 8 months of wages respectively.

[**Table 5 about here**]

Table 5 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.[22]

Severance pay marginally increases the number of non-searching workers, 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 saving and therefore the supply of assets. It follows that the equilibrium capital stock and output fall. Consumption follows a pattern similar to output, but its variability is substantially reduced. The fall in the asset supply, and therefore, in output and consumption is not monotonic though. As severance pay increases from 0.6 to 1.2 months per year of tenure, the asset supply increases as the average worker is overinsured and increases saving. 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 0.5 to 1 percentage point.

[22]The quantities with no meaningful unit of measurement, namely output, consumption and welfare, are reported as a percentage of their values in the benchmark economy. Welfare is measured as the proportional change in consumption in the benchmark economy that makes average lifetime utility in the benchmark economy equal to the utility in the counterfactual economy. This is the same welfare metric used in Alvarez and Veracierto (2001).

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. On the other hand, it increases the return to saving. Table 6 reports the results for the same policy change, but at constant interest rate. Comparing the welfare changes with their counterparts in Table 5 reveals that the second effect prevails. The general equilibrium increase in the interest rate adds 0.2 to 0.3 percentage points to the welfare gains at constant interest rate. This despite the smaller fall in consumption variability which reflects the relative higher variance of assets due to the increase in the interest rate and the associated reduction in impatience.

[**Table 6 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 of about 0.5 percentage points at constant interest rate and 0.3 in general equilibrium.[23]

In our framework a severance payment of 1.2 months per year of tenure—i.e., on average eight 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

[23] 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 CCRA 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 $\eta = 2$.

in every period. This cumulates to a larger overall risk and implies a 50 per cent larger gain at constant interest rate. The difference in welfare gains is even larger, three times as much, in general equilibrium, as the complete elimination of risk in Rogerson and Schindler's (2002) setup implies that the only welfare consequence of the general equilibrium increase in the interest rate is a fall in output. As we have seen, this effect is more than offset by the improved return to self-insurance in our model.

4.2 No job-specific human capital

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).[24] 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 very close to Alvarez and Veracierto (2001). The main difference is that in their model there is no loss of job-specific human capital; the only risk associated with job loss is that of transiting temporarily through unemployment. To understand the quantitative importance of the loss of job-specific human capital we simulate our model by shutting down the tenure-related component of productivity. The results are reported in Table 7 and are very much in line 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. The welfare gains are negative and similar in magnitude

[24] 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.

to Alvarez and Veracierto (2001).

[Table 7 about here]

In fact the comparison of the welfare gains in our Table 5 and Table 7 reveals out that the *differential* welfare gains from providing insurance against persistent earnings losses are even larger than the net gains in Table 5. Intuitively, in the absence of persistent earnings losses, the job loss risk is easily insured given the duration of the average unemployment spell. On the other hand, the loss of specific human capital associated with displacement is persistent for two reasons. First, the higher the tenure in the previous job the longer it takes to rebuild the lost human capital in the new match, even conditionally on the match surviving. Second, the probability of job loss is decreasing in tenure. Therefore, the gains from insuring against displacement risk are sizable.

4.3 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 4.1. Given an average completed job tenure of 6.7 years, this implies a severance pay of 2, 4, 6 and 8 months, respectively. Table 8 reports the results. Comparing them to those in Table 5 reveals that, for the same average transfer, welfare gains are between 15 and 20 per cent larger in the economy in which severance pay increases linearly with tenure.

[Table 8 about here]

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

4.4 Severance pay versus unemployment benefits

One way to better understand the role of severance pay in the model economy is to compute the size of the reduction in unemployment benefits that the average worker in the benchmark economy is willing to accept in exchange for the introduction of severance pay. To do so, we compare average welfare in the benchmark economy, with no severance pay and a 0.5 replacement rate, to welfare in a series of counterfactual economies featuring a severance pay of 1.2 months per year of tenure and progressively lower replacement rates.

[**Table 9 about here**]

The first row in Table 9 reports the partial equilibrium welfare change—relative to the benchmark economy—when benefits are progressively reduced in the economy with severance pay. The average worker is willing to accept a reduction of the replacement rate of slightly more than 0.2 (from 0.5 to between 0.3 and 0.2) for the introduction of the severance pay under consideration. Given an average unemployment duration of four months, a fall in the benefit replacement rate by 0.2 implies an increase in the present value of the income loss from unemployment of 0.8 monthly wages against an average severance pay of 8 months (1.2 months per year times an average completed job tenure of 6.7 years). This suggests that severance pay and unemployment benefits are highly imperfect substitutes.[25] Intuitively, unemployment benefits are more effective than self insurance at providing insurance against the tail risk of an unemployment spell of above average length. This is confirmed by the fact that in general equilibrium the supply of asset increases and the interest rate falls as the replacement rate is reduced. The general equilibrium increase in output is strong enough that the welfare gains from the introduction of the severance pay considered more than offset the losses associated with the reduction in the replacement rate relative to the benchmark.

For comparison lines 3 and 4 in the table report the results of the same exercise but for the economy with no severance pay. In partial equilibrium reducing the benefit replacement rate monotonically reduces welfare and significantly more so than in the presence of severance pay. In general equilibrium, reducing the replacement rate down to 0.4 leaves welfare unaffected

[25] This is particularly true for low tenure workers in the case, considered in this section, in which severance pay is proportional to tenure.

as the increase in the capital stock stemming from the fall in precautionary saving more than compensates for the reduction in insurance. Further reductions lower welfare below its level in the benchmark economy.

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 focused 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.

The assumption that wages are constrained efficient, and therefore 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 fact, their result would still hold qualitatively under complete markets (see Fella 2000) while severance pay would be neutral absent wage rigidities, as first pointed out by Lazear (1990).

Relatedly, assuming an exogenous separation rate is not very restrictive in the light of our wage setting structure. Under complete markets, the separation rate would indeed be unaffected by the introduction of severance pay. Fella and Tyson (2013) show that efficient wage bargaining ensures that severance pay has a negligible effect on the separation rate even when the latter is endogenous and markets incomplete.

The assumption that workers have all the bargaining power in wage negotiations substantially simplifies the model computation. If firms had positive bargaining power, the distribution of wages would depend on the workers' asset distribution, as shown by Krusell et al. (2010). Reassuringly, though, Krusell et al. (2010) find that, with the exception of the very poorest workers, the dependence of wages on workers' asset position does not have significant quantitative effects.

Our assumption of an exogenous matching rate, conditional on job search, abstracts from the standard matching externalities discussed in Hosios (1990). Appendix E endogenizes the job finding rate by allowing for a standard matching function and a fixed stock of firms.[26] Endogenizing matching rates has negligible quantitative effects as returns to matching are only marginally affected by severance pay under flexible wages.

6 Conclusion

As noted by LaLonde (2007) "For long-tenured workers, job loss is potentially as costly as a serious automobile accident, having one's house burn down, or becoming permanently disabled. Moreover, costly displacement appears to be more likely to occur than these other dramatic events in a person's life." 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 losses referred to by LaLonde (2007) and 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 the severance pay emphasized in previous literature.

We find that the introduction of severance pay entails sizable welfare gains. These gains are entirely 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 welfare if the only cost of job displacement is the transitory income loss associated with transiting through unemployment. The welfare gains we find are higher if severance pay is an increasing function of tenure, consistently with observed privately-negotiated and mandated severance packages.

[26]The stock of firms cannot be endogenized since it is indeterminate under our bargaining assumption.

Parameter	Value	Source
a_0 - Newborns asset endowment	0	–
η - CRRA coefficient	2.0	Attanasio (1999)
π_i - Age ($i = 20, 25, \ldots, 65$) transition	0.033	A jump every 5 years
ρ_i - Retirement prob.	0 ($i < 50$);	Median age of workers
	0.02 ($i \geq 50$)	
π_d - Pensioners' death prob.	0.0238	% of retirees $\approx$ 16%(Census)
π_t - Tenure ($t = 0, 2, \ldots, 20$) transition	0.077	A jump every 2 years
RR - UI benefit replacement rate	0.5	Avg. replacement rate
π_b - UI benefit loss prob.	0.333	Avg. time limit 6 months
g - Food stamps	0.077	Avg. transfer ($140/m) (USDA 2014)
y_p - Pension	$0.394 * \bar{w}$	OECD (2011)
γ_t - Severance Payments	0	Employment at will
α - Capital share	0.3	NIPA
δ - Capital depreciation rate	0.017	$I/Y = 0.21$ (NIPA)
$\phi(1)$ - Job finding prob.	0.052	Un. duration $\approx$ 16.4w (CPS)
ε_s - Productivity values	See Table 2	Regression on CPS data

Table 1: Value of assigned parameters in the benchmark

Parameter	OLS	Tobit
Age	.0242675	.0243549
	(17.72)	(20.33)
Age^2	$-.0000467$	-0.0000468
	(-15.54)	(-18.36)
Age*Tenure	$-.0000498$	$-.0000456$
	(-1.30)	(-1.25)
Age^2*Tenure	$9.32e-08$	$8.48e-08$
	(1.11)	(1.10)
Age*$Tenure^2$	$1.11e-07$	$1.18e-07$
	(1.25)	(1.40)
Tenure	.0125501	.0121697
	(3.01)	(3.01)
$Tenure^2$	$-.0000556$	-0.0000584
	(-2.04)	(-2.19)
Constant	5.318899	5.308133
	(36.43)	(40.70)
N. Obs	5844	5844
R^2 (Pseudo R^2)	0.2056	(0.1042)

Table 2: Log Earnings Regressions, t-statistics in parenthesis. For the Tobit model, the right censoring point is 9.72, and there are 145 censored observations. (Data: CPS Feb 1996)

Parameter	Value	Moment targeted
v - Disutility of search effort	3.815	0.06 - ratio of marginally-attached to unemployed workers (CPS)
$\overline{\sigma}$ - Job losing prob. baseline	0.032	Unemployment/tenure moments (CPS)
$\overline{\sigma}_t$ - Job losing prob. tenure gradient	0.034	”
$\overline{\sigma}_i$ - Job losing prob. age gradient	0.086	Unemployment/age moments (CPS)
d - Borrowing limit	1.276	15% - share of households with negative net worth (SCF)
β - Rate of time preference	0.996	4% - annual interest rate

Table 3: Value of calibrated parameters and targeted moments

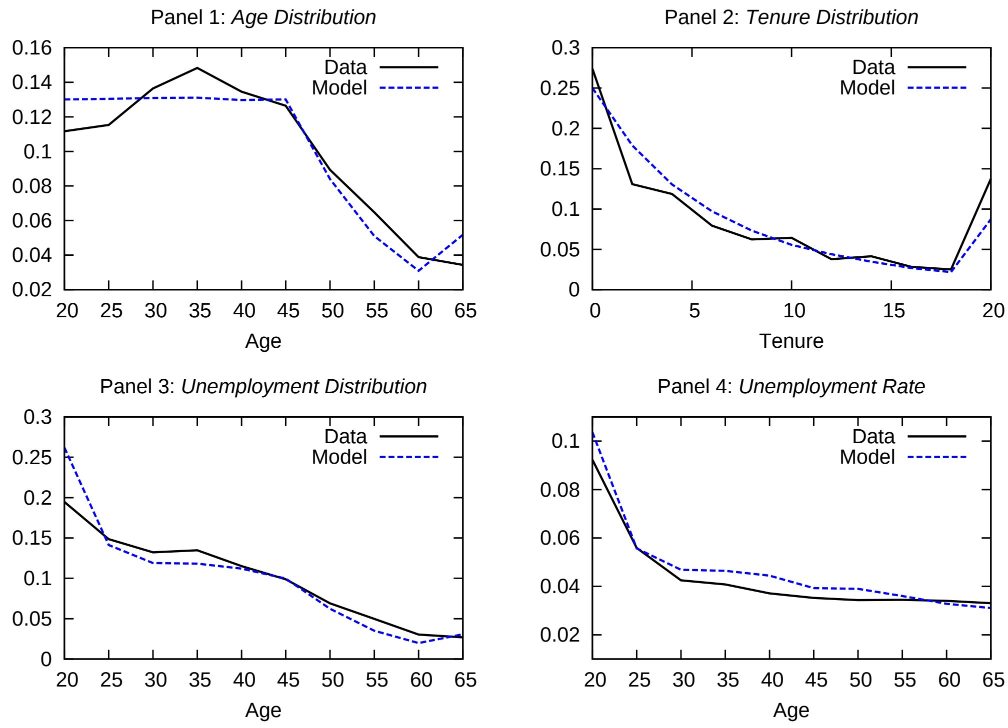

Figure 1: Calibration - Model Fit.

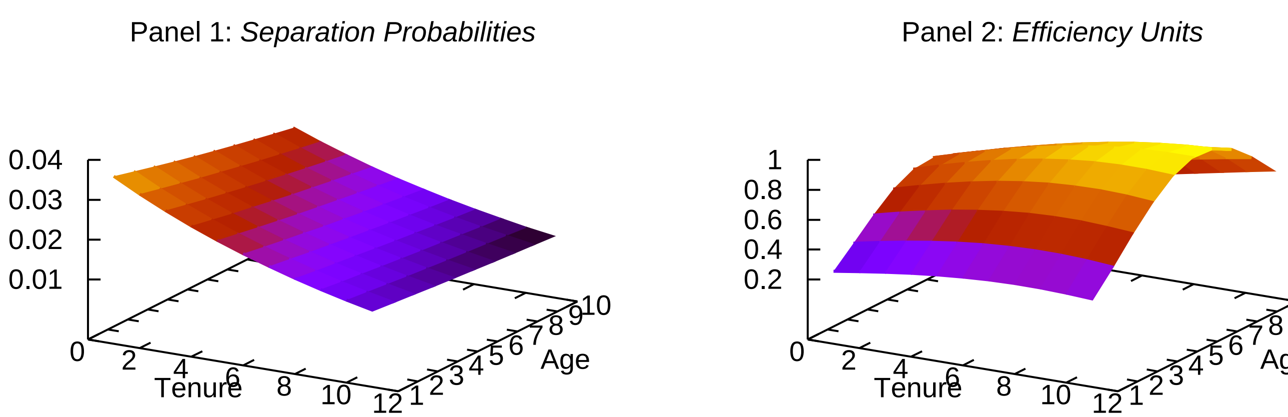

Figure 2: Calibration - Computed Job Separation and Productivity Profiles over Age and Tenure.

	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 4: 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.

	Severance pay				
Months of wages/year	0	0.3	0.6	0.9	1.2
Unemployment rate (%)	5.5	5.5	5.6	5.6	5.7
Non-searchers/searchers (%)	5.9	7.3	7.5	8.0	9.9
Output	100.0	99.5	99.2	99.3	99.4
Capital	100.0	98.7	98.0	98.2	98.7
Assets	100.0	98.6	97.7	97.8	98.1
Consumption	100.0	99.8	99.7	99.7	99.6
S.D. consumption	100.0	97.2	95.2	94.1	93.0
Welfare	100.0	100.4	100.6	100.7	101.0

Table 5: 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 (%)	5.5	5.5	5.5	5.6	5.6
Non-searchers/searchers (%)	6.0	6.3	6.8	7.4	8.8
Output	–	–	–	–	–
Capital	–	–	–	–	–
Assets	100.0	96.8	94.9	94.3	94.7
Consumption	100.0	99.8	99.7	99.7	99.8
S.D. consumption	100.0	95.9	93.3	92.1	91.9
Welfare	100.0	100.1	100.3	100.5	100.8

Table 6: 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 (%)	5.3	5.3	5.3	5.3	5.3
Non-searchers/searchers (%)	0.6	1.1	1.0	1.7	1.8
Output	100.0	99.9	100.0	100.2	100.5
Capital	100.0	99.5	99.8	100.5	101.5
Assets	100.0	99.4	99.5	100.1	100.9
Consumption	100.0	100.0	100.0	100.0	100.2
S.D. consumption	100.0	99.8	100.0	100.6	101.7
Welfare	100.0	99.9	99.8	99.7	99.6

Table 7: Allocational and welfare effects of linear severance-pay: no job-specific human capital

	Severance pay				
Months of wages	0	2	4	6	8
Unemployment rate (%)	5.5	5.5	5.5	5.5	5.5
Non-searchers/searchers (%)	5.9	6.2	7.1	7.3	6.6
Output	100.0	99.5	99.2	99.1	99.3
Capital	100.0	98.7	98.0	97.8	98.2
Assets	100.0	98.6	97.7	97.4	97.7
Consumption	100.0	99.8	99.7	99.7	99.7
S.D consumption	100.0	98.2	96.6	95.4	94.2
Welfare	100.0	100.3	100.4	100.6	100.8

Table 8: Allocational and welfare effects of (tenure-independent) severance-pay

	$RR = 0.5$	$RR = 0.4$	$RR = 0.3$	$RR = 0.2$	$RR = 0.1$
$\gamma_t = 1.2m/y$:					
Partial eq.	100.7	100.4	100.2	99.8	99.5
General eq.	101.0	100.8	100.8	100.7	100.7
$\gamma_t = 0$:					
Partial eq.	100.0	99.7	99.7	99.0	98.8
General Equilibrium	100.0	100.0	99.9	99.9	99.8

Table 9: Welfare effects of severance pay vs. unemployment benefits

Moment	*US - Data*	*US - Model*	*Moment*	*US - Data*	*US - Model*
r	0.0400	0.0392	*U. rate*		
% in Debt	0.1500	0.1579	*Age = 20*	0.0923	0.1037
			Age = 25	0.0559	0.0557
Tenure distribution			*Age = 30*	0.0425	0.0468
Tenure = 0	0.2741	0.2501	*Age = 35*	0.0408	0.0464
Tenure = 2	0.1309	0.1787	*Age = 40*	0.0371	0.0444
Tenure = 4	0.1186	0.1305	*Age = 45*	0.0352	0.0393
Tenure = 6	0.0794	0.0972	*Age = 50*	0.0343	0.0390
Tenure = 8	0.0623	0.0732	*Age = 55*	0.0345	0.0360
Tenure = 10	0.0644	0.0556	*Age = 60*	0.0340	0.0328
Tenure = 12	0.0378	0.0439	*Age = 65*	0.0330	0.0311
Tenure = 14	0.0415	0.0347	*U. distribution*		
Tenure = 16	0.0284	0.0269	*Age = 20*	0.1947	0.2621
Tenure = 18	0.0251	0.0218	*Age = 25*	0.1485	0.1413
Tenure = 20	0.1375	0.0873	*Age = 30*	0.1322	0.1189
Discouraged workers	0.0604	0.0627	*Age = 35*	0.1348	0.1182
			Age = 40	0.1150	0.1120
			Age = 45	0.0988	0.0997
			Age = 50	0.0690	0.0623
			Age = 55	0.0498	0.0351
			Age = 60	0.0302	0.0198
			Age = 65	0.0268	0.0307

Table 10: Model Fit - Empirical vs. Predicted Moments, US Economy

	Severance pay				
Months of wages/year	0	0.3	0.6	0.9	1.2
Unemployment rate (%)	5.5	5.6	5.6	5.6	5.6
Non-searchers/searchers (%)	5.9	6.8	7.7	8.4	8.7
Output	100.0	99.5	99.2	99.2	99.5
Capital	100.0	98.8	97.9	97.9	98.1
Assets	100.0	97.0	96.6	96.6	96.7
Consumption	100.0	99.8	99.6	99.7	99.7
S.D. consumption	100.0	97.4	95.4	94.2	93.5
Welfare	100.0	100.3	100.5	100.8	100.9

Table 11: Allocational and welfare effects of linear severance-pay: endogenous job finding rate

References

Abraham, Katherine and Farber, Henry (1987), 'Job duration, seniority, and earnings', *American Economic Review* **77**, 278–297.

Altonji, Joseph G. and Shakotko, Robert A. (1987), 'Do wages rise with job seniority?', *The Review of Economic Studies* **54**, 437–459.

Altonji, Joseph G. and Williams, Nicolas (2005), 'Do wages rise with job seniority? a reassessment', *Industrial and Labor Relations Review* **58**, 370–397.

Alvarez, Francesco and Veracierto, Marcelo (2001), 'Severance payments in an economy with frictions', *Journal of Monetary Economics* **47**, 477–98.

Attanasio, Orazio (1999), Consumption, *in* John B.Taylor and MichaelWoodford, eds, 'Handbook of Macroeconomics', Vol. 1B, North Holland, Amsterdam.

Attanasio, Orazio and Davis, Steven J. (1996), 'Relative wage movements and the distribution of consumption', *Journal of Political Economy* **104**, 1227–62.

Boeri, Tito, Garibaldi, Pietro and Moen, Espen R. (2014), Severance pay. CEPR Discussion Paper No. DP10182.

Couch, Kenneth A. and Placzek, Dana W. (2010), 'Earnings losses of displaced workers revisited', *American Economic Review* **100**(1), 572–89.

Farber, Henry 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, Giulio (2000), 'Efficiency wages and efficient redundancy pay', *European Economic Review* **44**, 1473–1490.

Fella, Giulio (2007), 'When do firing taxes matter?', *Economics Letters* **97**, 24–31.

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

Fella, Giulio and Tyson, Christopher J. (2013), 'Privately optimal severance pay in a matching model', *B.E. Journal of Macroeconomics* **13**.

Garibaldi, Pietro and Violante, Giovanni L. (2005), 'The employment effects of severance payments with wage rigidities', *Economic Journal* **115**, 799–832.

Gottschalk, Peter and Moffitt, Robert (1999), 'Changes in job instability and insecurity using monthly survey data', *Journal of Labor Economics* **17**, S91–S126.

Hayashi, Fumio, Altonji, Joseph and Kotlikoff, Laurence (1996), 'Risk-sharing between and within families', *Econometrica* **64**, 261–94.

Hosios, Arthur J. (1990), 'On the efficiency of matching and related models of search and unemployment', *Review of Economic Studies* **57**, 279–298.

Jacobson, Louis S, LaLonde, Robert J and Sullivan, Daniel G. (1993), 'Earnings losses of displaced workers', *American Economic Review* **83**, 685–709.

Jung, Philip and Kuester, Keith (2014), 'Optimal labor-market policy in recessions', *American Economics Journal: Macroeconomics* . Forthcoming.

Krebs, Tom (2007), 'Job displacement risk and the cost of business cycles', *American Economic Review* **97**(3), 664–686.

Krusell, Per, Mukoyama, Toshihiko and Sahin, Aysegül (2010), 'Labour-market matching with precautionary savings and aggregate fluctuations', *Review of Economic Studies* **77**, 1477–1507.

LaLonde, Robert J. (2007), The case for wage insurance, Technical report, Council on Foreign Relations.

Lazear, Edward P. (1990), 'Job security provisions and employment', *The Quarterly Journal of Economics* **105**, 699–726.

Ljungqvist, Lars (2002), 'How do layoff costs affect employment?', *Economic Journal* **112**, 829–853.

Lorences, Joaquín, Fernandez, Víctor and sar Rodriguez, C (1995), 'Diferencias interterritoriales de salarios y negociacion colectiva en España', *Investigaciones Economicas* **XIX**, 309–324.

Michelacci, Claudio and Ruffo, Hernán (2014), 'Optimal life cycle unemployment insurance', *American Economic Review* . Forthcoming.

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

Mortensen, Dale T. and Pissarides, Christopher A. (1994), 'Job creation and job destruction in the theory of unemployment', *Review of Economic Studies* **61**, 397–415.

Neumark, David, Polsky, Daniel and Hansen, Daniel (1999), 'Has job stability declined yet? new evidence for the 1990's', *Journal of Labor Economics* **17**, S29–S64.

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, Donald O. (2013), Understanding severance pay. IZA Discussion Paper No. 7641.

Pissarides, Christopher A. (2001), 'Employment protection', *Labour Economics* **8**, 131–159.

Rogerson, Richard and Schindler, Martin (2002), 'The welfare costs of worker displacement', *Journal of Monetary Economics* **49**, 1213–34.

Shimer, Robert (2005), 'The cyclical behavior of equilibrium unemployment and vacancies', *American Economic Review* **95**, 25–49.

Topel, Robert (1990), Specific capital and unemployment: Measuring the costs and consequences of job loss, *in* Olivier J. Blanchardet al., ed., 'Carnegie-Rochester Conference Series on Public Policy", North-Holland, Amsterdam.

Topel, Robert (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.

Appendix A - 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 $150,000$ individuals for $1,000$ 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 (34) 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 10. 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 119.28.

Appendix B.1 - Solution Algorithm

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 $\overline{\mu}_{r,0}$.
- 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 $\tau'_0 = \lambda_l \tau_0 + (1 - \lambda_l) \tau_1$ (with λ_l 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 B.2 - Solution Algorithm with Endogenous Tightness

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

- Guess the unemployment rate u_0.
- Guess the labor force participation rate L_0.
- Compute the labor market tightness ξ_0.
- Guess the measure of retirees $\overline{\mu}_{r,0}$.
- Guess the interest rate r_0.
- Guess the proportional tax τ_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 $\tau_0' = \lambda_l \tau_0 + (1-\lambda_l)\, \tau_1$ (with λ_l 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 $\tau_{l,1} \simeq \tau_{l,0}$, $\overline{\mu}_{p,1} \simeq \overline{\mu}_{p,0}$.

- Compute u_1, L_1.
- Update $u_0' = \lambda_u u_0 + (1 - \lambda_u) u_1$ (with λ_u an arbitrary weight).
- Update $L_0' = \lambda_L L_0 + (1 - \lambda_L) L_1$ (with λ_L an arbitrary weight).
- Iterate until $u_1 \simeq u_0$ and $L_1 \simeq L_0$, which implies $\xi_1 \simeq \xi_0$.
- Compute the consumption functions $c_e(s, a), c_u(s, b, a), c_r(a)$.
- Compute the welfare effects.

Appendix C - Stationary Equilibrium

- **Stationary distributions:**

Let $\mathbb{I}_{(\cdot)}$ denote an indicator function taking value one if the condition in parenthesis is satisfied and zero otherwise.

The stationary distributions $\{\mu_e(i, t, a), \mu_u(i, t, b, a), \mu_r(a)\}$ satisfy

$$\mu_e(i', t', a') = (1 - \rho_i) \Bigg[\int_{\{(i,t)\in\mathcal{S}\}\times\{a:a_e'(i,t,a)=a'\}} \pi(i'|i)\pi(t'|t)(1 - \sigma_{(i,t)}) d\mu_e(i, t, a) + \mathbb{I}_{t'=1} \int_{\{(i,t)\in\mathcal{S}\}\times\mathcal{B}\times\{a:a_u'(i,t,b,a)=a'\}} \pi(i'|i)\phi(i, t, b, a) d\mu_u(i, t, b, a) \Bigg] \tag{7}$$

$$\mu_u(i', t', b', a') = \int_{\{i\in\mathcal{I}\}\times\mathcal{B}\times\{a:a_u'(i,t',b',a)=a'\}} (1 - \rho_i)\pi(i'|i)(1 - \phi(i, t', b', a)) d\mu_u(i, t', b', a) + \mathbb{I}_{b'=1} \Bigg[\int_{\{(i,t)\in\mathcal{S}\}\times\{a:a_e'(i,t',a)=a'\}} (1 - \rho_i)\sigma_{(i,t)}\pi(i'|i) d\mu_e(i, t', a) + \pi_d \mathbb{I}_{i'=1,a'=a_0} \int_{\mathcal{A}} d\mu_r(a) \Bigg] + \int_{\{i\in\mathcal{I}\}\times\{a:a_u'(i,t,b,a)=a'\}} \mathbb{I}_{b'=0}\pi_b(1 - \rho_i)\pi(i'|i)(1 - \phi(i, t', 1, a)) d\mu_u(i, t', 1, a) \tag{8}$$

$$\mu_r(a') = (1-\pi_d)\int_{\{a:a'_r(a)=a'\}} d\mu_r(a) + \left[\int_{\{(i,t)\in\mathcal{S}\}\times\{a:a'_e(i,t,a)=a'\}\}} \rho_i d\mu_e(i,t,a) + \int_{\{(i,t)\in\mathcal{S}\}\times\mathcal{B}\times\{a:a'_u(i,t,b,a)=a'\}} \rho_i d\mu_u(i,t,b,a)\right] \quad (9)$$

In equilibrium the measure of agents in each state is time invariant and consistent with individual decisions, as given by the above three equations (7), (8), and (9).

Appendix D - Data and model fit

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 20 and 65, in the labor force, and with a valid observation for the tenure variable when computing the wage regressions.

Table 10 reports the fit of the model in terms of the set of moments targeted in the calibration.

[**Table 10 about here**]

Appendix E - Endogenous job finding rate

This section endogenizes the job finding rate using a standard matching function. We assume that the matching technology is Cobb-Douglas with the number of matches satisfying $M = U^{\nu}V^{1-\nu}$ where U and V denote the stock of unemployed workers and unfilled vacancies.

We maintain the assumption that firms create vacancies at zero cost and we close the model by assuming that the total number of firms, denoted by N, is exogenous. As each firm employs only one worker, the assumption implies that the number of vacancies V equals the number of firms N minus the number of employed workers. Normalizing to 1 the total size of the workers' pool and denoting by O the stock of non-searchers it follows that

$$V = N - (1 - U - O). \tag{10}$$

The calibration procedure for the baseline economy is similar to that in the main text. We follow Shimer (2005) and set the value of the matching function elasticity to $\nu = 0.72$. It follows that the unemployment exit rate satisfies

$$p(V/U) = (V/U)^{1-\nu}.$$

Given the targets for the unemployment exit rate p^* and the stock of unemployed workers U^* used in the baseline calibration in the main text, the above equation determines the associated stock of vacancy V^* in arbitrary units. Given the target for the stock of jobless non-searchers, equation (10) pins down the associated number of firms N^* in the benchmark economy with matching function.

We are now in a position to repeat the analysis in Section 4 for the economy with endogenous job finding rate. Table 11 is the counterpart of Table 5 in Section 4.

[**Table 11 about here**]

The results are very much in line with their counterparts in Table 5. In particular, despite the fact that the economy does not satisfy the Hosios (1990) condition, the changes in the number of unemployed workers and market tightness are small enough as to imply only marginal changes in the welfare gains from severance pay relative to the economy with constant job finding rate.