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Optimal Life Cycle Unemployment Insurance†

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We argue that US welfare would rise if unemployment insurance were increased for younger and decreased for older workers. This is because the young tend to lack the means to smooth consumption during unemployment and want jobs to accumulate high-return human capital. So unemployment insurance is most valuable to them, while moral hazard is mild. By calibrating a life cycle model with unemployment risk and endogenous search effort, we find that allowing unemployment replacement rates to decline with age yields sizeable welfare gains to US workers. (*JEL* D91, E24, J13, J64, J65)

The thesis that government transfers and taxes should be conditional on observable, immutable indicators of skills goes back at least to Akerlof (1978). More recently Kremer (2001); Erosa and Gervais (2002); Gervais (2012); Farhi and Werning (2013); Gorry and Oberfield (2012); Mirrlees et al. (2010); and Weinzierl (2011) have also called for setting labor and capital income tax rates on the basis of age, for an efficient tax system. In principle, this logic also applies to unemployment insurance (UI) and other labor market institutions. Such key economic variables as wages, wealth, consumption, and unemployment duration vary over the life cycle, which suggests that workers' incentives to search for a job and their ability to cope with unemployment risk vary accordingly. Here we argue that, given present US labor market institutions, overall welfare would be improved if unemployment insurance were increased for relatively young workers (in their mid-twenties and early thirties) and decreased for older workers (in their forties and mid-fifties).

The idea is that unemployment insurance is most valuable to young workers—because they typically have little means to smooth consumption during a spell of unemployment—while the costs of the implicit problem of moral hazard are minor—because young workers want jobs anyway to improve life-time career prospects, and build up human capital whose marginal return is high when young. The underlying intuition emerges from a simple formula. Consider a government that uses one

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dollar to finance an increase in unemployment benefits b_n for a given age group n. Denote by μ_n the number of unemployed workers in the age group, by c_{un} their consumption level when unemployed, and by $u'(c_{un})$ their marginal utility of consumption. If all currently unemployed workers receive one unit of money, welfare would increase by $\mu_n u'(c_{un})$. But standard moral hazard problems imply that more generous transfers drive up unemployment, and each unemployed worker receives benefits b_n. So a marginal increase in transfers yields only $1/[\mu_n + b_n d\mu_n/db_n] = 1/[\mu_n(1 + \eta_n)]$ units of income to a currently unemployed worker, where η_n is the elasticity of group n unemployment to the corresponding unemployment benefits. By multiplying the two terms we find the following welfare gains from the marginal change in government transfers:

$$\varrho_n = \frac{u'(c_{un})}{1 + \eta_n}. \tag{1}$$

Intuitively the numerator gives the marginal value of the increase in unemployment insurance, the denominator the incentive costs of moral hazard. Generally a revenue-neutral change in unemployment insurance that raises benefits for a given age group n and lowers them for another age group m is welfare improving whenever $\varrho_n > \varrho_m$, which can be used to identify possible gains from redistributing unemployment insurance over the life cycle. This logic focuses on redistributing a given amount of government income across unemployed workers of different ages. But government income is typically financed through tax revenue, which is affected by the age profile of unemployment benefits through its effects on employment and human capital accumulation. In the paper we discuss how to incorporate this and other effects into (1) and also study the relative quantitative importance of tax effects, which have been greatly emphasized by the public finance literature, see for example Mirrlees et al. (2010).

We start documenting how ϱ_n in (1) varies across age groups. First we use data from the Panel Study of Income Dynamics (PSID) and show that the consumption of unemployed workers is strictly increasing in age. Roughly speaking, an unemployed worker in his thirties consumes 30 percent less than one in his fifties. We also use data from the Current Population Survey (CPS) and from the Survey of Income and Program Participation (SIPP) to analyze how the level of unemployment in different age groups responds to changes in unemployment benefits. As in Chetty (2008), we exploit changes in the level of benefits within US states over time. We find that while the elasticity of unemployment to benefits is small and statistically insignificant for workers in their mid-twenties and early thirties, it is positive and significant for workers in their mid-forties and fifties. Meyer and Mok (2007) find similar results. Gritz and MaCurdy (1992) also show that changes in benefits have insignificant effects on the level of unemployment among young workers. This evidence indicates that providing additional insurance to young workers is highly valuable, while the incentive costs of moral hazard are small, which implies that ϱ_n is unambiguously larger for younger than for older workers.

The data also offer more direct evidence of the high value and low moral hazard of unemployment insurance for young workers. We show that consumption losses upon unemployment are greater for younger than for older workers, and that the job search behavior of young workers is strongly responsive to the provision of severance payments at the time of job loss. This indicates that young unemployed workers have little ability to smooth consumption and require more liquidity and insurance. Chetty (2008) observes that the effect of benefits on the unemployment of wealthy workers—who arguably have greater ability to smooth consumption—measures the severity of the moral hazard problem. We find that the unemployment duration of older workers with substantial assets is affected powerfully by benefits, while that of young wealthy workers is relatively insensitive to benefits. This suggests that the moral hazard problem is severe among older workers while it is relatively insignificant among younger workers. This squares with the idea that young workers want jobs not only to increase their current income but also to acquire labor market skills and so improve career prospects and lifetime income.

To study the magnitude of the potential welfare gains of age-dependent unemployment insurance, we consider a conventional life cycle model with decreasing returns to labor market experience and ongoing unemployment risk. Workers are born with zero human capital and no assets and can save in a riskless bond. When employed, they accumulate human capital, receive wages, and pay income taxes to finance unemployment insurance and retirement pensions. Workers may lose their jobs and suffer a depreciation of their human capital. When unemployed they choose the intensiveness of job search. During unemployment they receive benefits that are a constant fraction of past wages. The model is calibrated to match US labor market institutions and other key features of the workers' life cycle.

We optimally choose age-dependent replacement rates and/or income tax rates to maximize the worker's initial expected utility.[1] We find that under the optimal age-dependent policy, replacement rates would rise from 50 percent as now to around 80 percent for workers in their mid-twenties and 60 percent for those in their thirties. Workers in their forties and fifties, instead, would get benefits of less than 10 percent of their last wage. When allowing for just age-dependent replacement rates, the welfare gain is equivalent to almost 1 percent of lifetime consumption. When combining age-dependent unemployment insurance with age-dependent taxes, the gain increases to more than 3 percent of lifetime consumption.

To analyze whether age-dependent policies would use up a significant part of the potential gains inherent in current US labor market institutions, we consider the problem of an agency that must optimally choose benefits, taxes, and pensions as a function of the worker's entire history. The agency can observe workers' assets as well as search effort, so unemployment insurance creates no moral hazard. Although age-dependent policies can reproduce the solution of the optimal program only imperfectly, we surprisingly find that making both unemployment insurance and taxes age-dependent yields 90 percent of the welfare gains obtained under the optimal program. Around a quarter of these gains are due to age dependent unemployment benefits.

[1] An alternative would be to make replacement rates and taxes conditional on current assets, not age. Although this would distort saving incentives and is in principle inferior to age-dependent policies, it could still yield substantial gains in welfare. This point is made by Conesa, Kitao, and Krueger (2009); Rendahl (2012); and Koehne and Kuhn (2014).

Further Relation to the Literature.—Using diverse methodologies, several authors have argued that the level of unemployment benefits is close to optimal in the United States, see, for example, Davidson and Woodbury (1997); Shimer and Werning (2007); Pavoni (2007); and Chetty (2008). Our results show that, while they are optimal on average, sizable welfare gains are still possible by redistributing unemployment benefits over the life cycle—increasing them for the young and decreasing them for the old.

This paper relates to the literature that, since Hopenhayn and Nicolini (1997), has analyzed the optimal design of labor market institutions, including Pavoni and Violante (2007); Shimer and Werning (2008); Pavoni (2009); Rendahl (2012); and Pavoni, Setty, and Violante (2010). These works typically posit an initially unemployed worker who becomes permanently employed upon finding his first job. Except for Hopenhayn and Nicolini (2009), they neglect recurrent spells of unemployment. This literature has also abstracted from life cycle effects due to nonlinear returns to labor market experience and asset accumulation which constitute the main focus of this paper.

Baily (1978) and Chetty (2006) have proposed simple formulas to evaluate whether unemployment benefits are on average optimal. Our formula ϱ_n is similar, but focuses on possible gains from redistributing benefits over the life-cycle or more generally across any groups of workers classified by observable, immutable skill characteristics including gender or race. The formula ϱ_n works exactly in the stylized model of Section I. But the quantitative analysis also indicates that the key forces highlighted in ϱ_n dominate in today's US labor market institutions. To be sure, the simple formula ϱ_n neglects the effects of age-specific changes in benefits on tax revenue, on worker human capital, and on unemployment among age groups not directly targeted by the policy change. And we show that these considerations lead to an extended redistribution formula that works exactly in the quantitative model. But although the simple and extended formula could differ, we find that, in our laboratory economy, they exhibit a remarkably similar age profile.

Shimer and Werning (2007) and Chetty (2008) have criticized Baily's formula for relying on highly controversial preference parameters. Our own formula is less subject to their criticism in that its ability to identify redistribution gains just relies on signing the relative magnitude of ϱ_n across skill groups. This is often possible just by comparing unemployment elasticities and consumption levels when unemployed across skill groups, without having to specify any preference parameter.

Chéron, Hairault, and Langot (2011, 2013) have studied the role of age-dependent labor market policies in a search model with finitely lived workers à la Mortensen and Pissarides (1994). Our paper is obviously related, but with some important differences. Chéron, Hairault, and Langot (2011, 2013) emphasize the demand side of the labor market and the role of age-dependent policies in solving the conventional search inefficiencies in vacancy creation typically found in random search models; see Pissarides (2000) for an introduction to this class of models. Search inefficiencies naturally vanish in extended versions of the search model in which firms post wage contracts, workers observe them, and direct their search accordingly; see for example Moen (1997); Acemoglu and Shimer (1999); Shimer (2005); and more recently Menzio and Shi (2011). Here we emphasize labor supply effects and the variation over the life cycle in the trade-off between the gains from unemployment insurance and the incentive costs of moral hazard.

Section I uses a stylized life cycle model to discuss the formula in (1) and its extension. Section II presents preliminary evidence. Section III describes our laboratory economy. Section IV solves for the first best. Section V studies age-dependent policies, Section VI discusses robustness and Section VII concludes. The online Appendix provides the details on data and computation.

I. A Stylized Life Cycle Model

We present a simple stylized life cycle model in which our simple formula holds exactly. We then extend it to incorporate additional effects that lead to an extended formula. We later show that these formulas work well in a more conventional life cycle model more suitable for quantitative analysis.

A. *The Worker's Problem*

In this stylized model workers live for six periods ($i = 1$–6). They are young, $n = y$, during the first three periods ($i = 1$–3), and old, $n = o$, during the last three ($i = 4$–6). The sole risk is unemployment. Workers are employed with probability one in all periods except in period 2 and 5, when they must search for a job. This characterizes the fact that unemployment risk is recurrent, it affects both young and old, and it has transitory effects. Unemployment is endogenous due to search intensity decisions. Search intensity reduces both the probability of unemployment and one's leisure time. We assume that a worker who is unemployed with probability μ at the end of period 2 or 5 enjoys utility from leisure equal to $\psi(\mu)$, with $\psi'(\mu) > 0$ and $\psi''(\mu) < 0$. Workers initially have no wealth. They cannot borrow but can save via a risk-free bond that pays a constant interest rate r equal to their subjective discount rate. So the workers' subjective discount factor is equal to $\beta = 1/(1 + r)$. Following well established evidence from wage regressions, we assume that wages when young w_i ($i = 1$–3) increase over time, while wages when old w_i ($i = 4$–6) are flat and equal to $\bar{w}$, with $w_1 < w_2 < w_3 < \bar{w}$. If unemployed at age $n = y, o$ (end of period 2 or 5) workers receive unemployment benefits b_n. Consumption utility in a period is $u(c)$.

We assume that consumption is equal to income for young workers: a young worker expects future increases in labor income and would like to borrow to smooth consumption but cannot owing to the borrowing constraint.[2] This simplifying assumption implies that old workers' decisions are not affected by their employment history, which guarantees that changes in benefits when young (old) do not affect unemployment when old (young). As is noted in Section IC, this separability property is required for the formula to hold exactly. Separability implies that the worker's initial expected utility can be expressed as equal to

$$W(b_y, b_o) \equiv Y(b_y) + O(b_o), \tag{2}$$

[2]Even if wages are growing and the interest rate is equal to the worker's subjective discount rate, young workers might want to accumulate some precautionary savings to insure against the risk of unemployment in period 2. Here we assume that consumption smoothing dominates the precautionary savings motive so that $u'(w_1) \geq \mu_y u'(b_y) + (1 - \mu_y)u'(w_2)$ where μ_y is the equilibrium unemployment probability in period 2.

where $Y(b_y) = \max_\mu \tilde{Y}(b_y, \mu)$ and $O(b_o) = \max_\mu \tilde{O}(b_o, \mu)$ are the sum of discounted utilities when young ($i = 1$–3) and when old ($i = 4$–6), respectively. The expression

$$(3) \quad \tilde{Y}(b_y, \mu) \equiv u(w_1) + \beta\big[\psi(\mu) + \mu u(b_y) + (1 - \mu)u(w_2)\big] + \beta^2 u(w_3),$$

is the sum of utilities obtained by young workers for a given unemployment probability μ in period 2, while

$$(4) \quad \tilde{O}(b_o, \mu) \equiv \beta^3 \max_{a \geq 0} \Big\{ u(\bar{w} - a) + \beta\psi(\mu) + \beta\mu\Big[u\Big(b_o + \frac{a}{\beta}\Big) + \beta u(\bar{w})\Big] + \beta(1 - \mu)(1 + \beta)\, u\Big(\bar{w} + \frac{a}{1 + \beta}\Big)\Big\}$$

is the analogous sum for older workers when the unemployment probability μ in period 5 is taken as given. In (4), a denotes the precautionary savings that the household accumulates in period 4 to finance consumption during unemployment in period 5, which occurs with endogenously determined probability μ. If instead the worker remains employed, a serves to increase consumption equally in periods 5 and 6. This accounts for the last term in (4).[3]

B. *The Government's Problem*

As is standard in the optimal unemployment insurance literature—see, for example, Hopenhayn and Nicolini (1997) and Shimer and Werning (2007, 2008)—we assume that government interventions are actuarially fair so that the present value of UI transfers is equal to the present value of some exogenous government income T, which we later endogenize. The government chooses b_n, $n = y, o$, so as to maximize workers' expected utility W in (2) subject to the budget constraint

$$(5) \quad \beta_y \mu_y(b_y) b_y + \beta_o \mu_o(b_o) b_o = T,$$

where $\beta_y = \beta$ and $\beta_o = \beta^4$ are the discount factors, while the functions $\mu_y(b_y)$ and $\mu_o(b_o)$ determine the age-specific unemployment probabilities μ_y and μ_o given the age-specific benefit levels b_y and b_o, respectively. Given (3) and (4) these functions are implicitly defined by the conditions $\mu_y = \arg_\mu \max \tilde{Y}(b_y, \mu)$ and $\mu_o = \arg_\mu \max \tilde{O}(b_o, \mu)$, respectively. The Lagrangian of the problem reads as

$$L(b_y, b_o, \lambda) = Y(b_y) + O(b_o) + \lambda\big[T - \beta_y \mu_y(b_y) b_y - \beta_o \mu_o(b_o) b_o\big],$$

where λ is the Lagrange multiplier of the budget constraint in (5). Taking the first order condition with respect to b_n, $n = y, o$, and using the envelope theorem, we immediately find that it is optimal to increase b_n if

[3] In equilibrium a will always be in the interval $(0, \bar{w} - b_o)$, so the constraint $a \geq 0$ will be slack, while the borrowing constraint will be binding in period 5 if the worker is unemployed.

$$\beta_n \mu_n u'(c_{un}) \; > \; \lambda \beta_n \mu_n \; + \; \lambda \beta_n \frac{d\mu_n}{db_n} b_n, \tag{6}$$

where c_{un} denotes consumption when unemployed at age n. Rearranging, the above condition is equivalent to

$$\varrho_n \equiv \frac{u'(c_{un})}{1 + \eta_n} > \lambda, \tag{7}$$

where $\eta_n \equiv \frac{d \ln \mu_n}{d \ln b_n}$ is the elasticity of unemployment to benefits of age group n. The ratio on the left-hand side is the net welfare gain of marginally increasing government transfers to unemployed workers of age n: the numerator measures the value of the marginal increase in UI benefits, the denominator the cost of the induced increase in unemployment. Optimal life cycle unemployment insurance requires $\varrho_n = \lambda$ for any age group n. Generally there are welfare gains from increasing transfers to young unemployed workers at the expense of the old whenever

$$\varrho_y > \varrho_o. \tag{8}$$

Interestingly, the comparison does not require evaluating consumption losses upon displacement. This is simply because the government compares the gains of increasing transfers to unemployed workers of different ages whose marginal value is measured by their state contingent marginal utility of consumption. The derivation that leads to (8) is hardly affected in several extensions of the baseline model. In particular the formula remains valid in cases of:

(i) *Differences in workers demand and/or supply.*—The utility from leisure is age-specific, $\psi_n(\mu)$, $n = y, o$, with $\psi_n'(\mu) > 0$ and $\psi_n''(\mu) < 0$. This accounts for possible differences in the demand for workers of different ages as well as in their labor supply, both of which can affect job-finding probabilities.[4]

(ii) *Varying job loss probabilities.*—Workers search for a job in periods 2 and 5 with age-specific probability δ_n, $n = y, o$ (in the baseline model $\delta_y = \delta_o = 1$), to account of the fact that the risk of job loss varies over the life cycle.

(iii) *Other income.*—Workers have access to other sources of income y_n (say, the spouse's earnings), whose relative importance varies over the life cycle.

[4] To see why an age-dependent Ψ function subsumes age effects in both labor demand and supply, assume that, as in standard search models (Pissarides 2000), the unemployment probability of workers of age n is a decreasing function of both their search effort s and market tightness θ_n for that age group of workers, so that $\mu = \mu(s, \theta_n)$. Age-specific differences in demand are reflected in θ_n. The disutility of search effort is $\tilde{\Psi}_n(s)$, which is age-specific to characterize age differences in labor supply. We can then invert the function μ to express search effort as function of μ and θ_n so as to obtain the simple formulation in the text based on $\Psi_n(\mu) \equiv \tilde{\Psi}_n(\mu^{-1}(\mu, \theta_n))$.

(iv) *Changing household size*.—The household is represented by a simple unitary model with consumption utility $m_n u(C/m_n)$, where m_n denotes household size when household head has age n, while C denotes household total consumption expenditures. This takes into account that household size changes over the life cycle with marriage, the birth of children, and their growing up and leaving home. Due again to the envelope theorem, the marginal value of a unitary increase in benefits is $u'(C/m_n)$. This implies that c_{un} in (7) has to be interpreted as per capita household consumption when a household head of age n is unemployed.

(v) *Tax effects*.—The UI program is financed through income taxes equal to a (possibly) age-specific proportion τ_n, $n = y, o$, of net wages w_i, $i = 1$–6, so that

$$T \equiv T(b_y, b_o) = \bar{T} - \beta_y \mu_y(b_y)\tau_y w_2 - \beta_o \mu_o(b_o)\tau_o w_5.$$

Here $\bar{T} = \tau_y \sum_{i=0}^{2} \beta^i w_{i+1} + \tau_o \sum_{i=3}^{5} \beta^i w_{i+1}$ denotes the present value of tax revenue under no unemployment, while the last two terms measure the fall in tax revenue due to unemployment in period 2 and 5. By applying the same logic as in (6), we then obtain the following slightly modified version of ϱ_n:

$$\hat{\varrho}_n = \frac{u'(c_{un})}{1 + \eta_n\left(1 + \frac{\tau_n}{\rho_n}\right)},$$

where $\rho_y \equiv \frac{b_y}{w_2}$ and $\rho_o \equiv \frac{b_o}{w_5}$ denotes the UI replacement rate at age $n = y$ and $n = o$, respectively. $\hat{\varrho}_n$ differs from ϱ_n in (7) just because of the quantity $\eta_n \frac{\tau_n}{\rho_n}$ in the denominator of $\hat{\varrho}_n$, which measures the fall in taxes due to the age-specific increase in benefits. When the tax system has no age-specific features (ρ_n and τ_n are both independent of n), $\hat{\varrho}_n$ and ϱ_n have the same age profile. But in practice, the ratio $\frac{\tau_n}{\rho_n}$ is increasing in n, since wages rise with age and higher wages make τ_n higher—due to the progressivity of the tax system—and ρ_n lower—since UI replacement rates are typically constant up to a maximum. Since this effect makes it more likely that $\hat{\varrho}_n$ is decreasing in n, $\hat{\varrho}_y > \hat{\varrho}_o$ is implied by the condition $\varrho_y > \varrho_o$—at least provided that $\eta_o \geq \eta_y$, which, as we show in Section II, is the empirically relevant case. This simply means that the inequality in (8) based on ϱ_n indicates the existence of welfare gains from redistributing UI benefits from the old to the young even in the presence of tax effects.[5]

[5] Of course with different tax effects, it could well be that $\hat{\varrho}_n$ is more useful than ϱ_n for identifying welfare gains from redistribution. We thank one of the referees for this discussion.

C. *The Extended Redistribution Formula* $\tilde{\varrho}$

The simple redistribution formula ϱ in (7) can be modified to extend the analysis in three ways. First, we allow young workers in period 1 to save. Second, we allow for a general tax revenue function $T(b_y, b_o)$, which is more in keeping with the quantitative analysis of Section III, where tax revenue depends on workers' employment status and human capital. Third, the optimal choice of benefits is now subject to the feasibility constraint that benefits cannot fall below a minimum level $\bar{b}_n$ so that

$$b_n \geq \bar{b}_n, \quad \forall n = y, o. \tag{9}$$

In the quantitative analysis of Section III, this minimum is set to zero.

Since young workers can save, their employment state will affect their future decisions when they get old. Generally the choices for assets and unemployment probabilities at any time i are now contingent on the history up to that time. Moreover, since asset choices are forward-looking, the equilibrium unemployment probability at a given age is a function of both b_y and b_o, so we now have $\mu_y = \mu_y(b_y, b_0)$, and $\mu_o = \mu_o(b_y, b_0)$. The full analysis of the extended model is in the online Appendix, where we show that the value of marginally increasing benefit transfers to unemployed workers of age n—i.e., the analogue of ϱ_n in (7)—is now given by

$$\tilde{\varrho}_n = \frac{E\left[u'(c_{un})\right] + \frac{\omega_n}{\mu_n}}{1 + \tilde{\eta}_n - \frac{\partial T}{\partial b_n} \cdot \frac{1}{\mu_n}}. \tag{10}$$

In this expression $E\left[u'(c_{un})\right]$ is the expected marginal utility of consumption of unemployed workers of age n, $\omega_n \geq 0$, $n = y, o$ is the current value Lagrange multiplier of the benefits feasibility constraint in (9), while

$$\tilde{\eta}_n = \sum_{i=y,o} \frac{\partial \mu_i}{\partial b_n} \cdot \frac{\beta_i b_i}{\beta_n \mu_n} \tag{11}$$

is the modified elasticity of unemployment to account for the fact that changing benefits for a given age group n potentially affects the unemployment level of other age groups. Finally, $\frac{\partial T}{\partial b_n}$ is the partial derivative of tax revenue with respect to the change in benefits. Generally, there are welfare gains from increasing transfers to young unemployed workers at the expense of the older whenever

$$\tilde{\varrho}_y > \tilde{\varrho}_o. \tag{12}$$

There are four simple reasons why $\tilde{\varrho}_n$ differs from ϱ_n.

(i) *Heterogeneity in assets.*—Since assets depend on employment histories, unemployed workers of the same age may now have different consumption levels. This is why the expected marginal utility of consumption forms part of the numerator of (10).

(ii) *Unemployment cross derivatives*.—Since the unemployment probability at a given age is a function of the overall age profile of benefits, increasing benefits for an age group n can affect the unemployment level of any age group. Thus, the present value of total UI expenditures generally increases by $\beta_n \mu_n(1 + \tilde{\eta}_n)$.

(iii) *Reduction in tax revenue*.—Benefits reduce government revenue T because of lower labor income, due to higher unemployment and less human capital accumulation. This cost is measured by the derivative $-\frac{\partial T}{\partial b_n}$.

(iv) *Positive benefits*.—When ω_n is positive (the constraint in (9) is binding), the government would like to decrease benefits further for unemployed workers of age n, because their consumption is inefficiently high. In the quantitative analysis of Section III, this constraint will be binding for older workers.

Although $\tilde{\varrho}_n$ and ϱ_n are different in general, we will see that, in the baseline calibration of the laboratory economy set out in Section III, $\tilde{\varrho}_n$ and ϱ_n exhibit a remarkably similar age profiles, which indicates similar welfare gains from redistributing unemployment insurance over the life cycle. Differences begin to be significant only when the optimal values for age-dependent benefits are selected. A simple interpretation is that the differences between $\tilde{\varrho}_n$ and ϱ_n matter only when policies are close to optimal, while, under current US labor market institutions, the key forces highlighted by the simple formula in (7) dominate.

II. Some Empirical Evidence

We now show that, in the United States, the elasticity of unemployment to unemployment insurance (UI) benefits and consumption while unemployed are both lower for young than for older workers. This indicates that inequality (8) holds both because young workers' incentives to search for a job are less strongly affected by benefits (the denominator in (7) is smaller) and because they value unemployment insurance more (the numerator is higher). We then provide more direct evidence (i) that the moral hazard induced by unemployment insurance is modest for young workers, and (ii) that young workers have little ability to smooth consumption during unemployment and therefore value the insurance and liquidity provided by benefits more highly. We will use this evidence later to evaluate the quantitative properties of the model of Section III. We start with a brief discussion of the datasets used, for full details on data construction and sample selection criteria, see the online Appendix.

A. *The Data*

Our data come from the Survey of Income and Program Participation (SIPP), the Current Population Survey (CPS), the Panel Study of Income Dynamics (PSID), and surveys collected by Mathematica on behalf of the US Department of Labor. The SIPP and Mathematica data are used for an unemployment duration analysis at individual level; the CPS to estimate the aggregate effects of benefits on unemployment; and the PSID for evidence on consumption. In all cases the analysis focuses on working-age men. Sample periods vary but run roughly from the 1980s to the early 2000s. Sample selection in the SIPP and the Mathematica data is exactly as in Chetty (2008). As far as possible we apply the same criteria to the construction of the CPS and PSID samples.

We use two measures of UI benefits. One is the imputation of *individual* benefits in the SIPP data by Chetty (2008). The other is a measure of the *average* benefits received by unemployed workers of different age groups in each US state and year. The construction of this latter measure mirrors Chetty (2008) but with CPS data: we first use the March CPS survey to impute pre-unemployment wages to each unemployed worker in the sample and then gauge individual UI benefits using the calculator devised by Cullen and Gruber (2000). The resulting individual benefits are then averaged for age-groups, states, and years.

Consumption in PSID is measured using either food consumption at home, which is reported directly by PSID, or total consumption expenditure for nondurables, which is imputed using the methodology of Blundell, Pistaferri, and Preston (2008) as in Hryshko, Luengo-Prado, and Sørensen (2010). The imputation covers both the core and the SEO sample in PSID, which gives us a more representative sample than in Blundell, Pistaferri, and Preston (2008). Consumption corresponds to the average per capita weekly expenditures in the household, which, like Blundell, Pistaferri, and Preston (2008), we interpret as measuring household consumption in an average week around the time of the survey week.

B. *Elasticity of Unemployment to Benefits*

To calculate the elasticity of unemployment to benefits for workers of different ages, we start splitting the SIPP sample into two age groups, 20–40 and 41–60. This split is justified by the fact that after age 40, the return to labor market experience substantially flattens while assets increase significantly. We show later that this is important in determining the value and the moral hazard costs of UI. For each sample, we then estimate the following semi-parametric Cox proportional-hazards regression for unemployment duration:

$$\ln h_{it} = \beta \ln b_{it} + \theta X_{it} + \text{err}, \tag{13}$$

where i denotes the worker, t the duration of the current unemployment spell, h_{it} the job finding probability at unemployment duration t, b_{it} the level of UI benefits, and X_{it} a set of controls including worker's age, years of education, a marital status dummy, previous job tenure, a spline in logged past wages, dummies for year, state, and unemployment duration, and the interaction of benefits with unemployment duration. The effects of benefits are identified by a difference-in-differences strategy that exploits changes in unemployment benefits rules of US states over time. Table 1 reports the results for the two measures of benefits. Panel A shows individual benefits, panel B age-specific average benefits.[6] The first column of panel A shows the full sample estimates, which are analogous to those in Chetty (2008).

[6] Much of the variation by age in UI replacement rates is due to the fact that wages are typically replaced by a constant percentage, usually 50 percent, but only up to a maximum that differs from state to state. Since wages generally increase with age, this implies that actual replacement rates are lower for older than for younger workers.

TABLE 1—JOB FINDING ELASTICITY TO BENEFITS, SIPP

	All	20–40 yrs.	41–60 yrs.
Panel A. Individual UI benefits			
ln benefits	−0.36***	−0.23	−0.86***
	(0.11)	(0.16)	(0.19)
Number of spells	4,529	2,858	1,522
Panel B. Age-specific average UI benefits			
ln benefits	−0.34*	−0.19	−1.36***
	(0.20)	(0.25)	(0.46)
Number of spells	4,380	2,858	1,522

Notes: Estimates of β in the Cox regression (13) using SIPP data. In panel A benefits are individually imputed, in panel B they are age-specific state-year averages. The first column shows full sample; the second and third workers in age groups 20–40 and 41–60, respectively. Standard errors clustered by state in parentheses.

***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

Here the elasticity of the job finding probability to benefits is very close to one-third and highly significant. The results in the following two columns show that the full sample estimates in Chetty (2008) conceal substantial heterogeneity according to age. For the sample of workers aged 20–40, the effects of UI benefits on job finding are small and not statistically significant for either measure of benefits. For the sample of older workers, the estimated elasticity is instead close to 1 and strongly significant for both measures.[7]

We now split the data into finer age groups. To maintain sample size, we estimate the unemployment duration regression in (13) using nine partly overlapping samples with age differences of ten years. To measure the elasticity of unemployment to benefits, we use the relation $d\ln u/d\ln b = -(1-u)d\ln f/d\ln b$, where $d\ln f/d\ln b$ is the estimated elasticity of job finding while u and f are the sample average of the unemployment rate and the finding rate, respectively. The relation is exact if benefits affect unemployment only though the job finding rate. Panel A in Figure 1 reports the age profile of the resulting elasticity of unemployment based on individual benefits. The results with the age-specific average measure of benefits are in Figure A1 in the online Appendix. The dotted lines represent 90 percent confidence intervals. The elasticity of unemployment is around 20 percent for workers in their twenties and early thirties and nearly 100 percent for those in their mid-forties and early fifties. For workers close to retirement it tends to fall, but confidence intervals are very large, indicating imprecise estimates.

So far we have focused on how UI benefits affect job finding rates. But benefits can also affect unemployment through labor force participation or through the unemployment inflow rate, and they may have aggregate equilibrium effects not

[7] We checked that these results are robust to including as controls the log of individual wealth or of net liquid assets at the time of job loss, or to using a Weibull regression for unemployment duration. We have also split the sample into three educational groups (less than high school, high school graduates, at least some college) and found similar results for the three groups.

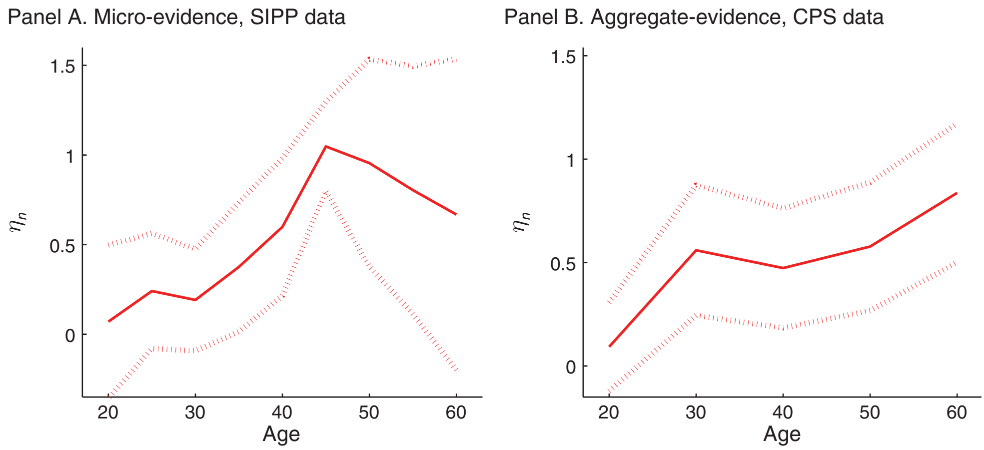

Figure 1. Elasticity of Unemployment to Benefits by Age Group

Notes: Elasticity of unemployment to benefits by worker's age. Panel A estimates are based on (13) using SIPP data and individual benefits. Unemployment elasticities are calculated using the formula $\frac{d \ln u}{d \ln b} = -(1-u)\frac{d \ln f}{d \ln b}$, where u and f are the sample average of the unemployment rate and the finding rate, respectively. Panel B are estimates of β_n in (14) using US states aggregate unemployment data from CPS. Dotted lines are 90 percent confidence intervals.

properly measured by unemployment duration regressions. To address some of these concerns, we use US states' aggregate unemployment data from CPS and the age-specific average measure of benefits to estimate the following regression:

$$\ln u_{itj} = \sum_n \beta_n q_j^n \ln b_{itj} + \theta X_{itj} + \text{err}, \tag{14}$$

where i stands for the state, t for the period (half and year), and j for age group, u_{tij} is the ratio of unemployment to population for age group j in state i in period t, q_j^n is a dummy variable which is equal to 1 if the observation corresponds to age group n, and b_{itj} is the imputed age-specific average benefit level deflated with the CPI. The variables X_{itj} are a set of controls, including time, state, and age-group dummies, the imputed log of average pre-unemployment wages (again deflated with the CPI), the proportion in the group of white men, of married workers, of workers with working spouse, and of unemployed workers with five different educational levels. Standard errors are clustered at the state level, since different US states are considered as partially segmented labor markets. Panel B of Figure 1 plots the estimated values of β_n in (14), which measure the elasticity of unemployment to benefits for workers of age n. Dotted lines are 90 percent confidence intervals. The estimated elasticities of unemployment are again increasing in age. They are very close to zero for workers in their twenties and around 0.7 for those in their fifties. Estimates are comparable to those from the unemployment duration analysis in panel A, although they are now slightly smaller and there is no longer any evidence that the elasticity falls toward zero for workers close to retirement.[8]

[8] The CPS results are robust to controlling for the maximum duration of benefits in the state and to instrumenting benefits using their own lagged value to deal with endogeneity problems—say because average benefits change over the business cycle due to changing composition in the pool of the unemployed (see Mueller 2010). The IV

C. *Consumption While Unemployed*

To estimate how the consumption of unemployed workers varies with age, we run the following regression on PSID data:

$$\ln c_{it} = \sum_n \beta_n^e e_{it}^n + \sum_n \beta_n^u u_{it}^n + \theta X_{it} + \text{err}, \tag{15}$$

where i denotes the worker, t the year, c_{it} consumption per capita in the household, e_{it}^n and u_{it}^n are employment status dummies that are equal to one if, at the interview date, the household head of age n is employed or unemployed, respectively. Finally X_{it} are a set of controls, including dummies for the educational level and the race of the household head, time dummies, and the number of household members. To account for serial correlation in the errors, a GLS random-effects estimator is used. Figure 2 shows the estimated age profile of consumption of employed workers as a dashed line and of unemployed workers as a solid line. Panel A shows food consumption, panel B total nondurable consumption. The consumption of employed workers increases with age reaching a peak at around 50 years of age. That of unemployed workers also increases with age and is generally lower than that of the employed.[9]

We also estimate the age pattern of consumption losses upon unemployment. To do so, we follow Gruber (1997) and estimate equation (15) but now including individual fixed effects and dummy variables for changes in employment status. The resulting regression is estimated using a fixed-effects (within) regression estimator. The coefficient for the change in employment status from employed to unemployed characterizes the size of the average consumption loss. We allow this effect to vary by age. Figure 3 shows the age profile of consumption losses for food (left panel) and total nondurable consumption (right panel). Consumption losses are around 17 percent for workers in their twenties and thirties but less than 5 percent for those in their fifties and sixties.[10] Consumption losses are slightly greater for total nondurable consumption, but in both cases they fall significantly as age increases.

D. *Moral Hazard and Liquidity Effects*

These results indicate that unemployment insurance induces mild incentive costs and it is most valuable to young workers. We now provide more direct evidence that (i) the moral hazard created by unemployment insurance is mild for young workers and (ii) that they value unemployment insurance highly because they have limited other means to smooth consumption during unemployment.

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estimates are larger and more in line with the estimates from the unemployment duration analysis, which might indicate that compositional changes raise income replacement rates in recessions.

[9] The results are robust to including temporarily laid-off workers among unemployed, to weighting observations, to using total food expenditures either at home or out of the home, and to dropping observations with consumption levels below the first or above the ninety-ninth percentile of the consumption distribution. We also find that consumption of unemployed workers increases with age not only on average but also in the first-order stochastic dominance sense.

[10] There is a substantial literature measuring consumption losses upon unemployment, see Gruber (1997); Browning and Crossley (2001); Bloemen and Stancanelli (2005); and Sullivan (2008). All studies note that average consumption losses result from aggregating vastly heterogeneous individual responses. Our results indicate that part of this heterogeneity is life-cycle-related.

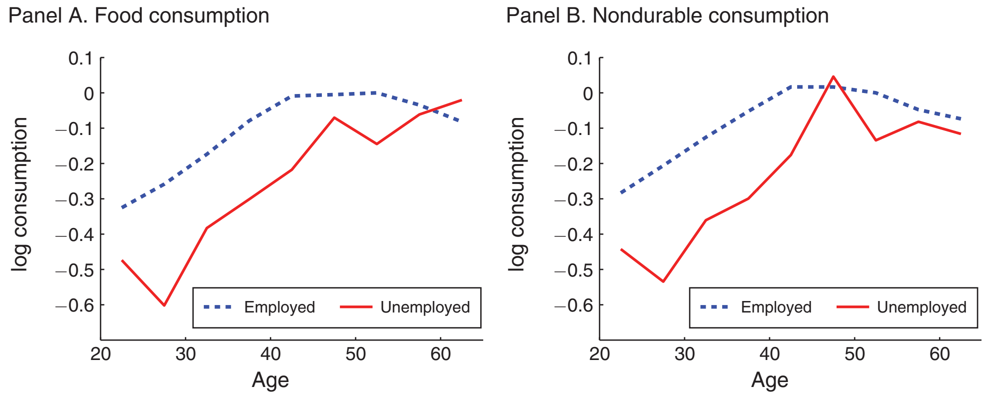

Figure 2. Food and Total Nondurable Consumption by Age, PSID

Notes: Life cycle profile of logged household per capita consumption. Equation (15) is estimated on PSID data. Left column is for food consumption, right column for total consumption expenditure on nondurables. The log consumption of employed workers 50–55 years of age is normalized to zero.

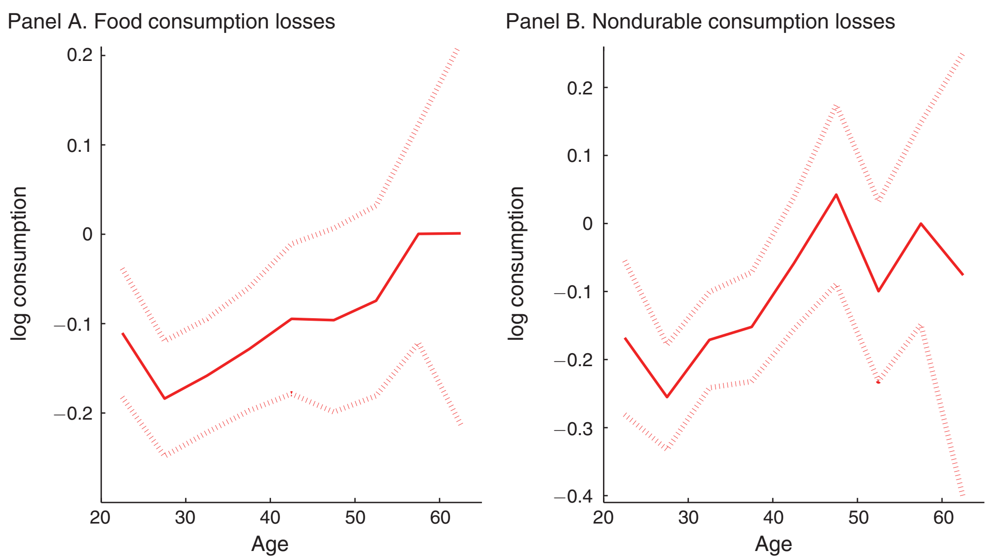

Figure 3. Consumption Losses upon Unemployment

Notes: Consumption losses upon unemployment by age, PSID data. Dotted lines are 90 percent confidence intervals.

Moral Hazard Effects by Age.—As is shown by Chetty (2008), UI benefits increase the duration of unemployment owing to a conventional moral hazard effect (benefits reduce the net income gains from finding a job) and a liquidity effect (benefits tend to equalize the marginal utility of consumption when employed and unemployed). So the evidence that the elasticity of unemployment to benefits increases with age does not necessarily indicate that the moral hazard problem is milder for younger than for older workers. Chetty (2008) argues that the severity of the moral hazard problem is measured by the job finding response to benefits of workers with high asset levels: wealthy workers have great ability to smooth consumption during

Table 2—Elasticity of Job Finding to Benefits by Assets, SIPP

	All	20–40 years	41–60 years
Panel A. Individual UI benefits			
$Q_1 \times \ln$ benefits	−0.64***	−0.55*	−1.32***
	(0.24)	(0.30)	(0.43)
$Q_2 \times \ln$ benefits	−0.76***	−0.93***	−0.26
	(0.22)	(0.24)	(0.55)
$Q_3 \times \ln$ benefits	−0.56***	−0.31	−1.11***
	(0.16)	(0.25)	(0.35)
$Q_4 \times \ln$ benefits	0.02	0.66	−0.79*
	(0.26)	(0.35)	(0.47)
$Q_1 = Q_4$ *p*-value	0.09	0.01	0.34
$Q_1 + Q_2 = Q_3 + Q_4$ *p*-value	0.06	0.00	0.67
$Q_1 = Q_2 = Q_3 = Q_4$ *p*-value	0.18	0.00	0.25
Number of spells	4,054	2,498	1,420
Panel B. Age-specific average benefits			
$Q_1 \times \ln$ benefits	0.12	−0.49	−1.40*
	(0.20)	(0.52)	(0.74)
$Q_2 \times \ln$ benefits	0.02	−0.49	−1.62*
	(0.20)	(0.47)	(0.96)
$Q_3 \times \ln$ benefits	0.09	0.39	−1.86***
	(0.20)	(0.40)	(0.49)
$Q_4 \times \ln$ benefits	0.14	0.95	−1.80***
	(0.21)	(0.71)	(0.50)
$Q_1 = Q_4$ *p*-value	0.95	0.03	0.51
$Q_1 + Q_2 = Q_3 + Q_4$ *p*-value	0.80	0.00	0.52
$Q_1 = Q_2 = Q_3 = Q_4$ *p*-value	0.95	0.00	0.85
Number of spells	4,054	2,498	1,420

Notes: Estimates of β_n in the Cox regression (16) using SIPP data. Q_j, $j = 1, 2, 3, 4$ are the quartiles of the wealth distribution in the entire sample. Other details are as in Table 1.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

unemployment, so liquidity effects are absent and benefits lengthen unemployment duration because of moral hazard alone. To pursue this logic, we use the SIPP data to estimate the following Cox regression for unemployment duration analogous to (13):

$$\ln h_{it} = \sum_n \beta_n q_{it}^n \ln b_{it} + \theta X_{itj} + \text{err}, \tag{16}$$

where q_{it}^n is an indicator variable equal to 1 if the worker's wealth is in quartile n (with higher n indicating greater wealth). Wealth quartiles are calculated for the entire sample. The results change little when wealth quartiles are age-specific. Controls are as in the estimation of equation (13) with the addition of wealth dummies and their interaction with unemployment duration. Table 2 reports the estimated β_n coefficients in the full sample and in the samples of "young" and "old" workers. There is evidence that benefits reduce the job finding rates of older workers with assets in the top two quartiles. The effects are somewhat stronger when measuring benefits with state averages. Standard significance tests also indicate that for older workers we cannot reject the null hypothesis that the effect of benefits is the same for the wealthiest as for the least wealthy. This is indirect evidence that benefits increase the unemployment duration of old workers mainly because of moral hazard, with liquidity effects being somewhat less important. For young wealthy workers UI benefits have no significant effect on unemployment. Overall the evidence is consistent with the thesis that the moral hazard inherent in unemployment insurance is more severe for older than for younger workers.

Liquidity Effects by Age.—Table 2 offers evidence that UI benefits increase the unemployment probability of young poor workers, especially when the measure used is individual benefits. This jibes with the idea that benefits provide valuable liquidity to young workers that enables them to better smooth consumption. The age pattern of consumption losses upon unemployment in Figure 3 is also consistent with the view that young workers value unemployment insurance highly because they have little possibility of smoothing consumption during unemployment, as they have little precautionary savings and limited liquidity. We can now provide more direct evidence consistent with this view. We borrow from Chetty (2008) the idea that severance payments provide liquidity to unemployed workers with no moral hazard costs.[11] By comparing the search behavior of unemployed workers who have and who have not received severance payments, we can identify the importance of liquidity effects. As in Chetty (2008), we then exploit the fact that the Mathematica data contain information on whether displaced workers received severance payments at the time of the job loss, so we can estimate the following Cox proportional hazards regression analogous to (13):

$$\ln h_{it} = \beta Sev_i + \theta X_{it} + \text{err}, \tag{17}$$

where Sev_i is an indicator equal to 1 if the displaced worker has received a severance payment. The additional controls X_{it} include worker's age, four education dummies, splines in past tenure and past wages, the log of unemployment benefits, fixed effects for state, occupation, and industry, unemployment duration dummies, and the interaction of the severance payment dummy with unemployment duration. Again the model is estimated for the full sample and separately for the two age groups. The resulting estimate for β is reported in Table 3. The first column reproduces the full sample results in Chetty (2008), which indicate that unemployed workers with severance pay have job finding rates about a quarter lower. When we split the sample by age, the reduction in finding rates for younger workers is around a third, while for older workers it is close to zero and not statistically significant at conventional levels. This is again consistent with the idea that young workers have trouble smoothing consumption during unemployment, due to lack of liquidity.

[11] Here we focus on the effects on search effort, but of course severance payments can affect workers' incentives to accumulate precautionary savings and, in this sense, they also induce a moral hazard problem.

Table 3—Elasticity of Job Finding to Severance Pay, Mathematica Data

	All	20–40 years	41–60 years
Severance pay	−0.23***	−0.35***	−0.08
	(0.07)	(0.09)	(0.11)
Number of spells	2,428	1,514	790

Notes: Estimates of β in (17) using Mathematica data. Further details are as in Table 1.
***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

III. The Laboratory Economy

We now consider a life cycle model with ongoing unemployment risk which we use as a laboratory economy to examine three questions: we study the magnitude of the welfare gains of age-dependent unemployment insurance, compare them with those under the unconstrained optimal scheme for unemployment insurance over the life cycle, and then analyze how accurately the simple formulas discussed in Section I identify welfare gains of age-dependent policies. We first characterize the economy. Then we turn to calibration and discuss key properties of the calibrated economy. The study of the first best policy is in Section IV, the analysis of age-dependent policies in Section V.

A. *Assumptions*

There is a mass 1 of workers who live for $\bar{n}_w + \bar{n}_r$ periods. They are active in the labor market in the first $\bar{n}_w$ periods and retired in the last $\bar{n}_r$. Allowing for retirement is necessary in order to get an empirically plausible age profile of assets. Workers have discount factor β and receive utility from consumption $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$, with $\sigma > 0$. They are born with no job, no human capital, $e = 0$, no assets, $a = 0$, and can save in a riskless bond that pays a constant interest rate r satisfying $\beta = \frac{1}{1+r}$. Workers have limited ability to borrow, and their assets cannot be less than the borrowing limit l. In each period of employment, workers accumulate one unit of human capital and receive wages $w(e)$ that satisfy $w' \geq 0$ and $w'' \leq 0$. This formalizes the notion that there are positive but decreasing returns to labor market experience. Employed workers of age n lose their job with probability δ_n, and when unemployed they choose how intensively to look for a new job. We allow the separation rate to be age-dependent in order to match the age profile of unemployment in the data. Search intensity reduces the probability of unemployment and the amount of leisure.[12] We assume that a worker who receives job offers with probability $1 - \mu$

[12] We model the moral hazard of UI by relying on search effort decisions. There is evidence from time use surveys that job search intensity is inversely related to the generosity of unemployment benefits (see Krueger and Mueller 2010). But the moral hazard induced by UI generally leads both to a decrease in search effort and to an increase in reservation wages. Like Shimer and Werning (2007, 2008), we believe that the main implications of the paper are little affected by whether the moral hazard is characterized in terms of search effort or of reservation wages.

enjoys utility from leisure $\psi(\mu)$, with $\psi'(\mu) > 0$ and $\psi''(\mu) < 0$. Here μ denotes the within-period unemployment probability of a worker searching for a job. We adopt the same timing convention as Lentz and Tranaes (2005) and Chetty (2008), whereby successful search in a period leads to a job in the same period. If a worker of age n is jobless at the end of the period, he receives unemployment benefits which are a fraction ρ_n of his last wage in the job. At the end of each period of unemployment there is a probability γ of the worker's human capital being depreciated to an amount $\kappa(n, e) \leq e$, which is dependent on the worker's age n and human capital in his previous job e. If, at some point during the unemployment spell, worker's human capital has depreciated, the worker is reemployed with human capital $\kappa(n, e)$. This induces wage losses upon displacement, which increase substantially with age as is documented in Davis and von Wachter (2011) and Johnson and Mommaerts (2011). Unemployment and the associated human capital losses are the only source of risk. During the last $\bar{n}_r$ periods of their life, workers receive retirement pensions π which, as in Conesa, Kitao, and Krueger (2009), are independent of earnings history. During employment, workers of age n pay income taxes that are a fraction τ_n of their labor income. Taxes finance the unemployment insurance program and retirement pensions. Like Hopenhayn and Nicolini (1997) and Shimer and Werning (2007, 2008), we assume that workers and government face the same interest rate and that government policies are actuarially fair. This implies that the expected present discounted value of all transfers received by the worker is equal to the present value of the tax revenue he expects to pay over his working life.[13]

B. *The Worker's Maximization Problem*

Let $c^e(n, e, a, a') = (1 - \tau_n)w(e) + (1 + r)a - a'$ denote the consumption of an employed worker of age $n \leq \bar{n}_w$ with human capital e and assets a, who chooses asset level a' for the next period. Since a' should be greater than the borrowing limit l, the value of being employed for this worker satisfies:

$$(18) \quad V(n, e, a) = \max_{a' \geq l} uc\_\hat{}e(n, e, a, a') + \beta\big[(1 - \delta_n)V(n + 1, e + 1, a') + \delta_n J(n + 1, e + 1, a')\big],$$

where the last term incorporates the fact that with probability δ_n a worker of age n has to search for a new job, which has value

$$(19) \qquad J(n, e, a) = \max_{\mu \in [0, 1]} \psi(\mu) + \mu U(n, e, a) + (1 - \mu)V(n, e, a).$$

This uses the timing convention that search leads to a job in the period with probability $1 - \mu$; otherwise the worker remains unemployed, which has value

[13]This government budget constraint can also be justified assuming that in every period new cohorts of workers enter the labor market, that the size of these cohorts increases at rate r over time, and that the government budget is balanced, so that the total tax revenue net of transfers across cohorts is zero in each period.

$$(20)\qquad U(n, e, a) = \max_{a' \geq l} u(c^u(n, e, a, a')) + \beta(1-\gamma) J(n+1, e, a') + \beta\gamma J^*(n+1, e, a'),$$

where $c^u(n, e\, a, a') = \rho_n w(e) + (1+r)a - a'$ denotes current period consumption when unemployed at age n. With probability γ the worker undergoes a loss of human capital and the function J^* denotes the value of search after this loss. It satisfies the following Bellman equation:

$$(21)\quad J^*(n, e, a) = \max_{\mu \in [0,1]} \psi(\mu) + \mu U^*(n, e, a) + (1-\mu) V(n, \kappa(n, e), a),$$

which incorporates the assumption that after the loss in human capital the worker is reemployed with human capital $\kappa(n, e) \leq e$, where e is his human capital in the previous job.[14] In the expression above, U^* denotes the value of being unemployed after a loss in human capital, which satisfies

$$(22)\qquad U^*(n, e, a) = \max_{a' \geq l} u(c^*(n, e, a, a')) + \beta J^*(n+1, e, a'),$$

where $c^*(n, e, a, a') = \rho_n w(e) + (1+r)\, a - a'$ denotes per period consumption and e refers to worker's human capital at the time of displacement. In writing (18), (20), and (22) we adopted the convention that

$$V(\bar{n}_w + 1, e, a) = U(\bar{n}_w + 1, e, a) = U^*(\bar{n}_w + 1, e, a) = \frac{1-\beta^{\bar{n}_r}}{1-\beta} u(c^r(a)),$$

where the last term is the value of retiring at $n = \bar{n}_w + 1$ with assets a, which is equal to the discounted value of consuming in every remaining period $c^r(a) = \pi + \frac{ra}{1-\beta^{\bar{n}_r}}$.

Government policies are actuarially fair in that the expected present value of the income taxes collected over the working life of a worker is equal to the present value of the UI benefits and retirement pensions the worker expects to obtain over his entire life. This implies the condition

$$(23)\qquad \sum_{n=1}^{\bar{n}_w} \beta^n \int_{R^+} \rho_n w(e)\, \chi^u(n, de) + \sum_{n=\bar{n}_w+1}^{\bar{n}_r} \beta^n \pi \chi^r(n) = \sum_{n=1}^{\bar{n}_w} \beta^n \int_{R^+} \tau_n w(e)\, \chi^e(n, de),$$

where the integrals are conventionally defined Lebesgue integrals (see Stokey, Lucas, and Prescott 1989). Here $\chi^e(n, e)$ denotes the measure of employed workers of age n and experience e, $\chi^u(n, e)$ denotes the mass of workers of age n

[14] Notice that the human capital loss $e - \kappa(n, e)$ depends on age at reemployment and not at displacement. This is a simplifying assumption allowing to economize on the number of state variables.

who collect benefits and who were displaced with human capital e, and $\chi^r(n) = \int \chi^e(\bar{n}_w, de) + \int \chi^u(\bar{n}_w, de) = \chi^r$ denotes the measure of retired workers of age n, which is constant and independent of age.[15] Of course, since the mass of workers in the economy is 1, these three measures taken together form a probability measure:

$$\sum_{n=1}^{\bar{n}_w} \left[\int_{R^+} \chi^u(n, de) + \int_{R^+} \chi^e(n, de) \right] + \bar{n}_r \chi^r = 1.$$

C. *Calibration*

The model is calibrated at quarterly frequency to data for male workers in the United States. The parameters are determined jointly to match the calibration targets in Table 4. This process can be seen as estimation by indirect inference (see for example Gourieroux, Monfort, and Renault 1993). The resulting parameter values are in Table 5. The online Appendix contains details on the construction of the calibration targets in the data and in the model. We now discuss how the parameters are identified starting from moment conditions.

Technology.—We assume that workers are born at 20 years of age, are active for 45 years, $\bar{n}_w = 180$, and live 20 years after retirement, $\bar{n}_r = 80$. The wage function $w(e)$ is restricted to be nondecreasing and is characterized by a cubic spline at the ten skill knots reported in Table 5. The values at the knots are set to match the average wage levels for the eight age groups in Table 4, plus the normalization condition that $w(0) = 1$ and that wages are constant for workers in their sixties. The age profile of wages in the data is obtained from the CPS for 1990–2010, using a sample of working-age men: wages increase on average by around 90 percent over the life cycle.

The separation rate function δ_n is characterized by a five-value cubic Hermite spline with age knots at $n = 10, 40, 80, 120, 160$. To make sure that δ_n always lies in the interval $[0, 1]$ we impose the boundary constraints that for $n \leq 10$, $\delta_n = \delta_{10}$ while for $n \geq 160$, $\delta_n = \delta_{160}$. The five values of the spline are implicitly calibrated to match the average unemployment rate of the five age groups in Table 4. Henceforth in the construction of age groups, we drop workers aged 20 and 65 because in the model the former are mostly unemployed and the latter about to retire. The resulting δ_n function is plotted in the online Appendix. The mean separation rate is 0.035 which is roughly consistent with the data on average job tenure and with the mean separation rate from JOLTS over the period 2005–2007.

To calibrate the borrowing limit l, we take the distribution of net worth of workers under 35, who are the most likely to be financially constrained in the model. In practice l is set to be equal to minus 61 percent of the mean quarterly total income (i.e., from both labor and capital) in the economy. In the 2007 Survey of Consumer Finances (SCF) this corresponds to the fifth percentile of the distribution of the

[15] For expositional simplicity we do not make these measures explicitly dependent on some policy-relevant state variables, such as assets or depreciation of human capital.

Table 4—Calibration Targets and Model Fit

Moment condition	Data	Model	Source
Mean wages relative to 20 years old			
21–24 years	1.12	1.14	CPS
25–29 years	1.37	1.39	CPS
30–34 years	1.60	1.62	CPS
35–39 years	1.76	1.76	CPS
40–44 years	1.85	1.84	CPS
45–49 years	1.93	1.89	CPS
50–54 years	1.93	1.92	CPS
55–59 years	1.90	1.93	CPS
Unemployment rate			
21–24 years	0.104	0.104	CPS
25–34 years	0.058	0.058	CPS
35–44 years	0.046	0.046	CPS
45–54 years	0.042	0.042	CPS
55–64 years	0.041	0.041	CPS
Proportion of displaced workers with benefits who experience a wage loss	0.57	0.57	SIPP
Median wage loss upon re-employment			
21–30 years	0.00	0.00	SIPP
31–50 years	−0.07	−0.07	SIPP
51–64 years	−0.10	−0.10	SIPP
Unemployment duration (in weeks			
21–30 years	17.1	17.0	CPS
35–45 years	20.2	20.6	CPS
50–60 years	25.8	25.7	CPS
Elasticity of unemployment to benefits			
21–30 years	0.24	0.24	SIPP
35–45 years	0.60	0.60	SIPP
50–60 years	0.80	0.85	SIPP
UI benefit replacement rate	0.50	0.50	SIPP
Retirement pensions over mean wages	0.39	0.39	OECD
Minimum assets for workers of age $\leq$ 35 over mean quarterly total income:	−0.61	−0.60	SCF

Notes: Unless otherwise specified all statistics are averages for either the entire working-age population or the corresponding age group. The age profiles of wages, unemployment rates, and unemployment duration are from CPS data on a sample of working-age males for 1990–2010. The minimum asset level in the data comes from SCF in 2007 and it corresponds to the fifth percentile of the net worth of workers younger than 35 over the mean quarterly total income in the working-age population. Wage loss statistics are from SIPP for 1996–2007, for working-age white males displaced from a full time payroll job and who have cashed UI benefits at some point during their unemployment spell. Displaced workers are identified as in Johnson and Mommaerts (2011). Retirement pensions statistic is from OECD (2007). UI benefits replacement rate is as in Chetty (2008). See the online Appendix for further details on calibration targets in data and model.

net worth of these workers over average quarterly income (from labor and other sources) in the Survey.

Wage Losses Upon Reemployment.—To calibrate the human capital loss function $\kappa(n, e)$ and the wage loss probability parameter γ, we use information on wage losses upon reemployment from SIPP over the period 1996–2007. We take a sample of working-age white males displaced from full-time payroll jobs and who have received UI benefits at least at some point during their unemployment spell.[16] Wage

[16] We do not use earlier panels in SIPP because they lack detailed information on why respondents leave their jobs, which we use to separately identify quits from dismissals. To focus on displacement for exogenous reasons, we classify unemployed workers as displaced if they report separating from their employer because of layoff, slack work, employer bankruptcy, or because the employer sold the business, which follows Johnson and Mommaerts (2011).

Table 5—Parameter Values

Parameter	Definition	Value
$\bar{n}_w$	Working periods	180
$\bar{n}_r$	Periods in retirement	80
β	Discount factor	0.99
ρ	UI benefit replacement rate	0.50
π	Retirement pension level	0.66
l	Borrowing constraint	-1.12
σ	Risk aversion	2.0
τ	Tax rate	0.0707
$w(e)$	Wages at $e = 20j, j = 0, 1, \ldots, 9$	$\{1.0, 1.29, 1.56, 1.73, 1.84, 1.92, 1.95, 1.96, 1.97, 1.97\}$
δ_n	Separation rate (in percentage) at $n = \{10, 40, 80, 120, 160\}$	$\{8.5, 3.49, 3.07, 2.44, 2.13\}$
γ	Wage loss probability parameter	0.41
$\bar{\kappa}_n$	Wage losses at $n = \{1, 40, 80, 160, 180\}$	$\{1, 1, 0.93, 0.90, 0.899\}$
$\psi(\mu)$	Search effort function at $\mu = \{0, 0.25, 0.47, 0.75, 1.0\}$	$-\{7.25, 1.78, 0.49, 0.021, -0.203\}$

Note: The functions $w(e)$, δ_n, $\bar{\kappa}_n$, and $\psi(\mu)$ are cubic splines through values in table.

losses are measured as the log difference between the wage in the last job in the month before displacement and the wage in the new job in the first month after reemployment. The median wage loss in our data is zero for workers under 30 and increases to around 10 percent for workers above 50.

To characterize the human capital loss function $\kappa(n, e)$, we assume that if the worker's human capital has depreciated during unemployment, the worker is reemployed with a wage that is a fraction $\bar{\kappa}_n$ of his previous wage $w(e)$. This implies that $\kappa(n, e) = w^{-1}(\bar{\kappa}_n w(e))$, where w^{-1} is the inverse function of $w(e)$, which is well defined since $w(e)$ is nondecreasing in e.[17] The wage loss function $\bar{\kappa}_n$ is characterized by a five-value cubic Hermite spline with knots at the age levels $n = 1, 40, 80, 160, 180$. The five values at the age knots are chosen to match the median wage losses for the three age groups in Table 4 plus the boundary constraints that for $n \leq 40$, $\bar{\kappa}_n = \bar{\kappa}_{40}$ while for $n \geq 160$, $\bar{\kappa}_n = \bar{\kappa}_{160}$ which guarantees that $\bar{\kappa}_n$ always lie in the $[0, 1]$ interval. The resulting $\bar{\kappa}_n$ function is plotted as a dotted line in panel A of Figure 14. The parameter γ, the probability of a wage loss, is chosen so that a worker who collects UI benefits at some point during his job search spell has a 57 percent probability of experiencing a wage loss upon reemployment, which is in line with evidence from our SIPP sample.[18]

Search Effort.—To characterize the within-period unemployment probability function $\psi(\mu)$ we start by observing that the second derivative of the function ψ is crucial in determining the value of the elasticity of unemployment to benefits. Accordingly we model its profile explicitly and constrain it to always be non-positive, $\psi'' \leq 0$ (see

[17] For the range of values of e for which the $w(e)$ function is constant, the inverse function w^{-1} is defined as selecting the minimum value of e over the corresponding range.

[18] The values of $\bar{\kappa}_n$ at the age knots are similar to the median wage losses of the corresponding age groups in Table 4. This is because the wage loss of a reemployed worker of a given age n is a binary random variable, with a mass probability at zero which is less than half. So the median wage loss coincides with the positive wage loss, $1 - \bar{\kappa}_n$, experienced by workers whose human capital has depreciated during unemployment.

the online Appendix for further details). In practice the ψ function is approximated by a cubic spline evaluated at the five age knots reported in Table 5, with the middle knot corresponding to the endogenously determined value of μ at which the second derivative of ψ peaks (i.e., reaches its minimum absolute value). The six moment conditions needed to pin the function down are the average unemployment duration and the elasticity of unemployment to benefits for the three age groups reported in Table 4. In the model, the elasticity for workers of age n, η_n, is calculated considering changes in replacement rates at p consecutive quarters starting from age n. To be sure, let $\boldsymbol{\rho} = \{\rho_1, \ldots, \rho_{\bar{n}_w}\}$ denote the vector containing the age profile of UI replacement rates in the baseline economy. For every n, the unemployment elasticity, η_n, is calculated considering two economies, one with lower and one with higher replacement rates at age n than in the baseline economy.[19] The resulting $\psi(\mu)$ function is depicted in panel A of Figure 4.

Remaining Preferences.—We set β to 0.99, to match an annual interest rate of approximately 4 percent. The CRRA parameter σ is chosen to be equal to 2, as in Conesa, Kitao, and Krueger (2009) when using a specification with separable utility between consumption and leisure.

Policy Parameters.—The income replacement rates of benefits ρ_n are assumed to be equal to a constant value ρ, which following Chetty (2008) is calibrated to 0.5.[20] The retirement pensions π are set equal to 0.662, which yields a ratio of retirement pensions over mean quarterly labor income of 0.39 in line with aggregate statistics from OECD (2007). The tax rate $\tau = 7.07$ percent keeps the government budget constraint in (23) satisfied.

D. *Further Properties of the Calibrated Economy*

Panels B–H of Figure 4 characterize the age profile of key variables in the model economy and in the data. In all panels, the solid line corresponds to the model, the dashed and dotted lines to the data. To facilitate comparison, we form the age groups 21–25, 26–35, 36–45, 46–55, and 56–64. As before we exclude workers aged 20 and 65 because in the model they are mostly unemployed or on the verge of retirement. We then calculate averages for wages (panel B), unemployment rates

[19] The lower and the higher replacement rates at age n are characterized by the vector $\boldsymbol{\rho}_n^i = \{\rho_1, \ldots, \rho_{n-1}, \vartheta_n^i, \vartheta_{n+1}^i, \ldots, \vartheta_{n+p-1}^i, \rho_{n+p}, \ldots, \rho_{\bar{n}_w}\}$, $i = l, h$ where $\vartheta_{n+j}^l = \rho_{n+j} - \frac{\epsilon}{2}$ and $\vartheta_{n+j}^h = \rho_{n+j} + \frac{\epsilon}{2}$, $\forall j = 0, 1, p-1$. In the paper we work with $\epsilon = 0.02$ and $p = 4$, which corresponds to a change in benefits for an age group of one year. We checked that results are not greatly affected by reducing ϵ or p. We consider changes in benefits for p consecutive quarters both to increase sample size and to reduce the likelihood that the policy change affects workers' search effort decisions through effects on unemployment duration dependence in benefits, which is an issue somewhat unrelated to age-dependent policies. To avoid this problem we could have indexed the level of replacement rates not to current age but to the age at which the worker is displaced. But this alternative specification would require an additional state variable, which would involve additional computational costs.

[20] In practice, replacement rates in the United States are not completely independent of age since wages are typically replaced by a constant percent but with a cap. This implies that effective replacement rates are lower for groups with higher wages (such as older workers). Matching this feature of the US system would require making UI replacement rates a function of both n and e. In any case age differences in actual replacement rates are small (about 10 percent) compared with those that arise under the optimal age-dependent policies studied in Section V.

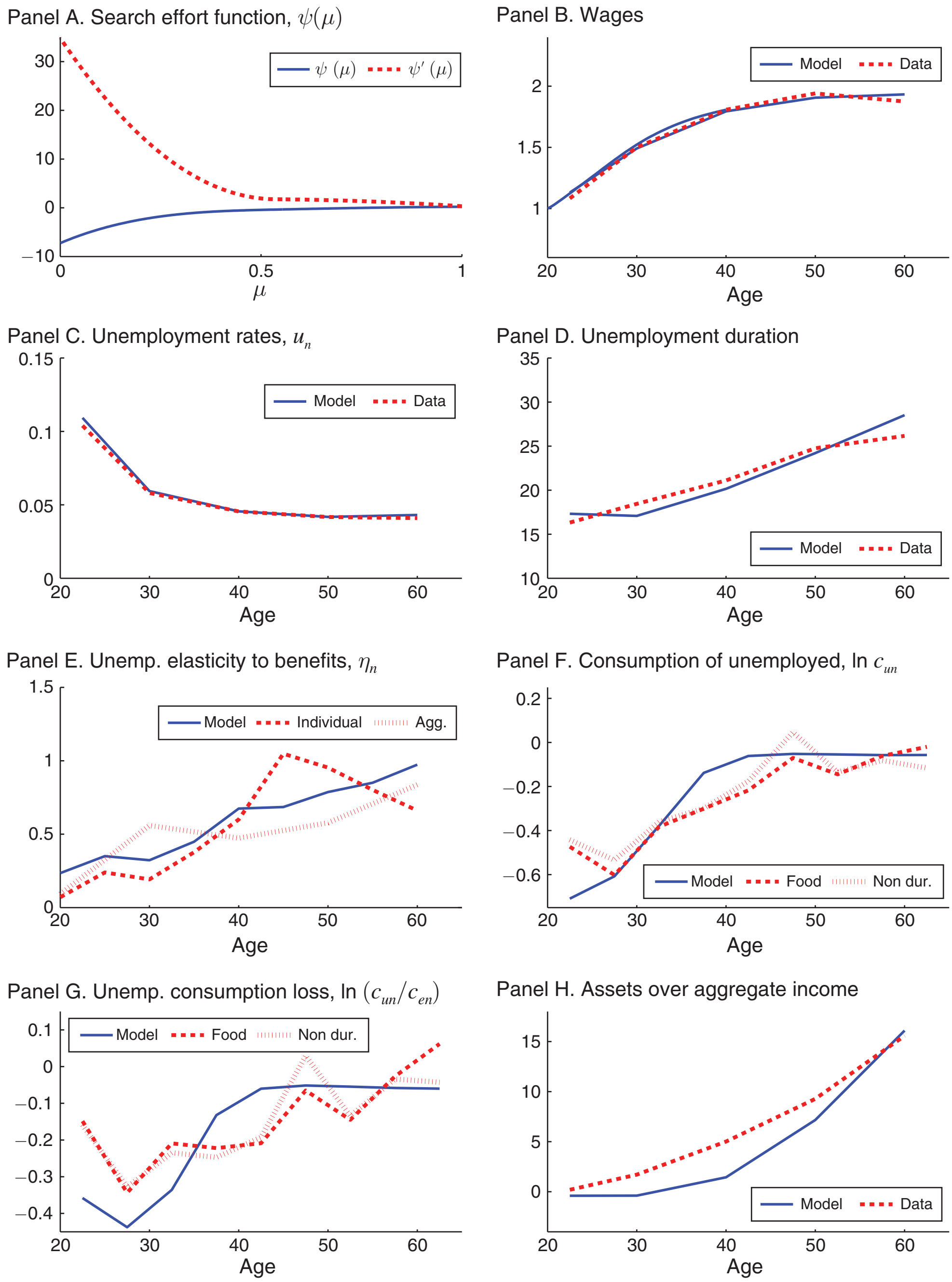

Figure 4. Properties of Laboratory Economy

Notes: With the exception of panel A, solid lines correspond to model, dashed and dotted lines to data. The dashed lines in panels B, C, and D are from CPS. Dashed and dotted lines correspond: in panel C to panels A and B of Figure 1, respectively; in panel D to the solid lines in panels A and B of Figure 2, respectively; in panel E to differences between solid line and dashed line in panels A and B of Figure 2, respectively. Dashed line in panel E is the ratio between households' net worth in the age group and households' average quarterly total income in SCF. In panel F the log consumption of employed workers aged 50–55 is normalized to zero, which is as in Figure 2.

(panel C), unemployment duration (panel E), and net assets over average quarterly total income in the economy (panel H). Data averages for the elasticity of unemployment to benefits (panel E), consumption when unemployed (panel F), and consumption differences between employed and unemployed (panel G), correspond to the analogous profiles in Figures 1 and 2.

The model matches well the profile of wages, unemployment rates, and unemployment duration, panels B–D. All these were explicitly used as calibration targets. The model just tends to overpredict the unemployment duration of workers in their early sixties. This is because the ψ function in panel A is strictly positive at a within-period unemployment probability equal to 1, so unemployed workers close to retirement always tend to shirk. The unemployment risk faced by workers over their working life is sizeable: around 24 percent of workers have to search for a new job in at least one out of ten periods of their working life. The model also matches the age profile of the elasticity of unemployment to benefits in the data reasonably well: the model counterpart tends to lie between the estimated value based on the unemployment duration analysis in SIPP and the value obtained using aggregate state level data from CPS.

As regards consumption, the model approximates moderately well the age profile of consumption when unemployed in the data (panel F), although the model tends to reach a plateau a couple of years earlier. Also the model's profile of consumption losses upon unemployment—as measured by the log difference between the average consumption of the employed and the unemployed—is reasonably in line with the data. Finally panel H shows the age profile of net assets. Asset levels are higher in the data, but overall the model reproduces the average increase of assets over the life cycle quite well. This is remarkable, considering that the calibration used no information on consumption and only limited information on assets.

E. *Elasticities and Redistribution Formulas*

Panel A of Figure 5 plots the age profile of the simple redistribution formula ϱ_n in (7) as a solid line and that of the extended redistribution formula $\tilde{\varrho}_n$ in (10) as a dashed line. The simple redistribution formula is calculated as $\varrho_n = \frac{u'(c_{un})}{1+\eta_n}$ where c_{un} denotes the expected consumption of unemployed workers of age n. To calculate $\tilde{\varrho}_n$ at each n we again exploit changes in income replacement rates at p consecutive quarters starting from age n. We use these policy changes to calculate the cross elasticity of unemployment

$$\tilde{\eta}_n = \sum_{i=1}^{\bar{n}_w} \frac{\partial \mu_i}{\partial \rho_n} \cdot \frac{\beta^i \rho_i}{\beta^n \mu_n}, \tag{24}$$

which is analogous to (11). Here $\mu_n \equiv \int_{R^+} \chi^u(n, de)$ denotes the mass of workers of age n who collect benefits. We also define the present value of total tax revenue as equal to

$$T(\boldsymbol{\rho}) = \sum_{n=1}^{\bar{n}_w} \beta^n \int_{R^+} \tau_n w(e)\, \chi^e(n, de),$$

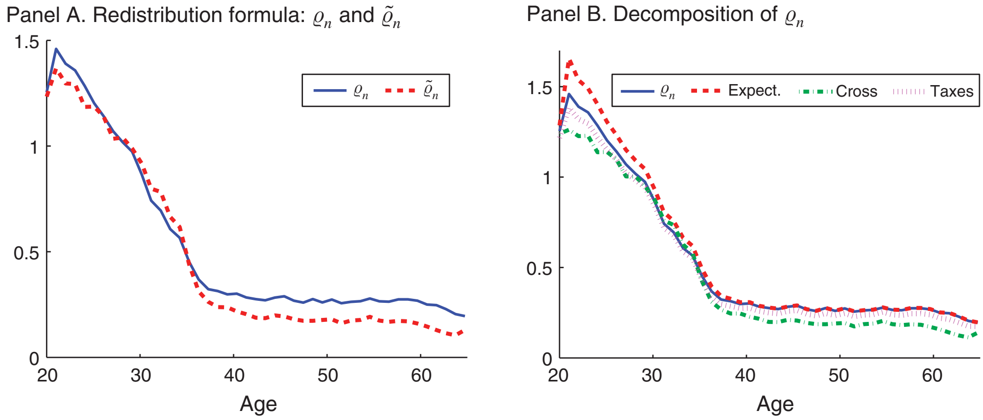

Figure 5. Comparison between Simple, ϱ_n, and Extended, $\tilde{\varrho}_n$, Redistribution Formula

and calculate the derivative of T with respect to the age-dependent change in benefits. We then use (10) to calculate $\tilde{\varrho}_n$ (see the online Appendix for further details).

The age profiles of ϱ_n and $\tilde{\varrho}_n$ in Figure 5 are remarkably similar, which indicates similar welfare gains from redistributing unemployment insurance over the life cycle. Both ratios are generally decreasing with age and have values close to 1.5 for workers in their twenties and close to 0.25 for those in their forties and early fifties. On the whole, this suggests that one unit of government money would yield six times more welfare gains when assigned to young unemployed workers than to middle-aged unemployed workers. As is implied by the discussion in Section IC, there are three reasons why in the baseline calibration ϱ_n differs from $\tilde{\varrho}_n$: (i) ϱ_n focuses on the marginal utility of expected consumption, not the expected marginal utility of consumption; (ii) ϱ_n misses the effects of age-specific changes in benefits on the unemployment level of age groups other than those directly targeted by the change in benefits; and (iii) ϱ_n neglects the effects of UI on tax revenue.[21] Since the marginal utility of consumption is convex, effect (i) tends to make ϱ_n less than $\tilde{\varrho}_n$ while effects (ii)–(iii) tend to make it greater. To analyze the contribution of each factor separately, in panel B of Figure 5 we compute ϱ_n adding one source of difference at a time: the solid line corresponds to the profile of ϱ_n in panel A; the dashed line is analogous, but with ϱ_n calculated using the expected marginal utility of consumption rather than the marginal utility of expected consumption; the dash-dotted line corresponds to calculating ϱ_n using the extended elasticity of unemployment $\tilde{\eta}_n$ in (24) rather than the simple elasticity η_n; and finally the dotted line is obtained by calculating ϱ_n after adding to the denominator the effect of taxes, as measured by $\frac{\partial T}{\partial b_n} \cdot \frac{1}{\mu_n}$. For workers under 40, consumption is low, which makes the marginal utility of consumption highly convex. For these workers the positive effect on $\tilde{\varrho}_n$ of taking expectations almost exactly cancels out the negative effects on $\tilde{\varrho}_n$ due to unemployment cross-derivatives and taxes. So the simple and extended formulas, $\tilde{\varrho}_n$ and ϱ_n, almost overlap in panel A. But for workers above 40, consumption is high enough to make the marginal utility of consumption almost linear. For these

[21] In the baseline calibration $\rho_n > 0, \forall n$, so the feasibility constraint is never binding and ω_n in (10) is always equal to zero.

workers, the effects of cross-derivatives and taxes necessarily dominate, so $\tilde{\varrho}_n$ falls below ϱ_n.

IV. Optimal Life Cycle Unemployment Insurance

At birth, workers have to look for a job, they have no experience and no assets so their welfare is given by $W_s \equiv J(1, 0, 0)$. Before analyzing age-dependent policies, let us study the first best problem faced by an agency that observes workers' assets and search effort and maximizes initial worker's utility W_s by choosing benefits $\boldsymbol{\rho}$, taxes $\boldsymbol{\tau}$, and pensions π as a function of the worker's entire history. The government budget is balanced, so an expression analogous to (23) holds. Since assets are observable, we can posit that the agency directly controls workers' consumption. Search effort too is observable, so there is no moral hazard problem and the agency can achieve perfect consumption smoothing by guaranteeing the worker a constant consumption level c through his entire life. As a result consumption losses upon unemployment are zero. Let $\Upsilon(n, e, c)$ denote the total net cost of providing a constant consumption flow c to a worker of age $n \leq \bar{n}_w$ with human capital e who has just started looking for a job. This cost is equal to the difference between the present value of consumption expenditure and the expected present value of the income $Y(n, e, c)$ generated by the worker:

$$\Upsilon(n, e, c) = \frac{1 - \beta^{\bar{n}_w + \bar{n}_r + 1 - n}}{1 - \beta} c - Y(n, e, c). \tag{25}$$

In each period the within-period unemployment probabilities are set to maximize the utility value of Y net of the disutility cost of job search (see the online Appendix for details). The function $\Upsilon(n, e, c)$ in (25) is decreasing in c, because higher consumption implies greater expenditure and lower future income Y, as higher c reduces search effort due to a conventional income effect. The optimal value of c, denoted by c^*, is set to make $\Upsilon(n, e, c)$ at worker's birth equal to zero

$$\Upsilon(1, 0, c^*) = 0.$$

The solid line in panel A of Figure 6 characterizes the age profile of job finding rates under the optimal policy. The finding rate for workers of age n, f_n, is simply the ratio between the number of workers of age n who find a job in a period and the number of workers of the same age searching for a job.[22] Finding rates are slightly increasing with age until two years before retirement, when they fall rapidly to zero. Since the ψ-function is concave, the agency would like to smooth search effort over time, but the opportunity cost of having an old, typically high-skilled worker unemployed is high in view of his high productivity. So finding rates slightly increase with age.

[22] Let $\chi^s(n, e) = \chi^u(n-1, e) + \delta_{n-1}\chi^e(n-1, e-1)$ denote the measure of workers of age n searching for a job who had human capital e at the time of displacement. Notice that $\chi^s(n, e)$ is the sum of two terms: the first is the mass of workers of age $n-1$ who collect benefits in a period and who will search for a job in the next period when they are one period older; the second is the fraction δ_{n-1} of employed workers of age $n-1$ and human capital $e-1$ losing their job. With this notation we have that the number of workers of age n searching for a job is $\sigma_n = \int_{R^+} \chi^s(n, de)$, which allows us to express the job finding rate as equal to $f_n = \frac{\sigma_n - \mu_n}{\sigma_n}$.

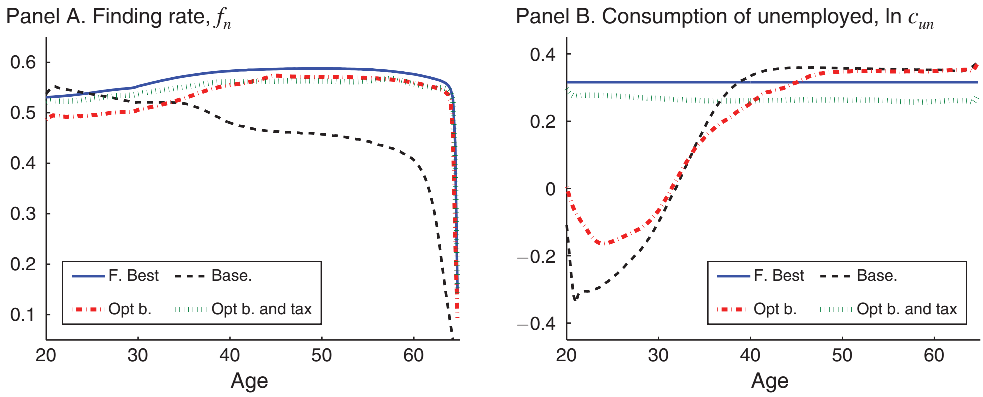

Figure 6. First Best Policy and Optimal Age-Dependent Policies

Note: Solid lines correspond to the first best economy; dotted lines to the baseline economy; dashed lines to the economy with age-dependent replacement rates; dash dotted lines to the economy with age-dependent replacement rates and tax rates.

Just before retirement, search is unprofitable since little time is left to capitalize on the investment, so finding rates drop to zero.

To analyze the profile of income replacement rates under the optimal policy, we follow the optimal unemployment insurance literature (Hopenhayn and Nicolini 1997) and define $\frac{c^*}{w(e)}$ as the optimal replacement rate of a worker whose human capital at the time of displacement was equal to e. Similarly we can consider an employed worker with human capital e and define the tax rate implied by the optimal policy as equal to $1 - \frac{c^*}{w(e)}$: Figure 7 characterizes the age profile of the average replacement rate (solid line) and average tax rates (dashed line). Since wages $w(e)$ tend to increase with age and the agency guarantees perfect consumption insurance to workers, we have that replacement rates are on average decreasing with age while tax rates are increasing. Table 6 compares welfare under the optimal policy and in the baseline economy.[23] Gains relative to the status quo are sizable, roughly equivalent to a 3.4 percent increase in per period consumption.

V. Age-Dependent Policies

In the previous section transfers could be conditional on workers' entire labor market history as well as on their assets, age, experience, and employment status, thus guaranteeing perfect consumption insurance. We now study age-dependent policies, where the government can make income replacement rates, ρ_n, and labor income tax rates, τ_n, conditional on age n alone. Pension levels are left unchanged, while tax levels are always adjusted to satisfy the government budget constraint (23).

[23] In the baseline economy the average income replacement rate of UI benefits might not be optimal. To better isolate the effects of age-dependent policies, welfare gains are always measured relative to the economy with an optimal replacement rate. In practice, like many others (see Davidson and Woodbury 1997; Shimer and Werning 2007; Pavoni 2007; and Chetty 2008), we find that the optimal replacement rate—0.51—is close to the actual US level. Differences with the baseline economy of Section III are therefore minimal.

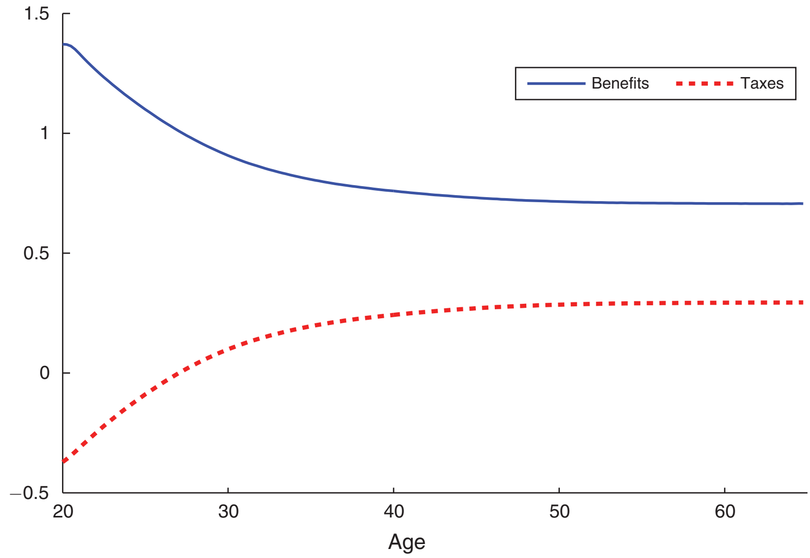

Figure 7. Income Replacement Rates and Tax Rates in First Best Policy

Note: Age profiles of UI income replacement rate, $\frac{c^*}{w(e)}$, (solid line) and income tax rate, $1 - \frac{c^*}{w(e)}$, (dashed line) as implied by the first best policy.

Table 6—Welfare Comparisons

Economy	Welfare gains (percent)	Consumer equivalent (percent)
Baseline economy with optimal replacement rate (51 percent)	0	0
Age-dependent replacement rate	23.3	0.8
Age-dependent tax rate	68.3	2.4
Age-dependent replacement rate and tax rate	92.4	3.2
First best economy	100.0	3.4

A. *The Problem*

An optimal age-dependent income replacement rate policy is a choice for the vector of replacement rates $\boldsymbol{\rho}$ that maximizes $W_s \equiv J(1, 0, 0)$ subject to the budget constraint in (23), workers' optimal choices as implied by (18)–(21), and a feasibility constraint that requires replacement rates to be nonnegative $\boldsymbol{\rho} \geq 0$.[24] We model ρ_n as the maximum between zero and a cubic spline at the ten age knots corresponding to $n = 1, 20, 40, 60, 80, 100, 120, 140, 160, 180$. We search for the value at the knots that maximize workers utility at birth W_s and check that the results are not altered greatly by increasing the number of knots. We then allow income tax rates also to vary with age. This problem is analogous to the foregoing: the government chooses $\boldsymbol{\rho} \geq 0$ and the vector of tax rates $\boldsymbol{\tau}$ to maximize W_s subject to exactly the

[24] We impose this constraint because the worker could always opt to drop out of the labor market and so receive zero benefits.

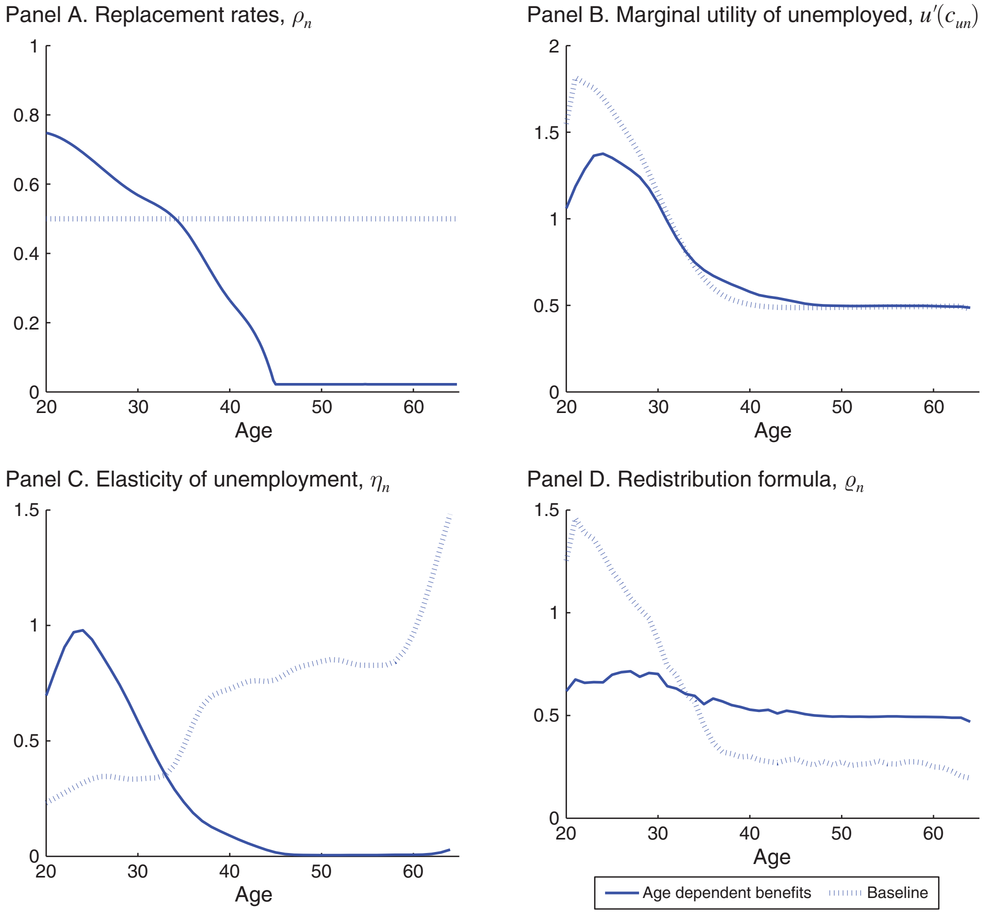

Figure 8. Age-Dependent Replacement Rates Only

Note: Dotted lines correspond to the baseline economy, solid lines to the economy with optimal age-dependent income replacement rates from UI and constant income tax rates.

same constraints. To solve this problem, we again assume that ρ_n and τ_n are a cubic spline at the previously defined age knots where the former function is restricted to be nonnegative. For each policy, we study how replacement rate and tax rates vary by age and analyze the properties of the ϱ_n ratio in (1) as well of the modified redistribution formula $\tilde{\varrho}_n$ in (10). We then quantify the gains from age-dependent policies and compare them with those attained under the optimal life cycle unemployment insurance problem of Section IV. In comparing welfare gains we also consider an economy in which the income replacement rates of unemployment insurance are maintained at the current US level, while the age profile of labor income tax rates $\boldsymbol{\tau}$ is chosen to maximize W_s subject to exactly the same constraints as before.

B. *Optimal Policies*

The solid lines in the four panels of Figure 8 characterize the economy with optimal age-dependent replacement rates and constant income tax rates. Dotted lines correspond to the baseline economy of Section III. Panel A shows the optimal age

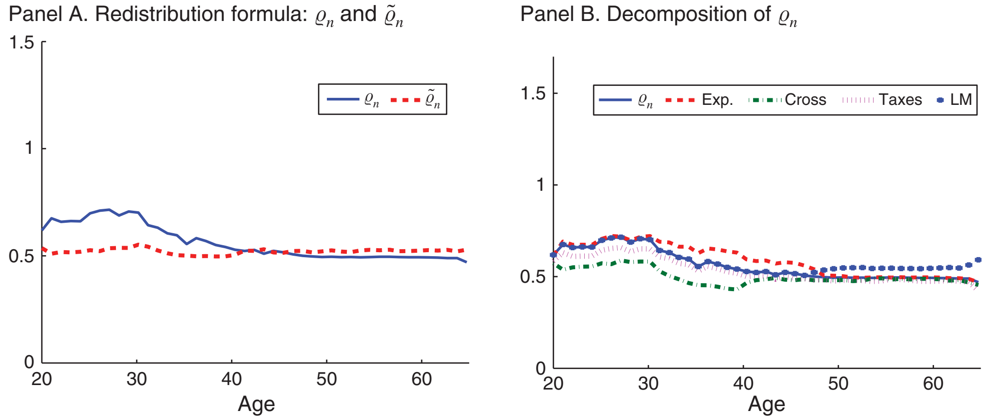

FIGURE 9. ϱ_n AND $\tilde{\varrho}_n$ IN THE ECONOMY WITH OPTIMAL AGE-DEPENDENT UI BENEFITS

Note: Lines are as in Figure 5 except for the bold dotted line in panel B, which corresponds to the effects of the Lagrange multiplier on the feasibility constraint $\rho_n \geq 0$.

profile of replacement rates, panel B the profile of the marginal utility of average consumption when unemployed, panel C the elasticity of unemployment to benefits, and panel D the profile of ϱ_n as previously defined. Under the optimal age-dependent policy, replacement rates are raised from the current value of 50 percent to around 80 percent for workers in their mid-twenties and to 60 percent for those in their thirties. Workers in their forties and fifties, by contrast, get almost no benefits. The age profile of the average marginal utility of consumption when unemployed is substantially flatter than in the baseline economy. The elasticity of unemployment to benefits, η_n, is generally smaller than in the baseline economy and tends to decrease with age. Because of this, the age profile of the ϱ_n ratio is now substantially flatter than in the baseline economy.

Let us consider why ϱ_n does not become completely independent of age under the optimal age-dependent UI benefits policy. In panel A of Figure 9 we plot the age profiles of ϱ_n and $\tilde{\varrho}_n$ in the economy with optimal age-dependent income replacement rates. As expected, $\tilde{\varrho}_n$ is approximately flat while ϱ_n is greater than $\tilde{\varrho}_n$ for workers under 40 and lower for those over 40. To see why the two profiles differ, we perform a decomposition exercise identical to that in panel B of Figure 5 but now also taking into account that for workers older than 40 the feasibility constraint $\rho_n \geq 0$ is binding, so that the Lagrange multiplier ω_n in (10) is strictly positive. The contribution of the Lagrange multiplier corresponds to the bold dotted line in panel B, which is obtained by calculating ϱ_n after adding to the numerator in (1) the Lagrange multiplier $\frac{\omega_n}{\mu_n}$, which is positive when the feasibility constraint $\rho_n \geq 0$ is binding. All the other lines are as in panel B of Figure 5: the solid line corresponds to the profile of ϱ_n in panel A; the dashed line is analogous, but with ϱ_n calculated using the expected marginal utility of consumption rather than the marginal utility of expected consumption; the dash-dotted line corresponds to calculating ϱ_n using the elasticity of unemployment extended to include cross-derivatives $\tilde{\eta}_n$, not the simple elasticity η_n; finally the dotted line is obtained by calculating ϱ_n after adding to the denominator the effect of taxes, as measured by $\frac{\partial T}{\partial b_n} \cdot \frac{1}{\mu_n}$. For workers under 40,

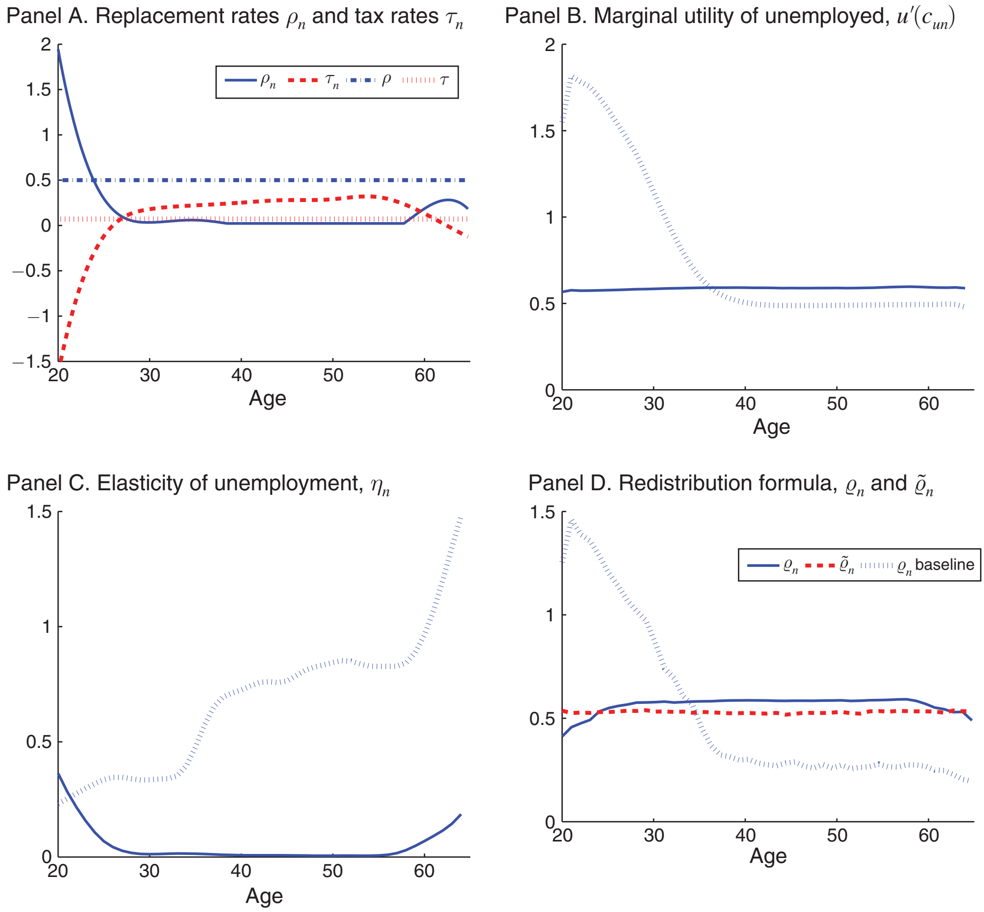

Figure 10. Age-Dependent Replacement Rates and Tax Rates

Notes: In all panels dotted lines correspond to the baseline economy, solid lines to the economy with optimal age-dependent income replacement rates from UI and labor income tax rates. In panel D the dashed line corresponds to the profile of $\tilde{\varrho}_n$ in the economy with optimal age-dependent policies.

ϱ_n is greater than $\tilde{\varrho}_n$ mainly because $\tilde{\eta}_n$ is greater than η_n—that is, because changes in benefits for one age group increase unemployment for other age groups as well. For workers above 40, ϱ_n falls below $\tilde{\varrho}_n$ just because the feasibility constraint $\rho_n \geq 0$ is binding, which makes the Lagrange multiplier $\frac{\omega_n}{\mu_n}$ strictly positive.

Figure 10 is analogous to Figure 8, but now we also optimally choose the age profile of labor income tax rates. Taxes are generally set to achieve a smooth age profile of consumption. Tax rates increase with age until the very late fifties when they start to fall steeply until retirement. Taxes before retirement are low in order to provide strong incentives to highly productive older workers, as well as to finance high consumption during retirement.[25] The age profile of replacement rates is decreasing in age as in Figure 8, but now the rates are significantly lower for workers in their

[25] Since the retirement age is exogenous, workers in their sixties have little incentive to search for a job. Moreover we are not maximizing with respect to the level of retirement pensions π, which affects the choice for the

thirties. Just before retirement, benefits increase slightly, which follows from the analysis of $\tilde{\varrho}_n$ in (10): for this age group tax rates are negative, so $\frac{\partial T}{\partial b_n}$ is positive, which pushes up the value of $\tilde{\varrho}_n$ and thereby justifies increasing ρ_n. The age profiles of the marginal utility of consumption when unemployed and of the elasticity of unemployment to benefits become substantially flatter than in the baseline economy. As a result the profile of ϱ_n becomes almost invariant to age except for very young and very old workers, for whom ϱ_n falls to around 10 percentage points below its average. As expected, the age profile of $\tilde{\varrho}_n$ is completely flat (dashed line in panel D). A decomposition exercise analogous to the one performed in panel B of Figure 9 shows that almost all the differences between ϱ_n and $\tilde{\varrho}_n$ are due to the age profile of taxes: when taxes are negative, $\frac{\partial T}{\partial b_n}$ in (10) is positive, which makes $\tilde{\varrho}_n$ greater than ϱ_n; when taxes are positive, $\frac{\partial T}{\partial b_n}$ is negative and $\tilde{\varrho}_n$ falls below ϱ_n.

C. *Welfare Comparisons*

Figure 6 characterizes the age profile of job finding rates (panel A) and consumption when unemployed (panel B) in the baseline economy (dotted line), in the economy with optimal age-dependent benefits (dashed line), in the economy with the combined age-dependent policy for benefits and taxes (dash dotted line), and in the optimal problem studied in Section IV (solid line). Age profiles in the four economies do differ. In the first-best economy and under age-dependent policy, job finding rates are mildly increasing with age. Both in the first best economy and in that with combined age-dependent benefits and taxes, consumption is flat, and consumption losses are small and relatively independent of age. In the baseline economy, finding rates are strongly decreasing in age, consumption is increasing, and consumption losses are large for workers in their twenties and thirties.

Table 6 quantifies the welfare gains under the different allocations. The first best policy with observable search effort yields welfare gains equivalent to a 3.4 percent increase in consumption. The table normalizes these gains to 100 percent and compares them with those attained under alternative age-dependent policies. With age-dependent income replacement rates, welfare gains are equivalent to just under a 1 percent increase in lifetime consumption. Combining age-dependent unemployment insurance with age-dependent taxes, the gain rises to 3.2 percent. That is, simple age-dependent policies yield more than 90 percent of the welfare gains of the optimal unemployment insurance program.[26] It is also useful to study the economy where the income replacement rates are maintained at the current US level and labor income tax rates are allowed to vary with age. In this economy, tax rates are implicitly set to smooth the age profile of income, so consumption is relatively smooth over the life cycle but not across employment states. The economy with age-dependent income tax rates yields welfare gains equivalent to about two-thirds

age profile of taxes before retirement: when we double the value of π, taxes fall significantly less in the five years before retirement.

[26] As in Shimer and Werning (2008), there is small welfare gain from making UI benefits dependent on unemployment duration. As workers spend more time unemployed, their assets as well as their human capital fall, which drives their consumption down. This gives unemployed workers close-to-optimal incentives to search for new jobs.

of those under the combined age-dependent policy for replacement rates and taxes, with the uncovered one-third due to age-dependent income replacement rates. As is discussed below, a good part of the welfare gain comes from relaxing financial constraints over the life cycle: in the baseline economy of Section IIIC, when we set the borrowing limit l at its natural level—so that no worker is financially constrained—welfare increases by around 3 percent in consumption equivalent, a large share of the gains from age-dependent policies.[27]

Decomposing Welfare Gains.—The welfare gains stem from five different first-order effects: better consumption smoothing over the life cycle, better consumption smoothing across employment states, a lower incidence of unemployment, a changing allocation of search effort, and finally production efficiency, insofar as output increases. Production efficiency gains are equal to the expected increase in the present value of output produced by a worker at birth. To measure the contribution of the other four effects, we take the expected initial utility of a fictional worker representative of a given economy, up to first order effects. Second order effects due to changes in the dispersion of consumption and search effort are measured as residuals. The representative worker is active in the labor market for $\bar{n}_w$ periods and retired for the remaining $\bar{n}_r$ periods of his life. At each age n the worker has a probability ν_n of being unemployed, equal to the age-specific unemployment rate in the economy. If employed, he has consumption c_n equal to the analogous economy-wide average. If unemployed, his consumption level is $c_n(1-\varphi_n)$, where φ_n denotes the average consumption loss upon unemployment at age n in the economy. The mass of people searching is $\frac{\delta_n}{1-(1-\delta_n)\bar{\mu}_n}$ and the within-period unemployment probability is $\bar{\mu}_n = 1 - f_n$, equal to the average probability of remaining unemployed for a worker searching for a job at age n. The initial utility of the representative worker is set equal to

$$\mathbf{UR}(\tilde{c}, \tilde{\varphi}, \tilde{\nu}, \tilde{\mu})$$

$$= \sum_{n=1}^{\bar{n}_w+\bar{n}_r} \beta^{n-1}\left[(1-\nu_n)\,u(c_n) + \nu_n u(c_n(1-\varphi_n)) + \frac{\delta_n \psi(\bar{\mu}_n)}{1-(1-\delta_n)\bar{\mu}_n}\right],$$

which is a function of the sequence of consumption $\tilde{c}$, of consumption losses upon unemployment $\tilde{\varphi}$, of the incidence of unemployment $\tilde{\nu}$, and of within-period unemployment probabilities $\tilde{\mu}$. The last term in square brackets is set to zero for $n > \bar{n}_w$. We checked that UR approximates the initial utility of the corresponding economy reasonably well. This is because, after conditioning for age, cross-sectional heterogeneity in consumption and search effort is relatively small. We calculate *UR* in the baseline economy and then measure how it varies when replacing (one at a time) $\tilde{c}$, $\tilde{\varphi}$, $\tilde{\nu}$, and $\tilde{\mu}$ of the baseline economy with the corresponding values for the economy with age-dependent policies. This measures the gains from better consumption smoothing over life cycle, from better consumption smoothing across employment

[27] Notice that the natural borrowing limit is a function of worker's age n and worker's human capital e, $l(n, e)$, see the online Appendix for details.

Table 7—Decomposing Welfare Gains of Age-Dependent Policies

Source of gain	Age-dependent benefits only	Age-dependent benefits and taxes
Production efficiency	0.05	0.58
Consumption smoothing over time	0.11	1.55
Consumption smoothing across states	0.46	1.07
Incidence of unemployment	0.12	0.27
Search effort over time	−0.06	−0.35
Sum	0.68	3.07
Residual (second order effects)	0.10	0.11
Total	0.78	3.18

Note: Equivalent consumption percentage increases relative to the baseline economy.

states, from lower incidence of unemployment, and from changing search effort, respectively. The sequence of consumption $\tilde{c}$ from the economy with age-dependent policies is scaled down by the size of the production efficiency gains. The measures of gains are converted into equivalent consumption units and correspond to percentage increases. The resulting gains are reported in Table 7 both for the economy with age-dependent benefits only (column 2) and for the economy where both taxes and benefits are age-dependent (column 3). In the economy with age-dependent benefits only, most gains come from better consumption smoothing across employment states. In the economy with age-dependent benefits and taxes, there are also important gains from smoothing consumption over the life cycle, which represent almost a 2 percent increase in life time consumption. These gains are smaller, but still present even in the economy with age-dependent benefits only, because young workers use their high UI replacement rates to obtain a smoother consumption profile over the life cycle. As is discussed below the magnitude of these gains is affected by the financial constraint l. The contribution of the changing allocation of leisure is negative, since average search effort in the economy increases.

VI. Further Discussion

Now let us examine the robustness of the result that UI income replacement rates should generally decrease with age to alternative specifications of the baseline model. We first study the effects of relaxing the borrowing constraint l, and then analyze the effects of changing the return to skill. We also consider a version of the model in which the government budget constraint (23) is age-specific, barring income redistribution across age groups. Then we study the role of age-dependent severance payments in insuring workers against unemployment risk over the life cycle. Finally we consider larger wage losses during unemployment $\bar{\kappa}_n$. In analyzing the alternative specifications, we always recalibrate the economy to hit exactly the same targets in Section IIIC.

A. *Relaxing the Borrowing Limit*

To study the effects of relaxing the borrowing constraint l, we multiply its value by a factor of three—so we now have $l = -3.36$. The solid line in Figure 11 shows the new optimal profile of age-dependent UI income replacement rates in the

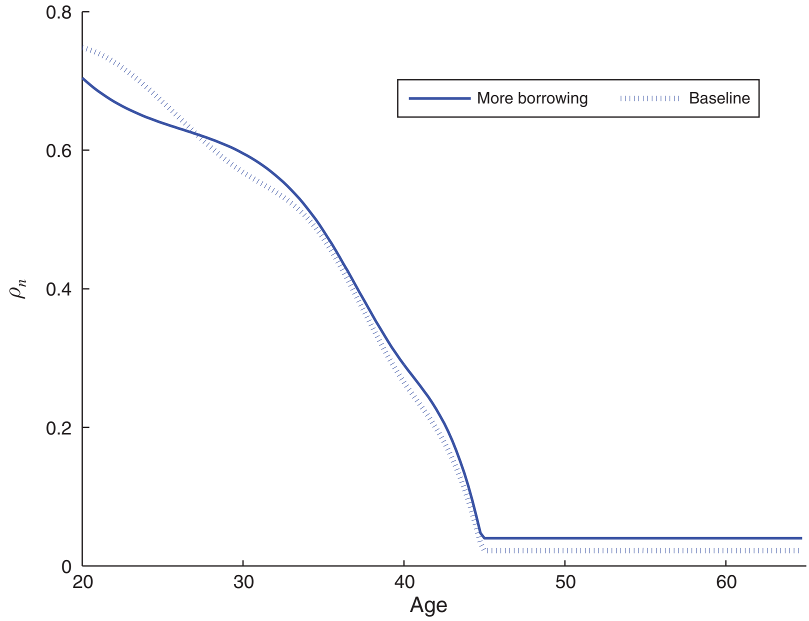

Figure 11. Age-Dependent UI Income Replacement Rates with Relaxed Borrowing Constraints

Notes: Profile of UI income replacement rates in the economy with optimal age-dependent replacement rates and constant income tax rates. Solid line corresponds to the economy with relaxed borrowing constraint, dotted line to baseline economy.

economy with constant income tax rates. The replacement rates basically duplicate the profile of the age-dependent policy version of the baseline economy, but they are lower for young workers, who are now less financially constrained. We have also studied the welfare gains of optimally choosing age-dependent replacement and tax rates, which diminishes now to a 2.2 percent increase in consumption by comparison with the economy with an optimal constant replacement rate—which now becomes 48 percent. This confirms that in our model a substantial part of the welfare gains from age-dependent policies stem from relaxing financial constraints.

B. *Changing the Return to Experience*

The return to labor market experience varies significantly by type of workers. For example, wage increases over the life cycle are substantially greater for college than for high school graduates: roughly speaking the former attain an increase that is 20 percent more than in our baseline economy, the latter 20 percent less. To analyze the sensitivity of our results to changes in the return to skill, we take the experience function $w(e)$ with the normalization condition $w(0) = 1$ and set the values of the spline at all age knots to $1 + \zeta[w(e) - 1]$. The constant $\zeta - 1$ represents a percentage change in the return to labor market experience. We then analyze the optimal age profile of UI income replacement rates in two economies one with $\zeta = 0.9$ and another with $\zeta = 1.1$ (about a 20 percent difference in the return to experience). This offers preliminary evidence on how the age profile should change with

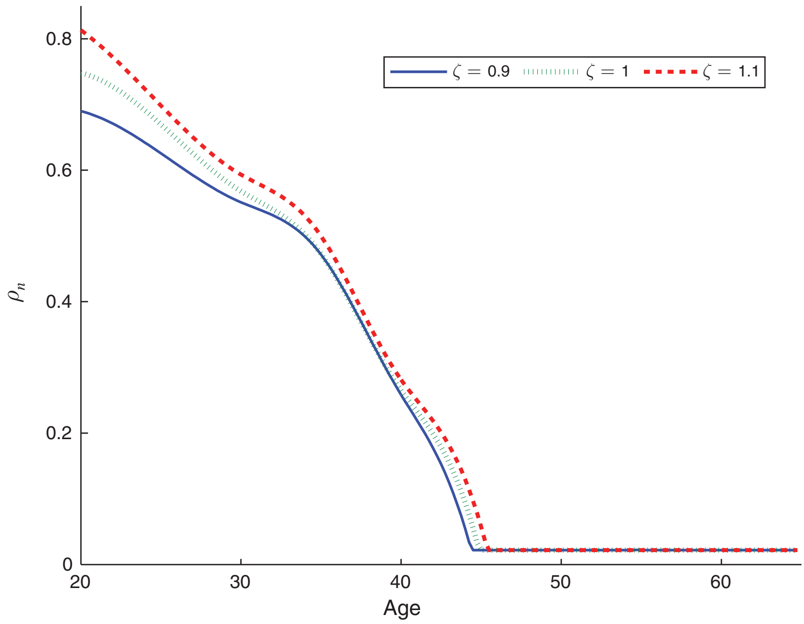

Figure 12. Age-Dependent UI Replacement Rates and the Return to Experience

Notes: Profile of UI replacement rates in the economy with optimal age-dependent UI replacement rates and constant income tax rates. Dotted lines correspond to the baseline economy, other lines correspond to economy with lower $\zeta = 0.9$ (as a solid line), and higher $\zeta = 1.1$ (as a dashed line) return to experience.

education.[28] We find that the results change very little: there are always welfare gains from allowing UI income replacement rates to decrease with age, while the profile of replacements rates is also similar across groups (Figure 12). But notice that a fall in the return to experience produces a flatter age profile and smaller welfare gains. When the return to experience falls, the government can insure young workers less because the moral hazard problem is more severe. Moreover, with lower returns to experience, younger workers are less financially constrained and value unemployment insurance less highly.

C. *Age-Dependent Government Budget Constraints*

The budget constraint in (23) implies that part of the welfare gains from age dependent benefits comes because some tax revenue is redistributed from older wealthier workers to younger less wealthy ones. We now show that this is not the main reason why replacement rates should decrease with age, studying an economy where benefit expenditures for workers of a given age are financed by taxes levied just on workers of the same age (no tax revenue redistribution across age groups).[29] We divide the

[28] Of course, one should be careful in taking education as exogenous, since the return to education and hence the incentive for it is itself affected by labor market institutions. To be sure, here we are not advocating that UI income replacement rates should be education specific.

[29] We are thankful to Emmanuel Farhi, Juan Pablo Nicolini, and Robert Shimer for suggesting this exercise.

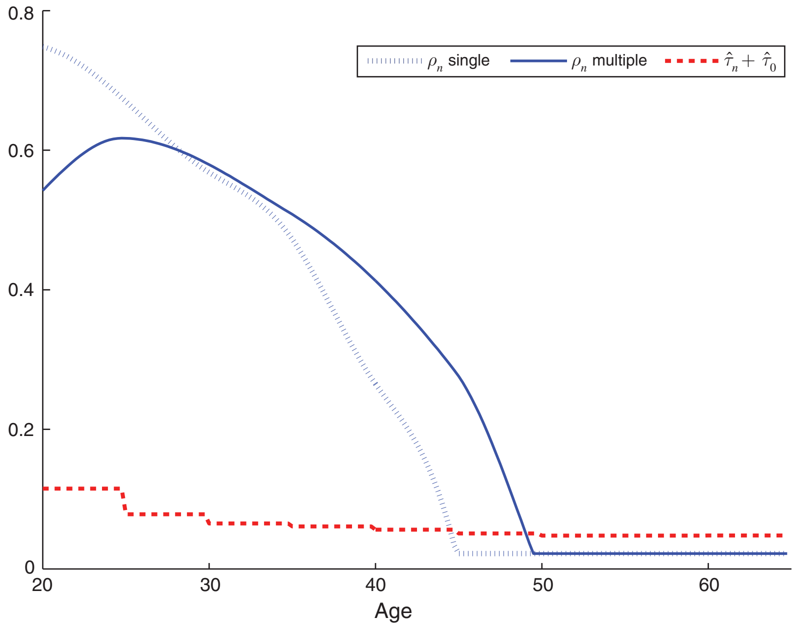

Figure 13. Age-Dependent Replacement Rate with Age-Specific Budget Constraint

Notes: The age-specific budget constraint is satisfied for nonoverlapping age groups of five years. Solid line is the age profile of replacement rates, dashed line is that of income tax rates. Dotted line corresponds to the optimal profile of UI income replacement rates in Figure 8.

population into N mutually exclusive age groups with maximum age difference $k = 20$ within the group, so that $Nk = \bar{n}_w$. The set of age levels for the ith age group, $i = 1, 2. \dots, N$, is given by $\Gamma_i = \{(i-1)k+1, (i-1)k+2. \dots, ik\}$. Income taxes are the sum of two rates, one used to finance benefits for the specific age group denoted by $\bar{\tau}_n$, the other to finance retirement pensions, denoted by $\hat{\tau}_0$. So we have $\tau_n = \bar{\tau}_n + \hat{\tau}_0$ (see the online Appendix for details). We then search for the age profile of the UI income replacement rate $\boldsymbol{\rho} \geq 0$ that maximizes the worker's initial wealth W_s subject to the same constraints as before but where now the tax rates $\hat{\tau}_i$s $i = 1, \dots, N$ satisfy the N age-specific government budget constraints while $\hat{\tau}_0$ is set to finance pensions. The resulting optimal age-dependent replacement rate under the age-specific budget constraints corresponds to the solid line in Figure 13. For comparison, the optimal age-dependent replacement rate from Figure 8 is also plotted (dotted line). The replacement rate is again generally decreasing in age (at least for workers over 25), but, as no intergenerational redistribution is allowed, the age profile is now marginally flatter.

D. *Severance Payments*

To insure workers against wage loss upon displacement, it might be useful to include severance pay in the optimal unemployment insurance package. Here we show that age variation in severance payments helps little in enhance welfare compared with the economy with optimal age-dependent benefits and taxes. To do so, we now allow for age-dependent severance payments: upon job displacement workers receive a government transfer equal to $\varsigma_n w(e)$ (age n and human capital e here refer to the last period before job displacement). All the other assumptions of the baseline model remain as in Section III. We keep the profiles of age-dependent benefits and taxes as given. To be sure, let ρ_n^* and τ_n^* denote the optimal age profile of benefits and taxes as in Figure 10. Here we assume that $\rho_n = \rho_n^*$ and $\tau_n = \tau_n^* + \bar{\tau}$, where $\bar{\tau}$ is needed to satisfy the budget constraint. We then search for the vectors of severance payments $\boldsymbol{\varsigma} = \{\varsigma_1, \ldots, \varsigma_{\bar{n}_w}\}$ and the value of the tax rate $\bar{\tau}$ that maximize worker's initial utility $W_s \equiv J(1, 0, 0)$ subject to the new budget constraint (see the online Appendix for details). Exactly as in Section V, we assume that ς_n is a cubic spline at the previously defined ten age knots and search for the value at the knots that maximize W_s. When severance payments are independent of age $\varsigma_n = \varsigma, \forall n$, the optimal constant over age severance payment is $\varsigma = 1.4$. This economy yields welfare gains equivalent to a 3.3 percent increase in life time consumption relative to the baseline economy. This is a 0.1 percentage point more than in the economy with optimal age-dependent benefits and taxes. If severance pay varies with age, we find virtually no additional gains (up to the fourth order).

E. *Wage Losses During Unemployment*

In the online Appendix we compare earnings losses upon displacement in our model with estimates from the empirical literature (Stevens 1997; Couch and Placzek 2010; Davis and von Wachter 2011) and other theoretical models (Jung and Kuhn 2012). In our baseline calibration, the model tends to underestimate earning losses upon displacement, especially in the long term (more than three years after displacement); losses in the model are around half those in the empirical data. We accordingly analyze the robustness of our results when the wage loss during unemployment $\bar{\kappa}_n - 1$ is doubled. The new age profile of $\bar{\kappa}_n - 1$ is plotted in panel A of Figure 14, the new optimal age-dependent UI income replacement rate ρ_n in panel B. Solid lines correspond to the new specification, dotted lines correspond to baseline. It is apparent that the profile of the optimal age-dependent ρ_n is virtually unchanged compared to the baseline calibration. As discussed in the online Appendix, this is a general property of the model: the optimal age profile of ρ_n is very little affected by changes in either the level or the age profile of $\bar{\kappa}_n$.[30]

VII. Conclusion

Unemployed young workers have a high marginal utility of consumption, suffer large consumption losses upon unemployment, and respond little to changes in unemployment benefits. This indicates that they value unemployment insurance highly, while the problem of moral hazard is mild. Using a life cycle model with

[30] In practice this happens because the age profile of the extended redistribution formula $\tilde{\varrho}$ changes little in response to changes in the profile of $\bar{\kappa}_n$. For example, with a lower $\bar{\kappa}_n$, the marginal utility of consumption of the unemployed goes up which pushes up the value of the numerator of $\tilde{\varrho}$. But the lower $\bar{\kappa}_n$ also makes tax effects more important, so $-\frac{\partial T}{\partial b_n}$ goes up, which increases the denominator of $\tilde{\varrho}$ and on balance leaves the overall profile of $\tilde{\varrho}$ unchanged.

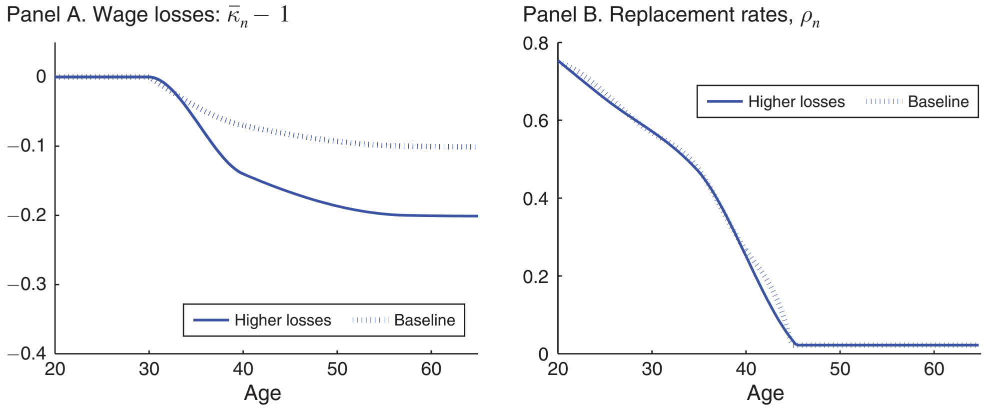

Figure 14. Age-Dependent UI Income Replacement Rates and Wage Losses upon Reemployment

Notes: Panel A plots the age profile of wage losses during unemployment in the baseline calibration (dotted line) and in the economy where wage losses are doubled (solid line). Panel B plots the optimal age-dependent UI income replacement rate ρ_n in the two economies.

unemployment risk and endogenous search effort, we find that under the optimal age-dependent policy, income replacement rates should increase from the current level of 50 percent to around 80 percent for workers in their mid-twenties and 60 percent for those in their thirties. Workers in their forties and fifties, instead, get benefits of less than 10 percent of their last wage. Allowing unemployment benefit replacement rates and other government transfers to decline with age yields sizable welfare gains that amount to around 90 percent of the gains attained under the unconstrained optimal scheme for unemployment insurance over the life cycle. Around a quarter of these gains are due to age dependent unemployment benefits. The quantitative analysis also shows that the age variation in the ratio of the marginal utility of consumption when unemployed to one plus the elasticity of unemployment to benefits closely identifies the existence of welfare gains from redistributing unemployment insurance over the life cycle. This simple ratio neglects the effects of age-specific changes in benefits on tax revenue and on unemployment among age groups not directly targeted by the policy change. Incorporating these effects leads to an extended redistribution formula that works exactly in our quantitative model and that might prove to be substantially more accurate than the previously discussed simple ratio in other attempts of identifying the gains from redistributing benefits across workers of different age, gender, or race.

We purposely simplified the theoretical analysis in some ways. For example, we have assumed that job separation rates are exogenous, while in practice UI benefits affect the outside options of employed workers which can lead to higher separation rates and more occupational mobility, which we know (Kambourov and Manovskii 2008, 2009) are higher for the young than for the old. Our modeling of wage losses upon displacement also assumes the depreciation of human capital during unemployment, but in practice workers could have accumulated job-specific human capital that is immediately lost upon displacement regardless of the duration of unemployment. Allowing for job-specific human capital could weaken our conclusion that age-dependent severance payments do little toward achieving the welfare gains obtained under the optimal program. Still, we believe that our results on the optimal age profile of UI benefits are robust to alternative modeling choices for the process that leads to wage loss upon displacement.

Our analysis suggests that age-dependent policies are Pareto-improving when applied solely to new generations of workers entering the labor market, but as policy reforms cannot ordinarily be applied to specific cohorts, the introduction of age-dependent labor market institutions might have to deal with important redistribution concerns. In studying age-dependent labor market institutions, we have focused only on the amount of unemployment benefits, but the analysis could well be extended to other features, such as benefit duration, maximum benefit level, and eligibility as well as to other labor market institutions, such as employment protection and poverty programs. Along some of these dimensions it could well turn out that older workers require more protection than younger workers.

Future research should also evaluate the welfare gains from age-dependent policies for unemployment insurance programs different from those currently in place in the United States. In particular Feldstein and Altman (1998) and Feldstein (2005) have advocated individual saving accounts to attenuate the moral hazard implicit in unemployment insurance. The concept is that the employed worker saves a fraction of his earnings in an individual saving account which he draws on when unemployed to receive the benefit payments dictated by the current US unemployment system. At retirement, any residual positive balance is transferred back to the worker. The quantitative welfare gains of saving accounts systems have been studied by Ferrada (2010); Setty (2010); and Pallage and Zimmermann (2010). Our robustness exercise shows that replacement rates should decline with age also when workers face a loose borrowing constraint. Since savings accounts are essentially a means of providing greater liquidity to unemployed workers, this suggests that welfare gains should accrue from having unemployment insurance income replacement rates decrease with age also in plausible implementation of the saving account proposal. This squares with the conclusions of Setty (2010), who introduced elements favoring younger workers in his proposed implementation of the savings account system.

REFERENCES

Acemoglu, Daron, and Robert Shimer. 1999. "Efficient Unemployment Insurance." *Journal of Political Economy* 107 (5): 893–928.

Akerlof, George A. 1978. "The Economics of 'Tagging' as Applied to the Optimal Income Tax, Welfare Programs, and Manpower Planning." *American Economic Review* 68 (1): 8–19.

Autor, David H., David Dorn, Gordon H. Hanson, and Jae Song. 2013. "Trade Adjustment: Worker Level Evidence." National Bureau of Economic Research Working Paper 19226.

Baily, Martin Neil. 1978. "Some Aspects of Optimal Unemployment Insurance." *Journal of Public Economics* 10 (3): 379–402.

Bloemen, Hans G., and Elena G. F. Stancanelli. 2005. "Financial Wealth, Consumption Smoothing and Income Shocks Arising from Job Loss." *Economica* 72 (287): 431–52.

Blundell, Richard, Luigi Pistaferri, and Ian Preston. 2008. "Consumption Inequality and Partial Insurance." *American Economic Review* 98 (5): 1887–1921.

Browning, Martin, and Thomas F. Crossley. 2001. "Unemployment Insurance Benefit Levels and Consumption Changes." *Journal of Public Economics* 80 (1): 1–23.

Chéron, Arnaud, Jean-Olivier Hairault, and François Langot. 2011. "Age-Dependent Employment Protection." *Economic Journal* 121 (557): 1477–1504.

Chéron, Arnaud, Jean-Olivier Hairault, and François Langot. 2013. "Life-Cycle Equilibrium Unemployment." *Journal of Labor Economics* 31 (4): 843–82.

Chetty, Raj. 2006. “A General Formula for the Optimal Level of Social Insurance.” *Journal of Public Economics* 90 (10-11): 1879–1901.

Chetty, Raj. 2008. “Moral Hazard versus Liquidity and Optimal Unemployment Insurance.” *Journal of Political Economy* 116 (2): 173–234.

Conesa, Juan Carlos, Sagiri Kitao, and Dirk Krueger. 2009. “Taxing Capital? Not a Bad Idea after All!” *American Economic Review* 99 (1): 25–48.

Couch, Kenneth A., and Dana W. Placzek. 2010. “Earnings Losses of Displaced Workers Revisited.” *American Economic Review* 100 (1): 572–89.

Cullen, Julie Berry, and Jonathan Gruber. 2000. “Does Unemployment Insurance Crowd Out Spousal Labor Supply?” *Journal of Labor Economics* 18 (3): 546–72.

Davidson, Carl, and Stephen A. Woodbury. 1997. “Optimal Unemployment Insurance.” *Journal of Public Economics* 64 (3): 359–87.

Davis, Steven J., and Till von Wachter. 2011. “Recessions and the Costs of Job Loss.” *Brookings Papers on Economic Activity* (2): 1–55.

Erosa, Andres, and Martin Gervais. 2002. “Optimal Taxation in Life-Cycle Economies.” *Journal of Economic Theory* 105 (2): 338–69.

Farhi, Emmanuel, and Iván Werning. 2013. “Insurance and Taxation over the Life Cycle.” *Review of Economic Studies* 80 (2): 596–635.

Feldstein, Martin. 2005. “Rethinking Social Insurance.” *American Economic Review* 95 (1): 1–24.

Feldstein, Martin, and Daniel Altman. 1998. “Unemployment Insurance Savings Accounts.” National Bureau of Economic Research Working Paper 6860.

Ferrada, Christian. 2010. “Individual Savings Accounts in Chile: Income vs. Substitution Effects and Saving Responses.” Unpublished.

Gervais, Martin. 2012. “On the Optimality of Age-Dependent Taxes and the Progressive US Tax System.” *Journal of Economic Dynamics and Control* 36 (4): 682–91.

Gorry, Aspen, and Ezra Oberfield. 2012. “Optimal Taxation over the Life Cycle.” *Review of Economic Dynamics* 15 (4): 551–72.

Gourieroux, C., A. Monfort, and E. Renault. 1993. “Indirect Inference.” *Journal of Applied Econometrics* 8: S85–118.

Gritz, R. Mark, and Thomas MaCurdy. 1992. “Unemployment Compensation and Episodes of Nonemployment.” *Empirical Economics* 17 (1): 183–204.

Gruber, Jonathan. 1997. “The Consumption Smoothing Benefits of Unemployment Insurance.” *American Economic Review* 87 (1): 192–205.

Hopenhayn, Hugo A., and Juan Pablo Nicolini. 1997. “Optimal Unemployment Insurance.” *Journal of Political Economy* 105 (2): 412–38.

Hopenhayn, Hugo A., and Juan Pablo Nicolini. 2009. “Optimal Unemployment Insurance and Employment History.” *Review of Economic Studies* 76 (3): 1049–70.

Hryshko, Dmytro, Maria Jose Luengo-Prado, and Bent E. Sørensen. 2010. “House Prices and Risk Sharing.” *Journal of Monetary Economics* 57 (8): 975–87.

Jacobson, Louis S., Robert J. LaLonde, and Daniel G. Sullivan. 1993. “Earnings Losses of Displaced Workers.” *American Economic Review* 83 (4): 685–709.

Johnson, Richard W., and Corina Mommaerts. 2011. “*Age Differences in Job Loss, Job Search, and Reemployment.”* Urban Institute Working Paper 11-01.

Jung, Philip, and Moritz Kuhn. 2012. “Earnings Losses and Labor Mobility over the Life-Cycle.” Unpublished.

Kambourov, Gueorgui, and Iourii Manovskii. 2008. “Rising Occupational and Industry Mobility in the United States: 1968–97.” *International Economic Review* 49 (1): 41–79.

Kambourov, Gueorgui, and Iourii Manovskii. 2009. “Occupational Specificity of Human Capital.” *International Economic Review* 50 (1): 63–115.

Koehne, Sebastian, and Moritz Kuhn. 2014. “Should Unemployment Insurance be Asset-Tested?” *Review of Economic Dynamics*. doi:10.1016/j.red.2014.09.005.

Kremer, Michael. 2001. “Should Taxes be Independent of Age?” Unpublished.

Krueger, Alan B., and Andreas Mueller. 2010. “Job Search and Unemployment Insurance: New Evidence from Time Use Data.” *Journal of Public Economics* 94 (3-4): 298–307.

Lentz, Rasmus, and Torben Tranaes. 2005. “Job Search and Savings: Wealth Effects and Duration Dependence.” *Journal of Labor Economics* 23 (3): 467–89.

Menzio, Guido, and Shouyong Shi. 2011. “Efficient Search on the Job and the Business Cycle.” *Journal of Political Economy* 119 (3): 468–510.

Meyer, Bruce D., and Wallace K. C. Mok. 2007. “Quasi-Experimental Evidence on the Effects of Unemployment Insurance from New York State.” National Bureau of Economic Research Working Paper 12865.

Michelacci, Claudio, and Hernán Ruffo. 2015. "Optimal Life Cycle Unemployment Insurance: Dataset." *American Economic Review*. http://dx.doi.org/10.1257/aer.20111559.

Mirrlees, James, Stuart Adam, Timothy Besley, Richard Blundell, Stephen Bond, Robert Chote, Malcolm Gammie, Paul Johnson, Gareth Myles, and James Poterba, eds. 2010. *Dimensions of Tax Design: The Mirrlees Review*. Oxford, UK: Oxford University Press.

Moen, Espen R. 1997. "Competitive Search Equilibrium." *Journal of Political Economy* 105 (2): 385–411.

Mortensen, Dale T., and Christopher A. Pissarides. 1994. "Job Creation and Job Destruction in the Theory of Unemployment." *Review of Economic Studies* 61 (3): 397–415.

Mueller, Andreas. 2010. "Separations, Sorting and Cyclical Unemployment." Unpublished.

Organisation for Economic Co-Operation an Development (OECD). 2007. *Pensions at a Glance: Public Policies Across OECD Countries*. Paris: OECD.

Pallage, Stephane, and Christian Zimmermann. 2010. "Unemployment Benefits vs. Unemployment Accounts: A Quantitative Exploration." Unpublished.

Pavoni, Nicola. 2007. "On Optimal Unemployment Compensation." *Journal of Monetary Economics* 54 (6): 1612–30.

Pavoni, Nicola. 2009. "Optimal Unemployment Insurance, with Human Capital Depreciation, and Duration Dependence." *International Economic Review* 50 (2): 323–62.

Pavoni, Nicola, Ofer Setty, and Giovanni L. Violante. 2010. "Search and Work in Optimal Welfare Programs." Unpublished.

Pavoni, Nicola, and G. L. Violante. 2007. "Optimal Welfare-to-Work Programs." Review of Economic Studies 74 (1): 283–318.

Pissarides, Christopher A. 2000. *Equilibrium Unemployment Theory*. 2nd ed. Cambridge, MA: MIT Press.

Rendahl, Pontus. 2012. "Asset Based Unemployment Insurance." *International Economic Review* 53 (3): 743–70.

Ruggles, Steven, J. Trent Alexander, Katie Genadek, Ronald Goeken, Matthew Schroeder, and Matthew Sobek. 2010. "Integrated Public Use Microdata Series: Version 5.0." Minneapolis, MN: Minnesota Population Center.

Setty, Ofer. 2010. "Unemployment Accounts." Unpublished.

Shimer, Robert. 2005. "The Assignment of Workers to Jobs in an Economy with Coordination Frictions." *Journal of Political Economy* 113 (5): 996–1025.

Shimer, Robert, and Iván Werning. 2007. "Reservation Wages and Unemployment Insurance." *Quarterly Journal of Economics* 122 (3): 1145–85.

Shimer, Robert, and Iván Werning. 2008. "Liquidity and Insurance for the Unemployed." *American Economic Review* 98 (5): 1922–42.

Stevens, Ann Huff. 1997. "Persistent Effects of Job Displacement: The Importance of Multiple Job Losses." *Journal of Labor Economics* 15 (1): 165–88.

Stokey, Nancy L., Robert E. Lucas, Jr., and Edward C. Prescott. 1989. *Recursive Methods in Economic Dynamics*. Harvard University Press.

Sullivan, James X. 2008. "Borrowing during Unemployment: Unsecured Debt as a Safety Net." *Journal of Human Resources* 43 (2): 383–412.

Weinzierl, Matthew. 2011. "The Surprising Power of Age-Dependent Taxes." *Review of Economic Studies* 78 (4): 1490–1518.