Indivisible Labor, Human Capital, Lotteries, and Personal Savings:
Do Taxes Explain European Employment?*

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Abstract

To appreciate a 'not-so-well-known aggregation theory' that underlies Prescott's (2002) finding that higher taxes on labor have depressed Europe relative to the U.S., this paper compares aggregate outcomes for economies with two alternative arrangements for coping with indivisible labor: (1) employment lotteries plus complete consumption insurance, and (2) individual consumption smoothing via borrowing and lending at a risk-free interest rate. Under idealized conditions, the two arrangements support equivalent outcomes when human capital is not present; when it is present, outcomes are naturally different. Households' reliance on personal savings in the incomplete markets model constrains the 'career choices' that are implicit in their human capital acquisition plans relative to those that can be supported by lotteries and consumption insurance in the complete markets model. Lumpy career choices make the incomplete markets model better at coping with a generous system of government funded compensation to people who withdraw from work. Adding generous government supplied benefits to Prescott's model with employment lotteries and consumption insurance causes employment to implode and prevents the model from matching outcomes observed in Europe.

Key words: Employment lotteries, indivisible labor, labor supply elasticity, labor taxation, social insurance, private insurance, human capital, employment.

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"The differences in the consumption and labor tax rates in France and the United States account for virtually all of the 30-percent difference in the labor input per working-age person. ... if France modified its intratemporal tax wedge so that its value was the same as the U.S. value, French welfare in consumption equivalents would increase by 19 percent." Prescott (2002, p. 13, p. 1)

"In a modern society, in which human capital is a larger component of wealth than is land, a proportional tax on human capital is like a nondistorting Henry George tax as long as labor supply responses are negligible. Estimated intertemporal labor supply elasticities are small, and welfare effects from labor supply adjustment are negligible. ... Taxes on human capital should be *increased*, whereas taxes on capital should be decreased, to promote wage growth and efficiency." Carneiro and Heckman (2003, p. 196)

1 Introduction

Prescott (2002) used a growth model with a stand-in household and a special assumption about the government's disposition of tax revenues to conclude that cross-country differences in taxes on labor account for cross-country differences in hours per capita. This paper examines the sensitivity of Prescott's analysis to his assumptions about private risk sharing arrangements, labor markets, human capital acquisition, the government's disposition of tax revenues, and the presence of government supplied benefits to people who withdraw from work.

Section 2 adds an important element of the European landscape that Prescott ignored: government supplied non-employment benefits in the form of a replacement ratio times foregone labor income. Martin (1996) documents that benefits with high replacement rates prevail for European members of the OECD. Our modification of Prescott's model reveals that a benefit rate wedge works just like Prescott's labor-tax wedge (see the multiplication of wedges that appears in our (4)). With the high labor supply elasticity calibrated by Prescott, benefit wedges of magnitudes calibrated by Martin (1996) lead to deep depressions that Europe has not witnessed. This is good news for Europe but bad news for the fit of the model. The high labor supply elasticity that underlies these outcomes comes from Prescott's use of a "not so well known" aggregation theory due to Hansen (1985) and Rogerson (1988) that assumes indivisible labor, employment lotteries, and perfect consumption insurance. How do Prescott's conclusions, and the bad fits that result after we extend his analysis to acknowledge those generous European inactivity benefits, depend on that aggregation theory?

Mulligan (2001) recently suggested that Prescott's aggregation theory is not needed because if we lengthen a worker's horizon, then by borrowing and lending a risk-free asset bearing a sufficiently high interest rate, he can smooth consumption across alternating periods of work and nonwork. Section 3 formulates a version of Mulligan's argument in a single-agent setting. We show that whether Mulligan's time averaging leads to outcomes equivalent to ones with Hansen's and Rogerson's employment lotteries depends on whether human capital is absent (here the answer is yes) or present (now the answer is no). Introducing a stylized version of a human capital acquisition technology like those of Shaw (1989) and Imai and Keane (2004) creates a nonconvexity over careers and allows a stand-in household to achieve allocations with employment lotteries that individuals cannot attain by time averaging. The single agent models in section 3 thus reveal how human capital acquisition matters for whether, by smoothing consumption across nonemployment spells by borrowing and lending a risk-free asset, isolated individuals in an incomplete markets economy can imitate the outcomes of a social arrangement featuring employment lotteries and perfect consumption insurance.

A key question studied in the remaining sections of this paper is whether the tax and benefit wedges continue to operate in the multiplicative fashion of the model of section 2 when we add human capital. For a general equilibrium model with incomplete markets, our answer is 'no' for reasons that the simple section 3 model of time-averaging anticipates. The presence of human capital induces a notion of 'careers' that makes the aggregate response of the employment lotteries model to government supplied benefits diverge from that for the incomplete markets model even though the aggregate responses to tax increases are similar.[1]

We study general economic equilibria of economies with a human capital acquisition technology. Section 4 describes the general equilibrium model and its calibration, after which sections 5 and 6 report aggregate outcomes together with the decision rules that contribute to the aggregate outcomes under incomplete markets. Within these general equilibrium settings, section 7 revisits the same issues about the contributions of taxes and benefits to outcomes that the section 2 calculations exposed. In the spirit of Prescott (2002), we first compare aggregate responses to labor tax increases under the two market structures in the absence of benefits. Remarkably, the general equilibrium models of sections 5 and 6 show that when the government spends tax revenues in the way that Prescott (2002) assumed, and when benefit rates for government supplied inactivity levels are zero, the responses of aggregate employment outcomes to labor tax increases are similar in the complete and incomplete markets models *despite* the presence of human capital and despite the incidences of employment across individuals being quite different in the two market arrangements (see figure 3). Under both market structures, the aggregate results resemble Prescott's. But then section 8 conducts a stylized experiment that offers individuals government supplied life-time nonemployment benefits. The presence of human capital makes aggregate outcomes respond to these government benefits very differently under complete and incomplete markets. Why? Because with incomplete markets, households face lumpy decisions about whether to pursue careers either in the labor market or in the social insurance program, while the stand-in household faces no such lumpiness.

[1]But see section 9.5 for some caveats.

1.1 Recurring issues

Several issues repeatedly intrude when we modify the stand-in household model of section 2 by adding human capital and incomplete markets:

- As emphasized by Imai and Keane (2004), when we add human capital, the marginal condition describing leisure-consumption tradeoffs acquires an additional term that measures the effect of current work experience on the continuation value via the accumulation of human capital. From the vantage of models with human capital, the marginal condition in the model of section 2 is misspecified, creating an apparent 'wedge'.

- The employment lotteries with complete markets and the incomplete markets models say very different things about the identities of nonemployed (or disingenuously disabled or prematurely retired at government expense) workers and how their consumption compares to those who are working.[2]

- There is perfect 'nonemployment' or 'inactivity' insurance in the employment lotteries model. Because this insurance is *private*, the stand-in household internalizes its costs. In contrast, government supplied inactivity benefits induce distortions because households do not internalize their cost. These distortions differ in the employment lotteries and the incomplete markets models.

A virtue of the kind of quantitative work based on explicit theorizing that is well represented in Prescott (2002) is that everything is on the table and a critic can 'talk to' the agents in the model and ask questions about what would change if this or that feature of the environment were different. We intend it as a tribute to Prescott that we take his Ely lecture as our point of departure. However, we confess to being biased readers of Prescott's work because in Ljungqvist and Sargent (2005b), we assert that it is better to account for cross-country differences in employment rates by emphasizing cross-country differences in benefits rather than taxes.[3]

[2]Gruber (1997) and Browning and Crossley (2001) investigate how well people smooth consumption across unemployment spells. Gruber (1997, p. 195) summarizes as follows: "The results, therefore, decisively reject the notion that there are complete private insurance markets for unemployment spells, since variation in publicly provided UI generosity is a significant determinant of individual consumption behavior." However, Browning and Crossley (2001, sec. 5) suggest interpreting Gruber's results cautiously and say that the main quantitative effects of publicly provided UI that they can detect from a Canadian data are on a subset of people who have unusually low asset levels at the time of job displacement.

[3]Alesina et al. (2005) documented that the European deficit in hours worked per capita relative to the U.S. can be decomposed into fewer hours in a normal work week, fewer weeks worked in a year, and fewer people employed. Our analysis focuses on the last component. This component is also a policy concern in Europe (especially with respect to the large number of nonemployed who are supported with government funds). Our analysis of indivisible labor says nothing about the other two components that reflect the intensive rather than the extensive margin in labor supply.

2 Prescott's model with government supplied benefits

2.1 The model and equilibrium relationships

To create a supply side explanation of international differences in hours worked, Prescott (2002) uses the standard growth model with a labor supply elasticity set high enough to make employment vary substantially over the business cycle. In this section, we describe how Prescott appeals to an employment lotteries model to justify a representative household whose choices exhibit that high labor supply elasticity; how that high labor supply elasticity also makes Prescott's representative household's leisure choice respond enthusiastically to government supplied benefits for those not working, even with moderate income replacement rates; and how Prescott's assumption about what the government does with its tax revenues disarms an income effect that would substantially affect outcomes. We point out that adding government benefits while keeping Prescott's calibrated labor supply elasticity causes the fit of the model to deteriorate substantially, creating the 'puzzle' of why Europeans work so *much*.

Prescott's stand-in household has preferences ordered by

$$\sum_{t=0}^{\infty} \beta^t N_t \Big[\log(c_t) + \alpha \log(1 - h_t)\Big]. \tag{1}$$

There is a Cobb-Douglas production function with capital share parameter θ and flat rate taxes $\tau_{kt}, \tau_{ht}, \tau_{ct}$ on earnings from capital and labor and consumption, respectively.

2.1.1 The stand-in household's budget set with benefits

It is remarkable that Prescott's supply side analysis succeeds in explaining cross-country differences in hours while completely ignoring cross-country differences in government supplied benefits to people not working. To appreciate Prescott's statement that he had expected "... the nature of the unemployment benefits system to be more important" (Prescott 2002, p. 9), we add publicly supplied inactivity benefits to Prescott's model. Following Prescott, let p_t be the time 0 price of a unit of consumption at time t, w_t the pre-tax wage, T_t the government lump-sum transfer, δ the depreciation rate, and r_t the pre-tax rental rate on capital, and let k_t, h_t, c_t, respectively, be capital, hours, and consumption per person. Assume that population $N_{t+1} = \eta N_t$, $\eta > 0$, and that there is a constant geometric gross rate of Harrod neutral technical progress of γ. We augment Prescott's version of the stand-in household's intertemporal budget constraint to include a contribution from government supplied inactivity benefits:

$$\sum_{t=0}^{\infty} p_t N_t \Big[(1+\tau_{ct})c_t + \eta k_{t+1} - [1 + (r_t - \delta)(1-\tau_{kt})]k_t \\ -(1-\tau_{ht})w_t h_t - \rho(1-\tau_{ht})w_t \max\{0, \bar{h} - h_t\} - T_t\Big] \leq 0\,, \tag{2}$$

where $\rho(1-\tau_{ht})w_t \max\{0, \bar{h}-h_t\}$ represents government benefits, which we intend to include a broad set of programs for rewarding people who are said to be disabled, prematurely retired, and unemployed. The stand-in household receives government supplied subsidies for time spent not working in the form of a replacement rate $\rho \in [0,1)$ times after tax earnings that it forgoes when it sets $h < \bar{h}$. If the household's hours fall short of $\bar{h}$, the government replaces a fraction ρ of the deficiency of after-tax labor income relative to $w(1-\tau_h)\bar{h}$. We suppose that parameter values are such that the household chooses to supply labor h_t in an amount strictly less than $\bar{h}$. Figure 1 portrays the household's budget set.

By using Abel's summation formula, the terms in capital in (2) can be expressed as

$$\begin{aligned}\sum_{t=0}^{\infty} p_t N_t \Big[\eta k_{t+1} - (1+(r_t-\delta)(1-\tau_{kt}))\, k_t\Big] &= -p_0 N_0 [1+(r_0-\delta)(1-\tau_{k0}]k_0 \\ &\quad + \sum_{t=1}^{\infty}\Big(\eta p_{t-1}N_{t-1} - p_t N_t[1+(r_t-\delta)(1-\tau_{kt})]\Big)k_t.\end{aligned}$$

A no arbitrage argument[4] implies that the coefficients on k_t should be zero for $t \geq 0$, so that

$$\frac{p_{t-1}}{p_t} = [1+(r_t-\delta)(1-\tau_{kt})] \tag{3}$$

for $t \geq 1$, with the initial value of the stand-in household's capital being $p_0[1+(r-\delta)(1-\tau_{k0})]N_0 k_0$. The marginal conditions for consumption imply $\frac{p_{t-1}}{p_t} = \frac{c_t}{\beta c_{t-1}}$. In a steady state, $c_t = \gamma c_{t-1}$, so that $\frac{p_{t-1}}{p_t} = \frac{\gamma}{\beta}$. Substituting this into (3) and imposing $\tau_{kt} = \tau_k$ gives Prescott's equation (10):

$$r = \delta + \frac{i}{1-\tau_k},$$

where $1+i = \frac{\gamma}{\beta}$ would be the gross interest rate on a tax-free one period bond in this economy.

2.1.2 An altered $h - c/y$ relationship

Prescott's conclusion that cross-country differences in tax wedges account for cross-country differences in hours depends sensitively on how he treats the consumption-output ratio c/y. We follow Prescott (2002) and use the household's first-order conditions with respect to consumption and leisure, and also the constant labor share implied by the Cobb-Douglas production function, to derive an equilibrium relationship between h and c/y:

$$h_t = \left[1 + \frac{\alpha c_t/y_t}{1-\theta}\frac{1+\tau_{ct}}{1-\tau_{ht}}\frac{1}{1-\rho}\right]^{-1}. \tag{4}$$

When $\rho = 0$, this is the same as expression (12) in Prescott (2002, p. 7). Prescott called this an 'equilibrium relationship' because the consumption-output ratio c/y is endogenous.

[4] For example, see Ljungqvist and Sargent (2004b, ch. 11).

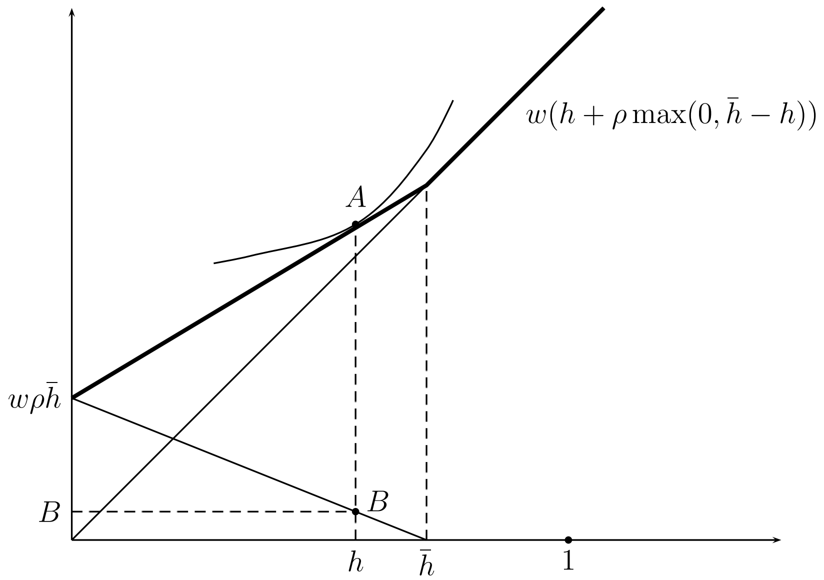


Figure 1: Modification of the budget set in Prescott's model when $\tau_h = 0$. If the family sets $h < \bar{h}$ it receives benefits (B) of $\rho w(\bar{h} - h)$. The tangency at A instructs the family to choose to send a fraction h to work, $\bar{h} - h$ to enjoy leisure and collect benefits, and a fraction $1 - \bar{h}$ to enjoy leisure and not collect benefits. The family enjoys leisure in the amount $1 - h$.

In the spirit of Prescott (2004), we define the *intratemporal tax-benefit wedge* as

$$\frac{1+\tau_{ct}}{1-\tau_{ht}}\frac{1}{1-\rho} \equiv \frac{1}{1-\tau_t}\frac{1}{1-\rho}, \tag{5}$$

which is a product of a benefit rate and Prescott's intratemporal tax wedge $\frac{1}{1-\tau_t} \equiv \frac{1+\tau_{ct}}{1-\tau_{ht}}$, where $\tau_t \equiv \frac{\tau_{ht}+\tau_{ct}}{1+\tau_{ct}}$.

2.2 Why do French people work so much?

We use the same parameter values that underlie Prescott's computations (2002, table 4) to construct our figure 2.[5] We take the United States as the benchmark economy against which to measure the employment effects of taxes and benefits. Setting the effective marginal tax rate equal to 40 per cent for the U.S., Prescott argues that the French effective marginal tax rate is 20 percentage points higher than the American tax rate. Prescott confines himself to the back of figure 2, where the replacement rate is $\rho = 0$. There, a tax rate differential of 20 percentage sends the employment index down to 0.73. Thus, we successfully reproduce Prescott's finding that this tax differential can indeed explain why France is depressed by 30 percent relative to the United States when we suppose along with Prescott that $\rho = 0$.

[5]Prescott's (2002) calibration can be extracted from the numbers reported in his Table 4 together with equilibrium relationship (4). In particular, we can deduce that $\alpha(c_t/y_t)/(1-\theta) \approx 1.65$.

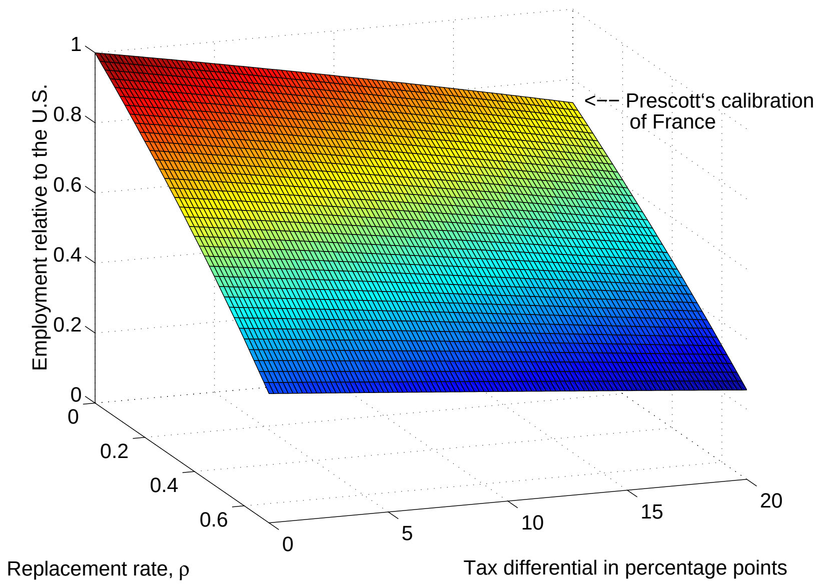


Figure 2: Employment effects of taxation and social insurance in Prescott's (2002) framework. Prescott's calibration of the United States serves as the benchmark economy where the effective marginal tax rate on labor income is 40 per cent and there is no social insurance ($\rho = 0$).

When we move forward from the back of figure 2, we see dramatic effects of publicly provided benefits. At Prescott's calibration of .2 for the French tax wedge differential relative to the U.S., as we raise the social insurance replacement rate ρ above 0, employment plummets. The model sets the employment index equal to 0.55, 0.41, and 0.25 when the replacement rate is equal to 0.30, 0.50, and 0.70, respectively. Of course, the French economy was not depressed by 45, 59 or 75 per cent relative to the United States. With Prescott's calibration of the other parameters, setting the replacement rate ρ to one of the values reported by Martin (1996) makes the puzzle become: why do French people work so much?

2.3 Government expenditures, income effects of taxes, and c/y

Prescott's calibration of c/y is a big part of his supply side story and his treatment of government expenditures determines how he estimates c/y in the $\rho = 0$ version of his workhorse formula (4). Let g denote 'government expenditures' that are not substitutes for private consumption and assume that g is a constant fraction ζ of tax revenues:

$$g = \zeta[\tau_c c + \tau_h w h + \tau_k (r - \delta) k].$$

We assume that the government returns lump sum rebates of $(1 - \zeta)$ times its tax revenues to the stand-in household, which then consumes it in a steady state. The above formula for

g, feasibility, and the formula for the equilibrium capital stock can be combined to yield the following formula for the equilibrium value of c/y:

$$c/y = \frac{(1-\theta)(1-\zeta\tau_h) + \theta(1-\zeta\tau_k)\left(\frac{i}{i+(1-\tau_k)\delta}\right)}{1+\zeta\tau_c}. \tag{6}$$

Under Prescott's preferred value of $\zeta = 0$, this formula simplifies to

$$c/y = (1-\theta) + \theta\left(\frac{i}{i+(1-\tau_k)\delta}\right). \tag{7}$$

Under Prescott's $\zeta = 0$ assumption about government expenditures, (7) makes c/y independent of the intratemporal tax wedge (there remains an effect from capital taxation). But with $\zeta > 0$, formula (6) activates income effects from the intratemporal wedge to c/y that Prescott disables.

Prescott (2002, p. 7) acknowledges that his assumption about c/y substantially affects outcomes:

> "The assumption that the tax revenues are given back to households either as transfers or as goods and services matters. If these revenues are used for some public good or are squandered, private consumption will fall, and the tax wedge will have little consequence for labor supply. If, as I assume, it is used to finance substitutes for private consumption, such as highways, public schools, health care, parks, and police protection, then the c_t/w_t factor will not change when the intratemporal tax factor changes. In this case, changes in this tax factor will have large consequences for labor supply."

Prescott assumes not only that all public expenditures are substitutes for private consumption but also that the government allocates resources as efficiently as when households choose for themselves.

Although the calculations in figure 2 accept Prescott's (2002) assumption that "all [tax] receipts are distributed lump-sum back to the stand-in household," it is worth noting that Prescott (2004) proceeded differently when he studied the time series evidence for the tax explanation of the European employment experience:

> "All tax revenue except for that used to finance the pure public consumption is given back to the households either as transfer payments or in-kind. These transfers are lump sum, being independent of a household's income. Most public expenditure are substitutes for private consumption in the G-7 countries. Here I will assume that they substitute on a one-to-one basis for private consumption with the exception of military expenditures. The goods and services in question consist mostly of publicly provided education, health care, protection services, and even judiciary services. My estimate of pure public consumption g is two times military's share of employment times GDP." Prescott (2004, p. 4)

The cross-country differences in c/y that result from that assumption contribute to the success that Prescott (2004) ascribes to the tax explanation of the European employment experience.

Thus, as described by Ljungqvist (2005), Prescott's (2004, Table 2) time series analysis of the European employment experience rests on variations in *both* the tax wedge *and* the ratio c/y. For example, even in the 1970s, France and Germany had tax wedges 9 and 12 percentage points higher than the United States, respectively. Prescott fits French and German employment levels that are comparable to those in the United States in the 1970s only by plugging in c/y's for the 1970s that were 8 percentage points lower in the two European countries than in the United States. Thus, a significant qualification applies to Prescott's conclusion that "an important observation is that when European and U.S. tax rates were comparable, European and U.S. labor supplies were comparable." We could instead say of the 1970s that while French and German tax rates already exceeded the U.S. rate by about half of the tax differential of 20 percentage points that were later to prevail during the 1990s, Prescott's estimates of low c/y ratios for France and Germany in the 1970s allow the model to fit the outcomes then. If it had not been for those low c/y ratios, the model would have predicted significantly depressed employment levels during the 1970s instead of the observed outcomes in which both countries' employment rates exceeded that in the United States.

2.4 The appeal to an aggregation theory

To justify the high labor supply elasticity that he attributes to the stand-in household, Prescott (2002, p. 4) referred to "some not-so-well-known aggregation theory behind the stand-in household utility function (1) (see Gary D. Hansen, 1985; Richard Rogerson, 1988; Andreas Hornstein and Prescott, 1993)." Hansen (1985) and Rogerson (1988) assume indivisibilities in households' choice sets for labor, like some models to be described in sections 3 and 4. Employment lotteries and complete consumption insurance markets imply a stand-in household that wants to maximize

$$\sum_{t=0}^{\infty} \beta^t N_t \Big[\log(c_t) + \phi_t \alpha \log(1 - \hat{h})\Big], \tag{8}$$

where ϕ_t is a choice variable that represents the fraction of people working and the parameter $\hat{h}$ equals the indivisible number of hours supplied by each worker. This functional form obviously fails to match (1). However, we understand that Prescott's point to be that the aggregation theory underlying (8) justifies his decision to use a value of α in (1) that gives a high labor supply elasticity.

Prescott (2006) assigns the same high importance to the aggregation theory underlying the stand-in household as he does to the aggregation theory behind the aggregate production function. He emphasizes that both types of aggregation divorce essential properties of the aggregated function from the properties of the individual functions being aggregated:[6]

> "Rogerson's aggregation result is every bit as important as the one giving rise to the aggregate production function. In the case of production technology, the nature of the aggregate production function in the empirically interesting cases is very different from that of the individual production units being aggregated. The same is true for the aggregate or a stand-in household's utility function in the empirically interesting case."

2.4.1 Sensitivity of results

We studied how Prescott's (2002) results would be affected were we to adopt the Hansen-Rogerson objective function (8). That preference specification implies the following equilibrium relationship for the fraction of employed households:

$$\phi_t = -\frac{1-\theta}{\alpha \log(1-\hat{h})\, c_t/y_t} \frac{(1-\tau_{ht})(1-\rho)}{1+\tau_{ct}}. \tag{9}$$

Because Prescott (2002) did not provide a complete account of his parameter settings, we also use the reported findings of Prescott (2004) when calibrating the Hansen-Rogerson framework.[7] Our computations indicate that the outcomes associated with preference specifications (1) and (8) are similar. As one would expect, because the Hansen-Rogerson framework has a more elastic labor supply results, increases in the tax wedge lead to larger negative employment effects. But the differences across the two preference specifications are not too big in our general equilibrium analysis. For example, a calculation from (9) that corresponds to Prescott's calibration of France yields an employment effect that is 6.5 percentage points more depressed with the Hansen-Rogerson utility function (8) as compared to Prescott's utility function (1).[8]

2.4.2 Are employment lotteries necessary?

The aggregation theory associated with the employment lotteries model is an important part of the reasoning that leads to Prescott's interpretation of how cross-country differences in

[6]For an alternate view that emphasizes the differences between using lotteries as an aggregation theory for firms versus households, see Ljungqvist and Sargent (2004a).

[7]Prescott (2002) uses a capital-share parameter $\theta = 0.3$ but he reports on neither the parameter α nor the ratio c/y. On the basis of Prescott (2004, Table 2), we proceed here with the value $c/y = 0.75$. We set $\hat{h} = 0.4$ as implied by a work week length of 40 hours and Prescott's (2004) assertion that "on a per person basis a household has about 100 hours of productive time per week." Given these parameter values, we can match the U.S. outcome in Prescott's (2002) Table 4 by choosing the utility of leisure parameter $\alpha = 1.64$. (For comparison, our calibration of $\alpha = 1.64$ for the utility function (8) is almost the same as the Prescott (2004) calibration of $\alpha = 1.54$ in a study using utility function (1).)

[8]Prescott (2002, p. 8) multiplies an average tax rate by 1.6 to obtain a marginal tax rate. That procedure fails to follow the recommendation of Mulligan (2001), who noted that because the social planner is considering variations in the extensive rather than the intensive margin, the average rather than the marginal tax rate is relevant in the Hansen-Rogerson framework.

the intratemporal tax wedge can account for observed differences in employment rates. In the next section, we study employment lotteries in more depth, partly with an eye toward understanding whether the aggregation theory that Prescott appeals to is necessary to justify his approach or whether it would work just as well to use an alternative aggregation theory proposed by Mulligan (2001) that allows each individual to choose alternating spells of work and leisure. As we shall see, the presence or absence of a human capital acquisition technology that features learning by working affects answers to these questions.[9]

3 Lotteries and time averaging

In this section, we show that without human capital, lotteries and time-averaging-with-savings give similar outcomes. In contrast, when work leads to human capital accumulation, lotteries give an allocation that differs from, and in terms of ex ante utility is superior to, the one attained with time averaging

Thus, we study two arrangements that allow an individual to attain a smooth consumption path when he faces the choice of either working or not at each moment. One arrangement was proposed by Hansen (1985) and Rogerson (1988), namely, an employment lottery supplemented with perfect consumption insurance. Another arrangement was discussed by Mulligan (2001) and has an individual alternate among spells of work and leisure and achieve intertemporal consumption smoothing by engaging in risk-free borrowing and lending subject to a 'natural' borrowing constraint.[10] Subsections 3.1, 3.2, and 3.3 describe a basic labor market participation decision, a static lottery model, and an intertemporal smoothing model, respectively, while subsection 3.4 sets forth an intertemporal lotteries model, all in a physical environment purposefully set up so that the only intertemporal tie-ins come from the presence of the employment indivisibility. In particular, in all of these subsections, there is no opportunity to acquire human capital. Although there is an indeterminacy in designing lotteries in the dynamic economy, comparable outcomes can emerge from all of these arrangements.

Subsections 3.5 and 3.6 study the intertemporal smoothing and employment lotteries models in an environment that allows human capital acquisition. Now the outcomes from the two arrangements are very different. Relative to the lotteries arrangement, the isolated-individual intertemporal smoothing model gives worse allocations: depending on parameter values, an individual works either too much or too little. The human capital acquisition technology confronts the planner with a 'mother of all indivisibilities' and, if lotteries are available, causes the planner to preside over a dual labor market in which some people specialize in work and others in leisure. This outcome mimics a stylized version of Europe in the sense that a significant fraction of workers seem have withdrawn from labor market activity permanently or at least for long spells. (However, please wait until after section 8

[9]Shaw (1989) and Imai and Keane (2004) are good examples of studies with econometric estimates of technologies by which work now builds human capital later.

[10]The natural borrowing constraint is weak enough to make the loan market perfect. See Aiyagari (1994) and Ljungqvist and Sargent (2004b) for discussions of the natural borrowing constraint.

to decide whether such 'careers' of specializing in leisure can be thought of as being carried on at government expense as many of them seem to be in Europe.)

3.1 A static participation decision model

As a warmup, consider a setting in which a person chooses $c \geq 0$ and $n \in \{0, 1\}$ to maximize

$$u(c) - v(n) \tag{10}$$

subject to $c \leq wn$ where u is strictly concave, increasing, and twice continuously differentiable and v is increasing, and, by a normalization, satisfies $v(0) = 0$. The following equation determines a reservation wage $\bar{w}$:

$$u(0) - v(0) = u(\bar{w}) - v(1).$$

A person chooses to work if and only if $w \geq \bar{w}$.

In this and all the other models with indivisible labor that we present below, the only pertinent features of the function v are $v(0)$ and $v(1)$. The curvature of v is irrelevant. However, the curvature of u will be important.

3.2 A static lotteries model

Each of a continuum of ex ante identical workers indexed by $j \in [0, 1]$ has preferences ordered by (10). A planner (or stand-in household) chooses an employment, consumption plan that respects $n^j \in \{0, 1\}$ and that maximizes

$$\int_0^1 [u(c^j) - v(n^j)]dj = \int_0^1 u(c^j)dj - v(1) \int_0^1 n^j dj \tag{11}$$

subject to

$$\int_0^1 c^j dj \leq \int_0^1 n^j dj.$$

The planner assigns consumption $\bar{c}$ to each individual j and administers a lottery that exposes each individual j to an identical probability $\phi = \int_0^1 n_j dj$ of working. Letting $B = v(1)$, the planner chooses $(\bar{c}, \phi)$ to maximize

$$u(\bar{c}) - B\phi$$

subject to $\bar{c} = w\phi$, a problem whose solution satisfies the first-order condition

$$u'(\phi w) = B/w \tag{12}$$

that evidently determines the fraction ϕ of people working as a function of the wage w, the utility of consumption $u(\cdot)$, and the disutility of work. Ex post, the utility of those who work is $u(\bar{c}) - v(1)$ and of those who do not is $u(\bar{c}) - v(0)$. Thus, the winners of the employment lottery are assigned to leisure.

From now on, we let $u(c) = \ln c$ to simplify some formulas.

3.3 An individual time averaging model

Mulligan (2001) pointed out that the passage of time and the opportunity to borrow and lend can facilitate outcomes similar to those supported by the social arrangements of an employment lottery plus complete consumption insurance. The idea is that with enough time, averaging over time can replace the lottery.[11] We guarantee that there is enough time by making time continuous.

A worker chooses $c_t, n_t, t \in [0,1]$, $c_t \geq 0, n_t \in \{0,1\}$ to maximize

$$\int_0^1 e^{-\delta t}[\ln c_t - Bn_t]dt \tag{13}$$

subject to

$$\int_0^1 e^{-rt}(wn_t - c_t)dt \geq 0 \tag{14}$$

where $\delta \geq 0$ and $r \geq 0$. We focus on the case $r = \delta$. The solution of this problem has consumption identical with the level (12) that emerges in the static lotteries problem, namely,

$$c_t = \bar{c} = w/B, \tag{15}$$

and makes the present value of the individual's labor supply over $[0,1]$ satisfy:

$$w\int_0^1 e^{-rt}n_t dt = \bar{c}\int_0^1 e^{-rt}dt. \tag{16}$$

The right side is the present value of consumption. The left side, the present value of wages, restricts the present value of time spent working, $\int_0^1 e^{-rt}n(t)dt$, but leaves its allocation over time indeterminate. Thus, the individual is indifferent between working steadily for the first ϕ moments and working steadily for the last β moments, provided that ϕ and β satisfy

$$\left[e^{-\phi r} - 1\right]/r = [e^{-r} - e^{-\beta r}]/r.$$

Of course, many other employment patterns also work, including ones that "chatter" by having the worker rapidly move back and forth between employment and leisure.[12]

3.4 A lotteries plus time averaging model

Now consider a continuum $j \in [0,1]$ of ex ante identical workers like those in subsection (3.3). A planner chooses a consumption and employment allocation $c_t^j \geq 0$, $n_t^j \in \{0,1\}$ to maximize

$$\int_0^1\int_0^1 e^{-\delta t}[\ln c_t^j - Bn_t^j]dt\,dj \tag{17}$$

[11]The individual time-averaging models in the following subsections can be viewed as adaptations of a model of occupational choice by Nosal and Rupert (2005).

[12]Nosal and Rupert (2005) study cases in which $r \neq \delta$ so that consumption and working schedules are tilted toward either the beginning or the end of the interval $[0,1]$.

subject to

$$\int_0^1 e^{-rt}\left[\int_0^1 c_t^j dj - w\int_0^1 n_t^j dj\right] dt = 0. \tag{18}$$

Thus, the planner can borrow and lend at an instantaneous rate r. We again assume that $r = \delta$. The planner solves this problem by setting $c_t^j = \bar{c}_t$ for all $j \in [0,1]$, by setting $\phi_t = \int_0^1 n_t^j dj$, exposing each household at time t to a lottery that sends him to work with probability ϕ_t, and choosing $\bar{c}_t$ and ϕ_t to maximize

$$\int_0^1 e^{-rt}[\ln \bar{c}_t - B\phi_t]dt \tag{19}$$

subject to

$$\int_0^1 e^{-rt}[w\phi_t - \bar{c}_t]dt \geq 0. \tag{20}$$

This problem is obviously equivalent to problem (13)-(14). It follows that there are many intertemporal lottery patterns that support the optimal consumption allocation $c_t^j = w/B$. Only the present value of time spent working is determined. Among the alternative types of lotteries that work are these:

1. *One lottery before time* 0*:* Before time 0, the planner can randomize over a constant fraction of people $\bar{\phi}$ who are assigned to work for every $t \in [0,1]$, and a fraction $1-\bar{\phi}$ who are asked to specialize in leisure, where $\bar{\phi}$ is chosen to satisfy the planner's intertemporal budget constraint (20).

2. *A lottery at each* t*:* At each time $t \in [0,1]$, the planner can run a lottery that sends a time invariant fraction $\bar{\phi}$ to work and a fraction $1-\bar{\phi}$ to leisure at instant t.

3. *Another lottery at each* t*:* At each time $t \in [0,1]$, the planner can run a lottery that sends a fraction ϕ_t to work and $1-\phi_t$ to leisure at instant t, where ϕ_t is free to be any function that satisfies the planner's intertemporal budget constraint (20). Only the present value of ϕ_t is determined.

The indeterminacy among such lotteries evaporates in the next section when by adding human capital we confront people with career choices.

3.5 Time averaging with human capital

We return to an isolated consumer who copes with the instantaneous labor supply indivisibility by borrowing and lending. We alter the consumer's choice set in the model of subsection 3.3 by adding a very simple technology that describes how work experience promotes the accumulation of human capital. Where $\bar{h} \in (0,1)$, the household's budget constraint is now

$$\int_0^1 e^{-rt}[w\psi(h_t)n_t - c_t]dt \geq 0 \tag{21}$$

where

$$h_t = \int_0^t n_s ds \tag{22}$$

$$\psi(h) = \begin{cases} 1 & \text{if } h_t < \bar{h}, \\ H > 1 & \text{if } h_t \geq \bar{h}. \end{cases} \tag{23}$$

Two solutions interest us:

- A corner solution in which $(\bar{h}, B, H)$ are such that the person chooses to set $\int_0^1 n_t dt < \bar{h}$. In this case, the model becomes equivalent with the model of subsection 3.3. The individual chooses to set

  $$\bar{c} = wB^{-1} \tag{24}$$

  and to work a present value of time at a low skilled wage that is sufficient to support this constant level of consumption.

- An interior solution for which $(\bar{h}, B, H)$ are such that the household chooses to set $\bar{h} < \int_0^1 n_t dt < 1$; i.e., the household chooses to become high skilled but also to enjoy some leisure. In such an interior solution, consumption $c_t = \bar{c}$ will satisfy[13]

  $$\bar{c} = wHB^{-1}. \tag{25}$$

  Time spent working when unskilled and skilled satisfy

  $$\bar{c} \int_0^1 e^{-rt} dt = w \left[\int_0^1 e^{-rt} n_t^L dt + H \int_0^1 e^{-rt} n_t^H dt \right] \tag{26}$$

  where

  $$n_t^L = \begin{cases} 1 & \text{if } n_t = 1 \text{ and } h_t < \bar{h}, \\ 0 & \text{otherwise} \end{cases} \tag{27}$$

  and

  $$n_t^H = \begin{cases} 1 & \text{if } n_t = 1 \text{ and } h_t \geq \bar{h}, \\ 0 & \text{otherwise.} \end{cases} \tag{28}$$

  The first term on the right side of (26) is the marginal product of a low productivity person times the present value of the time that a worker works when unskilled. The

[13]The individual's first-order conditions for labor choice can be expressed as $-B + w\psi(h_t) + \theta_t > 0$ or < 0 or $= 1$ if $n_t = 1$ or $n_t = 0$ or he is indifferent between working and taking leisure, respectively, and where the Lagrange multiplier θ_t obeys the generalized differential equation $\frac{d}{dt}\theta = -w\psi'(h_t)n_t + \theta_t\delta$, where $\psi'(h_t)$ is the generalized derivative of ψ. (The generalized derivative of g is the delta function $-w(H-1)\delta_D(h - \bar{h})$, where δ_D is the Dirac delta generalized function.) At our interior solution in which the worker chooses eventually to become skilled, $\theta_0 > 0$ and θ_t rises over time at a constant geometric rate δ until $\bar{h}$, then jumps once and for all to zero. The multiplier θ_t is a (current value) component of the worker's indirect utility contributed by accumulating human capital at date t.

second term is the marginal product of a high productivity person times the present value of working time when skilled.

Backloading: When $r = \delta > 0$ and $(\bar{h}, B, H)$ call for a solution that is interior in the sense that $1 > \int_0^1 n_t dt > \bar{h}$, the problem of maximizing (13) subject to (21) and (22) has the following solution. There exists an s that solves

$$\bar{c} \int_0^1 e^{-rt} dt = w \left[\int_s^{s+h} e^{-rt} dt + H \int_{s+h}^1 e^{-rt} dt \right]$$

and such that the household sets $n_t = 0$ for $t < s$ and $n_t = 1$ for $t \geq s$. Thus, the household 'back loads' all of its work and takes leisure early. To understand why this is the solution, consider the disutility of work associated with this solution:

$$\bar{B} = B \int_s^1 e^{-rt} dt. \tag{29}$$

Starting from this allocation, consider a perturbation in which the household puts in some labor earlier and takes some leisure later, but keeps the disutility of labor fixed at $\bar{B}$. Because of discounting, such a shift allows the household to work less total time over the interval $[0, 1]$ (i.e., $\int_0^1 n_t dt$ would be smaller), but involves working a smaller *proportion* of its time as a high skill worker. That would lower the present value of income associated with a given disutility of labor and so is suboptimal.

3.6 Lotteries with human capital

Now suppose that a planner designs a consumption sharing plan and an intertemporal employment lottery to maximize (17) subject to

$$\int_0^1 e^{-rt} \int_0^1 [w\psi(h_t^j) n_t^j - c_t^j] dj \ dt \geq 0 \tag{30}$$

where each household j has the skill accumulation technology described in subsection 3.5.

A perturbation argument leads to the conclusion that the planner administers a life-time employment lottery once and for all before time 0 and assigns a fraction ϕ of people to work always ($n_t^j = 1$ for all $t \in [0, 1]$ for these unlucky people) and a fraction $1 - \phi$ always to enjoy leisure ($n_t^j = 0$ for all $t \in [0, 1]$ for these lucky ones).[14] The planner's problem then becomes to choose $\bar{c}$ and $\phi \in [0, 1]$ to maximize

$$(\ln \bar{c} - B\phi) \int_0^1 e^{-\delta t} dt$$

[14]Consider a perturbation that deviates from this allocation by taking any positive measure of the workers and letting them enjoy a small positive measure of leisure, then making up the deficiency in output by assigning some of those specializing in leisure to work. It can be verified that this perturbation increases the ex ante disutility of work component of (17).

subject to

$$\phi w \left[\int_0^{\bar{h}} e^{-rt} dt + H \int_{\bar{h}}^1 e^{-rt} dt \right] \geq \bar{c} \int_0^1 e^{-rt} dt.$$

An interior solution sets ϕ to satisfy

$$\bar{c}[1 - e^{-r}]/r = \phi w \left[\int_0^{\bar{h}} e^{-rt} dt + H \int_{\bar{h}}^1 e^{-rt} dt \right]. \tag{31}$$

Consumption $\bar{c}$ satisfies

$$\bar{c} = w \left(B \int_0^1 e^{-rt} \right)^{-1} \left[\int_0^{\bar{h}} e^{-rt} dt + H \int_{\bar{h}}^1 e^{-rt} dt \right]. \tag{32}$$

3.6.1 Comparison of outcomes

In the individual time averaging model of subsection 3.5, when $(\bar{h}, B, H)$ are such that the household chooses the corner solution $\int_0^1 n_t dt < \bar{h}$ (i.e., he chooses not to acquire skills), consumption given by (24) is less than given in formula (32) for the lotteries economy. But when $(\bar{h}, B, H)$ are such that the household chooses an interior solution $\int_0^1 n_t > \bar{h}$ (i.e., he chooses to acquire skills), his consumption level under time-averaging (25) exceeds that attained in (32) under lotteries. It follows that in the model with human capital, lotteries significantly change allocations relative to the individual time averaging model. In the presence of human capital, the lottery model achieves an allocation with a higher ex ante utility than can be attained by having the individual alternate between work and leisure and smooth consumption by borrowing and lending. It does so by convexifying a 'mother of all indivisibilities', the decision to acquire skills over individual lifetimes.

4 A two skill level, two age class general equilibrium model of careers

We alter the partial equilibrium models of sections 3.5 and 3.6 so that they become general equilibrium models in which people have careers. In addition to introducing a production technology that employs labor and capital, we embellish households' optimization problems by assuming stochastic skill accumulation and stochastic aging. Workers move stochastically through two skill levels and two age classes, young and old, then retire to face uncertainty about their longevity.

4.1 The environment

A continuum of agents on the unit interval are divided into three age classes: young workers $(x = 1)$, old workers $(x = 2)$, and retirees $(x = 3)$. An agent faces a probability $\chi(x, x')$ that his age class is x' at the beginning of next period, conditional on currently belonging to age class x. Agents who die are replaced by newborn workers, keeping the total population and the shares of age classes constant over time.

Agents experience stochastic accumulation or deterioration of skills conditional on employment status. There are two possible skill levels indexed by $h \in \{1, H\}$, where $h = 1$ denotes the low skill level normalized to one, and $h = H$ denotes the high skill level where $H > 1$. All newborn agents enter the economy with the low skill level. An employed (nonemployed) agent with skill level h faces a probability $p^n(h, h')$ ($p^u(h, h')$) that his skill level at the beginning of next period is h'.

Preferences are ordered by

$$E_0 \sum_{t=0}^{\infty} \beta^t (1 - o_t)^t \left[\log c_t - B n_t + D \frac{(1 - s_t)^\gamma - 1}{\gamma} \right], \qquad \text{with } B, D > 0, \;\; \gamma > -1, \tag{33}$$

where $(1-o_t)$ is a survival probability that depends on the agent's age class; c_t is consumption; n_t equals one if the agent is working and equals zero otherwise; and $s_t \in [0, 1)$ is the agent's choice of search intensity if nonemployed and of working age. The search intensity s_t determines a nonemployed agent's probability s_t^ξ of finding a centralized labor market in the next period, where $0 \leq \xi \leq 1$.[15]

Aggregate production obeys

$$F(K_t, L_t) = K_t^\theta L_t^{1-\theta}, \qquad \text{with } \theta \in (0, 1), \tag{34}$$

where K_t is the aggregate capital stock that depreciates at the rate δ, and L_t is the measure of employed agents weighted by their skill levels. Output can be devoted to consumption and investment in physical capital.

Labor income is taxed at a flat tax rate τ_h. The government wastes a fraction $\zeta \in [0, 1]$ of the tax revenues, and hands back the remaining fraction $(1 - \zeta)$ as lump-sum transfers to the agents. Let ϵ and ϵ_r denote the per-capita lump-sum transfer to persons of working age and of retired age, respectively.

4.2 Incomplete-markets economy

4.2.1 Household's problem

In the incomplete-market economy, the only vehicle for savings is a risk-free claim on capital. Agents are subject to a non-negativity constraint on their asset holdings,[16] and any accidental

[15]The search technology and the disutility of searching are taken from Alvarez and Veracierto (2001). Our motivation for including search is a computational one for the incomplete-market economy. Search removes chattering as an optimal behavior, which otherwise would have imposed higher demands on the fineness of the asset grid to ensure numerical accuracy. In the case of the complete-market model, search is better omitted from the analysis. (See footnote 17).

[16]Thus, we tighten the borrowing constraint relative to the natural borrowing constraint mentioned in footnote 10.

bequests from deceased agents are collected by the government and returned lump sum to the living. We include these bequests in the above transfer scheme $\{\epsilon, \epsilon_r\}$, in the same proportions as the lump-sum return of tax revenues.

We define three value functions $V^n(x,a,h)$, $V^u(x,a,h)$, and $V^r(a)$ for an employed agent, a nonemployed agent, and a retired agent, respectively. The state variables are age (x), last period's assets (a), and skill level (h). The value function for an employed agent is

$$V^n(x,a,h) \;=\; \max_{c,a'}\left[\log c - B + \beta \sum_{x'} \chi\,(x,x')\, V^{n+}(x',a',h)\right], \tag{35}$$

where

$$V^{n+}(x',a',h) = \begin{cases} V^r(a')\,, & \text{if } x'=3; \\ \sum_{h'} p^n(h,h') \max\Big\{V^n(x',a',h')\,,\, V^u(x',a',h')\Big\} & \text{otherwise;} \end{cases} \tag{36}$$

subject to

$$\begin{aligned} c + a' &\;\le\; (1+i)\,a + (1-\tau_h)\,h\,w + \epsilon\,, \\ c,\, a' &\;\ge\; 0\,, \end{aligned}$$

where i is net real interest rate on savings and w is the wage rate per unit of skill. Policy functions $\bar{c}^n(x,a,h)$ and $\bar{a}^n(x,a,h)$ give optimal levels of consumption and savings, respectively. The solution of maximum problem (36) can be expressed in terms of an indicator function:

$$\bar{n}\,(x',a',h') = \begin{cases} 1, & \text{if } V^n(x',a',h') \ge V^u(x',a',h')\,; \\ 0, & \text{otherwise,} \end{cases} \tag{37}$$

where $\bar{n}\,(x',a',h')$ indicates whether a worker finds it optimal to keep a job ($\bar{n}=1$) or to quit ($\bar{n}=0$).

The value function for a nonemployed agent is

$$V^u(x,a,h) \;=\; \max_{c,a',s}\left[\log c + A\frac{(1-s)^\gamma - 1}{\gamma} + \beta \sum_{x'} \chi\,(x,x')\, V^{u+}(x',a',h)\right], \tag{38}$$

where

$$V^{u+}(x',a',h) = \begin{cases} V^r(a')\,, & \text{if } x'=3; \\ \sum_{h'} p^u(h,h') \Big[s^\xi \max\Big\{V^n(x',a',h')\,,\, V^u(x',a',h')\Big\} & \\ \qquad\qquad + \big(1-s^\xi\big)\, V^u(x',a',h')\Big] & \text{otherwise;} \end{cases} \tag{39}$$

subject to

$$\begin{aligned} c + a' &\;\le\; (1+i)\,a + \epsilon\,, \\ c,\, a' &\;\ge\; 0 \quad \text{and} \quad s \;\in\; [0,1)\,. \end{aligned}$$

Three policy functions $\bar{c}^u(x,a,h)$, $\bar{a}^u(x,a,h)$, and $\bar{s}\,(x,a,h)$ describe optimal levels of consumption, savings, and search effort, respectively. The solution of the maximization problem in expression (39) is given by an indicator function $\bar{n}\,(x',a',h')$, as defined in (37).

The value function for a retired agent is

$$V^r(a) = \max_{c,a'} \Big[\log c + \beta\,\chi(3,3)\,V^r(a') \Big] \tag{40}$$

subject to

$$\begin{aligned} c + a' &\leq (1+i)\,a + \epsilon_r\,, \\ c,\, a' &\geq 0\,. \end{aligned}$$

Two policy functions $\bar{c}^r(a)$ and $\bar{a}^r(a)$ give optimal consumption and savings, respectively.

4.2.2 Firm's problem

The production side of the economy is the same as in a standard growth model. Steady-state prices satisfy

$$i = \frac{\partial F(K,L)}{\partial K} - \delta, \tag{41}$$

$$w = \frac{\partial F(K,L)}{\partial L}. \tag{42}$$

4.2.3 Steady state

Time-invariant measures $y^n(x,a,h)$, $y^u(x,a,h)$ and $y^r(a)$ describe, respectively, the cross-sectional distribution of employed, nonemployed, and retired households across individual states. These measures are implied by the optimal decision rules:

$$\begin{aligned} y^n(x',a',h') = \sum_x \chi(x,x') \Bigg[&\sum_{a,h:\bar{a}^n(x,a,h)=a'} p^n(h,h')\,y^n(x,a,h)\,\bar{n}\,(x',a',h') \\ &+ \sum_{a,h:\bar{a}^u(x,a,h)=a'} p^u(h,h')\,\bar{s}(x,a,h)^{\xi}\,y^u(x,a,h)\,\bar{n}\,(x',a',h') \Bigg], \end{aligned} \tag{43}$$

$$\begin{aligned} y^u(x',a',h') = \sum_x \chi(x,x') \Bigg\{ &\sum_{a,h:\bar{a}^n(x,a,h)=a'} p^n(h,h')\,y^n(x,a,h)\,\Big[1-\bar{n}\,(x',a',h')\Big] \\ &+ \sum_{a,h:\bar{a}^u(x,a,h)=a'} p^u(h,h')\,y^u(x,a,h)\,\Big[1-\bar{s}\,(x,a,h)^{\xi}\,\bar{n}\,(x',a',h')\Big] \Bigg\} \\ &+ I(x',a',h')\;(1-\chi(3,3)) \sum_a y^r(a)\;, \end{aligned} \tag{44}$$

where $I(x', a', h')$ is an indicator function that is equal to one if $x' = 1$ and $a' = h' = 0$ and is equal to zero otherwise;

$$\begin{aligned} y^r(a') &= \chi(3,3) \sum_{a:\bar{a}^r(a)=a'} y^r(a) \\ &\quad + \chi(2,3) \Bigg[\sum_{a,h:\bar{a}^n(2,a,h)=a'} y^n(2,a,h) + \sum_{a,h:\bar{a}^u(2,a,h)=a'} y^u(2,a,h) \Bigg]. \end{aligned} \tag{45}$$

The market-clearing condition in the goods market is

$$C + \delta K + G = F(K, L), \tag{46}$$

where C, K, L and G are aggregate consumption, the aggregate capital stock, the aggregate labor supply in skill units, and government tax revenues that are wasted, respectively, as given by

$$C = \sum_{x,a,h} \Big[\bar{c}^n(x,a,h)\, y^n(x,a,h) + \bar{c}^u(x,a,h)\, y^u(x,a,h) \Big] + \sum_a \bar{c}^r(a)\, y^r(a), \tag{47}$$

$$K = \sum_{x,a,h} a \Big[y^n(x,a,h) + y^u(x,a,h) \Big] + \sum_a a\, y^r(a), \tag{48}$$

$$L = \sum_{x,a,h} h\, y^n(x,a,h), \tag{49}$$

$$G = \zeta\, \tau_h\, w\, L. \tag{50}$$

As stated earlier, the government wastes a fraction $\zeta \in [0, 1]$ of the tax revenues, as given by expression (50), and returns the other fraction $(1 - \zeta)$ together with accidental bequests as lump-sum transfers to the agents. Since we restrict attention to steady-state equilibria without government debt, the government satisfies the stationary budget constraint:

$$(1-\zeta)\tau_h\, w\, L + (1 - \chi(3,3)) \sum_{a'} (1+i)a' \sum_{a:\bar{a}^r(a)=a'} y^r(a) = \epsilon(1-M) + \epsilon_r M \tag{51}$$

where M is the fraction of the population that is retired, $M = \sum_a y^r(a)$.

4.3 Complete-market economy

To convert the incomplete-market economy into a version of Prescott's stand-in household model, we assume that agents belong to dynastic lineages. Though subject to the fragility of life through stochastic aging, each agent *de facto* has an infinite horizon because he cares about his offspring and the survival probability of his lineage is one. We represent the complete-market economy as a stand-in household that consists of a continuum of such lineages indexed on the unit interval. In a steady state, the age distribution of the household's members is the same as the stationary age distribution in the aggregate economy.

The stand-in household's utility function over consumption and the work of all of its lineage members is

$$\int_0^1 \sum_{t=0}^{\infty} \beta^t \Big[\log c_t^j - B n_t^j\Big] dj \,, \tag{52}$$

where c_t^j is lineage j's consumption at time t and n_t^j equals one if the current member of lineage j is working and equals zero otherwise. Compared to utility function (33), the survival probability is set equal to one, as we have explained, and the term for the disutility of searching is omitted (and so is the search technology). Our reason for omitting search is purely for simplicity and it is inconsequential for our numerical analysis.[17]

Leaving the employment lottery design aside, the stand-in household chooses measures of employed workers within age and skill groups. Let N_{xht} be the measure of agents of age $x \in \{1 \text{ (young)}, 2 \text{ (old)}\}$ and skill level $h \in \{1 \text{ (low)}, H \text{ (high)}\}$ who are employed in period t. Analogously, let X_{xht} denote the total measure of the household's population belonging that age and skill group in period t, and let X_{3t} be the measure of retirees in period t. Given the additively separable disutility of working, the optimal consumption allocation has all agents consuming the same amount, c_t. The stand-in household's optimization problem can then be formulated as:

$$\max_{\{c_t, a_{t+1}, \{N_{xht}\}_{xh}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \Big[\log c_t - B\Big(N_{11t} + N_{1Ht} + N_{21t} + N_{2Ht}\Big)\Big] \tag{53}$$

subject to

$$c_t + a_{t+1} \;\leq\; (1+i_t)a_t + (1-\tau_{ht})w_t\Big[N_{11t} + N_{21t} + H\big(N_{1Ht} + N_{2Ht}\big)\Big], \tag{54}$$

$$N_{xht} \;\leq\; X_{xht}, \tag{55}$$

and laws of motion for age and skill groups X_{xht}; $x \in \{1,2\}$, $h \in \{1,H\}$, and $t \geq 0$.

The solution to this problem and the characterization of a steady state are relegated to the appendix. The economy is a version of the representative family model analyzed by Ljungqvist and Sargent (2005a).

4.4 Calibration

We set the model period to one quarter. We set the discount factor $\beta = 0.99$, making the annual interest rate in the complete-market economy 4.1 percent. There are two working age classes with probabilities of remaining within an age class equal to $\chi(1,1) = 0.99$ for the

[17] In the complete-market model, a search cost would remove some indeterminacies in the design of lotteries by ruling out lotteries that involve switching the identities of employed workers within a given skill and age group. By avoiding unnecessary churning among the employed, total search costs are kept to a minimum. And given our calibration of the search technology and the disutility of searching, the households' total search costs would be minuscule and any computed equilibrium with search would not be discernibly different from our computed equilibria without search.

first age class and $\chi(2,2) = 0.9833$ for the second age class. The time spent in an age class is geometrically distributed with an expected duration of 25 years in the first age class (young workers) and 15 years in the second age class (old workers). The probability that a retired agent remains in that state is $\chi(3,3) = 0.9875$, making the expected duration of retirement 20 years. Hence, on average agents spend 2/3 of their adult life in the labor force and 1/3 in retirement.

There is a constant-returns-to-scale Cobb-Douglas technology with capital share parameter $\theta = 0.333$. The quarterly depreciation rate is $\delta = .02$. The curvature of the search technology and the disutility of searching are taken from Alvarez and Veracierto (2001), who specify $\xi = 0.98$ and $\gamma = 0.98$, respectively, making these close to linear.

There are two skill levels. The high skill level is twice the low skill level, $H = 2$. All newborn agents start with the low skill level that we normalize to 1. Agents gains skills by working. After each period of employment, workers at the low skill level transition to the high skill level with probability $p^n(1, H) = 0.0125$, making the expected time to become a high-skilled worker 20 years.[18] Employed workers who have reached the high skill level retain those skills until they become nonemployed. In the benchmark parameterization, all workers who choose nonemployment revert to the low skill level, $p^u(H, 1) = 1$. (Under the opposite assumption of no skill loss, we show, surprisingly enough, that the effects of taxation are almost unchanged in the relevant range of tax rates.)

In the benchmark parameterization, the government hands back all tax revenues as equal per-capita lump-sum transfers to the agents. In the incomplete-market economy, these transfers also include accidental bequests from retired agents who have died with positive amounts of assets.

We set the disutility of working $B = 1$. This value implies that at tax rates below 3.8 percent all agents are employed throughout their working age in the complete-market economy. In the incomplete-market economy, we also scale the disutility of search as $D = B$. This means that a nonemployed worker who exerts maximum search effort incurs the same disutility as someone working.

5 Career choices: who are the nonemployed?

5.1 Complete-market economy

The stand-in household efficiently assigns work and leisure, using an individual's history of skill and age realizations to determine his future activities. (See the appendix for details.) Low amounts of leisure in a steady state are best generated by allocating old workers with low skills to nonemployment. Even though both old and young workers with low skills have the same ability to become high-skilled workers, old workers have a shorter expected time horizon to retirement. That makes young agents a better repository for skill accumulation.

[18]We thank Dan Hamermesh for conversations about his data explorations of wage-experience profiles. Our assumption that work experience alone can double a worker's earnings seems to line up well with data for full-time male workers in the U.S. manufacturing industry.

After all old workers with low skills have been assigned to nonemployment, the stand-in household generates any additional amount of leisure by furloughing some young agents with low skills into nonemployment.

We begin by assuming along with Prescott (2002) that the government rebates all of its tax collections as described above. The optimal division between work and leisure is illustrated in table 1, where the stand-in household's total nonemployment is increasing in the labor tax rate. The upper dashed line in figure 3 depicts the aggregate nonemployment rate in the complete-market economy as a function of the labor tax rate. The first upward-sloping segment describes how the stand-in household furloughs old agents with low skills into nonemployment, while the second upward-sloping segment entails assigning young agents with low skills to nonemployment because all old agents with low skills are already nonemployed.

The plateau between the two upward-sloping segments of the upper dashed line in figure 3 reflects a corner solution in the stand-in household's optimization problem. At the labor tax rate $\tau_h = 0.17$, the marginal condition for assigning an old agent with low skills to specialize in leisure holds with equality when the household assigns everyone in that category to enjoy leisure. Since that marginal condition holds with equality, it follows that the household's first-order condition for letting a young agent with low skills enjoy leisure is a strict inequality (because of the higher expected return of skill accumulation for young agents as compared to old agents). Thus, at the labor tax rate $\tau_h = 0.17$, the household strictly prefers to send all young agents with low skills to the labor market. The stand-in household does not want to exchange the future earnings potential of a young worker for the additional leisure that person can generate. However, as the labor tax is raised further, it will eventually reach a point where the stand-in household's first-order condition with respect to the career choice of a young agent with low skills holds with equality. That point occurs at the tax rate $\tau = 0.26$ in figure 3. After that point, further tax increases prompt the stand-in household to furlough more and more young agents with low skills into nonemployment.

As in Ljungqvist and Sargent (2005a), workers who have attained the high skill level are destined to work until retirement. Depending on their luck in the employment lottery, agents with the same *ex ante* expected life-time utility find themselves assigned to different career paths. Given the additively separable disutility of working, all agents consume the same amount regardless of their age, skill, and employment status.

5.2 Incomplete-market economy

To study the allocation of leisure in the incomplete-market economy, we examine the optimal decision rules as functions of age, skill level and asset holdings. Figure 4 shows decision rules of young agents in panels (a) and (b), and of old agents in panels (c) and (d). For a given age and skill level, a panel depicts decision rules as functions of the agent's asset holdings. The figure refers to an equilibrium with zero labor taxation. (For data on aggregate equilibrium outcomes in the incomplete-market economy with zero labor taxation, see the leftmost column in tables 1 and 2.)

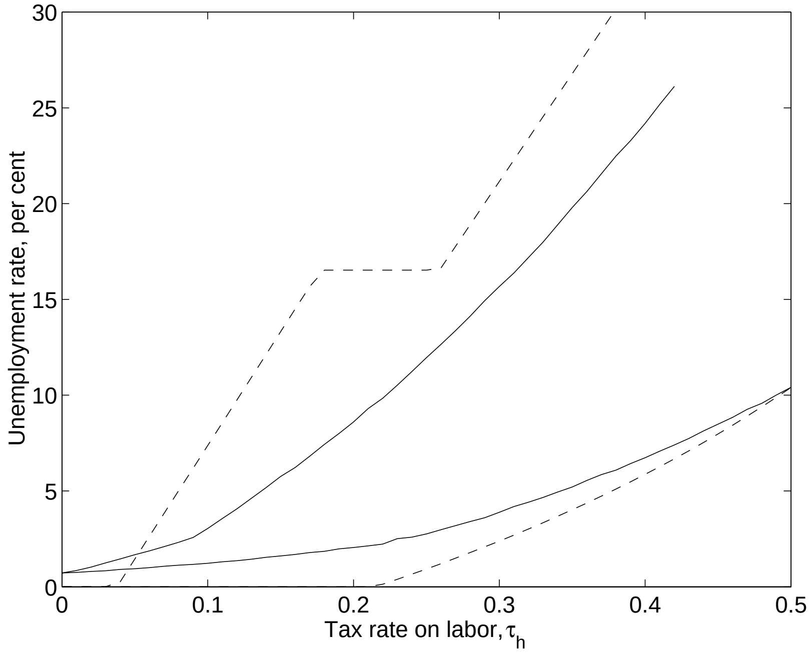
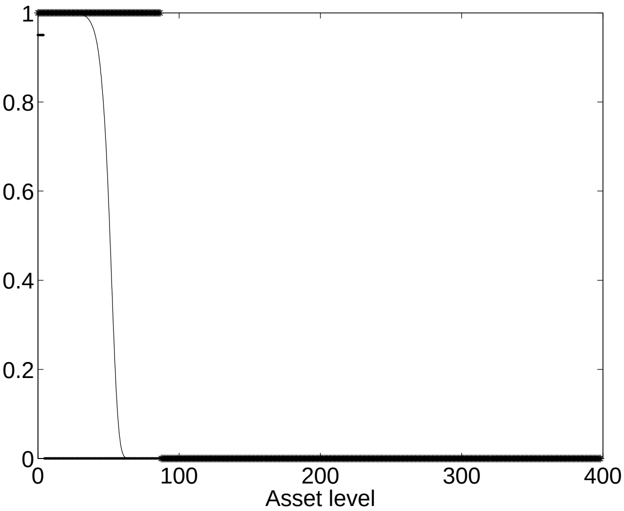


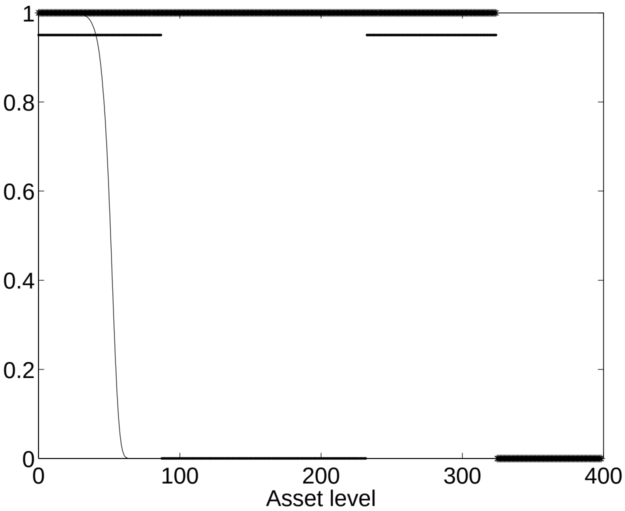
Figure 3: Unemployment effects of taxation with and without lump-sum transfers. The solid (dashed) lines refer to the incomplete-market (complete-market) economy. For each economy, the upper line depicts equilibrium outcomes when tax revenues are returned as lump-sum transfers to the households, while the lower line depicts equilibrium outcomes when tax revenues finance government expenditures that are not substitutes for private consumption.

	Labor tax rate, τ_h				
	0	0.10	0.20	0.30	0.40
Young, $h = 1$	0.6 (0.0)	0.6 (0.0)	0.6 (0.0)	0.6 (3.5)	0.6 (11.9)
Young, $h = H$	0.0 (0.0)	0.2 (0.0)	2.3 (0.0)	5.2 (0.0)	8.7 (0.0)
Old, $h = 1$	0.0 (0.0)	0.0 (7.4)	0.1 (16.5)	0.7 (17.7)	2.4 (20.5)
Old, $h = H$	0.1 (0.0)	2.3 (0.0)	5.6 (0.0)	9.1 (0.0)	12.5 (0.0)
Total	0.7 (0.0)	3.1 (7.4)	8.6 (16.5)	15.6 (21.2)	24.2 (32.4)

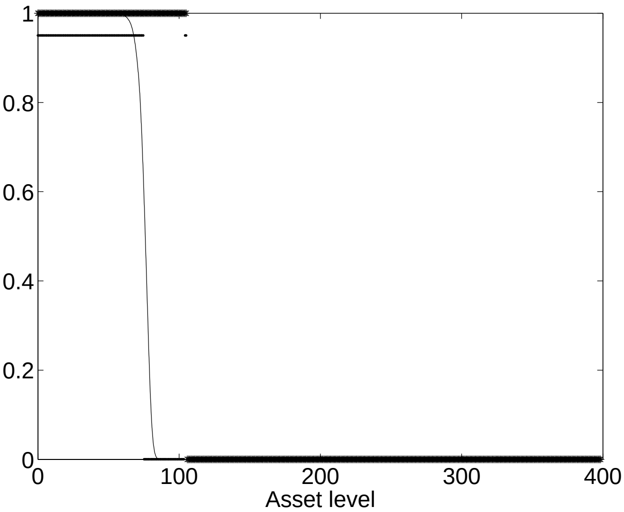
Table 1: Unemployment rates in percent, expressed in terms of the labor force for different age groups, conditional on whether the agents have ever experienced the high skill level ($h = H$) or only the low skill level ($h = 1$). The numbers without (within) parentheses refer to the incomplete-market (complete-market) economy.



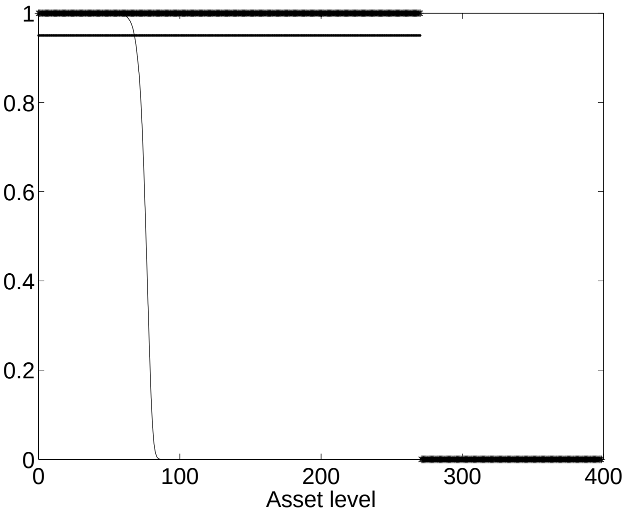
(a) Young with low skills



(b) Young with high skills



(c) Old with low skills



(d) Old with high skills

Figure 4: An agent's decision rules as functions of his age, skill level and asset holdings (in the incomplete-market economy with zero labor taxation). The thick horizontal line is the employment decision of an employed worker, which assume the value 1 if employment is preferred to nonemployment, and 0 otherwise. The thin horizontal line describes an employed worker's asset decision, which takes on value 0.95 if the agent increases his assets next period and a value of 0 otherwise. The thin curve, in form of an inverted-S shape, is a nonemployed worker's search intensity, $s \in [0, 1)$.

	Labor tax rate, τ_h				
	0	0.10	0.20	0.30	0.40
Interest rate	2.8 (4.1)	3.4 (4.1)	3.6 (4.1)	3.7 (4.1)	3.9 (4.1)
Wage rate	9.4 (8.9)	9.1 (8.9)	9.1 (8.9)	9.0 (8.9)	9.0 (8.9)
Output	15.1 (14.4)	14.3 (13.5)	13.1 (12.3)	11.8 (11.6)	10.2 (10.0)
Capital stock	47.0 (39.8)	42.2 (37.2)	37.9 (34.0)	33.9 (32.1)	29.0 (27.5)
Transfer	0.0 (0.0)	11.6 (11.3)	24.2 (23.2)	37.4 (37.5)	50.9 (50.0)

Table 2: Annualized values of the interest rate, wage rate per unit of skill, and output per capita; capital stock per capita; and government lump-sum transfer per capita as a per cent of after-tax low-skilled earnings. The numbers without (within) parentheses refer to the incomplete-market (complete-market) economy.

In figure 4, the employment decision of an already employed worker is represented by the thick horizontal line that takes on a horizontal value of 1 if employment is preferred to nonemployment, and a value of 0 otherwise. The thin horizontal line is another dummy variable pertaining to an employed agent, which takes on a horizontal value of 0.95 if the employed agent wants to increase his assets to next period, and a value of 0 otherwise. Finally, the thin curve describes a nonemployed agent's search effort, $s \in [0, 1)$. The search effort is at the upper bound for low asset levels and is equal to zero for high assets. In the range between those low and high asset levels, the optimal search intensity takes on intermediate values, as shown by the thin curve in form of a drawn-out inverted-S shape that is almost a straight vertical line.

5.2.1 *Employed young workers*

In figure 4, panel (a), a young employed agent with low skill prefers to remain employed for asset holdings below approximately 90, as marked by the thick horizontal line at the top of the graph. However, this employed agent does not want to accumulate assets unless he is at the very low end of the asset range, as marked by the short thin horizontal line (which is really just a tick below the very beginning of the thick line). Since newborn agents start with zero assets, it follows that young agents with low skills will have only those very low asset holdings, as marked by the thin horizontal line. Moreover, newborn agents choose to expend full search effort at zero assets, so the equilibrium outcome is that all newborn workers search intensively for employment and then prefer to stay employed as long as they are young with low skills. If young agents become high-skilled, their decision rules in figure 4, panel (b), show that they start accumulating savings with target asset holdings of around 90. Since they strictly prefer to remain employed at that target asset level, it follows that all young workers, regardless of their skill level, are working in an equilibrium (except during their initial search for employment as newborn agents).

5.2.2 *Employed old workers*

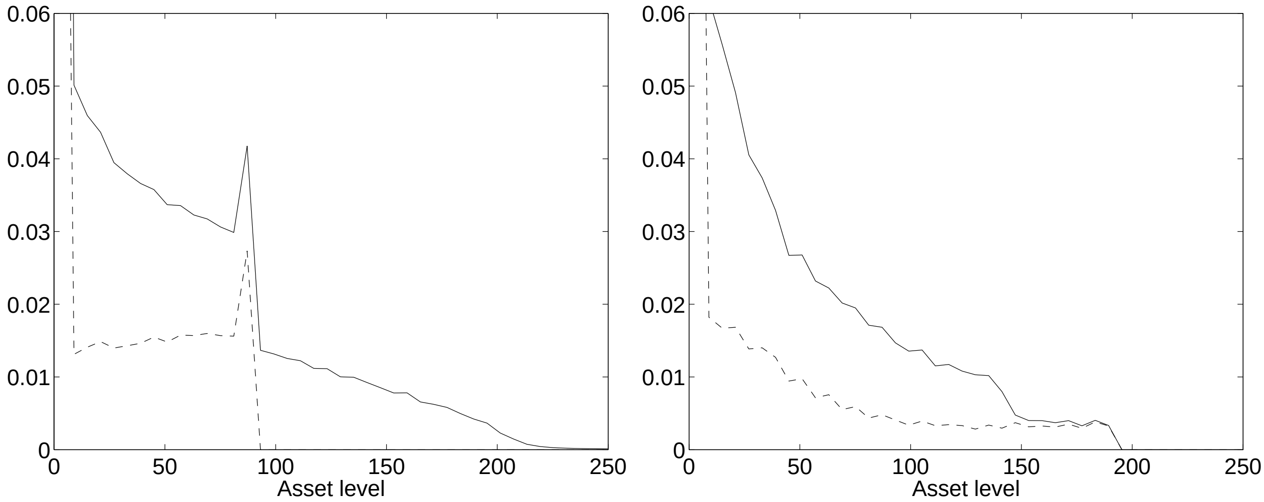
In figure 4, panel (c), an old employed agent with low skills behaves much like a young employed worker with high skills. An employed old agent has a target asset level that is in the interior relative to his choice of employment over nonemployment. Hence, all old agents with low skills and who have never attained the high skill level will work in an equilibrium. In the case of an old agent with high skills, figure 4, panel (d), shows how the dummy variables for employment and asset accumulation coincide, i.e., an employed worker will accumulate assets until he attains a target level of around 275, at which point he prefers to quit and enjoy leisure. The agent finances "early retirement" out of his assets and continues to enjoy leisure in working age until he either retires or his assets fall all the way down to a critical point of around 80 in figure 4, panel (c), at which point an old worker with low skills prefers to expend positive search effort to find employment. (Recall that the initially high-skilled worker becomes low-skilled upon entering nonemployment.)

5.2.3 *Distributions of assets*

The aggregate outcome from the interactions among agents' decision rules are summarized in the stationary asset distribution depicted in figure 5, panel (a). The solid line is distribution of assets held by the total population of workers and retirees. The dashed line separates young agents. Our description of optimal decision rules tells us that the peak in the distribution at an asset level at 90 reflects the target asset holdings of young agents with high skills. There is no discernible peak in the target asset level of old agents with low skills because of their slow rate of savings accumulation as they approach the end of the thin horizontal line in figure 4, panel (c). Similarly, old workers with high skills exhibit tepid saving rates when they approach the top asset levels in figure 4, panel (d), when they still prefer employment and asset accumulation over nonemployment and savings decumulation. As a result, very few old workers with high skills reach the upper bound on their desired assets and choose "early retirement" in working age. (According to table 1, only 0.1 percent of the labor force are nonemployed old agents who have been high-skilled.)

5.2.4 *Effects of taxation on the asset distribution*

Dramatic changes at the individual level underly the nonemployment effects of taxation in the incomplete-market economy, as depicted by the smooth upper solid line in figure 3. For example, compare the asset distribution when the labor tax rate is $\tau_h = .30$ in figure 5, panel (b), to that when there is no labor taxation in panel (a). First, the intermediate peak in the asset distribution has vanished because the desired asset level of young agents with high skills has substantially increased. The decision rules of young agents with high skills still look like those in figure 4, panel (b), except that the disjoint segments of the thin horizontal line are now connected. Hence, young agents with high skills accumulate sizeable assets, and if the target level is reached, they choose nonemployment to enjoy leisure as "early retirees." Second, the upper end of the asset distribution for tax rate $\tau_h = .30$, is dominated by young



(a) Labor tax rate $\tau_h = 0$

(b) Labor tax rate $\tau_h = 0.30$

Figure 5: Asset distribution in the incomplete-market economy for different labor tax rates. The solid line is the asset distribution for the entire population of workers and retirees. The dashed line separates young agents. The distributions have peaks at a zero asset level, which have been cropped in the figure.

rather than old agents. This can also be understood in terms of the decision rules in figure 4, panels (b) and (d). Note that even when there is no labor taxation, employed young agents with high skills prefer employment over nonemployment at asset levels that are higher than those of old agents with high skills. But while young agents with high skills in the economy with zero labor taxation are unwilling to accumulate savings and reach those high asset levels, their aspirations change when $\tau_h = 0.30$, as just delineated. Why would a higher distortionary labor tax motivate young agents with high skills to postpone consumption in order to accumulate assets? The answer is once again the prospect of early retirement either as a young worker or after becoming an old worker.

6 Nonemployment effects of taxation

Figure 3 depicts nonemployment outcomes for different labor tax rates in both the complete-market and incomplete-market economy, as shown by the upper dashed and upper solid line, respectively. We conclude that the nonemployment effects of taxation are quite similar across the two economies. In spite of the just detailed differences across the economies with respect to the incidence of nonemployment in different age and skill groups, the aggregate nonemployment outcomes are evidently quite similar.

Despite these outcomes, in sections 7 and 8, we warn against concluding that the choice between the complete and incomplete market settings is inconsequential for our understanding of observed employment outcomes and for conducting policy analysis. But before we do that, we study the robustness of our findings to perturbations in the way government revenues are handed back and a couple of other features.

6.1 How taxes are spent is crucial

Figure 3 demonstrates that equilibrium outcomes depend on how the government uses its tax revenues: either returning the revenues to households as lump-sum transfers or financing government expenditures that are not substitutes for private consumption. The dashed (solid) lines refer to the incomplete-market (complete-market) economy, where the upper line represents the outcomes with lump-sum transfers and the lower line describes the outcomes without transfers. In both economies, the nonemployment effects of taxation are rather small without transfers because of the negative income effect of taxation, while nonemployment increases sharply when tax revenues are handed back lump sum to the households. According to table 2, these transfers soon become large compared with the after-tax wage rate of a worker with low skills.

Figure 3 confirms Prescott's (2002, p. 7) observation about the importance of the assumption that tax revenues are handed back to households as transfers or as goods and services because "[i]f these revenues are used for some public good or are squandered, private consumption will fall, and the tax wedge will have little consequence for labor supply."

6.2 Potential skill loss suppresses nonemployment initially

Figure 6 examines the sensitivity of the effects of taxation to our stark assumption that an employed agent with high skills loses his skills and becomes low-skilled when entering nonemployment. As an alternative, we adopt the opposite assumption that there is no skill loss, i.e., once a high-skilled worker, always a high-skilled worker. Not surprisingly, the upper and lower dashed lines that represent the assumption of no skill loss in the incomplete-market economy with or without lump-sum transfers, respectively, lie above the corresponding solid lines under the benchmark assumption of skill loss. (The solid lines are the same as in figure 3.) At zero labor taxation, the figure shows that the nonemployment rate in the economy without skill loss is a couple of percentage points higher than in the economy with skill loss. Since agents are not threatened by skill loss when entering nonemployment in the former economy, their decision rules yield a higher incidence of early retirement.

It might seem surprising that the differences between the economies with and without skill loss vanish as the tax rate increases. The explanation is that at higher tax rates, agents plan for lengthy periods of nonemployment, so skill loss is less of a concern. Notwithstanding the probabilistic nature of aging, agents who choose early retirement expect to enter the exogenous final state of retirement rather than to return to the labor market in the future.

We need not recompute equilibrium outcomes for the complete-market economy under the alternative assumption of no skill loss. Recall that the stand-in household's optimal labor

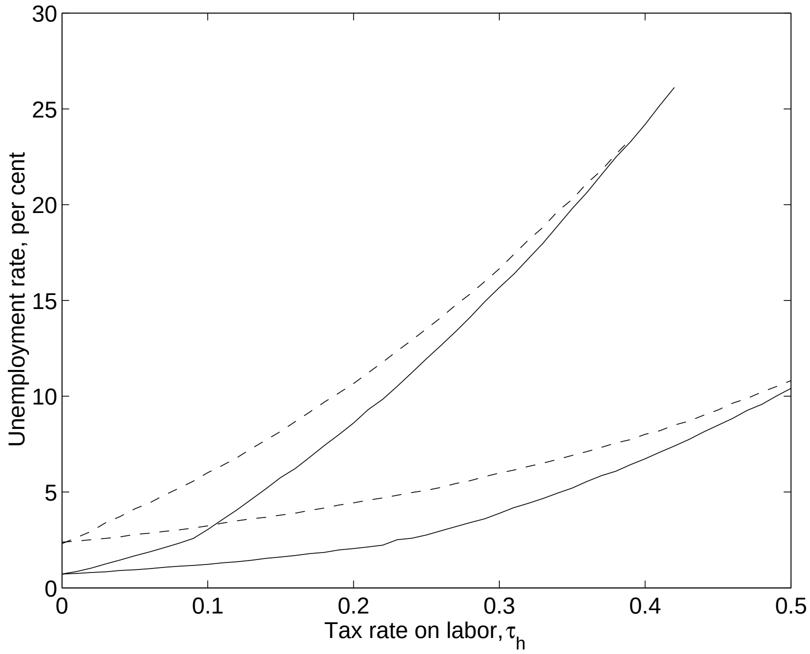


Figure 6: Unemployment effects of taxation with or without skill loss during nonemployment in the incomplete-market economy. The solid (dashed) lines refer to equilibrium outcomes in an economy with (without) skill loss during nonemployment, specifically, $p^u(h,1) = 1$ ($p^u(h,h) = 1$) for all h. For each economy, the upper line depicts equilibrium outcomes when tax revenues are returned as lump-sum transfers to the households, while the lower line depicts equilibrium outcomes when tax revenues finance government expenditures that are not substitutes for private consumption. (The solid lines are the same as in figure 3.)

allocation declares that all agents with high skills work. In the complete-market economy, there is no furloughing of highly productive workers into nonemployment, since leisure is most efficiently generated by low-skilled agents, and preferably *old* low-skilled agents.

6.3 Timing of transfers over the life cycle tilts the response

We are interested in how the nonemployment effects of taxation depend on the timing of government transfers over an agent's life cycle. Once again, this is not an issue in the complete-market economy where the stand-in household's allocation of labor and consumption is unaffected by any such reshuffling of transfers. But in the incomplete-market economy, it matters.[19] We consider two alternatives to the benchmark assumption that agents receive the same lump-sum transfer regardless of their age: retired agents receive per-capita transfers half and twice those of working age agents, respectively.

The dashed line in figure 7 describes equilibrium outcomes when retired agents are entitled to half of the transfer that working age agents receive. At low tax rates, we see that the nonemployment rate falls below that of the economy with equal transfers to all agents, as represented by the solid line (which is the same as the upper solid line in figures 3 and 6). Agents of working age who now receive the larger transfer choose to save more for their retirement state, when they know that the size of the government transfer will be cut in half. The higher savings manifest themselves in a larger capital stock. That increases the real wage, and as a result, agents work more and the nonemployment rate falls at those low tax rates. But evidently, this effect is overturned at higher tax rates, when transfers grow in size and become larger than half of the after-tax wage rate of a low-skilled worker. The nonemployment rate will then exceed that of the benchmark economy with equal transfers to all agents.

The dotted line in figure 7 describes equilibrium outcomes when retired agents are entitled to twice the transfer that working age agents receive. The equilibrium outcomes are now almost the mirror image of the previous experiment. At low tax rates, working age agents who know that they will be provided for in old age, choose to save and work a little less as compared to the benchmark economy with equal transfers to all agents. However, at higher tax rates, people find themselves working more than in the benchmark economy because they are faced with an ever larger tax bill that funds transfers to retired agents.

While the latter experiment with higher per-capita transfers to retirees moderates the nonemployment effects of taxation, it does not overturn the robust finding that labor taxes have a large positive effect on nonemployment when tax revenues are handed back as lump-sum transfers to the households.

6.4 Subjective discount factor plays no major role

As a last sensitivity test, we examine the effects of varying the subjective discount factor. Specifically, we assume that the agents are more patient with $\beta = 0.995$, cutting the an-

[19]This is a theme of Barsky et al. (1986).

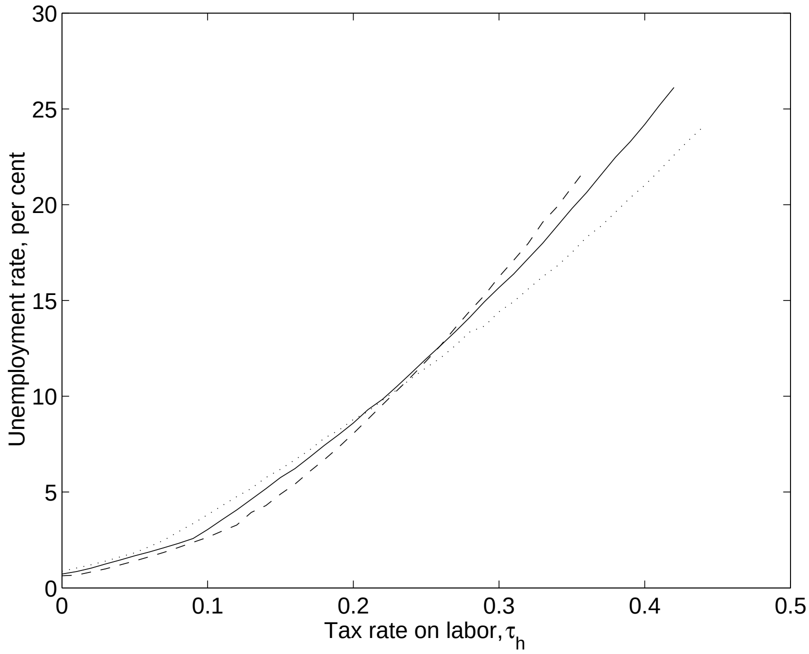


Figure 7: Unemployment effects of taxation with different timing of government transfers over the life cycle in the incomplete-market economy. All tax revenues are returned as lump-sum transfers to the households but with different distributions across age groups. The solid, dashed and dotted line refer to equilibrium outcomes in an economy where retired households receive per-capita transfers equal to, half of and twice that of working age households, respectively. (The solid line is the same as the upper solid line in figures 3 and 6.)

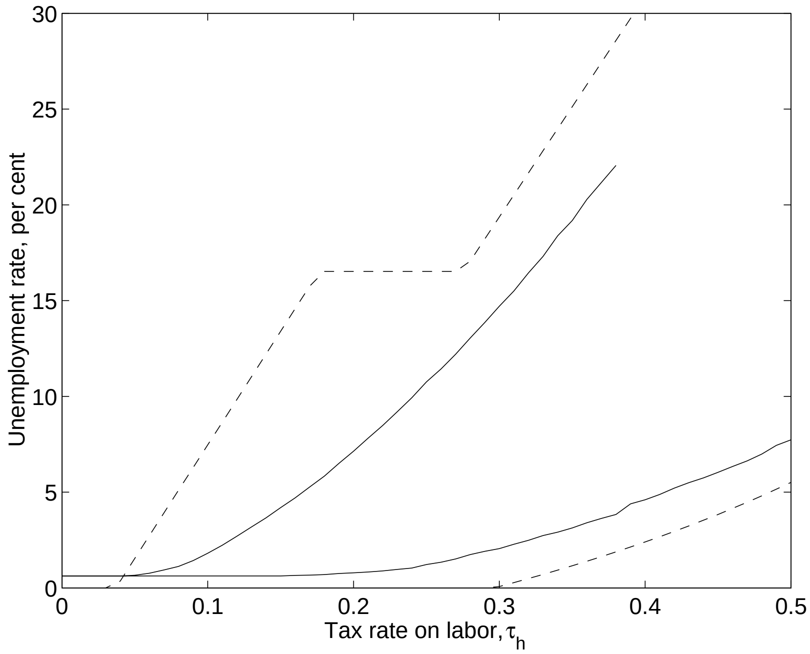


Figure 8: Unemployment effects of taxation with a higher discount factor ($\beta = .995$). The solid (dashed) lines refer to the incomplete-market (complete-market) economy. For each economy, the upper line depicts equilibrium outcomes when tax revenues are returned as lump-sum transfers to the households, while the lower line depicts equilibrium outcomes when tax revenues finance government expenditures that are not substitutes for private consumption.

nual interest rate in the complete-market economy in half to 2.0 percent. To facilitate a comparison with the benchmark economy, we also adjust disutility parameters of working and searching to $B = D = 1.1$, which implies similar equilibrium outcomes across the two parameterizations for the complete-market economy with transfers, as can be verified by comparing the upper dashed line in figures 3 and 8.

The impression to be gleaned from figures 3 and 8 is that our earlier findings about the similarities of the incomplete-market and complete-market economy and about the nonemployment effects of taxation are not sensitive to variations within a commonly used range of subjective discount factors.[20]

[20]We have not explored parameterizations with $\beta > 1$ that are sometimes assumed in calibrations of overlapping-generations models, see e.g. Ríos-Rull (1996). Such parameterizations would of course not be permissible in our complete-market economy with an infinitely-lived stand-in household.

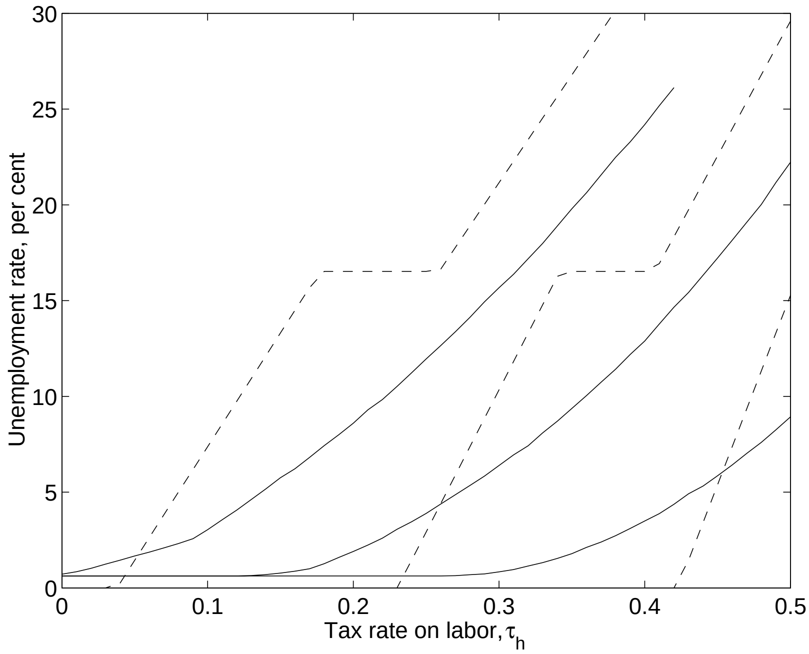


Figure 9: Unemployment effects of taxation with lump-sum transfers. The solid (dashed) lines refer to the incomplete-market (complete-market) economy. From left to right the curves for each economy depict disutility of working and searching ($B = D$) equal to 1.0, 0.8, and 0.6, respectively.

7 Taxes with social insurance

Prescott (2002, p. 9) summarized his findings by saying: "I find it remarkable that virtually all of the large difference in labor supply between France and the United States is due to differences in tax systems. I expected institutional constraints on the operation of labor markets and the nature of the nonemployment benefit system to be more important." Because generous social insurance is indeed a pervasive phenomenon in Europe, accounting for cross-country employment differences with any model that ignores it is naturally subject to the suspicion that one has miscast other parameters in order to fit the employment observations. Figure 2 confirms that suspicion about the complete-market employment-lottery model.

Temporarily setting aside the issue of social insurance, what changes in the model can reduce the nonemployment effects of taxation and thereby potentially make room for the inclusion of social insurance and its effects on nonemployment? An obvious candidate is to reduce the agents' discomfort from working. Figure 9 demonstrates how successive reductions in the disutility of working, $B \in \{1, 0.8, 0.6\}$, mute the nonemployment effects of taxation.[21] This approach would not be attractive to those who calibrate stand-in household models, because their corresponding preference parameter is used to match employment to population

[21]In figure 9, we keep our scaling convention for the disutility of employment search by setting $D = B$.

ratios or work week lengths (see footnote 7) rather than confronting the life-cycle career choices in our analysis.

If we do not want to change the parameterization of preferences, another possible avenue is to alter Prescott's assumption that all tax revenues are handed back lump sum to households as transfers or as goods and services. By letting part of tax revenues be used to finance public goods that are poor substitutes for private consumption, we can get intermediate positions on the nonemployment-taxation relationship in figure 3, i.e., a new curve between the current upper and lower curve that represent the economy with all tax revenues handed back to households and none handed back, respectively. Rogerson (2006) provides a good schematic exposition of how the nonemployment effects of taxation depend on the ways tax revenues are spent in a static economy.[22] Rogerson uses his framework to explain how high taxation and high employment in Scandinavia are consistent with the stand-in household model allowing, for example, for the high government spending on family services such as child care that prevails there.

Rogerson (2006) also considers social insurance that he interprets as subsidies to leisure: "unemployment insurance programs, social security programs and traditional welfare programs all involve a transfer of resources that is conditional upon not engaging in market work and hence implicitly involve marginal subsidies to leisure." We like Rogerson's description of an economic reality that pertains especially to Europe, but question his implicit assumptions about replacement rates in European social insurance programs. Referring to Prescott (2004), Rogerson calibrates the preference parameter α in the stand-in household's utility function (1) so that $h = 1/3$ at the U.S. tax level, and then assumes that $\bar{h} = 1$ in budget constraint (2). The replacement rate ρ is implicitly determined by his assumptions about government taxes and tax revenues. In a key calibration that provides an explanation for why hours of work in Continental Europe are only 2/3 of those in the U.S., Rogerson assumed that both economies hand back lump sum the tax revenues raised by the U.S. level of taxes, while the 20 percentage points incremental taxation in Continental Europe are used to finance the subsidy to leisure. A back-of-the-envelope calculation then yields a replacement rate of 15%.[23] The low replacement rate that he calibrates is much lower than the replacement rates estimated by Martin (1996), which are more like 50% and above. Figure 2 tells why Rogerson wants a low replacement rate.

When it comes to understanding cross-country differences in employment and nonemployment, the choice of whether to use the complete market or incomplete market model matters significantly. For understanding European employment outcomes, social insurance is the Achilles' heal of the complete-market employment-lottery model. In that model, any social insurance program will be abused with a vengeance when households *de facto* pool

[22]For related work that study the effects of government spending and the inclusion of home production, see Olovsson (2004) and Ragan (2005).

[23]Hours of work in Continental Europe should be $h = 2/9$, since those hours are only 2/3 of the U.S. value $h = 1/3$. After multiplying the hours worked by the incremental tax rate of 0.2 that pays for the subsidy to leisure, and then dividing by the number of hours eligible for the subsidy $(1 - h = 7/9)$, we arrive at a replacement rate on gross earnings of $\rho(1 - \tau_h) = 0.057$. Hence, given the calibrated Continental European tax rate $\tau_h = 0.6$, the replacement rate on net-of-tax earnings is $\rho = 0.1425$.

their resources and randomize over participation in the labor market and social safety nets. As indicated in the next section, such disastrous abuses are not inevitable in the incomplete-market economy when solitary households face lumpy decisions about whether to pursue permanent careers either in the labor market or in social insurance programs.

8 Government supplied life-time benefits: complete versus incomplete markets

This section puts a stylized government program that subsidizes 'careers' of inactivity into both the complete and incomplete market versions of our 2 skill, 2 ages model. We cast the program in a way that eases our computations but that can also highlight how the two different market arrangements cope with the 'mother of all convexities' identified in the time-averaging model of section 3. The program allows each new born agent to choose once-and-for all a lifetime within the benefits program or a lifetime at work. The once-and-for-all nature of this choice is especially limiting for the incomplete markets model because, if they were also given option to take up benefits later in their lives, some workers might want to time-average by moving repeatedly between employment and accepting inactivity benefits. Despite this shortcoming of our benefits experiment, the exercise identifies an important difference between the complete markets and incomplete markets models that shapes our alternative vision below for formulating models that can explain the European employment experience in the presence of both high taxes and generous benefits. (See section 9.5.)

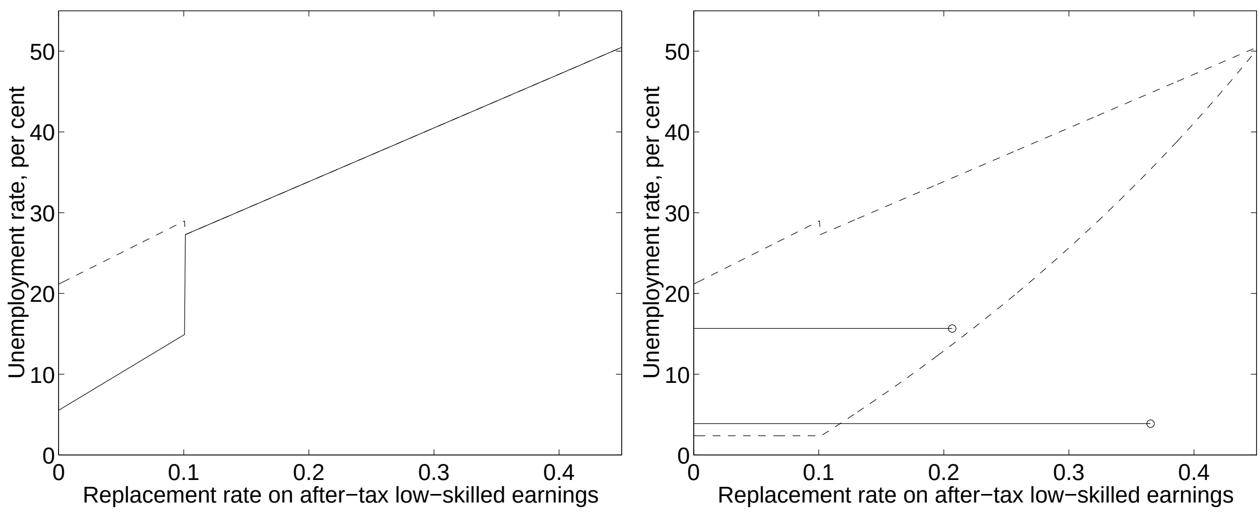
Thus, consider the following government scheme for supplying life-time benefits to the agents. Newborn workers are free to choose once-and-for-all between a labor market career or receiving a constant per-period benefit b over their life time. For purposes of comparison, we express benefits in terms of a replacement rate ρ on after-tax low-skilled earnings, i.e., $b = \rho(1 - \tau_h)w$. The government finances the benefits out of labor tax revenues, which means that any existing scheme with lump-sum transfers to the households must be reduced by the same amount. How would such a policy affect equilibrium outcomes in the complete-market and incomplete-market economies? While relegating the characterization of decision rules and steady states to the appendix, we discuss here outcomes when the labor tax rate is $\tau_h = 0.30$. The equilibrium nonemployment rates without benefits can be read off from the curves in figure 3.

Panel (a) of figure 10 shows how total nonemployment (the dashed line) responds to the replacement rate ρ in the complete-market economy with lump-sum transfers. The solid line separates the nonemployed workers who receive benefits. Recall that the total nonemployment rate without benefits in table 1 is equal to 21% of which 3.5 percentage points are made up of low-skilled young workers. It follows trivially that after the introduction of benefits, the stand-in household collects benefits on the low-skilled young workers who are anyway assigned to enjoy leisure. Moreover, these young workers continue to collect benefits when turning old (and also after retiring). The steady-state percentage of the labor force collecting benefits at an infinitesimal replacement rate becomes 5.5%.[24] At successively higher replacement rates, the stand-in household furloughs more and more newborn workers into the benefit program while sticking with its original decision to let all low-skilled old workers enjoy leisure. Recall that the marginal condition for leisure in that latter group is satisfied with strict inequality when there are no benefits. (In any steady state with nonemployed low-skilled young workers, the stand-in household strictly prefers to furlough all low-skilled old workers into leisure.) When the replacement rate becomes high enough that the marginal leisure conditions for low-skilled of both age groups hold with equality, any further increase in benefits results in a complete substitution away from assigning old workers to early retirement and toward assigning newborn agents who are entitled to benefits to life-time leisure. Notice that the total nonemployment rate actually falls somewhat when that substitution occurs. The cause is the income effect that occurs when the stand-in household loses the wage income that low-skilled old workers had earned as young workers before they were furloughed into early retirement after turning old with low skills. At replacement rates exceeding 10%, total nonemployment is made up solely of agents who receive benefits.

Panel (b) of figure 10 depicts total nonemployment rates in both the complete-market and incomplete-market economy with and without lump-sum transfers. Starting with the complete-market economy, the upper dashed line is the same as in panel (a), i.e., the economy with transfers. The lower dashed line is the complete-market economy without transfers but with the described benefit scheme. In this economy, the equilibrium total nonemployment rate is initially unresponsive to the replacement rate. Recall from figure 3 (lower dashed line) that the total nonemployment rate without benefits was 2.4% in that economy and all the nonemployed were low-skilled old workers. Hence, the stand-in household strictly preferred to send newborn workers to the labor market, and a low replacement rate will not change that decision until the replacement rate reaches 10%. At that critical replacement rate, the household chooses to substitute all of its leisure away from early retirement of low-skilled old workers to newborn agents who specialize in leisure for their entire lives (not shown in the graph). Hence, at replacement rates exceeding 10%, total nonemployment consists only of workers who receive benefits, and it increases sharply until it intersects with the upper dashed line at a nonemployment rate of 50%. At that point, the government has exhausted all of its tax revenues paying for the benefit scheme, making the economies with and without transfers the same.

The upper and lower solid line in panel (b) of figure 10 represent the incomplete-market economy with and without transfers, respectively. In these economies, a solitary household compares the expected utility of entering the benefit program to the expected utility of a career in the labor market. The optimal decision rule is a reservation benefit level $\bar{b}$ such that the expected life-time utility of consuming $\bar{b} + \epsilon$ forever is the same as the expected value of a career in the labor market, which is equal to $V^u(1, 0, 1)$ as given by expression (38), i.e., the value function of a nonemployed worker evaluated for the young ($x = 1$) with no

[24] Recall that the average time spent in the young and old age group are 25 and 15 years, respectively. Hence, the steady-state fraction of the labor force collecting benefits is obtained by multiplying the fraction of young workers collecting benefits, 3.5%, by the ratio $(25 + 15)/25$.



(a) Complete markets with transfers

(b) (In)complete markets with(out) transfers

Figure 10: Unemployment effects of government supplied life-time benefits. Panel (a) depicts the complete-market economy with transfers, where the dashed line refers to total nonemployment and the solid line separates the nonemployed who receive benefits. Panel (b) depicts total nonemployment, where the solid (dashed) lines refer to the incomplete-market (complete-market) economy. For each economy, the upper line depicts equilibrium outcomes when government surpluses after benefit payments are returned as lump-sum transfers to households, while the lower line depicts equilibrium outcomes when such surpluses finance government expenditures that are not substitutes for private consumption.

assets ($a = 0$) and with the lowest skill level ($h = 1$).[25] The figure shows how the aggregate nonemployment rate remains constant for a considerable range of replacement rates because agents prefer to pursue labor market careers rather than to live on government benefits. The replacement rate at which a newborn worker is indifferent between the two options is marked by a circle on the solid lines in panel (b) of figure 10. That threshold is reached much earlier in the economy with transfers than in the economy without transfers, at replacement rates of 21% and 37%, respectively. At the points of indifference, the "invisible hand" can assign any fraction of newborn workers to the benefit program, so long as the tax revenues raised from the remaining population are sufficient to finance that program.

The outcomes in the incomplete-market economy are reminiscent of the findings in our single-agent model of a time-averaging problem with human capital in section 3.5. Depending on parameter values, an agent would work more or less compared to the optimal allocation attained with employment (career) lotteries in section 3.6. At low replacement rates in the current benefit experiment, a solitary household is inclined to work more than the average agent in the complete-markets economy, because a solitary household cannot afford to retire at those low benefit levels. But when the replacement rate gets high enough, all of the *ex ante* identical agents would like to join the benefit program (which is obviously not feasible because of the strain it puts on the government benefit program), i.e., they would seek to work less than the average agent in the complete-market economy. In the latter situation, the solitary households would ideally have preferred to exchange some of their leisure for additional consumption, but faced with a lumpy career choice, that is not possible.

8.0.1 Robustness of the incomplete markets economy to government benefits

To us, our admittedly stylized benefit experiment suggests why incomplete-market models might be better more generally at coping with social insurance than complete-market models. The employment lotteries in the complete markets model remove the lumpy nature of a choice over alternative 'careers' that either participate either in the labor market or live in dependency on the government benefits. So while there is no hope of reconciling the complete-market model with generous social insurance programs, the incomplete-market model offers insights about how such programs can be sustained in real-world economies. The incomplete-market model inspires us to look for different 'career costs' when agents consider their options of participating in labor markets versus social insurance programs. In that light, the following characterization of optimal disability insurance when disability is unobservable makes sense. Disability benefits are paid only "if an agent has assets below a specified maximum [because it is shown] that an agent who falsely claims disability has higher savings than a truly disabled agent, and an asset test prevents false claimants from

[25]Given that the market interest rate falls below agent's subjective discount factor (adjusted for survival probabilities), the optimal consumption decision of an agent with benefits is to consume $b + \epsilon$ every period, i.e., the sum of benefits b and the lump-sum transfer ϵ. Moreover, a newborn agent who has joined the benefit program would never want to reconsider that decision in a steady state: if the decision to accept benefits was optimal for a young worker without assets, it is also optimal for a low-skilled old worker without assets, and trivially also for a retired agent without assets.

receiving disability." (See Golosov and Tsyvinski (2004).) In contrast, the complete-market model would circumvent any such hurdles or lumpinesses in agents' choice sets, because disability/employment lotteries coupled with private transfers across agents contingent on the outcomes of the agent-specific lotteries would enable the stand-in household to game the social insurance program.

9 Concluding remarks

9.1 The greatest indivisibility – career choice

As in the single-agent model of section 3, the agents in our general-equilibrium framework are preoccupied with choosing a career. The stand-in household in the complete-market economy and the solitary households in the incomplete-market economy both make elaborate contingency plans about their life-time labor market careers. Planning turns out to be simple for the stand-in household who tells high-productivity agents to specialize in working and assigns the household's leisure to agents with less earnings potential. Outcomes are more complicated in the incomplete-market economy because individuals' chance outcomes in the labor market interact with their financial asset accumulation decisions to determine when they might exit the labor market and enjoy early retirement.

Labor taxation has different effects on particular individuals in the complete-markets and incomplete-market economies. Its convexified optimization problem allows the stand-in household to respond smoothly to higher taxes by adjusting the fraction of household members who are furloughed into leisure. In contrast, households in the incomplete-market economy are on their own when they face the indivisibility with which alternative labor market careers confront them. Higher taxes prompt agents to shorten those careers, i.e., to plan for early retirement at a future date when they have amassed enough assets to finance an idle life. Nevertheless, the *aggregate* responses to labor taxes are quite similar in the two types of economies, as figure 3 showed.

Labor market economists have long recognized the importance of life-cycle considerations and human capital in households' labor supply decisions. Shaw (1989) was among the first to estimate a dynamic labor supply model that includes human capital accumulation. In a recent study in which an individual's labor supply can be varied continuously at any moment, Imai and Keane (2004) emphasize how a human capital acquisition technology can reconcile a rather flat life-cycle labor supply path with a high intertemporal elasticity of substitution, which they estimate to be 3.8. However, an elasticity of 3.8 in the Imai-Keane model does not imply the same large aggregate response to wage increases that an elasticity of 3.8 would imply in Prescott's model from section 2. In particular, in the presence of human capital, there is an important difference between a high curvature parameter on the disutility of working and the optimal response of workers with these preferences to fluctuations in the wage rate. This is forcefully illustrated by Imai and Keane (2004, figure 8) in a computational experiment that imposes a temporary wage increase of 2% and finds that a person at age 20 would respond by increasing hours only by around 0.6%. As Imai and Keane (2004) explain, the presence of human capital adds a term representing the continuation value to what had been an *intratemporal* marginal condition for moment t labor supply in models without human capital; the presence of this term means that the wage understates a worker's value of time, especially a young worker's. The response of hours to a temporary wage jump increases with age, especially towards the end of an agent's labor market career. While this finding does not shed light on the business-cycle fact that most variations in hours are borne by young workers,[26] it does accord with the life-cycle career paths experienced by the agents in our model.

In a model of indivisible labor like ours, the disutility of work function is evaluated only at $n \in \{0, 1\}$, so its curvature is irrelevant. Factors that do matter are his age and his plans about early retirement. The independence of the labor supply decision from the parameter associated with the supply elasticity is also noted by Chang and Kim (2005), who study a framework like ours and also focus on the extensive margin when labor is indivisible. In their model, agents are infinitely lived and, hence, the life-cycle dimension of careers is absent, but Chang and Kim enrich their analysis by studying two-person households.

9.2 Private versus social insurance

The agents in the complete-market economy agree only partially with Mulligan's (2001) list of real-world counterparts to the insurance arrangements that shield them from the outcomes of employment lotteries: "the sharing of resources by husbands and wives, sick pay, disability insurance, and intergenerational transfers (both public and private)." The agents disagree with the inclusion of any socially provided insurance because equilibrium outcomes would be very different if insurance were provided to them for free. Just look at figure 2.

Hansen (1985) shows that the allocation in the employment lottery framework can be interpreted as the outcome of a competitive equilibrium in which households can purchase arbitrary amounts of nonemployment insurance. Hansen's argument pertains to *private* insurance, where the stand-in household properly internalizes the costs and benefits of the insurance arrangement. In contrast, when the household collects government supplied nonemployment insurance, it does not internalize the costs, and this makes a big difference in outcomes. In particular, since the stand-in household takes tax rates as given and independent of its own use of government supplied insurance, the household will "abuse" the insurance system by choosing a socially inefficiently high probability of not working: because the government subsidizes nonemployment (leisure), households spend too much time nonemployed. As we have seen in section 2, the effect is large because the labor supply elasticity is so high in the stand-in household employment lotteries model. Hence, it is a mistake to think that government supplied nonemployment insurance facilitates implementing an optimal allocation either by completing markets or by substituting for private insurance in the employment lottery framework.

The agents in Prescott's stand-in household model enter private insurance arrangements and the outcomes are market-driven competitive equilibria, but it is also important to recog-

[26] See e.g. Gomme et al. (2004).

nize that Prescott (2002) assumes that huge redistributions occur in the U.S. and in Europe. The magnitudes of the redistributions might not be apparent at first because Prescott's stand-in household is also a representative agent without any distinguishing features. But imagine how governments actually collect those large tax revenues and then hand them back to citizens who value them as if they had privately purchased goods and services. This is indeed a grand redistribution from the people who generated the market earnings that are taxed to the transfer recipients. The transfers that underpin the calculations in Prescott (2002) cause the progressive proposals made by some interest groups, especially in Europe, who want the government to guarantee modest levels of a citizen's income, or "basic income," to pale by comparison. As defined by Guy Standing (2004) at the International Labor Office in Geneva, "a basic income is an income unconditionally granted to everybody on an individual basis ... regardless of gender, age, work status, marital status, household status or any other perceived distinguishing feature of individuals." The idea is partially to protect citizens from the vagaries of the market economy by providing a basic income that can be supplemented with market activities, if so desired. Some proponents argue that such a reform can be financed largely by reallocating spending from other government programs and expenditures. In the world of Prescott's (2002) analysis of European employment, there is no reason either to advocate or to oppose such a reform: it would have no impact on the equilibrium, since one kind of government lump-sum transfer would just replace another in the stand-in household's budget constraint.

9.3 Nuclear versus national family: incomplete versus complete markets

The stand-in household represents a large number of agents who, thanks to complete markets and employment lotteries, pool their resources and collectively choose their labor supply. The all-encompassing nature of the stand-in household tempts us to refer to it as the 'national family,' though still keeping in mind that the household acts competitively and does not internalize the effects of its decisions on equilibrium prices and government finances. The stand-in household framework stands in stark contrast to microeconomic models that study labor supply decisions that are made by either single agents or two-person households. For example, Chiappori (1997) develops a collective labor supply model of a two-member household that we would call a 'nuclear family.' The two frameworks offer very different perspectives on labor supply and its consequences. While labor services performed by a nuclear family determine its disposable income, there is no such simple relationship in the national family model because of its intricate consumption insurance and employment lotteries. So while it is important from the perspective of a nuclear family model to study the distribution of labor supply across households, in the national family model, we can just sum up the labor supplied by all households regardless of their labor market status and then focus on aggregates. The theory of the stand-in household tells us to expect private transfers across families: some of them specialize in generating leisure and others in providing for consumption goods. Shiller's (2003) vision for a new financial order in the 21st century with privately provided livelihood insurance and inequality insurance prevails in the stand-in household model.

Depending on the observations to be explained, the nuclear and the national family perspectives can lead either to similar or to very different conclusions. For example, both frameworks would encourage us to attribute the gap in European and U.S. marketization of household services to differences in taxation. As documented by Freeman and Schettkat (2005), traditional household production such as food preparation, childcare, elderly care and home cleaning are significantly less marketized in Europe. Because all households face the same choices of either purchasing household services in the market place or producing them on their own by letting one spouse emphasize home production, it should not be surprising that a nuclear and a national family model lead to similar conclusions about the effects of distortionary taxation. The crucial factor here is that the effects of distortionary taxation do not hinge on the existence of markets that facilitate private transfers across households. In contrast, consider figure 2 in Alesina et al. (2005) that documents a sharper decline in men's labor force participation in Europe than in the U.S. As discussed above, the national family model simply aggregates employment outcomes over all workers and need not worry about the labor market status of particular workers and whether there are any active 'breadwinners' in particular families. In contrast, the nuclear family perspective impels concern about how individual families support themselves when the main breadwinner is not employed.[27] Such an inquiry would uncover that most of these nonemployed European breadwinners are on the welfare rolls and would most likely find that those benefits are crucial for supporting those inactive workers and their families. The decline in employment among these workers who once were attached to the labor force, but who now live at government expense, is what most concerns European policy makers. High rates of nonemployment in that group not only reduce aggregate employment but also strain social insurance systems and government finances.

President Barroso of the EC (Commission of the European Communities (2005, p. 26)) deplores the fact that European workers "start exiting the labor market on a very large scale by the time they reach 55 years of age." From the perspective of the nuclear family, we are led to seek explanations for that behavior in generous European social insurance programs that enable people to retire early without having to amass personal savings, as would, for example, be necessary in our incomplete-markets model in section 4. The national family model would instead tell us that individual households can retire early without substantial personal savings. It is actually inefficient for individual households to engage in such private savings schemes when there are complete markets and employment lotteries. In the efficient complete-markets equilibrium, winners of the lotteries enjoy leisure while their material living standard is guaranteed by private consumption insurance contingent on the outcomes of those household-specific lotteries. However, it is troublesome that the complete-markets model with employment lotteries cannot cope with generous social insurance: that model predicts that employment in Europe should have plummeted to levels that, fortunately, we

[27]At the cost of appearing politically incorrect, we note that men are most often the main income earner of households, and presumably more so in Europe with its lower female labor force participation.

have yet to observe.[28]

9.4 Conjectures about Europe

We are not able to run large-scale policy experiment with real-world economies, but our models do invite us to entertain grand thoughts. The following question comes to mind. Faced with its predicament of too high nonemployment in the last 30 years, suppose that Europe had to choose between a reform that cuts labor tax rates to the levels of the U.S. or a reform that replaces its social insurance programs with U.S. style income support. Which reform would increase European employment the most? Using the stand-in household model, Prescott (2002) is already on the record suggesting that the solution to European nonemployment is to cut labor tax rates. For what it is worth, we would lean the other way and bet that reforming social insurance would go much farther in providing incentives for people to return to employment.

The incomplete-market economy with its solitary households who face endogenous indivisibilities in form of labor market careers rings truest to us. It seems to be supported by microeconomic studies. Our analysis suggests how households in such a world would choose to continue working in spite of relatively high tax rates. For example, as documented but not emphasized by Prescott (2004), tax rates in Europe were higher than those of the U.S. already in the 1970s. With an appropriately calibrated disutility of working and a proper account of the negative income effect of taxation, the incomplete-market economy would be consistent with households working in spite of those high taxes. Similarly, our analysis of the incomplete-market economy suggests how relatively generous social insurance programs can still allow a large majority of the population to choose a labor market career rather than to bail out into a social safety net. The reason for this outcome is the lumpiness in household decisions introduced by labor market careers. In the complete-market economy, the stand-in household with its convexified optimization problem sees no lumpiness in labor market careers.

The analysis leads us to think that the good performances of welfare states in Europe until the 1970s with their high taxes and generous benefits were possible because of the indivisibilites associated with labor market careers in a world without employment lotteries. Furthermore, tax revenues were funnelled to public goods and government expenditures that were poor substitutes for private consumption. The negative income effect of taxation worked in favor of sustaining high employment in the European welfare states.

But something went wrong in the late 1970s, and the media and social scientists who had proclaimed the success of the European welfare state grew silent. Today Europe is characterized by dual economies where the majority of its citizens remain gainfully employed,

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[28] We know one real-world situation for which the complete-markets model with employment lotteries and social insurance seems to be a good characterization. As described by May and Hollett (1995), community work-sharing arrangements in the depressed labor market in Newfoundland in Canada are designed to push recipients just above the bar to qualify for nonemployment benefits. Fortunately, the Newfoundland situation has not migrated to Europe.

but where a substantial minority has been marginalized and lives on government income support. The high taxes of Europe provide little of value to those who actually pay them because tax revenues accrue to people who are not working. So the good news is that the negative income effect of taxation helps to keep most people at work and stops them from planning accumulate private wealth with the thought of taking early retirement.[29]

So what went wrong in Europe in the late 1970s and early 1980s? As has been pointed out by many observers, there did not seem to be any major changes in European welfare polices at the time. Our conjecture is that something important in the economic environment changed. The European welfare states were ill-prepared for the increase in economic turbulence that has been documented by labor economists.[30] The Sirens' song telling the comforts of social safety nets became too tempting.[31]

9.5 Our alternative vision

We have shown that if we continue to play by Prescott's rules, meaning that we accept both his calibration of the disutility of working and his assumption about how the government spends the tax revenues, then our complete-market and incomplete-market economies generate the same responses to labor taxation.

However, because of the difficulties that both complete and incomplete markets versions of such models are likely to have in giving reasonable predictions once we incorporate realistic descriptions of the government supplied benefits that are actually available to Europeans,we believe that it will be better to construct a model in which (1) the disutility of working is smaller,[32] and (2) tax revenues are not handed back lump-sum but rather are used for public goods and targeted transfers to non-working, 'marginalized' population. We suspect that a framework with these features will impart effects to social inactivity insurance that look very much like the ones that we found in our earlier exercises with McCall search models in

[29] It can be objected that early retirement is in fact a major problem in Europe. But who finances the problematic people who have retired early in Europe? Mostly, governments do.

[30] See Katz and Autor (1999) for the empirical evidence and Ljungqvist and Sargent (2005b) for a theory of how increased turbulence causes long-term unemployment to erupt in European welfare states, especially among older workers.

[31] In a U.S. context, Autor and Duggan (2003) argue that reduced screening stringency since 1984 and rising replacement rates of the disability insurance program, have led to a higher propensity of workers facing adverse shocks to exit the labor force to seek disability benefits. Because of the progressive (i.e., concave) benefit formula, they find that these incentive effects apply foremost to high school dropouts. Autor and Duggan suggest that the measured unemployment rate in the U.S. would be about half a percentage point higher if the excessive enrollment in the disability insurance program were to be included. Hence, their reasoning is qualitatively the same as Ljungqvist and Sargent's (2005b) argument for Europe but the magnitudes are different. According to Autor and Duggan, 3.7% of Americans in ages 25-64 received disability insurance benefits in 2001 while, for example, Edling (2005) reports for the Swedish population in ages 20-64 that early retirees comprised 10% in 2004 and another 2.4% had received sick insurance benefits for more than a year in 2003.

[32] We think that after one takes into account the household production technology emphasized by Greenwood et al. (2005) and the within-family specialization decisions that nuclear families make in response to that technology, it is not wise to calibrate the disutility of working to the employment-population ratio.

Ljungqvist and Sargent (1998, 2005b) and Lucas-Prescott search-island models in Ljungqvist and Sargent (2005a), where the disutility of working was set to zero. In particular, we expect that only those workers who have experienced tough luck in the labor market will bail out into social insurance.

This paper has obviously *not* implemented that alternative vision but has instead tried to raise what we regard to be important issues about modeling social insurance while accepting Prescott's disutility of work calibration. Our stylized government benefit experiment sets apart the responses of the complete-market and incomplete-market economies to the availability of those benefits. We frankly *designed* that experiment to highlight the 'careers' of lifetime government benefit dependency that underly the aggregate employment outcomes in the stand-in household employment lotteries model. We suspect, however, that so long as we accept Prescott's modeling decisions about items (1) and (2), the stark difference in outcomes here is really due to the peculiar take-it-or leave-it choice of lifetime dependency on government benefits. If we were instead to allow workers to move in and out of benefits during their lifetimes, we suspect that, with Prescott's setting of the disutility of work and his assumption about the disposition of tax revenues, the time-averaging logic of section 3 would again make the outcomes under complete and incomplete markets similar, thus confirming that the tax wedge and the benefit wedge still affect outcomes in the same ways. That hunch and the poor fit of the outcomes in the south east corner of figure 2 push us toward our alternative vision.

References

Aiyagari, Rao S. 1994. Uninsured Idiosyncratic Risk and Aggregate Saving. *Quarterly Journal of Economics* 109 (3):659–684.

Alesina, Alberto, Edward Glaeser, and Bruce Sacerdote. 2005. Work and Leisure in the U.S. and Europe: Why so Different? In *NBER Macroeconomics Annual*, edited by Mark Gertler and Kenneth Rogoff. Cambridge Mass.: MIT Press, forthcoming.

Alvarez, Fernando and Marcelo Veracierto. 2001. Severance Payments in an Economy with Frictions. *Journal of Monetary Economics* 47:477–498.

Autor, David H. and Mark G. Duggan. 2003. The Rise in the Disability Rolls and the Decline in Unemployment. *Quarterly Journal of Economics* 118:157–205.

Barsky, Robert B., Gregory N. Mankiw, and Stephen P. Zeldes. 1986. Ricardian Consumers with Keynesian Propensities. *American Economic Review* 76 (4):676–691.

Browning, Martin and Thomas F. Crossley. 2001. Unemployment insurance benefit levels and consumption changes. *Journal of Public Economics* 80 (1):1–23.

Carneiro, Pedro and James J. Heckman. 2003. Human Capital Policy. In *Inequality in America: What Role for Human Capital Policies?*, edited by Benjamin Friedman, 77–239. Cambridge, Mass.: MIT Press.

Chang, Yongsung and Sun-Bin Kim. 2005. From Individual to Aggregate Labor Supply: A Quantitative Analysis Based on a Heterogeneous Agent Macroeconomy. *International Economic Review,* forthcoming.

Chiappori, Pierre-Andre. 1997. Introducing Household Production in Collective Models of Labor Supply. *Journal of Political Economy* 105:191–209.

Commission of the European Communities. 2005. Working Together for Growth and Jobs: A New Start for the Lisbon Strategy. Communication to the Spring European Council – COM (2005) 24, Brussels, February 2.

Edling, Jan. 2005. Alla behovs: Blott arbetsmarknadspolitik skapar inga nya jobb [Everybody is needed: Labor market policies on their own do not create any new jobs]. Unpublished, Timbro, Stockholm, Sweden.

Freeman, Richard B. and Ronald Schettkat. 2005. Marketization of Household Production and the EU-US Gap in Work. *Economic Policy* 20 (41):5–50.

Golosov, Mikhail and Aleh Tsyvinski. 2004. Designing Optimal Disability Insurance: A Case for Asset Testing. NBER Working Paper 10792, forthcoming in *Journal of Political Economy.*

Gomme, Paul, Richard Rogerson, Peter Rupert, and Randall Wright. 2004. The Business Cycle and the Life Cycle. In *NBER Macroeconomics Annual*, edited by Mark Gertler and Kenneth Rogoff, 415–461. Cambridge Mass.: MIT Press.

Greenwood, Jeremy, Ananth Seshadri, and Mehmet Yorukoglu. 2005. Engines of Liberation. *Review of Economic Studies* 72:109–133.

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

Hansen, Gary D. 1985. Indivisible Labor and the Business Cycle. *Journal of Monetary Economics* 16:309–327.

Imai, Susumu and Michael P. Keane. 2004. Intertemporal Labor Supply and Human Capital Accumulation. *International Economic Review* 45:601–641.

Katz, Lawrence F. and David H. Autor. 1999. Changes in the Wage Structure and Earnings Inequality. In *Handbook of Labor Economics, Vol. 3A*, edited by Orley Ashenfelter and David Card. Amsterdam: Elsevier.

Ljungqvist, Lars. 2005. Comment. In *NBER Macroeconomics Annual*, edited by Mark Gertler and Kenneth Rogoff. Cambridge Mass.: MIT Press, forthcoming.

Ljungqvist, Lars and Thomas J. Sargent. 1998. The European Unemployment Dilemma. *Journal of Political Economy* 106:514.

———. 2004a. Lotteries for Consumers Versus Lotteries for Firms. In *Frontiers in Applied General Equilibrium Modeling*, edited by Timothy J. Kehoe, T.N. Srinivasan, and John Whalley. Cambridge, UK: Cambridge University Press.

———. 2004b. *Recursive Macroeconomic Theory, Second Edition.* Cambridge, Mass.: MIT Press.

———. 2005a. Jobs and Unemployment in Macroeconomic Theory: A Turbulence Laboratory. Stockholm School of Economics and New York University.

———. 2005b. Obsolescence, Uncertainty, and Heterogeneity: The European Employment Experience. Stockholm School of Economics and New York University.

Martin, John P. 1996. Measures of Replacement Rates for the Purpose of International Comparisons: A Note. *OECD Economic Studies* 26:99–115.

May, Doug and Alton Hollett. 1995. *The Rock in a Hard Place: Atlantic Canada and the UI Trap.* Toronto: C.D. Howe Institute.

Mulligan, Casey B. 2001. Aggregate Implications of Indivisible Labor. *Advances in Macroeconomics* 1 (1).

Nosal, Ed and Peter Rupert. 2005. How Amenities Affect Job and Wage Choices over the Life Cycle Federal Reserve Bank of Cleveland.

Olovsson, Conny. 2004. Why Do Europeans Work So Little. Stockholm School of Economics.

Prescott, Edward C. 2002. Prosperity and Depression. *American Economic Review* 92:1–15.

———. 2004. Why Do Americans Work So Much More Than Europeans? *Federal Reserve Bank of Minneapolis Quarterly Review* 28:2–13.

———. 2006. The Transformation of Macroeconomic Policy and Research Forthcoming *Journal of Political Economy.*

Ragan, Kelly S. 2005. Taxes, Transfers and Time Use: Fiscal Policy in a Household Production Model. University of Chicago.

Ríos-Rull, José-Víctor. 1996. Life-Cycle Economies and Aggregate Fluctuations. *Review of Economic Studies* 63:465–489.

Rogerson, Richard. 1988. Indivisible Labor, Lotteries, and Equilibrium. *Journal of Monetary Economics* 21:3–16.

———. 2006. Taxation and Market Work: Is Scandinavia an Outlier? Arizona State University.

Shaw, Kathryn L. 1989. Life-Cycle Labor Supply with Human Capital Accumulation. *International Economic Review* 30:431–456.

Shiller, Robert J. 2003. *The New Financial Order: Risk in the 21st Century.* Princeton and Oxford: Princeton University Press.

Standing, Guy. 2004. About Time: Basic Income Security as a Right. In *Promoting Income Security as a Right: Europe and North America*, edited by G. Standing. London: Wimbledon, Anthem Press.