Finding a Way Out of America's Demographic Dilemma

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Abstract

U.S. demographic projections portend dramatic increases in payroll taxes to finance old age transfer programs. But this scenario ignores the potential for capital deepening associated with population aging. More capital per worker would raise wage rates and limit the required rise in tax rates. Yet capital deepening is not guaranteed since a rising payroll tax will itself reduce capital formation. This study develops a dynamic general equilibrium life-cycle simulation model to study these conflicting forces using a model that admits realistic patterns of fertility and lifespan extension. It also features heterogeneity, both within and across generations.

Unfortunately, under current policy, capital deepening does not occur, leading to deteriorating macroeconomic conditions that exacerbate our fiscal problems. Real wages fall 4 percent over the next 30 years and 10 percent over the century. And payroll and income tax hikes ultimately raise total taxes on labor income by 44 percent.

Is there a painless way out of our demographic dilemma? No. A much faster rate of technical progress would help, but still leave a major problem. Getting workers to retire later in life would increase aggregate labor supply, but reduce aggregate capital formation. And cutting Social Security benefits either directly or by raising the program's retirement age renders major welfare losses on current or near term retirees. However, advance funding the receipt of retirement income, while not being a free lunch, more evenly spreads the pain across generations: it entails moderate pain for living generations and provides major gains for future generations, particularly those with very low incomes.

I. Introduction

America is starting to grey, and the older it gets the worse may be not just its physical, but also its economic health. How exactly will our economy fare when the entire country becomes as old as today's Florida? On that day, which is 30 years off, all 77 million baby boomers will be retired, leaving twice the number of elderly relying on only 15 percent more workers for financial support. This support will be delivered primarily through the Social Security and Medicare programs, which will start paying benefits to baby boomers in just six and nine years, respectively.

Thus far, the government has done relatively little to confront Social Security's and Medicare's long-term fiscal problems. Indeed, the Social Security and Medicare Trustees project that they are one fifth short of the resources needed to pay benefits over the next 75 years. This funding assessment, presented in the most recent OASDI and HI Trustees Reports, is based on so-called "intermediate" economic and demographic assumptions. However, the appropriateness of these assumptions, particularly with respect to longevity, has been questioned by Social Security's own 1999 Technical Panel. The Panel also raised concerns about truncating the projection horizon at 75 years, pointing out the large cash flow deficits lying in 2076 and beyond.

What happens to the projections if one extends the horizon and adopts the Technical Panel's longevity assumptions? The OASDHI (Social Security plus Medicare) present-value funding shortfall doubles from one to two fifths.[1] As discussed in Gokhale and Kotlikoff (2000), eliminating this funding gap without cutting current or future benefits requires an immediate and permanent 10 percentage point increase in the FICA payroll tax which is currently at 15.3 percent of payroll.

[1]See The 1999 Technical Panel on Assumptions and Methods (1999).

Given the level of current U.S. tax rates, moving from a 15 percent to a 25 percent payroll tax rate would sharply increase the lifetime tax burdens and labor supply disincentives of current and future generations. As it is, today's newborns are projected to pay about one quarter of their lifetime earnings to the government in taxes net of transfers.[2] A 10 percentage-point payroll tax hike would raise this lifetime net tax rate to more than one third. It would also substantially raise the marginal tax brackets of America's workers, most of whom are currently paying close to 50 cents of every dollar earned to federal and state governments.[3] Since the economic costs of tax distortions rise with the square of the tax rate, putting workers into 60 percent rather than 50 percent effective marginal net tax brackets raises the tax system's excess burden from distorting labor supply by 44 percent. In contemplating the need for an immediate 25 percent payroll tax rate, one should bear in mind that delay in implementing reform will necessitate even larger tax increases or benefit cuts in the future.

The Hope for Capital Deepening

But is the situation really this bad? After all, these putative fiscal adjustments are calculated in partial equilibrium, i.e., they ignore general equilibrium feedbacks on wages and interest rates that may arise as part of the demographic transition. In particular, the aging of society could lead to capital deepening and higher real wages as the number of retirees with capital rises relative to the

[2] See Gokhale, Page, Potter, and Sturrock (2000).

[3] This total effective marginal tax rate includes a) marginal federal income taxes, marginal state income taxes, marginal payroll taxes, marginal sales taxes, and marginal excise taxes plus b) marginal reductions in earnings-tested transfer payments, including earned income tax benefits, welfare benefits, food stamps, housing assistance, and itemized tax deductions.

number of workers supplying labor.

Higher real wages would raise the wage base and, thereby, limit the increase in payroll tax rates. The potential for capital deepening was explored by Auerbach, Hagemann, Kotlikoff, and Nicoletti (1989) in an early simulation study of demographic change. But they also pointed out that capital deepening is not inevitable in an aging society because the associated payroll tax hikes will reduce the amount of their earnings available for workers to save and leave them accumulating less capital to finance their retirements.

This study revisits this issue as well as potential reforms using a new dynamic simulation model. The new model follows the significant lead of Fullerton and Rogers (1993) by incorporating intra- as well as inter-generational inequality. It builds on the Auerbach-Kotlikoff model, but has five critical features not included in Auerbach, et. al. (1989). These are 1) a much more realistic treatment of fertility, 2) cohort-specific longevity, 3) multiple earnings groups within each cohort[4], 4) the ability to simulate the model from non steady-state initial conditions, and 5) a more careful calibration of the model to U.S. fiscal conditions and institutions.

Several of these points deserve amplification. To begin, the model developed here permits households to give birth at different ages, rather than immediately upon reaching adulthood. It circumvents the discrete nature of whole births and the family-specific tracking that they would require by assuming that households give birth to fractions of children. This assumption dramatically improves the model's ability to replicate the initial population age distribution and to track changes in that distribution through time. Another advantage of modeling the right distribution of age gaps between parents and children involves bequests and inheritance. Since each cohort of

[4]This feature was introduced in Altig, Auerbach, Kotlikoff, Smetters, and Walliser (2001).

parents has children of different ages, bequests made by decedents are inherited by different age groups, rather than concentrated into the hands of a single age group.

Second, a significant share of the nation's projected aging is due, not to past fertility patterns, but to lifespan extension. According to the Social Security actuaries, today's 65 year-old Americans can expect to live to age 82; in contrast those 65 in 2050 will expect to live to age 84. Incorporating this growth in life expectancy turns out to be important for producing a realistic simulation of the U.S. demographic transition.

A third key element of the new model is its ability to begin simulations from arbitrary initial demographic and economic conditions. Auerbach, et. al. (1989) assumed the economy was in a steady state initially. Since the U.S. has been experiencing tremendous demographic changes over this century, it is very difficult to approximate the actual age distribution with one that would arise with constant fertility and mortality rates. The prevailing U.S. age-wealth distribution is also the result of historic demographic and economic circumstances that cannot easily be represented as steady-state outcomes. To summarize, by starting with the actual U.S. fiscal, economic, and demographic realities, the model herein generates a much more realistic time-path of economic outcomes, allowing us to address the capital deepening question much more rigorously than before.

Key Results

Our first goal in this study is understanding how the economy will fare over time given projected demographic changes and assuming ongoing pay-as-you-go financing of our social insurance programs. Will capital deepening save the day? Or, will larger payroll taxes prevent capital deepening and lead to macroeconomic outcomes that exacerbate our fiscal problems?

Unfortunately, our baseline demographic simulation, which assumes the continuation of current Social Security policy, shows deteriorating macroeconomic conditions that will exacerbate, rather than mitigate, our fiscal problems. Real wages per effective unit of labor fall 4 percent over the next 30 years and 10 percent over the century. The model's gradual capital shallowing reflects the concomitant major rise in tax rates. In 2030, payroll tax rates and average income-tax rates applied to wages are 77 and 9 percent higher, respectively, than in 2000. Together, these tax hikes raise the average total tax on labor income tax by 44 percent. These tax increases and the decline in the wage per unit of human capital will deprive the next generation of much of its natural economic endowment. Taking technology-driven productivity growth into account, workers after-tax real wages will be only 12 percent higher in 2030, compared with 35 percent higher if tax rates and the real wage per unit of human capital were fixed.

Our second goal is to determine whether there is a painless way out of our demographic dilemma. The answer is no. A much faster rate of technical progress would expand the wage base, but still leave a major problem since the value of Social Security benefits at the point of retirement are linked to wage growth. Getting workers to retire later in life would increase the labor supply but reduce capital formation. And cutting Social Security benefits, either directly or by raising the system's normal retirement age, would visit major welfare losses on current or near term retirees.

The advanced funding of retirement income, though, offers a potentially more attractive set of welfare changes. We use the term "advance funding" throughout this paper as a shorthand for a policy that 1) pays off the system's accrued liabilities and 2) requires workers to save the Social Security contributions they would otherwise have made. The model generates the same outcome whether workers' retirement accounts are controlled entirely by the workers themselves or are established and controlled for the workers by the government. While this reform is not a free lunch, it is able to spread the pain more evenly over generations: it entails moderate pain for living generations, but major welfare gains for future generations, particularly those with very low incomes.

Organization

Section II provides a literature review. Section III presents our model, paying particular attention to how we incorporate fertility and lifespan extension. This section also reviews our calibration and solution technique. Section IV presents our baseline simulations plus four variants: one that entertains the Technical Panel's projection of lifespan extension; one with delayed retirement by the elderly; one with twice the Social Security Administration's projected rate of technical progress; and, one with three times the Social Security Administration's projected rate of technical progress.

Section IV also considers different ways to limit Social Security payroll tax hikes while maintaining the pay-as-you-go structure of the system. The first is to gradually cut Social Security benefits in half by 2030. The second is to raise over the next 25 years Social Security's normal age of retirement to age 70 rather than to age 67, which is the policy currently under way. Three final options involve advanced funding Social Security in its entirety. These three options differ with respect to the method of financing the accrued benefit obligations of the old system. The welfare implications of the various reforms are discussed in Section V. Section VI concludes the paper with a summary and caveats about our findings and methodology.

II. Literature Review

The natural marker for any review of the economics of social security is Feldstein's (1974) seminal article contending that the program dramatically lowers national saving. Feldstein's paper spawned an enormous number of theoretical, empirical, and simulation studies. The simulation studies are of most relevance here. Their defining characteristic is the assumption of life-cycle microeconomic saving and labor supply decisions. These microeconomic behaviors are aggregated to determine macroeconomic outcomes. Early contributions here include Kotlikoff (1979), Auerbach and Kotlikoff (1983), and Seidman (1986). These papers confirmed Feldstein's theoretical prediction that unfunded social security systems significantly reduce nations' long-run capital intensivities and living standards. Kotlikoff (1979) and Auerbach and Kotlikoff (1983) examined how introducing "pay-as-you-go" social security **would worsen an economy's economic position through time, notwithstanding induced changes in retirement behavior. Seidman, in contrast, appears to be the first to study the economic gains from entirely eliminating unfunded social security. More recent contributions to the simulation literature include Auerbach and Kotlikoff (1987), Auerbach, Hagemann, Nicolette, and Kotlikoff (1989), Hubbard and Judd (1987), Hansson and Stuart (1989), Arrau and Schmidt-Hebbel (1993)**, Kotlikoff (1996), Samwick (1996), Hubbard, Skinner, and Zeldes (1994a,1994b, 1995), Kotlikoff, Smetters and Walliser (1997, 1998a, 1998b, 1999a, 1999b, and 2001), Huang, _mrohoro_lu, and Sargent (1997), and Imrohoroglu, Imrohoroglu, and Joines (1995, 1999), Knudsen, et.al, (1999), Fougere and Merette (1998, 1999), Scheider (1997), Raffelhüschen (1989,1993), Cooley and Soares (1999a, 1999b), Huggett and Ventura (498), De Nardi, _mrohoro_lu, and Sargent (1999), and Galasso (1999). These studies have included a range of additional important factors, including demographics, land, earnings uncertainty, liquidity constraints, and majority voting on the system's continued existence. They have also examined the different ways a transition to a fully advanced funded social security system could be financed.

Our own past work has explored advance funding, but in a model with no demographic change and, indeed, no children. The principal finding of this research, and one that is reinforced here, is that the method chosen to finance social security's advanced funding can make a major difference to macro- and micro-economic outcomes over the short and medium runs.

The impressive paper by De Nardi, _mrohoro_lu, and Sargent (1999) is the closest antecedent to our own with respect to studying the impact of demographic change on the U.S. economy, but their model differs in many respects. Relative to our model, their model has two strengths: it includes idiosyncratic earnings uncertainty and idiosyncratic longevity uncertainty. But their model is limited in other ways compared with our model: they assume quadratic preferences in order to simplify the solution technique; their model does not include the cost of consumption by children; it lacks intra-generational heterogeneity and, therefore, cannot be used to analyze intra-generational distributional issues; all inheritances are received at the beginning of adulthood; and, their model starts in a steady state. Our framework also carefully models non-Social Security fiscal policies with great precision, including the intricate federal, state and local tax structure as well as Medicare and Disability. Modeling these other fiscal policies in detail is important. For example, under our baseline, changes in Social Security tax rates required to maintain promised benefits will have a potentially much larger impact on capital deepening in the presence of higher non-Social Security tax rates. On the whole, therefore, we are able to more closely calibrate our model to the U.S. economy and demography as well as report the impact of various reforms on different lifetime income groups.

But like our model, Denardi, et. al. (1999) incorporate population aging, including aging arising from lifespan extension. Their baseline simulation, like ours, shows a major increase over time in payroll tax rates. However, their long-run payroll tax increase is roughly 50 percent larger than the increase we report. In addition, their baseline generates some modest long-run capital deepening, as opposed to the capital shallowing found in our study. Notwithstanding the different approaches and differences in certain findings, both studies conclude that advanced funding of Social Security generates major long-run welfare gains, albeit at a cost to transitional generations.

III. The KSW Model

This section describes what we'll refer to as the KSW Model for brevity as well as its calibration and solution methods. It draws, in part, on Altig, Auerbach, Kotlikoff, Smetters, and Walliser (2001) and Kotlikoff, Smetters, and Walliser (2001). However, as noted earlier, these two earlier papers do not contain a realistic treatment of fertility, demographics, and some other model features contained herein.

Preferences, Demographics, and Bequests

The model features twelve lifetime earnings classes in each cohort. An agent in income class *m* maximizes the following utility function:

(1) $$U^m = V(c_p^m, l_p^m) + H(c_k^m, l_k^m) + Z(b^m)$$

The function $V(,)$ records the household's utility from the lifetime consumption vector, $c_{p,}$ and lifetime leisure vector, $l_{p,}$ of the parent. The function $H(,)$ records the household's utility from the corresponding consumption and leisure vectors of young children. And the function $Z()$ measures the household's utility from leaving bequests of b^m per child at the end of life. By assumption, agents reside with their parents until age 20 and form their own households afterwards. So the elements of the vector c_k end at age 20.

To deal with the fact that household heads between the ages of 20 and 45 give "birth" to fractions of children, we define the function *kw(i,j)*, where *j* is the parent's age, ranging from 21 to 75, and *i* is the child's age, ranging from 1 to 20. The *kw(,)* function represents the share of children age *i* that have parents who are age *j*. For example, if *k*w(7,35)=0.05, 5 percent of seven year-olds have parents who are age 25.

(2) $$kw(i,j)=0 \quad if \quad (j-i)<20$$

(3) $$kw(i,j)=0 \quad if \quad j>45 \wedge (j-i)>20$$

Equations (2) and (3) condition the function *kw*. Equation (2) requires that children must be at least 20 years younger than their parents. Equation (3) stipulates that agents older than 45 years do not have any more children. For cohorts under the age of 30, it also holds that

(4) $$\sum_{j=21}^{d} kw(i,j)=1$$

because all of the parents of that cohort are still alive. In (4), *d* stands for the prevailing maximum age of life. However, for older cohorts summing over *j* will generally result in a value of less than 1 because some parents have already died.

The utility functions for parental consumption and leisure and child consumption and leisure are specified as follows:

$$V(\ ,\ )=\frac{1}{1-\frac{1}{\gamma}}\sum_{j=21}^{d}\left(\frac{1}{1+\delta}\right)^{j-21}\left[c_{p,j,m}^{1-\frac{1}{\rho}}+\alpha l_{p,j,m}^{1-\frac{1}{\rho}}\right]^{\frac{1-\frac{1}{\gamma}}{1-\frac{1}{\rho}}}$$

(5)

and

$$H(\ ,\ )=\frac{1}{1-\frac{1}{\gamma}}\sum_{j=21}^{d}\left(\frac{1}{1+\delta}\right)^{j-21}\sum_{i=1}^{20}\phi_i\, kw(i,j)\frac{P(i)}{P(j)}\left[c_{k,i,m}^{1-\frac{1}{\rho}}+\alpha l_{k,i,m}^{1-\frac{1}{\rho}}\right]^{\frac{1-\frac{1}{\gamma}}{1-\frac{1}{\rho}}}$$

(6)

where φ_i stands for the adult-equivalency scale of age-i children and *P(i)* is the size of cohort aged *i*. The cohort size is divided by the parent's cohort size to arrive at the number of children per parent. The utility a parent enjoys from having children is the sum of the welfare levels of all the children living in a parent's household at each age of the parent.

The utility for bequests is defined as follows:

(7)
$$Z(\ )=\left(\frac{1}{1+\delta}\right)^{d-21}\left(\sum_{i=21}^{d} kw(i,d)\, P(i)/P(d)\right)\mu^m\left[b^m\right]^{1-\frac{1}{\gamma}},$$

where b^m is defined as the bequest per child and μ is a bequest preference parameter. Equation (7) says that the parent receives utility from the bequests received by all her children. The number of her children is calculated by adding up all the children that were ever born to the cohort that is dying (the cohort that is currently age *d*) and then dividing by the size of the dying cohort.

Utility maximization by a 21 year-old born in year *t* is subject to the budget constraint given in (8). In this constraint, we do not subscript variables by the year of birth of the cohort or the current time period in order to limit notational complexity.

(8)
$$\sum_{j=21}^{d}\left[w_{j,m}(E-l_{p,j,m})-c_{p,j,m}-T_{j,m}\right]\prod_{s=1}^{j-21}\frac{1}{1+r_{t+s-1}}$$

$$- \sum_{j=21}^{d} \sum_{i=1}^{20} \left(kw(i,j) \frac{P(i)}{P(j)} c_{k,j,m} \right) \prod_{s=1}^{j-21} \frac{1}{1+r_{t+s-1}}$$

$$+ \sum_{j=21}^{d} kw(j,d)\, b^{m} \prod_{s=1}^{j-21} \frac{1}{1+r_{s-1}}$$

$$= b_{d}^{m} \sum_{i=21}^{d} kw(i,d) \frac{P(i)}{P(d)} \prod_{j=1}^{d-21} \frac{1}{1+r_{j-1}}$$

The first element of the budget constraint is the discounted present value of the household's labor income net of a) the amounts consumed by parents and b) the net taxes, of all kinds, paid by parents. Total time endowment is E. The term $T_{j,m}$ references the amount of net taxes paid at age j by income class m. These net taxes are not exogenous, but rather functions of the levels of the relevant bases of the tax and transfer systems that are operative.

The second line of the budget constraint captures the discounted present value of children's consumption. At each age j of the household, there are children of several ages in the household and the budget constraint sums over these children's consumption, giving appropriate weights to each cohort and scaling the consumption by cohort size. The budget constraint assumes that children do not work ($l_K = E$).[5]

The third line is the discounted present value of bequests an average member of cohort j receives over his or her life span. In each year, total bequests of the deceased cohort are distributed

[5] The model generates this outcome endogenously because we set children's wages to zero.

among cohorts who are 20 to 45 years younger (those with positive *kw*). Each cohort aged *j* receives a share of these bequests equal to its share of all the children of the members of the dying cohort. This is done on a class by class basis, so children with, for example, parents in the seventh highest earning class inherit only from parents who are in that earnings class.

The right-hand side of the equation uses the fact that the total value of inheritances received in a given year equals the total value of bequests left in that year. Bequests made by a decedent in a given year is calculated by multiplying the inheritance per capita received by children in that year by the total number of the decedent's children and then dividing by the number of decedents.

Bequests are received by children at the beginning of the period. The parameters μ^j are for each earnings class *j* are calibrated such that the ratio of the bequest to economy-wide mean income corresponds to the ratio originally estimated by Menchik and David (1982) and updated by Fullerton and Rogers (1993). We then inflation-adjusted their values to the year 2000. Bequests range from \$20,000 to \$450,000 for earnings group eight through group twelve, respectively.

Letting a_j^m stand for capital holdings of type *m* agents who are age *j*, a household's assets prior to its last year of life, when it makes its bequest, evolve according to equation (9), where we again ignore time subscripts to ease notation.

$$a_{j+1}^m = (1+r)(a_j^m + Ij^m) + w_j^m(El_j^m) - c_j^m - \sum_{i \in \tilde{T}} T^i\left(A_j^m\right). \tag{9}$$

In (9), r is the pretax return to savings, $I_{j,}^{m}$ are inheritances received from parents at age j, E is the time endowment, and the functions $T^k(\cdot)$ with tax base arguments $A_{j,t}^{m,i}$ determine net tax payments from income sources $i \in \tilde{T} = \{C, K, W, Y, S\}$, where $T^C(\ )$, $T^K(\ )$, $T^W(\ )$, $T^Y(\ )$ and $T^S(\ )$ are the respective tax bases for consumption, capital income, labor income, total income, and net social insurance taxes. Social insurance net taxes incorporate OASDHI payroll taxes net of the benefits of the OASI, DI, and HI programs. The tax system also features a personal income tax and a business profits tax. As discussed below, the base for OASDI payroll taxation is limited by the ceiling on taxable earnings.

Technical Change

Given the nature of our model, including its non-Cobb-Douglas preferences and leisure constraints, the standard assumption of labor-augmenting technological change, which entails multiplying the labor input entering the production function by a factor that grows at a constant rate through time, is not compatible with balanced growth; i.e., with such a formulation of technological change, the economy would never achieve a steady state even were demographics stable. Our solution method requires that the economy achieve balanced growth in the long run.[6] To achieve that end, but still incorporate technical change, we assume a different type of labor-augmenting technical change. Specifically, we assume that technical progress causes the time endowment of each successive generation to grow at rate λ.[7]

More precisely, if E_t^m is the endowment of cohort members of type *m* born at time *t*, then $E_t^m = (1+\lambda)E_{,t-1}^m$, for all *t* and *m*. The endowment $E_{,t}^{\ m}$ depends only on an agent's year of birth. Because *E* grows at rate λ from one cohort to the next, there is no underlying time trend imparted to the wage per unit of human capital, w_t. This fact notwithstanding, agents born later in time will, other things equal, have higher lifetime incomes. The reason is that they will have more time (more effective time units) to allocate to both work and leisure. So their lifetime earnings will be higher

[6] This provides us with a terminal condition that we use in solving for the transition path.

[7] See Auerbach, et al. (1989) for a more complete discussion of this strategy for dealing with balanced

than their forefathers and foremothers, even if they spend the same share of their time working and earn the same wage per effective time unit.

Note that our treatment of technological change is isomorphic to simply positing that each cohort's population size is λ percent larger than that of its immediate predecessor. Stated differently, assuming that each agent has more effective time units available to spend on leisure or working is equivalent to assuming that each agent has a fixed amount of time, but that there are more agents in the economy.[8]

Human Capital

We capture all age- and type-specific skill differences in a single efficiency parameter $\varepsilon_j^{\,m}$. Thus, the wage rate for an agent of type *m* and age *j* is $w_{j,m,,t} = \varepsilon_j^{m} w_t$, where w_t is the economy-wide real wage per unit of human capital at time *t*. The growth-adjusted earnings ability profiles take the form

$$\varepsilon_j^m = e^{a_0^m + a_1^m j + a_2^m j^2 + a_3^m j^3} (1+\lambda)^j \, h_j \tag{10}$$

Values of the *a* coefficients for *m*-type groups 1 through 12—in ascending order of lifetime income—are based on regressions fitted to the University of Michigan's Panel Study of Income Dynamics and are taken from Altig, et. al. (2001). Groups 1 and 12 comprise the bottom and top 2 percent of lifetime wage income earners, and groups 2 and 11 the remaining 8 percent of the top and bottom deciles. All other groups constitute 10 percent of the population. For example, group 3 is

growth.

[8] Note for the isomorphism to be exact, the Social Security ceiling on taxable earnings must be indexed to the rate of growth of effective units of time .

the second decile of lifetime-wage income, group four the third decile, and so on up to group 10.

In estimating these coefficients from the PSID's longitudinal data on wage rates, we abstracted from secular growth in real wages. Such secular growth, which is driven in large part by technological change, is, however, an important determinant of the growth over one's life cycle in real wages. Hence, we explicitly add this growth in our longitudinal real wage profile through the final multiplicative term involving λ. By assuming that growth in the lifetime time endowment and the technology component of growth in real wages over the life cycle both equal λ, we replicate two key features of traditional labor-augmenting technical change. First, in steady state, real lifetime earnings grow at the rate of technical change, and second, the longitudinal age-wage profile is steepened by this same rate of technical change.

The final factor determining real wage growth in equation (10) -- h_j -- is an old-age productivity factor. In our base-case simulation, this factor equals 1 through age 62 and .2 thereafter. This factor is included to model workers reaching a physical limit in their ability to work. Without its inclusion, our model would generate more old-age labor supply than is realistic. A useful byproduct of including this factor is that we can use it to consider whether delays in retirement could materially improve the U.S. fiscal picture. Specifically, in Section V we show how our base-case transition is altered if h_j equals 1 through age 65 and .2 thereafter.

Given our benchmark parameter values, peak hourly wages valued in 2000 dollars are \$4.00, \$14.70, and \$79.50 for individuals in classes 1, 6, and 12, respectively. Steady-state annual labor incomes derived from the model's assumptions and the endogenous labor supply choices range from \$9,000 to \$130,000.[9]

[9] These calculations do not include labor compensation in the form of fringe benefits.

Parameter Values[10]

The value for the time preference rate, δ, is .02. The intratemporal and intertemporal substitution elasticities, ρ and γ, are set to .4 and .25, respectively. The parameter α is chosen so that agents devote, on average, about 40 percent of their available time endowment (16 hours per day) to labor during their prime working years (ages 21-55). We assume a 1 percent value for λ, the rate of technological change. Hence, each successive cohort is endowed with 1 percent more time than its immediate predecessor.

[10] Parts of this section draw heavily from the appendix to Altig, et. al. (2001).

What is the relationship between our utility function parameter values and those typically estimated in the labor supply literature? Papers in this literature contain a variety of different labor supply elasticity concepts. Perhaps most useful from our perspective is that of the "λ-constant" or Frisch elasticity of labor supply (e.g., Thomas MaCurdy 1981), which measures the variation in labor supply along an optimal path holding the marginal utility of income constant.[11]

For our time-separable utility function, a λ-constant change in the after-tax wage, w_t, affects only consumption and leisure at date t. Thus, given the optimal path for these variables (Auerbach

$$l_t = \left(\frac{w_t}{\alpha}\right)^{-\rho}\left(1+\alpha^{\rho} w_t^{1-\rho}\right)^{\frac{\rho-\gamma}{1-\rho}} x(\lambda)$$

and Kotlikoff 1987, p. 31, expressions 3.11 and 3.12), date-t leisure may be shown to satisfy: where $x(\lambda)$ does not depend on w_t. Using (11), we derive the following expression for the λ-constant

$$\eta = \left(\frac{l}{L}\right)\left(\gamma\zeta + \rho(1-\zeta)\right)$$

elasticity of *labor* supply, L_t, with respect to w_t:

$$\zeta = \frac{\alpha^{\rho} w_t^{1-\rho}}{1+\alpha^{\rho} w_t^{1-\rho}}$$

where

[11] Our use of the variable λ here follows the notation found in the relevant literature, and should not be confused with its use in the body of the paper, to represent the rate of technological progress.

Note that ζ corresponds to leisure's "share" in the within-period utility function. Since we calibrate the model for different values of ρ and γ so that this share is roughly .6 (and the consumption/labor share is .4), the value of η from (12) is roughly $1.5(.6\gamma + .4\rho)$. Our values of ρ=.4 and γ=.25, this gives a value of η=.465. This elasticity is reasonable, given the range of values estimated in the literature, some of which are surveyed in Browning, Hansen and Heckman (1998).[12] Estimates for men are in some cases higher, but typically somewhat lower, while estimates for women are generally at least as high, and in some cases much higher.

[12] Other recent papers in the literature include Blundell, Meghir and Neves (1993), Mulligan (1998), and Ziliak and Kniesner (1999).

The Non-Social Security Government Budget Constraint

At each point in time, the government collects tax revenues and issues debt, which it uses to finance government purchases of goods and services (G_t) and interest payments on the existing stock of debt. Government expenditures are assumed to be unproductive and generate no utility to households.[13] The per capita values of government purchases and government debt are held fixed throughout the transition path. To do so, specific tax rates are made endogenous. The initial level of government debt in 2000 was chosen such that the associated real interest payments equal about 3.5 percent of national income in the economy's initial position. The statutory tax schedules, described below, generate a level of revenue above debt service such that the benchmark steady-state ratio of government purchases to national income equals 0.239. These values correspond very closely to the corresponding 2000 values for the combined local, state, and federal government in the United States.

Non-Social Security Taxes

The benchmark tax system in our economy's initial position is designed to approximate the salient aspects of the 2000 U.S. federal, state, and local tax and transfer system. It features separate wage and capital income taxes, a consumption tax, and a payroll tax. To adjust for tax evasion, we reduce income taxes by 2.6 percentage points. This adjustment is consistent with the degree of tax evasion reported in Slemrod and Bakija (1996). In the various alternative tax structure experiments we assume that evasion reduces the post-reform tax base (income net of deductions and exemptions) by the same percentage as before the reform. Thus, the level of tax evasion falls when the tax base

[13] Since G remains fixed in all of our experiments, incorporating G into the utility function is unimportant.

shrinks. We approximate the hybrid U.S. tax system by specifying a progressive wage-income tax, a flat-rate capital-income tax, a flat-rate state income tax, and a flat-rate consumption tax.

Wage Income Taxation

The wage-income tax structure has four elements: 1) a progressive marginal rate structure derived from a quadratic approximation to the 2000 federal statutory tax rates for individuals, 2) a standard deduction of \$4000 and exemptions of \$5660 (which assumes 1.2 children per agent, consistent with the model's population growth assumption), 3) itemized deductions — applied only when they exceed the amount of the standard deduction — that are a positive linear function of income estimated from data reported in *Statistics of Income*,[14] and 4) earnings-ability profiles, discussed above, that are scaled to incorporate pension and non-pension components of labor compensation.[15]

In the first year of the transition, the effective marginal tax rate on labor income at age 45

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[14] The data used in this estimation was taken from all taxable returns in tax year 1993. The function was obtained by regressing deductions exclusive of mortgage interest expense on the midpoints of reported income ranges. (The deduction of interest expense on home mortgages was included in our calculation of the capital-income tax rate, as we will subsequently describe.) The regression yielded a coefficient of 0.0755 with an R^2 equal to 0.99.

[15] We are indebted to Jane Gravelle of the Congressional Research Service and Judy Xanthopoulos of the Joint Committee on Taxation for providing the function relating fringe benefits to adjusted gross income. Based on this information we regressed total benefits on AGI. The regression yielded a coefficient of 0.11295 with an R^2 equal to 0.99. In defining the wage-tax base, we therefore exempt roughly 11 percent of labor compensation from the base calculations.

for those in the highest earnings group (12) is 24.2 percent and the average tax rate is 13.8 percent. The corresponding tax rates for age-45 members of group 6 are 18.1 and 10.9 percent. For group 1 members, the tax rates are 16.5 and 1.1 percent. Note that for those in group 1, their marginal tax rate includes the value of the shadow tax rate needed to induce them to voluntarily and optimally choose labor supply at the kink point on their budget constraint that is caused by the standard deduction and exemptions. These simulated tax rates are close to the empirical estimates, as discussed in Altig, et al, (2001).

Capital Income Taxation

Following Auerbach (1996), we assume that income from residential capital and non-residential capital are taxed at flat rates of 6 percent and 26 percent, respectively. Given the roughly equal amounts of these two forms of capital, the effective federal marginal tax rate on total capital income is 16 percent. However, this rate applies only to new capital. Existing capital faces a higher tax rate which, given depreciation schedules, is estimated to be 20 percent. We model this gap by assuming that all capital income faces a 20 percent tax, but that 20 percent of new capital may be expensed, thereby generating a 16 percent effective rate on new capital.

State Income Taxation

In addition to the federal taxation, both capital and wage income are subject to a proportional state income tax of 3.7 percent. This value equals total state income-tax revenue in 2000 divided by national income.

Consumption Taxation

Consumption taxes in the economy's initial position reflect two elements of the existing tax structure. First we impose an 8.8 percent tax on consumption expenditures consistent with values reported in the National Income and Product Accounts on indirect business and excise revenues. However, because contributions to both defined benefit and defined contribution pension plans receive consumption tax treatment, we levy an additional 2.5 percent tax on household consumption goods expenditures to account for the indirect taxation of labor compensation in the form of pension benefits (Auerbach 1996). This 2.5 percent tax replaces the wage tax that otherwise would apply to the fringe benefit component of labor compensation.

Social Security, Medicare, and Disability

The model has a social insurance system that incorporates social security Old-Age and Survivors Insurance (OASI), Social Security Disability Insurance (DI), and public health insurance taking the form of Medicare (HI). OASI benefits are calculated according to the progressive statutory bend-point formula. U.S. Social Security benefits are based on a measure of average indexed monthly earnings (AIME) over a 35-year work history. The AIME is converted into a primary insurance amount (PIA) in accordance with a progressive formula. In particular, the 2000 benefit formula has two bend points. The PIA is calculated as 90 percent of the first $437 of AIME, 32 percent of the next $2,198 of AIME, and 15 percent of AIME above $2,198. In the model, we wage-index past covered earnings based on the growth in the economy-wide real wage per unit of human capital.

We approximate the benefit formula with a sixth-order polynomial which is applied to the dollar-scaled AIME generated by the model. This polynomial approximation is very accurate with a $R^2 = 0.99$. We achieve replacement values between 25 and 75 percent for the lifetime richest and lifetime poorest, respectively. Since approximately 50 percent of Social Security benefits are paid to survivors and spouses, we multiply benefits by a factor of two. In ignoring the fact that the rich live longer than the poor, we may, as suggested by Fullerton , et. al. (2000), be overstating the program's degree of progressivity.

Our model has separate OASI, DI, and HI taxes. The values of the OASI tax rate are determined endogenously to finance benefits on a pay-as-you-go basis. The net OASI marginal tax rate enters agents' first-order conditions in determining their supplies of labor. These effective marginal net payroll taxes differ across agents. For example, low income agents receive a better return on their OASI contributions due to the progressivity of the system's benefit formula. This reduces the size of their effective net tax rate. And high earning agents face a zero net marginal OASI as well as DI tax since their marginal labor income is not subject to OASDI taxation. Our simulations assume full perception of marginal OASI net taxes, i.e., they assume that agents correctly foresee how their OASI payroll tax payments relate to their OASI future benefits.

The HI and DI levels of lump-sum transfers are chosen to generate payroll tax rates of 2.9 percent and 1.9 percent, respectively, corresponding to their 2000 statutory rates. Like the OASI taxes, DI contributions apply only to wages below $62,700. The HI tax, in contrast, is not subject to an earnings ceiling. Lump-sum HI and DI benefits are provided on an equal basis to agents above and below age 65, respectively.

Aggregation and Production

The aggregate supply of capital at a point in time is obtained from summing over individual asset holdings and subtracting the contemporaneous value of government debt. The aggregate supply of human capital at a point in time is calculated by summing together the effective labor supplies of all agents. Any particular agent's labor supply is simply given by the product of a) the difference between her time endowment and her leisure and b) her human capital efficiency coefficient specified in equation (10). Output (net of depreciation) is produced by identical competitive firms using a standard Cobb-Douglas production function, with a capital coefficient equal to .25.

Initial Demographic and Economic Conditions, Lifespan Extension, and Population Growth

Our kidweight function is assumed to remain fixed through time. Its values were obtained from Social Security Administration estimates for 2000. The same data source provides past and projected totals of cohort births, which we use to fill in our cohort population functions. The Social Security population projections extend through 2075, after which we assume that the birth rate stabilizes. We also used Social Security life expectancy data to calibrate the model's initial maximum age of life and changes in this age through time. The particular data we used here are Social Security's uni-sex life expectancies conditional on reaching age 65. Life expectancy equals 82 for the year 2000 and increases to 83 by 2010, 84 by 2030, and 85 by 2060.[16]

[16] As discussed by Fullerton, et. al. (2000), assuming all members of a given cohort die at the expected age of life misses some of the redistributive properties of Social Security associated with its provision of from survivor and children's benefits as well as the dispersion of death dates.

Table 1 compares our model's predicted population totals as well as population shares with those forecast by the Social Security Administration. Our population totals line up quite well over the next 30 years, but understate projected population growth thereafter. In 2030, the model predicts there will be 22.8 percent more Americans alive than are now living. The comparable Social Security figure is 22.6 percent.

The model also does a very good job tracking population shares. In 2075, the model predicts that 23 percent of the population will be 65 and older – the same share predicted by Social Security. In that year the model's and Social Security's predicted shares of those under age 20 differ by only 1 percentage point. Note that the U.S. population is predicted by both Social Security and our model to get old and stay old. Thus, unless policy is changed, the economic implications of America's aging will be here to stay.

Our model also requires an initial level and distribution of assets by age and earnings class. To obtain these initial conditions, we calculated average net worth by age of household head in the 1998 Survey of Consumer Finances. For each earnings class at a given age we set initial assets equal to the average for its age group multiplied by the ratio of the earnings class' wage at age 40 to that of earnings class 6's wage at age 40. Thus we determine relative initial assets by earnings class based on a rough measure of relative lifetime earnings capacity. Given this preliminary allocation of net worth by age and earnings class, we scale up or down each agent's assets by the same factor until the model produces a realistic year-2000 national saving rate.

Solving the Model

The model uses a Gauss-Seidel algorithm to solve for the perfect foresight general equilibrium transition path of the economy. The calculation starts with a guess for the time-paths of the aggregate supplies of capital and labor then iterates on those variables until a convergence criterion is met. In each iteration, the time-paths of aggregate factor supplies are set equal to their corresponding factor demands and are thus used to determine the time-paths of factor prices. These factor price time-paths are, in turn, used in conjunction with time-paths of tax rates and certain shadow prices to determine the household sector's supplies, over time, of labor and capital. In addition to this "outerloop" iteration, the model has "innerloop" iterations that ensure that, given the iteration's assumed time-paths of factor prices, households are properly maximizing lifetime utility subject to their lifetime budget constraints.

Household optimization includes the constraint that leisure not exceed the endowment of time. For those households who would violate the constraint, the model calculates shadow wage rates at which they supply exactly zero labor. The household's budget constraint is kinked due to the tax deductions applied against wage income. A household with wage income below the deduction level faces marginal and average tax rates equal to zero. A household with wage income above the deduction level faces positive marginal and average tax rates.

Due to the discontinuity of the marginal tax rates, it may be optimal for some households to locate exactly at the kink. Our algorithm deals with this problem as follows. We identify households that choose to locate at the kink by evaluating their leisure choice and corresponding wage income above and below the kink. We then calculate a shadow marginal tax rate from the first-order conditions that puts those households exactly at the kink. This procedure generates optimal forward-looking leisure and consumption choices for all periods of life.

The payroll tax ceiling introduces additional complexity by creating a non-convexity in the budget constraint. For those above the payroll tax ceiling, the marginal tax rate on labor falls to zero. We model this non convexity by assuming that earnings groups 8 through 12 face no marginal payroll tax on their labor supply, but rather simply an inframarginal payroll tax equal to the payroll tax rate times the payroll tax ceiling. For earnings groups 1 through 7, we assume that payroll taxes are assessed on all their earnings.[17]

[17] These assignments generate what appear to be minor degree of mis-assignment of payroll tax rates for members of groups 7 and 8 in certain years.

The sequence of calculations follows: An initial guess is made for the time-paths of aggregate factor supplies as well as for the shadow wage rates, shadow tax rates, endogenous federal wage-income or consumption tax rates, OASI, DI, and HI payroll tax rates, and the Social Security and Medicare benefit levels. The corresponding factor prices are calculated along with the forward-looking consumption, asset and leisure choices for all income classes in each current and future cohort. Shadow wages and shadow taxes are calculated to ensure that the time endowment and the tax constraints discussed above are satisfied. Households' labor supplies and assets are then aggregated by both age and lifetime income class at each period in time. This aggregation generates a new guess for the time-paths of the capital stock and labor supply. The tax rate, which is endogenous for the particular simulation, is updated to meet the relevant revenue requirement. OASI, HI, and DI payroll tax rates are also updated to preserve the pay-as-you-go financing of these benefits.[18] The new supplies of capital and labor generated by the household sector of our model are weighted, on an annual basis, with the initial guess of these supplies to form a new guess of the time path of these variables. The algorithm then iterates until the capital stock and labor supply time-paths converge. We give the economy 275 years to converge to its final steady state.

Checking the Solution and Uniqueness

Although the model is highly stylized, there are enough interacting and complex elements for a reader to wonder if one can really check the solution. Indeed, we can and do check that the transition path to which our program converges is indeed an equilibrium. We do this by verifying that a) supply for labor, capital, and output equal their respective demands in each year, b) all agents

[18] Note that the Social Security replacement rate and absolute level of Medicare benefits are exogenous.

in each cohort satisfy their intertemporal budget constraints, c) the constraint that leisure not exceed the endowment of time is never violated, and d) the government satisfies its intertemporal budget constraints.[19] A related question is whether the "box" we've created is black or whether we can see through it and provide the intuition for the results. We believe the results are easily explained and that differences across simulations are exactly what one would expect.

One might also wonder whether the transition paths we generate are unique. Although we have no formal proof of uniqueness, Laitner (1984) has proved uniqueness in a linearized version of the original Auerbach-Kotlikoff model for the same utility- and production-function parameter values entertained here. Another indicator of uniqueness is that we arrive at the same long-run steady state from any arbitrary initial conditions provided the policy chosen is held fixed. In addition, small perturbations in initial conditions generate transition paths that are very close to those without the perturbations. Were there multiple equilibria, one would expect that small differences in initial conditions could lead to substantial differences in how the economy progresses through time. Finally, we had no problem getting the model to converge for the simulations we report, which would be unlikely were their multiple paths on which the economy could embark. In contrast, despite several months of effort, we were unable to get a simulation to converge in which Social Security benefits are maintained *and* the ceiling on taxable payroll is eliminated. Apparently, placing high income households into much higher marginal tax brackets renders the model very hard to solve, suggesting that there may be an economic barrier to conducting certain policies.

[19] Given Walras' Law, some of these checks are redundant.

IV. Findings

This section first presents our base-case transition and explores its sensitivity to longevity, retirement behavior, and the rate of technical change. We then consider two reforms of the existing pay-as-you-go OASI program that would limit increases in the OASI tax rate. These are an additional 3-year increase in the normal retirement age and a gradual 50 percent cut in benefits. Social Security's normal retirement age is already scheduled to rise from 65 to 67 between now and 2025. In simulating the increase in the normal retirement age we simply modify the base case to phase in the higher age over the same time period. In simulating the benefit cut, we assume it occurs gradually over the next 30 years, with benefits for each year's new set of retirees declining an additional one thirtieth of 50 percent. Our remaining three policy simulations all fully advance fund the OASI system, but differ with respect to the method of financing benefits accrued under the old system. The three methods of transition finance are a proportional consumption tax, a proportional wage tax (with no ceiling on taxable earnings), and an increase in the model's income tax.

The Base-Case Demographic Transition

The first panel in Table 2 shows how key macroeconomic variables evolve in our base-case transition in which Social Security and Medicare tax rates are adjusted through time to finance the benefits of those programs on a strictly pay-as-you-go basis. The economy's year-2000 national saving rate is 4.6 percent, its pre-tax return to capital is 7.5 percent, and its OASDHI tax rate is 13.7 percent. The saving rate is within close range of the current U.S. national saving rate. The pre-tax return to saving also seems reasonable.[20] And, the model's combined OASDHI tax rate is with .6

[20] Calibrating a model of certainty to a world of uncertainty is a particular challenge when one considers

percentage points of the current combined cost rate of those three social insurance programs. Another important initial condition, not shown in the table, is the economy's capital-output ratio. This value is 3.3, which is at the lower range of recent estimates of this variable based on market valuations of assets.

Consider next the economy's evolution through time. Although the economy is aging, total effective labor supply continues to increase. Indeed, in 2030, labor supply is 58.7 percent larger than its initial value. This growth is due primarily to our assumed labor-augmenting technical change that raises successive cohorts' time endowments by 1 percent. Absent this technical change, the economy's 2030 labor supply would exceed its 2000 supply by only 24 percent.

The rapid aging of the population and the growth of labor income affect capital accumulation. According to the model, the nation's capital stock and output in 2030 are 36.6 percent and 52.9 percent greater than their respective 2000 values. Since labor supply growth over the next three decades exceeds growth in the capital stock, the capital-output ratio falls over this

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the return to capital. A 7.5 percent real return is somewhat below the historic per-tax return earned, on average, by U.S. corporate capital. But it's also higher than the much safer rate of return paid on government debt. Were we able, in our model, to incorporate uncertainty, agents' welfare changes arising from policy reforms would depend on their risk aversion and the degree to which the reform alters not only average levels of government receipts and payments, but also their distributions. I.e., welfare changes from reforms would depend on changes in the riskiness of government policy. Since our model incorporates neither micro or macro risk., risk-exacerbating policy, or risk-mitigating policy, it would not be appropriate to apply some external risk adjustment to the discount rate in our model for purposes of evaluating our model's policy-induced welfare changes. Instead, we need to consistently use our model and glean whatever lessons we can from it. Hopefully, these lessons will provide a useful reference point from which to consider the same policy reforms, but in a context of economic and policy uncertainty.

period, and, indeed, continues to fall over the remainder of the century. In 2030, the real wage is 3.7 percent lower than in 2000; in 2100, it's 9.8 percent lower. Over the next three decades, the real return to capital rises by almost 100 basis points and then increases by another 200 basis points over the rest of the century.

The good news then is that output growth will continue, provided technical change continues apace. The bad news is that the economy won't grow as rapidly as it might, that there is capital shallowing rather than capital deepening, that the real wage (the wage per unit of human capital) falls, and that the OASDHI payroll tax rate rises dramatically.

Whither the Increase in Capital Intensity?

The main reason the retirement of the baby boomers doesn't generate a rise in capital intensity, with its associated rise in real wages and decline in the real return to capital, is the presence of the Social Security and Medicare programs. As the next to the last column in Table 2 shows, the baseline transition features a remarkable increase in the OASDHI payroll tax rate -- from 13.7 percent in 2000 to 24.3 percent in 2030.[21] Most of this tax increase occurs between 2010 and 2030. As the payroll tax rises, it reduces significantly the amount of asset accumulation that occurs in these two decades, and this reduction in asset accumulation prevents the capital stock from rising relative to the work force. Between 2030 and 2100, the OASDHI tax rate rises to 26.5 percent. Hence, the payroll tax not only rises dramatically. It also stays very high for the rest of the century.

Are these tax rate increases plausible? They are, indeed. The last column in Table 2 shows

[21] Recall that our model's 13.2 percent value for the tax rate in 2000 is lower than the actual 15.3 percent OASDHI tax rate because we incorporate payroll taxes in excess of benefit costs as part of general revenue finance.

the Social Security Administration's (SSA's) own cost rate projections. SSA projects a 68 percent increase in cost rates between 2000 and 2030, compared with 77 percent in our model. In 2075, the model's and SSA's projected cost rates are almost identical.

A second factor preventing capital deepening is the increase over time in the rate of general revenue taxation. As previously mentioned, we model the federal income tax by a) taxing capital income at an effective rate of 20 percent, which we hold fixed through time, and b) taxing labor income on a progressive basis. Specifically, the marginal tax rate is zero for wage earnings below the level of minimum taxable earnings, which we calibrate based on existing deductions and exemptions, and a linear function of wage earnings for earnings above this minimum. Along the economy's baseline transition path, we adjust the intercept of this marginal tax rate function. This adjustment affects both the average and marginal rates of taxation of wage earner. In year 2000, the average value (across all wage earners) of the average labor income tax rate (not including Social Security, Medicare or Disability) is 11.3 percent. The average marginal tax rate in that year is 15.2 percent. By 2030, the average value of the average wage tax rate is 12.3 percent, while the average marginal rate is 14.3 percent.

The fact that workers have less disposable income from which to save as well as less incentive to can be seen in their asset accumulation. If one ignores the expansion of workers' time endowments through technical change and compares a middle-class (group 5) 40 year-old in 2030 with a 40 year-old in 2000, one finds the 40 year-old in 2030 holding 25.7 percent fewer assets.

A third point is that when the population is measured in terms of lifetime labor productivity, the nation's impending aging is much less significant. Table 3 compares the evolution of population shares measured in bodies with shares measured in units of lifetime labor productivity. Under the former measure, the share of the elderly in 2000 is 12 percent; under the later measure, it's 9 percent. In 2030, the elderly represent 22 percent of the population, but only 16 percent of the population adjusted for lifetime productivity. Thus, correcting for labor productivity, the population is substantially younger now and will be substantially younger in the future.[22]

A final possible reason that capital deepening does not arise is that the country is not starting its aging process from a steady state with a stable ratio of capital per effective unit of labor. If, because of historic reasons, including past fiscal policy and high asset valuations in 2000, the capital-labor ratio is unusually high, the country may, in part, be embarked on a transition path to a lower capital-labor ratio.

Living Standard Implications

As mentioned, payroll taxes in 2030 are 77 percent higher than in 2000, and average income tax rates are 9 percent higher. Together, these tax hikes raise the average total tax on labor income tax by 42 percent. These tax increases will deprive the next generation of workers of much of their natural economic inheritance. Taking technology-driven productivity growth into account, the after-tax real labor earnings for 40 year-old workers in 2030 will be only 12 percent higher because of the tax increases, compared with 35 percent higher were tax rates fixed.

[22] Recall that in our model, a higher rate of technical change has the same implications as a higher rate of population growth. And faster population growth translates into a younger society.

Alternative Life Expectancies

Although the Social Security Administration projects substantial growth in longevity, this growth falls short of that forecast by demographers Ronald Lee and Lawrence Carter in their most recent update of their original 1992 calculations. The Social Security Administration's projection assumes it will take Americans over four decades to start living as long as the Japanese now live. The more optimistic Lee-Carter projection was adopted by the 1999 Technical Panel of the Social Security Advisory Board. It foresees 65 year-old Americans in 2050 living to age 86 – three years longer than the Social Security Administration predicts.

The second panel of Table 2 shows the results of replacing the base-case longevity projection with that of Lee and Carter. The major differences between the base case and the Lee-Carter simulation involves the OASDHI tax rate. In 2030, the Lee-Carter tax rate is 0.6 percentage points higher than in the base case. By 2100 it is 2.6 percentage points higher. The need to save for a longer retirement stimulates some additional capital accumulation as well as more labor supply. In the long-run, the economy's capital-labor ratio and the real wage are essentially unchanged.

Delayed Retirement

Table 2's next panel considers whether getting retirees to go back to work would materially improve the situation. Specifically, it displays the results of assuming that workers remain fully productive through age 65 rather than through age 62, while still collecting their Social Security benefits at their normal retirement ages. Unfortunately, the results suggest that delayed retirement (as opposed to delayed receipt of benefits) is no panacea with respect to our social security problems. The 2030 OASDHI tax rate is essentially unchanged. Aggregate labor supply is not much affected by the increase in retirement because young and middle-aged agents spend some of their higher future earnings on more leisure. For example, in 2030, 40 year-olds in group 6 supply 0.6 percent less labor than in the base case.

Delayed retirement also leads workers to reduce their retirement saving. This means that, compared with the base-case transition, there is less capital accumulation along the economy's transition path. This, in turn, spells a great decline through time in the capital-labor ratio and the real wage. In 2030, the real wage is 4.2 percent lower than its initial value, compared with 3.7 percent lower in the base case. This decline in the real wage undoes the decline in the OASDHI tax rate associated with the expansion of the economy's labor supply from delayed retirement.

Can Higher Rates of Technical Change Save the Day?

The next two panels of Table 2 reproduce the baseline transition, but assume, respectively, 2 and 3 percent annual growth rates of technical progress rather than the 1 percent rate assumed in the base-case. These higher rates of growth in the size of the effective work force limit the rise in payroll tax rates through time. In 2030, the OASDHI tax rate is 24.3 percent in the base case, but 21.7 percent with 2 percent technical progress and 19.2 percent with 3 percent technical progress. In 2100 the base-case OASDHI tax rate is 26.5 percent; the corresponding tax rates assuming 2 and 3 percent technical progress are 19.7 and 14.7. One would expect higher rates of technical progress to effectively reduce the country's aging and materially limit the rise in the OASDHI tax rate. But even assuming an historically very high 3 percent rate of technical progress, the OASDHI tax rate still rises by one third between now and 2030.

Higher rates of technical progress have only minor implications for capital intensity. The capital shallowing exhibited in the base case occurs here as well, meaning that the real wage per unit of effective labor also declines. With a 2 percent rate of technical change, the long-run wage is 9.1 percent lower than its initial value; with a 3 percent rate of technical change, it's 8.7 percent lower. For point of reference, the long-run real wage decline in the base case is 9.8 percent. Other things equal, one would expect higher rates of technical change of the type we entertain to lower the real wage relative to the base case since it entails more rapid growth of the effective labor force. But there is a countervailing force at work, namely, the fact that more rapid growth in the labor force means a larger payroll tax base along the economy's transition path. This lessens the increase over time in the payroll tax rate, and, in turn, lessens the decline over time in capital per effective worker.

Gradually Cutting OASI Benefits By 50 Percent

The next set of results consider a gradual, 50 percent cut in OASI benefits. This reduction leaves the OASDHI tax rates in 2030 and 2100 only 2.0 and 3.5 percentage points above the 2000 level. Limiting the growth in payroll tax rates limits the extent of capital shallowing. Indeed, in 2030, the capital-labor ratio is the same as in 2000. Thereafter, the supply of capital does grow more slowly than labor supply. But the long-run wage per effective unit of labor supply ends up only 2.5 percent lower, compared with 9.8 percent lower in the base case.

What's interesting, though, is that the long-run wage falls at all. Absent major increases in the payroll tax rate, one might expect that U.S. population aging would generate a major increase in capital per unit of effective labor and, therefore, a substantial rise in the real wage. There are two explanations, mentioned above, why this doesn't occur. First, population aging measured in terms of the share of effective labor units over age 65 is substantially less than measured in terms of the share of bodies (agents) over age 65. Second, our intuition about population aging leading to a higher level of capital per unit of labor is predicated on a) starting out in a steady state, b) simply changing the economy's fertility rates over time, and c) considering where it will end up. But the actual U.S. is not now, and has not been, in a steady state and it is not now, and has not been, engaged in such a controlled experiment. Instead the economy is embarking on its future from a current endowment of capital per unit of effective labor that is the result of the very long and complicated history of U.S. capital formation. Thus the fact that the transition under this benefit-cut policy doesn't eventuate in a major increase in capital per effective unit of labor input relative to its current value appears to also reflect historical circumstances (the size of this initial condition).

While U.S. aging, in the absence of major payroll tax hikes, does not generate substantial increases in capital intensity relative to the historically determined current value, it does, nonetheless, generate major increases in capital intensity relative to base-case policy under which payroll tax rates rise dramatically.

Raising Social Security's Retirement Age

A three-year increase in the normal retirement age constitutes a roughly 17 percent benefit cut. The next panel in Table 2 shows the results of such a policy. While the OASDHI tax hike is mitigated, the effect is small. By 2030, the tax rate is 19.2 percent. At the end of the century, it's 20.9 percent. The message here is that even a very major increase in the OASI retirement age would not suffice to prevent major increases in the rate of payroll taxation.

Advanced Funding Social Security

Our next three simulations contemplate an even more dramatic change to the OASI program, namely its complete advance funding *at the margin* by paying out only those benefits accrued under the current system. To be precise, the three simulations pay the OASI benefits of initial retirees in full, and then linearly phase out OASI benefits for new retirees over a 45-year period starting in 2000, giving each future retiree a value roughly equal to the amount that they accrued under Social Security. In addition to providing current retirees their full accrued benefits and existing workers with their accrued benefits, each advanced funding policy eliminates the OASI tax rate and finances transitional OASI benefits with a new tax. Since workers in our model face no liquidity constraints, they are free and able to borrow against any funds they might be forced to save as part of this reform. Consequently, there is no need to specify the institutional arrangements attendant to the compulsory saving policy. Nor does it matter whether workers control their own compulsory private accounts or whether the government does so on their behalf; the outcome is the same.

Consider first using a specially dedicated consumption tax for transition finance. The required tax rate is initially 10.1 percent. It rises as the baby boomers retire to a value of 13.6 percent in 2020 and then gradually declines. After 2062, the added tax is zero. The combined OASDHI payroll tax is reduced immediately by 9 percentage points. It then grows by 3.4 percentage points over time as the demographics raise cost rates for the DI and HI programs. Since Social Security benefits are indexed to the consumer price level in the model, benefits are higher in each period along the transition path by a percentage equal to the prevailing consumption tax rate.

The long-run economic gains from advance funding are substantial. Compared with the base case, the real wage is 15.1 percent higher in 2100. These gains arrive, however, slowly. By 2030, the real wage is only 5.3 percent larger than it would have been in the absence of advance funding.

This relatively slow adjustment to Social Security's advance funding is not surprising given the enormous overhang of accrued OASI benefits that need to be paid.

The major rise in the real wage reflects significant capital deepening. By 2030, the capital stock is 22.5 percent larger than in the base case. By 2100, it's 77.6 percent larger. Long-run labor supply, in contrast, is somewhat smaller than in the base case. However, the stimulus to capital formation is, by itself, enough to generate more output. Indeed, output at the end of the century is 11.1 percent larger thanks to advance funding.

While the consumption-tax transition is slow, it is more rapid than either the wage- or income-tax financed transitions. Both of the later two transitions leave the economy in the same long-run position, but neither generates any capital deepening over the next thirty years. Indeed, in both cases there is capital shallowing at least through 2030 and aggregate output in that year is essentially the same as in the base case.

The explanation here is twofold. First, the consumption tax places more of its tax burden on the initial elderly, who, because they are close to the ends of their lives, have higher propensities to consume than do the initial middle-aged or the young. In placing a bigger share of the burden of paying off OASI on old spenders and lowering the fiscal burdens on young savers, the economy consumes less and saves more. Stated differently, with wage- and income-tax transition finance, the young and middle-aged are left with less disposable income that they can save for old age. The second reason is that the consumption tax represents, in part, a lump-sum tax on the economy's initial wealth. Because lump-sum taxes are non-distortionary, the consumption tax provides workers with better overall incentives to work and save.

V. Welfare and Distributional Effects of Alternative Reforms

Tables 4 through 8 show the welfare effects across multiple lifetime income groups of the five policy reforms discussed above. The welfare changes are measured as the equal percentage increase (decrease) in consumption and leisure needed by an agent in each year of her remaining life in the base-case transition to achieve the same level of remaining lifetime utility as under the policy. For brevity, the tables consider agents in five selected earnings classes born in different years, where the year of birth is measured relative to 2000.

Welfare Effects of Cutting Social Security Benefits or Raising the Normal Retirement Age

Table 4 displays the welfare effects from the gradual, 50 percent reduction in OASI benefits. This policy is fairly benign when it comes to the very oldest initial members of society, whose benefits are largely unchanged. But it visits some rather large welfare losses on initial middle-aged and low-income agents who are close to retirement and experience most of the benefit cut. The largest of the table's reported losses is the 7.0 percent loss of agents in class 1 who are initially age 60. In contrast, their highest-earning contemporaries, those in group 12, have a much smaller welfare change -- only .935 percent. This is expected given the comparatively small stake that high-income agents have in Social Security and the progressivity of the system's benefit formula.

While cutting OASI benefits in half is highly regressive in the short run, it's also highly progressive in the long run. Take those born 80 years after the policy begins. The poor in this cohort experience an 11.0 percent welfare gain, while the rich experience only a 2.8 percent gain. This long-run progressivity of reducing or eliminating pay-as-you-go Social Security is a feature of our other policy simulations as well.

What explains these long-run results? There are three offsetting factors at play. First, in cutting OASI benefits, we are cutting the benefits of a system that provides benefits on a progressive basis. This would suggest a regressive long-run outcome. But, secondly, in cutting benefits we are precluding major increases in the highly regressive Social Security payroll tax. Stated differently, maintaining the pay-as-you-go nature of Social Security is highly regressive given that it will visit major tax hikes on low- and middle-income workers, but not on high-income workers, given the ceiling on the payroll tax. The third factor involves the long-run increases in real wages arising under the different policies. High- as well as middle- and low-income agents experience the same percentage real wage increase. But since we are dealing here with large tax and wage changes, there is a significant interaction between the two; i.e., for those paying a larger share of their lifetime earnings in payroll taxes, the real wage increase coupled with the substantial long-run tax cut spells a larger percentage increase in lifetime after-tax earnings.

Table 5 shows the welfare effects from raising Social Security's normal retirement age by 5 rather than 3 years by 2025. As expected, the pattern of welfare changes is similar to that in Table 3 because this policy represents an indirect way of phasing it a major benefit cut. But because benefits are cut by a smaller percentage, the losses to the losers and gains to the winners are smaller than in the previous case.

Welfare Effects of Advance Funding the Receipt of Retirement Income

Tables 6 through 8 present welfare changes arising from phasing out the OASI program assuming consumption-, wage-, and income-tax finance of transition benefits. Note the remarkably large welfare gains advance funding generates for low- and middle-income agents in the long run. Class 3, for example, experiences close to a 21 percent gain. For Class 12, there is also a sizable, 5.2 percent long-run gain. Why are these long-run gains so large? First, advance funding the OASI system prevents the doubling over the course of the century of what is already a very high tax. Second, it eliminates this very high tax. And third, it leads to substantial capital deepening. Indeed, rather than declining by 10 percent, the real wage ends up rising by 5 percent. Compared with the base case, this long-run 15 percent increase in real wages and the roughly 20 percentage point decline in the payroll tax rate is strong medicine for what would otherwise be a rather ailing economy.

Since all three advance funding experiments generate the same long-run welfare levels, their welfare differences involve the treatment of initial generations. Wage-tax transition finance entails essentially no welfare changes for the initial elderly and very small welfare changes for those about to retire at the time of the reform. In contrast, initial young workers fare much worse with wage-tax finance than with either consumption-tax or income-tax finance. The reason is that under wage-tax finance, the initial elderly aren't asked to contribute very much to pay off the benefit liabilities of the old system.

Take, for example, initial 20 year-olds in class 6. Their welfare loss is 1.12 percent under wage-tax finance, whereas under consumption-tax and income-tax finance, they experience welfare gains of 1.26 percent and 1.02, respectively. In delaying the transition, wage-tax finance also reduces the welfare gains that would otherwise be enjoyed by generations born a short time after the reform. Class 6 members born five years after the reform begins experience a 4.78 percent welfare gain with wage-tax finance, but 8.48 percent and 7.22 percent gains under consumption- and income-tax financing of the transition.

A comparison of Tables 6 and 8 indicates the somewhat surprising fact that income-tax financing hurts the initial elderly more than does consumption-tax financing. There are three reasons. First, OASDHI benefits are indexed by the model to the price level, so the consumption tax used to finance the advance funding transition triggers a benefit adjustment that insulates the real purchasing power of the elderly's benefits. In contrast, this automatic tax protection isn't triggered by increases in the income tax. Second, one can, and our agents do, partly avoid the consumption tax by making bequests. This option isn't available with income taxation; i.e., agents pay the same income tax regardless of how they spend their money. Third, given our modeling of investment incentives as partial expensing of new capital goods, increases in the capital-income tax rate, which occurs under income-tax finance, generates a capital loss with respect to the value of existing capital. The initial elderly are primary owners of existing capital and are hit by this capital loss regardless of their expenditure choice with respect to consumption and bequests.

Finally, note that none of the advance funding simulations generate the quite large welfare losses observed in Tables 4 and 5, in which benefits are cut in half or greatly reduced via an increase in the age of normal retirement. In Tables 6 through 8, none of the welfare losses exceed 3 percent.

There are two reasons for the smaller losses for any generation associated with advanced funding. First, advance funding typically replaces a highly distorting and regressive payroll tax with a tax that involves some form of lump-sum levy on existing assets. Second, in our advanced funding experiments, payments are made to those that accrued benefits under Social Security. As a result, positive welfare gains associated with advance funding tends to be delayed by about a decade relative to a cut in 50 percent cut in benefits, as shown in Table 4. But comparing Tables 4 and 6, we see that advanced funding also increases long-run welfare by about twice the amount as a cut in benefits *and* advance funding avoids the sharp welfare losses to transitional generations.

VI. Summary and Conclusion

Our simulation model does a remarkably good job tracking the nation's aging process. And, while it abstracts from many features of economic reality, it seems to be a reasonable tool for studying the general equilibrium feedback effects of the demographic transition. Although many commentators have suggested that these feedbacks would ameliorate our social insurance financing problems, the model says otherwise. Over the next three decades, the model's dramatic 77 percent run-up in the payroll tax dissipates what would otherwise be a natural process of capital deepening. Indeed, labor will grow more rapidly than capital throughout this century leaving 2100 real wages per unit of effective labor about 10 percent lower than their current value. Although technical change will prevent the next generation of workers from experiencing absolute declines in their living standards, the payroll tax hikes needed to pay promised benefits will expropriate much of what would otherwise be a very healthy rise in their levels of welfare.

Maintaining the existing system, but preventing payroll taxes from dramatically rising would require cutting Social Security benefits in half or tripling the increase in Social Security's normal age of retirement that is now underway. Given this gloomy prognosis, does advance funding offer a solution? The answer is "yes," with a big "but." The "yes" refers to the fact that in advance funding retirement saving and eliminating the OASI payroll tax, workers will be given a much desired tax break. But the taxes needed to pay off the accrued liabilities of the old system will impose burdens of their own. Generations alive at the time of the reform would be hurt, with the identity of the worst hit depending on the choice of the transition tax. The sacrifices that would be extracted from initially living generations aren't trivial, yet they are smaller than, for example, stabilizing the payroll tax rate by gradually reducing benefits over time. Moreover, relatively speaking, advance funding generates much larger long-run welfare gains than the alternatives.

Is there a silver lining in the social insurance clouds that this paper misses? There could be. Our model treats technical change as exogenous and our base case assumes the 1 percent annual rate of this change will remain the same through time. Clearly, there is no way of knowing precisely how fast technology will progress. If it does advance much more rapidly, our children will be able to bear their higher OASDHI tax burdens more easily. But the possibility of slower technical progress also exists, and this possibility may deserve more weight if, as some believe, technical progress is due to entrepreneurial effort, which may be sensitive to after-tax incentives.

Our model can also be questioned because of its stylized nature. It abstracts from the choice of education (see Heckman, et al, 1998), uncertainty, international trade, monetary policy, borrowing constraints, and a number of other aspects of economic reality. Whether the inclusion of those factors would materially alter our conclusions is a question for future research. But our own sense is that it would not. Our nation's pending demographic change is so severe that any reasonable modeling of the economy will generate a fiscal dilemma of the first order.

References

Altig, David, Alan J. Auerbach, Laurence J. Kotlikoff, Kent Smetters, and Jan Walliser, "Simulating Fundamental Tax Reform in the U.S.," forthcoming, *The American Economic Review*, 2001.

Arrau, Patricio and Klaus Schmidt-Hebbel. (1993), "Macroeconomic and Intergenerational Welfare Effects of a Transition from Pay-as-You-Go to Fully Funded Pensions," Policy Research Dept., Macroeconomics and Growth Division, Washington, D.C.: World Bank, Washington, D.C.

Auerbach, Alan J. (1996), "Tax Reform, Capital Accumulation, Efficiency, and Growth," in Henry J. Aaron and William G. Gale," eds., in *Effects of Fundamental Tax Reform*, Washington, D.C.: The Brookings Institution.

Auerbach, Alan J. and Laurence J. Kotlikoff. (1987), *Dynamic Fiscal Policy*, Cambridge, England: Cambridge University Press.

———. **(1983), "An Examination of Empirical Tests of Social Security and Savings,"in *Social Policy Evaluation: An Economic Perspective*, Elhanan Helpman, et. al., eds., Academic Press.**

Auerbach, Alan, Robert Hagemann, Laurence J. Kotlikoff, and Giuseppe Nicoletti, "The Economics of Aging Populations: The Case of Four OECD Economies," in *OECD Staff Papers*, 1989.

Bohn, Henning, "Will Social Security and Medicare Remain Viable as the Population is Aging?," mimeo, Department of Economics, University of California at Santa Barbara, 1998.

Browning, Martin, Lars Peter Hansen, and James J. Heckman. "Micro Data and General Equilibrium Models," unpublished manuscript, September 1998.

Blundell, Richard, Costas Meghir, and Pedro Neves. "Labour Supply and Intertemporal Substitution," *Journal of Econometrics*, September 1993, *59*(1-2), pp. 137-60.

Cooley, Thomas F. and Jorge Soares. (1999a), "A Positive Theory of Social Security Based on Reputation," *Journal of Political Economy*, 107 (1), February, 135-60.

Cooley, Thomas F. and Jorge Soares. (1999b), "Privatizing Social Security," *Review of Economic Dynamics*, 2 (3), 731- 55.

De Nardi, Mariacristina, Selahattin Imrohoroglu, and Thomas J. Sargent, "Projected U.S. Demographics and Social Security," *Review of Economic Dynamics*, 2(3), July, 575-615.

Feldstein, Martin S. (1974), "Social Security, Induced Retirement, and Aggregate Capital Accumulation," ***Journal of Political Economy*****, 82, 905-26.**

Feldstein, Martin. (Summer, 1975), "Toward a Reform of Social Security." *Public Interest*, No. 40, 75 - 95.

——————. (1995), "Would Privatizing Social Security Raise Economic Welfare?" NBER Working Paper Series, Working Paper 5281.

——————. (1997), "Transition to a Fully Funded Pension System: Five Economic Issues." NBER Working Paper 6149.

Feldstein, Martin H. and Charles Horioka. (1980), "Domestic Savings and Capital Flows." *The Economic Journal* 90, 314-329.

Feldstein, Martin. (1998), "Introduction," **in: Martin S. Feldstein (ed.),** ***Privatizing Social Security*****, University of Chicago Press, 1-32.**

Feldstein, Martin and Samwick, Andrew. (1998), **"The Transition Path in Privatizing Social Security," in: Martin S. Feldstein (ed.),** ***Privatizing Social Security*****, University of Chicago Press, 215-64.**

Fullerton, Don, Julia Lynn Coronado, and Thomas Glass, "The Progressivity of Social Security," NBER working paper, no. 7520, February 2000.

Fullerton, Don and Julia Lynn Coronado, "Long Run Effects of Social Security Reform Proposals on Lifetime Progressivity," forthcoming in Martin S. Feldstein and Jeff Leibman, eds., ***The Distributional Effects of Social Security Reform*****, Chicago, Ill.: Chicago University Press..**

Fullerton, Don and Diane Lim Rogers. *Who Bears the Lifetime Tax Burden?* Washington, D.C.: The Brookings Institution, 1993.

Fougere, Maxime and Marcel Merette, "Economic Dynamics of Population Aging in Canada: An Analysis with a Computable Overlapping-Generations Model," paper presented at the Canadian Public Economics Study Group, Ottawa, Canada, May 1998.

Fougere, Maxime and Marcel Merette, "Population Aging, Intergenerational Equity and Growth: Analysis with an Endogenous Growth, Overlapping Generations Model," forthcoming in ***Using Dynamic Computable General Equilibrium Models for Policy Analysis*****," forthcoming, North Holland, 1999.**

Fullerton, Don and Diane Lim Rogers. (1993), *Who Bears the Lifetime Tax Burden?*, Washington, D.C.: The Brookings Institution.

Galasso, Vincenzo, "The U.S. Social Security System: What Does Political Sustainability Imply?," *Review of Economic Dynamics*, 2(3), July, 698-730.

Gokhale, Jagadeesh, Benjamin Page, Potter, and John Sturrock. "Generational Accounts for the U.S. – An Update," *The American Economic Review*, May 2000.

Gokhale, Jagadeesh and Laurence J. Kotlikoff, "Medicare, Social Security, and the Calm Before the Generational Storm," mimeo, Boston University, June 2000.

Hansson, Ingemar and Charles Stuart. (1989), "Social Security as Trade Among Living Generations," *American Economic Review*, December, 1182-95.

Heckman, James J; Lochner, Lance; Taber, Christopher. "Tax Policy and Human-Capital Formation." *American Economic Review*. Vol. 88 (2). p 293-97. May 1998.

Huang, He, Selo _mrohoro_lu and Thomas Sargent. (1997), "Two Computational Experiments to Fund Social Security." *Macroeconomic Dynamics*, 1: 7-44.

Hubbard, Glenn R. and Kenneth L. Judd, "Social Security and Individual Welfare: Precautionary Saving, Borrowing Constraints, and the Payroll Tax," The American Economic Review, 77 (4), Sept. 1987, 630-46.

Hubbard, Glenn R., Jonathan Skinner, and Stephen P. Zeldes, "Why do People Save?" The American Economic Review, 84 (2), May 1994a, 174-79.

Hubbard, Glenn R., Jonathan Skinner, and Stephen P. Zeldes, "The Importance of Precautionary Motives in Explaining Individual and Aggregate Saving," Carnegie-Rochester Conference Series on Public Policy, 40, 1994b, 59-125.

Hubbard, Glenn R., Jonathan Skinner, and Stephen P. Zeldes, "Precautionary Saving and Social Insurance," Journal of Political Economy, 103 (2), April 1995, 360-99.

Huggett, Mark and Gustavo Ventura, "On the Distributional Effects of Social Security Reform," *Review of Economic Dynamics*, 2(3), July, 498-531.

Imrohoroglu, Ayse, Selahattin Imrohoroglu, and Douglas H. Joines, (1999), "Social Security in an Overlapping Generations Economy with Land," *Review of Economic Dynamics*, 2(3), July, 638-65.

Imrohoroglu, Ayse, Selahattin Imrohoroglu, and Douglas H. Joines, (1995), "A Life Cycle Analysis of Social Security," *Economic Theory*, vol. 6, 83-114b.

Kotlikoff, Laurence J. (1979), "Social Security and Equilibrium Capital Intensity," Quarterly Journal of Economics, May.

——————. **(1996), "Privatizing Social Security: How It Works and Why It Matters," in: James M. Poterba (ed.), *Tax Policy and the Economy*, vol. 10, Cambridge, Mass.: MIT Press.**

——————. (1999), "The A-K Model – Its Past, Present, and Future," in *Using Dynamic Computable General Equilibrium Models for Policy Analysis*, forthcoming, North Holland.

Kotlikoff, Laurence J., Kent Smetters, and Jan Walliser. (1999a), "Privatizing U.S. Social Security – A Simulation Study," forthcoming in: Klaus Schmidt Hebbel (ed.), *Pension Systems: From Crisis to Reform,* Washington, D.C.: The World Bank.

——————. **(1997), "**The Economic Impact of Privatizing Social Security**," in *Redesigning Social Security*, Horst Siebert, ed., Tübingen: J.C.B. Mohr (Paul Siebeck), 1998.**

——————. **(1998a), "Opting Out of Social Security and Adverse Selection," NBER Working Paper 6430.**

——————. **(1998b), "Social Security: Privatization and Progressivity," *Papers and Proceedings of American Economic Review*, 137-s41.**

——————. **(1999b), "Privatizing Social Security in the U.S. -- Comparing the Options," *Review of Economic Dynamics*, 2(3), July, 532-74.**

——————. (2001), "Distributional Effects in a General Equilibrium Analysis of Social Security**," forthcoming in Martin S. Feldstein and Jeff Leibman, eds., *The Distributional Effects of Social Security Reform*, Chicago, Ill.: Chicago University Press.**

Knudsen, Martin B., Lars Haagen Pedersen, Toke Ward Petersen, Peter Stephensen, and Peter Trier, "A Dynamic CGE Analysis of the Danish Aging Problem," in *Using Dynamic Computable General Equilibrium Models for Policy Analysis*, forthcoming, North Holland, 1999.

Laitner, John, "Transition Time Paths for Overlapping Generations Models," *Journal of Economic Dynamics and Control*, 1984.

Lee, Ronald D. And Lawrence Carter, "Modelling and Forecasting the Time Series of U.S. Mortality," *Journal of the American Statistical Association*, v. 87., n. 419 (September): 659-71.

MaCurdy, Thomas E. "An Empirical Model of Labor Supply in a Life-Cycle Setting," *Journal of Political Economy*, December 1981, *89*(6) , pp. 1059-85.

Mulligan, Casey B. “Substitution Over Time: Another Look at Life-Cycle Labor Supply,” in Ben S. Bernanke and Julio J. Rotemberg, eds., *NBER Macroeconomics Annual 1998*. Cambridge: MIT Press, 1998, pp. 75-134.

Raffelhüschen, Bernd, "Funding Social Security Through Pareto-Optimal Conversion Policies," in Public Pension Economics, Bernhard Felderer, ed., Journal of Economics/Zeitschrift fur Nationalokonomie, Suppl. 7, 1993, 105-31.

Raffelhüschen, Bernd, "Anreizwirkungen des Systems der sozialen Alterssicherung. Eine dynamische Simulationsanalyse," Frankfurt 1989.

Schmidt-Hebbel, Klaus. "Pension Reform, Informal Markets, and Long-term Income and Welfare," forthcoming in Pension Systems: From Crisis to Reform, World Bank Volume.

Schneider, Ondrej, "Dynamic Simulation of Pension Reform," mimeo, Charles University, CERGE-EI, Prague, 1997.

Seidman, Laurence S. (1986), "A Phase-Down of Social Security: The Transition in a Life Cycle Growth Model." *National Tax Journal*, vol. XXXIX, 97-107.

“The 1999 Technical Panel on Assumptions and Methods,”Report to the Social Security Advisory Board, November 1999.

Ziliak, James P. and Thomas J. Kniesner. “Estimating Life Cycle Labor Supply Effects,” *Journal of Political Economy*, April 1999, *107*(2), pp. 326-59.

Table 1

Comparing the Model's and Social Security's Population Projections

	Social Security Population Projections				The Model's Population			
	Total Population Index (100 in 2000)	Population Shares			Total Population Index (100 in 2000)	Population Shares		
Year		**0-19**	**20 - 64**	**65 +**		0-19	**20 - 64**	**65 +**
2000	100.0	0.29	0.59	0.12	100.0	0.29	0.59	0.12
2005	104.1	0.28	0.60	0.12	104.6	0.27	0.60	0.13
2010	108.1	0.27	0.60	0.13	108.6	0.26	0.59	0.15
2020	116.0	0.25	0.58	0.16	116.0	0.25	0.57	0.18
2030	122.6	0.25	0.56	0.20	122.8	0.24	0.54	0.22
2050	131.2	0.24	0.56	0.21	124.2	0.23	0.53	0.23
2075	140.3	0.23	0.54	0.23	125.8	0.24	0.53	0.23

Table 2 Simulation Results

	Year	National Income	Capital Stock	Effective Labor Supply	National Saving Rate	Real Pre-Tax Wage	Interest Rate	OASDHI Cost Rates Model	OASDHI Cost Rates SSA
Base Case	2000	1.000	1.000	1.000	.046	1.000	.075	.137	.131
	2005	1.091	1.064	1.101	.044	.992	.077	.145	.136
	2010	1.191	1.137	1.209	.047	.985	.079	.158	.147
	2020	1.361	1.271	1.393	.030	.977	.081	.197	.183
	2030	1.529	1.366	1.587	.011	.963	.084	.243	.220
	2050	1.889	1.500	2.039	.015	.926	.095	.257	.237
	2075	2.479	1.845	2.736	.023	.906	.101	.264	.262
	2100	3.303	2.421	3.663	.027	.902	.103	.265	na
Lee-Carter Life Expectancies	2000	1.000	1.000	1.000	.051	1.000	.076	.136	.131
	2005	1.091	1.066	1.100	.048	.992	.077	.145	.136

Table 2 Simulation Results

	Year	National Income	Capital Stock	Effective Labor Supply	National Saving Rate	Real Pre-Tax Wage	Interest Rate	OASDHI Cost Rates Model	SSA
	2010	1.194	1.147	1.210	.053	.987	.079	.157	.147
	2020	1.368	1.294	1.393	.032	.982	.080	.203	.183
	2030	1.541	1.403	1.590	.014	.969	.083	.249	.220
	2050	1.918	1.548	2.060	.026	.931	.094	.265	.237
	2075	2.529	1.926	2.770	.021	.913	.099	.291	.262
	2100	3.358	2.480	3.715	.026	.904	.102	.291	na
Three-Year Later Retirement	2000	1.000	1.000	1.000	.041	1.000	.076	.137	.131
	2005	1.096	1.057	1.109	.042	.988	.079	.145	.136
	2010	1.197	1.129	1.220	.045	.981	.080	.157	.147
	2020	1.371	1.256	1.411	.029	.971	.083	.196	.183
	2030	1.539	1.353	1.607	.011	.958	.086	.241	.220
	2050	1.903	1.485	2.067	.015	.921	.097	.255	.237
	2075	2.500	1.832	2.772	.023	.902	.103	.262	.262

Table 2 Simulation Results

	Year	National Income	Capital Stock	Effective Labor Supply	National Saving Rate	Real Pre-Tax Wage	Interest Rate	OASDHI Cost Rates Model	SSA
	2100	3.330	2.408	3.711	.026	.898	.105	.263	na
2% Rate of Technical Progress	2000	1.000	1.000	1.000	.051	1.000	.087	.140	.131
	2005	1.102	1.083	1.108	.047	.994	.088	.147	.136
	2010	1.221	1.174	1.236	.049	.987	.090	.157	.147
	2020	1.461	1.350	1.500	.035	.974	.094	.188	.183
	2030	1.753	1.509	1.843	.022	.951	.101	.217	.220
	2050	2.578	1.960	2.824	.038	.913	.114	.198	.237
	2075	4.362	3.266	4.804	.046	.908	.116	.197	.262
	2100	7.453	5.593	8.202	.047	.909	.115	.197	na
3% Rate of Technical Progress	2000	1.000	1.000	1.000	.060	1.000	.100	.144	.131
	2005	1.115	1.115	1.115	.054	1.000	.100	.149	.136
	2010	1.257	1.237	1.264	.054	.994	.10	.158	.147

Table 2 Simulation Results

	Year	National Income	Capital Stock	Effective Labor Supply	National Saving Rate	Real Pre-Tax Wage	Interest Rate	OASDHI Cost Rates Model	OASDHI Cost Rates SSA
	2020	1.583	1.479	1.619	.040	.978	.107	.180	.183
	2030	2.033	1.731	2.145	.032	.948	.117	.192	.220
	2050	3.552	2.672	3.906	.053	.909	.132	.152	.237
	2075	7.692	5.820	8.442	.060	.911	.132	.147	.262
	2100	16.783	12.786	18.376	.061	.913	.131	.147	na
50% Cut in Benefits	2000	1.000	1.000	1.000	.065	1.000	.076	.136	.131
	2005	1.096	1.094	1.096	.062	.999	.076	.135	.136
	2010	1.200	1.198	1.201	.063	.999	.076	.138	.147
	2020	1.387	1.403	1.382	.048	1.004	.075	.148	.183
	2030	1.578	1.578	1.578	.029	1.000	.076	.156	.220
	2050	1.967	1.886	1.995	.027	.986	.079	.167	.237
	2075	2.602	2.423	2.665	.033	.976	.082	.171	.262
	2100	3.472	3.218	3.561	.035	.975	.082	.171	na
Raise Social Security's Retirement	2000	1.000	1.000	1.000	.059	1.000	.076	.136	.131
Age by 5 rather than 2 Years	2005	1.094	1.084	1.097	.055	.997	.076	.137	.136

Table 2 Simulation Results

	Year	National Income	Capital Stock	Effective Labor Supply	National Saving Rate	Real Pre-Tax Wage	Interest Rate	OASDHI Cost Rates Model	SSA
	2010	1.196	1.177	1.203	.057	.995	.077	.141	.147
	2020	1.381	1.356	1.389	.042	.994	.077	.156	.183
	2030	1.557	1.500	1.577	.020	.987	.079	.192	.220
	2050	1.934	1.721	2.011	.021	.962	.085	.204	.237
	2075	2.551	2.166	2.694	.028	.947	.089	.209	.262
Consumption-Tax Finance	2000	1.000	1.000	1.000	.063	1.000	.076	.047	.131
	2005	1.096	1.093	1.098	.062	.999	.076	.051	.136
	2010	1.201	1.199	1.202	.066	.999	.076	.056	.147
	2020	1.396	1.434	1.383	.059	1.009	.074	.068	.183
	2030	1.598	1.674	1.574	.046	1.016	.072	.081	.220
	2050	2.056	2.230	2.001	.051	1.027	.070	.081	.237

Table 2 Simulation Results

	Year	National Income	Capital Stock	Effective Labor Supply	National Saving Rate	Real Pre-Tax Wage	Interest Rate	OASDHI Cost Rates Model	SSA
	2075	2.753	3.145	2.633	.048	1.045	.066	.081	.262
	2100	3.684	4.299	3.499	.046	1.053	.065	.081	na
Wage-Tax Finance	2000	1.000	1.000	1.000	.052	1.000	.074	.044	.131
	2005	1.094	1.070	1.102	.054	.993	.076	.048	.136
	2010	1.198	1.162	1.211	.062	.990	.076	.052	.147
	2020	1.350	1.309	1.364	.035	.991	.076	.064	.183
	2050	2.044	1.894	2.096	.053	.975	.080	.080	.237
	2075	2.808	2.977	2.753	.057	1.020	.070	.081	.262
	2100	3.774	4.243	3.630	.048	1.040	.066	.081	na

Table 2 Simulation Results

	Year	National Income	Capital Stock	Effective Labor Supply	National Saving Rate	Real Pre-Tax Wage	Interest Rate	OASDHI Cost Rates Model	SSA
Income-Tax Finance	2000	1.000	1.000	1.000	.052	1.000	.076	.043	.131
	2005	1.083	1.067	1.088	.045	.995	.077	.047	.136
	2010	1.184	1.145	1.197	.051	.989	.079	.051	.147
	2020	1.368	1.318	1.386	.046	.988	.079	.061	.183
	2030	1.564	1.506	1.584	.038	.988	.079	.074	.220
	2050	2.021	2.037	2.016	.056	1.003	.076	.079	.237
	2075	2.731	3.060	2.629	.053	1.039	.068	.081	.262
	2100	3.664	4.271	3.482	.047	1.052	.065	.081	na

Table 3

The Projected Aging of the U.S. Population

Measured in Bodies and Units of Lifetime Labor Productivity

	Population Shares Measured in Bodies			Population Shares Measured in Units of Lifetime Labor Productivity		
Year	**0-19**	**20 - 64**	**65 +**	0-19	**20 - 64**	**65 +**
2000	0.29	0.59	0.12	0.36	0.55	0.09
2005	0.27	0.60	0.13	0.35	0.56	0.09
2010	0.26	0.59	0.15	0.34	0.56	0.10
2020	0.25	0.57	0.18	0.32	0.55	0.13
2030	0.24	0.54	0.22	0.32	0.52	0.16
2050	0.23	0.53	0.23	0.31	0.52	0.16
2075	0.24	0.53	0.23	0.31	0.52	0.16

Table 4

Welfare Effects of 50 Percent Cut in Benefits

(base-case percentage change in lifetime consumption and leisure needed to achieve policy-induced utility level)

Generation's Year of Birth Relative to Policy Start Year	Class 1	Class 3	Class 6	Class 9	Class 12
-81	.020	.024	.025	.025	.018
-70	-3.701	-3.269	-2.585	-2.115	-.735
-60	-7.049	-5.870	-4.599	-3.555	-.935
-50	-5.180	-4.424	-3.288	-2.587	-.787
-40	-3.136	-2.281	-1.748	-1.474	-.640
-30	-.467	-.294	-.246	-.310	-.419
-20	1.871	1.722	1.494	1.244	.142
5	8.468	8.088	7.176	6.258	1.583

Table 4

Welfare Effects of 50 Percent Cut in Benefits

(base-case percentage change in lifetime consumption and leisure needed to achieve policy-induced utility level)

30	10.320	10.450	9.483	8.296	2.383
55	10.795	11.142	10.221	9.085	2.735
80	10.959	11.369	10.450	9.300	2.823

Table 5

Welfare Effects of 5-Year Rather than 2-Year Increase in Social Security Normal Retirement Age

(base-case percentage change in lifetime consumption and leisure needed to achieve policy-induced utility level)

Generation's Year of Birth Relative to Policy Start Year	Class 1	Class 3	Class 6	Class 9	Class 12
-81	.012	.015	.015	.015	.011
-70	-3.088	-2.732	-2.292	-1.871	-.639
-60	-6.179	-5.115	-3.985	-3.064	-.776
-50	-4.423	-3.272	-2.417	-1.894	-.558
-40	-1.631	-1.190	-.917	-.795	-.376
-30	.148	.146	.100	.002	-.224
-20	1.612	1.446	1.241	1.040	.149
5	5.317	5.110	4.556	3.991	1.013
30	6.219	6.321	5.778	5.135	1.459
55	6.473	6.784	6.283	5.626	1.673

Table 5

Welfare Effects of 5-Year Rather than 2-Year Increase in Social Security Normal Retirement Age

(base-case percentage change in lifetime consumption and leisure needed to achieve policy-induced utility level)

80	6.561	6.915	6.420	5.756	1.725

Table 6

Welfare Effects of Advance Funding with Consumption-Tax Transition Finance

(base-case percentage change in lifetime consumption and leisure needed to achieve policy-induced utility level)

Generation's Year of Birth Relative to Policy Start Year	Class 1	Class 3	Class 6	Class 9	Class 12
-81	-.121	-.337	-.493	-.563	-.622
-70	-.574	-.820	-.978	-1.025	-1.271
-60	-1.502	-1.899	-1.972	-1.923	-1.507
-50	-2.858	-2.836	-2.598	-2.452	-1.605
-40	-2.935	-2.569	-2.294	-2.193	-1.813
-30	-1.641	-1.301	-1.177	-1.220	-1.810
-20	.876	1.254	1.258	1.109	-1.125
5	9.407	9.409	8.480	7.424	.941
30	17.982	17.853	16.019	14.022	3.994
55	20.172	20.340	18.353	16.113	4.994
80	20.692	20.941	18.921	16.620	5.221

Table 7

Welfare Effects of Advance Funding with Wage-Tax Finance

(base-case percentage change in lifetime consumption and leisure needed to achieve policy-induced utility level)

Generation's Year of Birth Relative to Policy Start Year	Class 1	Class 3	Class 6	Class 9	Class 12
-81	-.041	-.050	-.053	-.052	-.038
-70	-.150	-.194	-.214	-.217	-.214
-60	-.272	-.469	-.513	-.507	-.263
-50	-.551	-1.263	-1.349	-1.240	-.277
-40	-.797	-1.812	-1.945	-1.822	-.888
-30	.217	-1.421	-1.822	-1.863	-1.700
-20	2.506	-.207	-1.121	1.458	-3.037
5	9.194	6.365	4.782	3.741	-1.568
30	16.399	15.836	14.082	12.280	3.004
55	19.589	19.748	17.828	15.656	4.754
80	20.551	20.799	18.794	16.511	5.165

Table 8

Welfare Effects of Advance Funding with Income-Tax Finance

(base-case percentage change in lifetime consumption and leisure needed to achieve policy-induced utility level)

Generation's Year of Birth Relative to Policy Start Year	Class 1	Class 3	Class 6	Class 9	Class 12
-81	-.914	-1.116	-1.180	-1.161	-.848
-70	-.747	-.986	-1.109	-1.138	-1.189
-60	-1.059	-1.471	-1.595	-1.588	-1.260
-50	-2.333	-2.311	-2.153	-2.056	-1.358
-40	-2.652	-2.195	-1.941	-1.873	-1.627
-30	-1.845	-1.259	-1.069	-1.105	-1.763
-20	-.046	.828	1.023	.950	-1.245
5	7.396	7.850	7.220	6.366	.335
30	16.820	16.772	15.083	13.221	3.569
55	19.879	20.004	18.092	15.886	4.857
80	20.621	20.870	18.857	16.565	5.193