Strategies for Incorporating Risk, Uncertainty, and Private Insurance Mechanisms in Models of Social Insurance

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1. Introduction

This chapter surveys strategies for incorporating various forms of risk and uncertainty into policy models used by the Social Security Administration (SSA). These strategies range from relatively simple modifications to existing microsimulation models that can be implemented relatively quickly and cheaply, to much more substantial long term investments in developing dynamic stochastic overlapping generations general equilibrium models. We classify the relevant types of uncertainties and risks that individuals are concerned about and which SSA might be interested in including in its policy models. This is a somewhat broader classification than anticipated in the RFTOP, but is consistent with SSA's responsibilities in providing a broad array of social insurance in addition to old age insurance. We stress the importance of developing policy models that account for the key parts of the Social Security program in an integrated fashion. Further, these models should account for other actions individuals can take to insure against risks, including private insurance plans, pensions, savings, and family transfers. However we recognize that in the short term, there is a substantial interest within SSA in developing models that account for risks associated various plans to create "individual accounts" or to invest a share of the Trust Fund in equities. We devote a substantial share of this chapter to this specific issue.

In the course of our review of alternative modeling strategies, we survey the current state of the art in social insurance modeling, summarizing how various forms of uncertainty and private insurance mechanisms have been treated in academic models of Social Security. There are a number of promising models that have succeeded in incorporating many relevant forms uncertainty and features of the Social Security program at a fairly high level of realism and detail. These include individual agent dynamic programming (DP) models and multiple agent stochastic overlapping generations general equilibrium (SGE) models. SSA should give serious consideration to using these models, which represent the state-of-the-art in the analysis and forecasting of a broad range of policy issues it faces. The main drawback is that even the most ambitious, large scale academic models still cannot be regarded as providing a single "grand unified model" that is able to capture all of the important aspects of uncertainty and features of Social Security that SSA might be interested in analyzing. Instead academics have produced a patch-work of special-purpose models that provide relatively detailed treatments of specific policy issues associated with certain parts of the Social Security program. Most of these models do not have a sufficient "track record" for SSA

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to make an informed judgement as to whether their policy forecasts are sufficiently accurate to justify the costs of adopting them. There are also a number of practical obstacles that would make it difficult for SSA to adapt many state-of-the-art academic models for day-to-day use in policy forecasting in the short term, particularly with regard to their computational and data requirements.

Anticipating that some of the state-of-the-art approaches might be regarded as too difficult to implement or too experimental for use in the short term, we devote a substantial share of this chapter to considering “short-cut” approaches that that could enable SSA to account for key risks via relatively simple modifications to existing microsimulation models, including models that are currently used or are under development at SSA such as the Projected Cohorts Model (PCM) and the Model of Income in the Near Term (MINT). The main idea behind this approach is to assess risk via stochastic simulations of these models, using various summary statistics such as various “money’s worth” measures as indicators of the welfare and distributional implications of alternative policies. We discuss some of the pros and cons associated with the short-cut approach, providing a number of examples which illustrate its limitations and the potential for misleading policy conclusions.

Section 2 motivates the need for next generation models that are capable of accounting for risk and insurance. Section 3 summarizes the various types of risks that individuals face that Social Security needs to consider incorporating in its policy models. Section 4 reviews a “shortcut” approach for incorporating risk and insurance features into existing policy microsimulation models currently in use by SSA and elsewhere, and discusses some of its limitations. Section 5 summarizes the current state of the art in “academic modeling” of individual choice under uncertainty in both partial and general equilibrium contexts, and reviews how these theories have been applied to improve our understanding of the role private and social insurance mechanisms. Section 6 offers conclusions about the best strategies for incorporating various dimensions of risk and uncertainty into longer term policy models currently under development or that may be developed in the future by SSA.

Before we begin, one note about terminology is in order. The academic literature makes a technical distinction between *risk* which is a situation involving a random outcome with a *known* probability distribution (e.g. roulette) versus *uncertainty* where the random outcome has an *unknown* probability distribution. Although virtually all of the problems we face are best described as choices over uncertain outcomes (since we rarely have full knowledge of the probability distribution generating random outcomes), most academic models treat individuals as having full knowledge of the underlying probability distributions, i.e. as choices over risky outcomes. For this reason, we have used the terms “risk” and “uncertainty” interchangeably in this chapter. We briefly discuss new modeling approaches that can handle the subtle distinction between risk and uncertainty in section 5, but even in academic circles the practical payoff from attempting to model uncertainty (as opposed to risk) is unclear.

2. The Importance of Accounting for Risk and Insurance in Policy Models

Policy makers are increasingly aware of the limitations of current generation policy simulation models, especially with regard to their treatment of risk and uncertainty. These problems are not unique to the Social Security Administration: a recent paper by Bazelon and Smetters (1999) argued "that a significant amount of policy analysis conducted inside the Washington DC Beltway is potentially very flawed due to the improper treatment of risks associated with future costs and benefits of many government projects and programs." (p. 28). In the context of Social Security, the limitations of current policy models have been highlighted most recently by the dearth of models that allow meaningful distributional and welfare analyses of various proposals to "privatize" Social Security, including far less radical proposals such as the Administration's plan to invest a portion of the Social Security Trust Fund in equities. However it has long been known that existing models are deficient in their treatment of many other risks, including risks related to labor market opportunities, health status, and health care expenditures. This limits their usefulness for analyzing a wide range policies including proposed changes to the early and normal retirement ages, changes in the Medicare eligibility age, and changes in the process by which disability awards are made.

Many proposed policy changes involve subtle changes in who bears various risks. An example is the Administration's recent proposal to invest a share of the Trust Fund in equities while maintaining the existing "defined benefit" structure of Social Security. The only way such a policy can provide a guaranteed benefit is by shifting the risk of poor equity returns from current beneficiaries to future taxpayers. Proposals to increase the Medicare eligibility age involves an opposite shift, reducing risks to taxpayers while increasing the risks to Social Security beneficiaries. SSA needs models that can help it quantify how much various groups stand to gain or lose from alternative reform proposals. In certain cases, improved models might be able to help identify tax/transfer policies that Pareto-dominate existing policies: in these rare cases everyone benefits from the policy change. However most realistic policies impose gains and losses on various groups in the population, including complicated transfers between rich and poor within any given generation as well as intergenerational transfers between individuals in different birth cohorts. A further complication is that many of the intended effects of policy changes, including the gains and losses to various individuals, can be partially nullified by offsetting private transfers that occur from individuals' attempts to "self-insure" against various risks. These private transfers include payments from private insurance contracts and payoffs from private savings in financial securities and real assets, as well as changes in labor supply, human capital investments, and changes in altruistic transfers within families and charitable transfers between different individuals and organizations.

New investments in models that account for uncertainty and private mechanisms for insuring against risks are required in order to improve our understanding of the principal functions of Social Security and to provide feedback to policymakers in designing improved social insurance institutions. The complications noted above suggest that fairly sophisticated models will be required to model individuals' endogenous behavioral responses to policy changes. Many policies may also require the use of partial equilibrium models that endogenize responses by firms, in order to understand whether various policies complement or "crowd out" private pensions and markets for annuities, disability, and health insurance. Evaluation of more substantial policy changes such as privatization of Social Security are likely to require models that are capable of predicting longer term general equilibrium impacts on savings and capital accumulation, the equity premium, and the volatility of stock returns.

The amount of new investment required to develop next generation policy models is substantial, but the rate of return could also be very high. An analogy to computerized automobile crash tests suggests that it will be far cheaper to evaluate proposed policy changes via sufficiently realistic computer simulation models than to attempt to discover improved policies via trial and error. It is clearly prohibitively costly and time-consuming to use amendments to Social Security as a form of "social experimentation." Furthermore, our analysis suggests that policy changes can impose significant "political risks" on current and future beneficiaries and taxpayers which are very difficult to insure against. This may be one of the reasons why it is so difficult to attain political consensus to make any significant change to the status quo.

2.1 Insights and Limitations of Deterministic Models

Perhaps the most important initial cost/benefit calculation facing SSA is whether it is worthwhile to incorporate any form of uncertainty into its policy models in the first place. Note that until relatively recently academics and policy-makers have successfully used deterministic models to analyze a number of fundamental questions regarding the structure of Social Security. In particular, Social Security's fundamental role as mechanism for intergenerational transfers and its impact on private savings have been analyzed in models that abstract from uncertainty. For example most of the early analyses of Social Security, beginning with Samuelson's (1958) seminal overlapping generations model, demonstrated that Social Security can be viewed as a "social contrivance" that facilitates Pareto-improving system of intergenerational transfers, i.e. everyone in society is better off in the presence of Social Security than in its absence.

For many years subsequently, economists continued to ignore uncertainty and focused instead on extending Samuelson's simple endowment economy with perishable goods ("chocolates") to more realistic economies where capital is subject to less than 100% depreciation each period and where wages and interest rates are determined endogenously. These models include Diamond's (1965) analytically solved 2-period overlapping generations (OG) model and Auerbach and Kotlikoff's (1987) computationally solved 55-period OG model. The key policy question addressed in these models is whether it is better to finance Social Security on a pay-as-you-go or fully funded basis, or more radically, whether it is better to eliminate Social Security altogether. The main conclusion the emerged from these deterministic models is that as long as the economy is *dynamically efficient* (i.e. if the real interest rate exceeds the rate of growth of the real wage base), then in the absence of myopia and borrowing constraints, a pay-as-you-go Social Security security system is no longer Pareto improving. To the extent that Social Security has any impact at all, it is purely distortionary and reduces the level of welfare and capital accumulation in the economy. Thus, the use of purely deterministic models lead us to the conclusion that, ignoring the redistributional and paternalistic functions of Social Security, all individuals would prefer a privatized system. This would allow rational individuals to design their own optimal retirement plans without any interference from the government. If we allow Social Security to fulfill other functions (e.g. as tax/transfer scheme to reduce inequality via lifetime income redistribution), then certain individuals become better off at the expense of others and we enter the subjective realm of analysis of distributional consequences of alternative policies.

Most deterministic models predict that a fully funded Social Security system is superior to a pay-as-you-go system in the sense that the former system leads to a higher steady state level of (per capita) capital accumulation, consumption, and welfare. However these conclusions only hold in models that rule out the possibility that agents nullify policy via offsetting intergenerational transfers and bequests — the so-called *Ricardian Equivalence* proposition that was re-introduced by Barro (1974). Most economists do not believe Ricardian equivalence to be empirically plausible (see, e.g. Elemdorf and Mankiw, 1998). The conventional view is that the unfunded pension liabilities in a pay-as-you-go Social Security system can be viewed as a form of government debt that "crowds out" private capital formation, leading to lower wages and higher interest rates.

Thus, deterministic models lead us to the conclusion that in the absence of redistributional and paternalistic motivations for establishing a Social Security program, a pay-as-you-go Social Security system is either irrelevant (if Ricardian equivalence holds), or makes individuals worse off in comparison to a fully funded or "privatized" system. However there is reason to distrust these conclusions since they fail to assign any value to the important *risk-sharing* features provided by Social Security. Indeed, it has been known at least since Diamond's (1977) "Framework for Social Security Analysis" that another motivation for a government run Social Security program is to correct *market failure* that limits individuals' ability to insure against key risks using private mechanisms. In particular, it has been known since the seminal work of Rothschild and Stiglitz (1976) that moral hazard and adverse selection problems can lead to non-existence of competitive equilibrium in markets for insurance of various risks. This appears to be the key explanation why markets for annuities, disability insurance and health insurance either do not exist or are highly undeveloped. Analyses dating back to Eckstein, Eichenbaum, and Peled (1986) show how Social Security can "fill in" for these missing markets and make all individuals better off. Thus, in order achieve a better understanding of whether Social Security can be effective in counteracting market failure we need models that account for various forms of uncertainty, and also models that explain why private markets are incomplete or non-competitive.

3. What Risks and Insurance Mechanisms Should be Included in SSA's Policy Models?

Since its inception in 1935 Social Security has evolved into a program that does much more than help individuals prepare for retirement. Social Security is best viewed as a comprehensive social insurance program that covers individuals against a wide range of risks, including longevity (via the Old Age Insurance), mortality and widowhood (via Survivor's insurance and the death benefit), the costs of health care (via Medicare), disability and incapacity (via disability insurance and Supplemental Security Income), and unemployment (via Unemployment Insurance). Social Security also plays a significant as a redistributive anti-poverty program, and few economists dispute that it deserves much of the credit for significant reductions in the poverty rate among Americans over 65 (from 35% in 1959 to 10.5% in 1997). However it not as easy to quantify Social Security's success in insuring against the array of other risks that it covers, although the huge political popularity of the program suggests that its wider role in improving the "safety net" may be just as important as its impact on poverty rates among the elderly.

This suggests that to adequately understand the role Social Security we need a model that accounts for *multiple risks* in the context of a unified model of social insurance. Of course it will be significantly more costly to build a unified model of social insurance that provides an integrated treatment of the key risks individuals face compared to working with a patchwork of models that treat each component of the Social Security program in isolation. However there are significant dangers associated with a piece-meal approach to modeling Social Security. We argue that there are important interactions between the different components of the Social Security program that, if ignored, could result in misleading predictions. One example is the relationship between the Medicare eligibility age and the normal retirement age, which are both currently set to age 65.

Rust and Phelan (1997) showed that a combination of risk aversion and incompleteness in the market for private health insurance cause changes in the Medicare eligibility age to have a very strong impact on the timing of retirement. For example they showed that over half of the "spike" in retirements at age 65 are due to "health insurance constrained" individuals how have employer provided health insurance if they continue to work, but who do not have access to retiree health insurance if they were to quit working prior to being eligible for Medicare. Most previous analyses that didn't account for the interaction between Social Security and Medicare were unable to explain the magnitude of the age 65 spike, attributing it to a "social custom" (e.g. Lumsdaine and Wise (1994) and Gustman and Steinmeier, 1995). The Rust-Phelan model suggests that policies that attempt to delay retirement by increasing the normal retirement age or increasing the delayed retirement credit that were legislated in the 1983 Social Security amendments will have a relatively small impact unless accompanied by a corresponding increase in the Medicare eligibility age. Other studies using a variety of alternative econometric methods have come to similar conclusions about the importance of the interaction between labor supply and health insurance. In their survey of the literature on the relationship between health insurance and labor supply, Currie and Madrian (1998) concluded:

> "A large body of evidence supports the notion that health insurance affects employment outcomes by giving individuals who rely on their current employer for health insurance and incentive to remain employed, and by giving individuals with other sources of health insurance provision less reason to participate in the labor market. The effects appear to be strong among both older workers and married women, although there appear to be effects on prime age males as well." (p. 57).

Another example of potentially important interaction between components of the Social Security program is between Disability Insurance and Old Age Insurance. The Rust-Phelan model and other models suggests that another form of market incompleteness — liquidity constraints — can account for much of the peak in retirements at the early retirement age (currently 62). Legislation designed to delay retirement by increasing the early retirement age has a powerful effect in models that treat Old Age insurance in isolation. However the total impact on retirements and Social Security costs might be partially offset by increased incentives to apply for disability benefits. Even in the absence of changes in the early retirement age the gradual increase in the normal retirement age will, via the actuarial reduction in benefits, lead to a lower fraction of the PIA being paid at age 62 and thus increased incentives to apply for DI benefits. The Office of the Actuary relies on intuitive guessitmates of these effects in its 75 year projections of the Trust Funds. This may be due in part to the lack of models and econometric studies that have studied this interaction.[2]

More comprehensive models are also required to obtain more accurate estimates of the distributional impacts of Social Security. For example some recent analyses of the internal rate of return to Social Security (e.g. Beach and Davis, 1998a), show very low and sometimes even negative rates of return for certain groups such as young black males. However even ignoring criticisms about actuarial mistakes in carrying out these calculations (see Beach and Davis, 1998b), their results are suspect since they ignore disability insurance as one of the "payoffs" received by Social Security beneficiaries. Given the higher propensity of black males to apply for and be awarded DI benefits, an analysis that provided a more integrated treatment of Social Security would be less likely to show the large racial disparities in rates of return that Beach and Davis found. Indeed, other analyses have shown that when DI benefits are accounted for the Social Security system continues to remain progressive, with low earners receiving higher internal rates of return on contributions than higher earners, even accounting for the higher mortality rates of low earners (see, e.g. Goss, 1995).

These examples show the potential dangers in making policy forecasts and welfare evaluations in the context of piece-meal models of individual behavior that only consider individual components of the Social Security program in isolation. This suggests that SSA should give serious consideration to developing more comprehensive integrated models of Social Security. Sections 4 and 5 provide examples of models that handle multiple risks and multiple components of the Social Security program simultaneously. Section 6 presents our conclusions about the feasibility of extending these initial efforts to the sort of "grand unified" model of social insurance that we discussed in the introduction.

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[2] We are aware of only one study, which predicts the effect on employment levels and DI roles of the scheduled increase in the normal retirement age (NRA) from 65 to 67 between 2002 and 2022 (see, Wittenburg, Stapleton, *et. al.* 1998). This paper also assumes, counterfactually, that the Medicare eligibility age (MEA) also increases to 67. The study uses the 1993 SIPP survey to estimate what fraction of individuals aged 65 and 66 would retain both their Old Age and Medicare benefits by meeting the qualifications for Disability Insurance if the increase in the NAR and MEA had been immediately instituted in 1993. They find that 16% of Old Age beneficiaries and 10% of Medicare beneficiaries would retain their coverage via DI even if the NAR and MEA were increased to 67. They find that 32% of total Medicare expenditures for individuals aged 65 and 66 under an age 65 MEA would continue to be paid under an age 67 MEA due to individuals who were already disabled prior to age 65 and would continue to be eligible for Medicare as DI beneficiaries. Thus, by accounting for the interaction between the DI and OA program, this study suggests that the total savings of delaying the NRA and MEA to age 67 are far less than would be predicted by models that ignore this interaction.

3.1 Dimensions of Risk and Uncertainty

In the task order for this project, SSA suggested that an analysis of risk and

uncertainty should be structured according to a “two-by-two” classification that distinguishes between 1) labor earnings risk and rate of return risk on savings invested in equities, and 2) idiosyncratic vs. aggregate risk. This is a useful classification, but it neglects several other sources of risk that may be equally important to consider in policy models:

a) financial risks associated with wages changes and unemployment, and uncertainty about future job opportunities,

b) financial risks associated with uninsured health care costs,

c) risk of lost job earnings and psychic pain and suffering associated with poor health and disability,

d) personal risks associated with divorce or death of spouse and or other family members,

e) financial risks associated with uncertain asset returns, including equities and housing,

f) longevity risks arising from limited access to actuarially fair real annuities and pensions

g) political risks associated with unanticipated changes to Social Security tax rates and benefit formulas,

h) solvency risks associated with privately provided defined benefit pensions, annuities, and health insurance,

i) mobility risks associated with loss of pension coverage due to incomplete vesting and lack of portability of private pension plans.

In addition to this multiple classification of basic types or risk, we classify the three main ways individuals deal with risk, namely through:

1. various forms of private insurance provided by firms and pensions, as well as private transfers within the family and via charity,
2. “self-insurance” through precautionary savings, human capital investments, and labor supply decisions,
3. social insurance provided by Social Security.

For most Americans, personal labor supply, savings and Social Security are the main strategies for dealing with these risks, with Social Security becoming increasingly important as they age. For example, it is well known that the market for individual annuities is very small in the U.S. A number of studies have shown that due to adverse selection and high administrative costs, private annuities are not attractive investments for most individuals (Mitchell, Poterba and Warshawsky, 1997 and Walliser, 1997). Aside from private pensions and personal saving, Social Security provides the main retirement annuity for a majority of Americans. Similarly, large fractions of the U.S. population are not covered by private disability insurance or health insurance, whereas Social Security provides nearly universal disability coverage (although with low replacement rates for individuals in high income brackets) and health insurance coverage for individuals over 65 (although with limited coverage for certain catastrophic health care costs such as extended nursing home care). [3] The level of non-housing, non-pension financial savings appears to be too small to finance a significant share of retirement income for most Americans or provide an adequate reserve against the possibility of disability (see, e.g. Gustman and Steinmeier, 1998), it does appear to provide a significant buffer stock for unexpected short term events such as job loss or unexpected uninsured health care costs. Recent theoretical and empirical work by Hubbard, Skinner and Zeldes (1994, 1995) and Carroll and Samwick, (1995) suggest that a substantial share of private wealth, as much as 50%, can be attributed to such precautionary, self-insurance motives. A growing body of recent empirical work also suggests that family transfers is an important mechanism that can partially plugs gaps in incomplete private insurance markets (Altonji, Hayashi and Kotlikoff, (1996) and McGarry and Schoeni, 1995).

A comprehensive model of Social Security should attempt to incorporate the main components of the program (e.g. OA, SI, DI, UI and Medicare), the key risks facing individuals listed in points a) to g) above, and the effects of private means for dealing with risk in points 1) and 2) above, particularly individual savings and labor supply decisions. Of course, in the short run it won't be possible to build integrated models that encompass all these features. SSA needs to prioritize the most important risks that it is interested in analyzing, perhaps guided by surveys that provide some indication of the risks individuals are most concerned about.

There are not a lot of data that we are aware of that provide direct rankings of Americans' feelings about the severity and importance of various risks they face. Public opinion and voter surveys provide indirect evidence of Americans' concerns. These polls indicate that the stability and solvency of Social Security is high on the list of worries of older Americans. For example the Voter News Service conducted interviews of 1,109 voters aged 60 or over who were leaving polls after the November, 1998 elections. Thirty one percent of these voters listed Social Security as the issue that mattered most in deciding their votes for Congressmen. Eleven percent listed taxes, ten percent listed economy and jobs, and eight percent listed health care as the issues that mattered most. However an individual's ranking of their most important political issues may not necessarily be the same as their ranking of the risks that concern them the most. Even though health care was listed as only the sixth most important political issue in the voter survey, introspection suggests that it should rank nearly as high as concern over the solvency of Social Security, and risks of job loss and adverse changes in labor earnings. Indeed, the latest statistics indicate that as many as 43 million Americans have no formal type of health insurance, and despite the strong economy, over 1 million families are losing health insurance each year (Marmor and Mashaw, 1997). Of particular concern to many elderly is the cost of uninsured nursing home expenditures. Even though 10% of public medical spending is devoted to medical care, the majority of nursing home costs are still uninsured (Cutler and Sheiner, 1998). Feenberg and Skinner (1994) used simulations of dynamic

[3] Medicare is also available to DI recipients after two years. We refer to DI coverage as "near universal" since a worker is disability insured only if they had 20 quarters of coverage (QC) during the last 40 quarters, and are currently insured (i.e. they earned 6 QCs in the preceding 13 quarters, including the quarter of death).

programming models to show that "catastrophic health care insurance could yield large utility gains" and this may explain the concern over preserving and extending Medicare among senior citizens. Politicians such as the House minority leader Richard Gephardt appear to be in touch with the "issues of real importance to seniors — i.e., the patient bill of rights, getting prescription drugs to people on Medicare at a good price, ling-term care insurance and tax breaks for long-term care, shoring up and keeping strong Social Security and Medicare." (quote from *New York Times* article, "Shift by Older Voters to G.O.P. Is Democrat's Challenge in 2000", May 31, 1999).

SSA may also want to prioritize certain socio-demographic groups for which particular concern is warranted. It might be reasonable to assume that most high income individuals are able to "fend for themselves", so that attention can be focused on the most vulnerable parts of the population including those in the lowest income brackets, minorities, widows, children, and divorcees with dependent children. According to Burkhauser and Smeeding (1994), "The single greatest risk of falling into poverty in old age now comes after the death of a spouse, as the survivor faces life after marriage." (p. 1). For example, poverty rates among single women are 4 times higher than the poverty rate for married women. Data from the Health and Retirement Survey (see, e.g. Glasse, Estes and Smeeding, 1999) indicate that 41% of single women aged 51 to 61 fall into the lowest population decile of wealth, with a mean total wealth (including discounted Social Security benefits) of only $50,500. Social Security comprises over 92% of the wealth of these women, making them especially vulnerable to recently discussed changes in program rules such as increases in the minimum retirement age or decreases in the minimum benefit level.

Another particularly vulnerable group of Americans are those who suffer from disabilities and chronic health problems, including the nearly 5 million Social Security Disability Insurance recipients. A recent analysis by Benitez-Silva *et. al.* (1999b) using the Health and Retirement Survey (HRS) data documents that the disabled are severely economically disadvantaged relative to the non-disabled population, with annual labor income that is one tenth as large, and household income and net worth that are less than one half as large as the mean values for these quantities in the non-disabled population. In addition to having far worse health and higher incidence of impairments according to virtually all available measures of health and "activities of daily living", the disabled also have much higher medical expenditures, and significantly lower life expectancy than the non-disabled. For example, the incidence of severe medical conditions such as cancer, diabetes, lung disease, stroke, and congestive heart failure is more than three times as large among the disabled than the non-disabled. Approximately 67% of the non-disabled population expects to live to age 75, but fewer than 50% of the disabled population expects to live that long.

Compounding their problems, the fraction of the disabled population that have support from other family members such as a spouse is actually lower than in the non-disabled population. For example while over 80% of the non-disabled population is married, less than two thirds of the disabled population is currently married, and the fraction of the disabled who have never been married is twice as large as in the non-disabled population. Divorce rates among the disabled are twice as high as the non-disabled: 30% vs. 15%. Thus, the disabled individuals who qualify for Social Security Disability Insurance or Supplemental Security Income are likely to be highly dependent on these benefits, and would probably be greatly affected by reductions in benefit levels or restrictions in their access to medical care that might result from policies designed to reduce

Medicare costs such as shifting recipients into managed care. Benitez *et. al.* (1999a) find that DI applicants face a significant risk of rejection, but this risk can be reduced by exercising the option to appeal at the cost of long delays between an appeal and the final decision. Further, Benitez *et. al.* (1999b) provide evidence of substantial classification errors in the DI award process, with many rejected DI applicants appearing to be "observationally equivalent" to DI recipients. Although their analysis also identifies a significant fraction (nearly 20%) of "non-disabled" DI recipients, a major concern is the relatively large fraction of rejected DI applicants (nearly 50% after accounting for eligibility restrictions such as means-testing of other related sources of support such as SSI) who appear to be truly disabled according to SSA's definition of disability, but may have few other sources of support to fall back on.

Despite all the press and recent attention to the issue of investing the Trust Fund in equities, it is not clear whether the risks of equity investments would be extremely high up on the priority ranking of the risks that many elderly are most concerned about. There are several reasons why this might be the case, including 1) it is still the case that only a minority of upper income Americans have substantial equity holdings at the time of retirement, 2) stocks have performed so well in recent years that many people have become less aware of their downside risks relative to their upside potential, and 3) many proposals for creating individual accounts or investing the Trust Fund in equities involve implicit minimum benefit guarantees that effectively shift much of the downside risk of poor equity returns to future taxpayers. Although we believe there are many more important risks which justify higher priority in considerations of potential modeling improvements (including the risk of job loss, health risks including disability, and uninsured health care costs, particularly for catastrophic care and nursing home care), we have devoted special attention to models that are capable of evaluating these policies in the sections below due to the substantial current interest policy makers have in the issue of evaluating the risk of equity investments in individual accounts or in the Social Security Trust Fund.

4. A "Short-Cut" Approach to Incorporating Risk and Insurance in Policy Models

This section reviews a short cut approach to incorporating uncertainty in policy models. It can be described as a *simulation-based approach* to policy evaluation. This approach presupposes that we have access to a reliable behavioral or non-behavioral probability model to generate stochastic simulations of various outcomes of interest for the policies under consideration. The analyst is expected to assess the relative desirability of different policies based on their subjective evaluation of the distributions of simulated outcomes. Since stochastic simulations generate a large amount of "artificial data" that can be difficult to digest, a second aspect of the short-cut approach is to use relatively "objective", low-dimensional, and easily calculated summary measures of individual and social welfare resulting from alternative policies. Examples include expected discounted utility, expected discounted wealth including the expected present value of Social Security benefits net of taxes, internal rate of return on Social Security contributions, and related "money's worth" measures. In cases where policies involve evaluating financial risks such as investing the Trust Fund in equities, there is a question as to whether a risk-adjusted discount rate should be used to compute expected present values or utility levels. We argue that the process of choosing a risk-adjusted discount rate is rather *ad hoc* and that a better approach is to attempt to use market-based methods to evaluate the *price of risk.* An example is to use options to estimate the costs imposed on taxpayers of the Administration's recent proposal to invest Social Security Trust Funds in equities while maintaining minimum benefit guarantees to Social Security beneficiaries. Option pricing theory can be used to calculate the "premium" that would be required to insure against the risk in question. Thus, in some cases market-based measures can be used to help evaluate the costs and benefits of different policies.

The reason we refer to this as a short cut approach is that there is no attempt to work within a "closed model" where the simulation results are endogenously derived from the solution to an individual's dynamic programming problem, or to account for general equilibrium feedbacks via explicit solution to an SGE model. Instead major simplifications are obtained by treating the simulations as realization from an exogenously specified stochastic process. Endogenous feedback and policy effects are either ignored or forecasted via extrapolations or intuitive adjustments to the underlying simulation model. This avoids the need for more complicated numerical dynamic programming and general equilibrium methods to derive individuals' "best replies" and general equilibrium feedbacks. It also avoids the associated econometric problems involved in selecting empirically justified values of the unknown parameters characterizing individuals' and firm's beliefs, preferences, and profit (objective) functions. These problems require a more ambitious approach that is the topic of section 5.

4.1 An Illustration of the Short-cut Approach to Accounting for Risk.

A recent paper by Feldstein and Ranguelova (FR) (1998) provides a simple example of the simulation based approach. There are a number of other stochastic simulation models that we could have chosen to illustrate the simulation-based approach, including non-academic models that have been used for policy simulation and forecasting within Social Security and elsewhere. These include the MINT model and its forerunners (Iams and Sandell, 1997 and Iams, Sandell, and Butrica, 1999), as well as aggregate level simulation models (see, e.g. Foster, 1994, Holmer, 1995, 1999, and Tuljapurkar, Lee and Anderson 1998, and MaCurdy and Shoven, 1999). While aggregate level stochastic simulations are of considerable interest to the Social Security Actuary for forecasting the impact of uncertain changes in death rates, birth rates, immigration flows, inflation rates, and productivity growth on variables such as the date of exhaustion of the Trust Fund and the long-run actuarial balance of the program, they are less useful for individual-level analyses of the welfare and distributional consequences of different policies. We chose the FR paper since it accounts for risk at the individual level, which is the primary focus of this chapter. The other reason why we choose to focus on the FR paper is that it analyzes the impact of "privatizing" Social Security via creation of individual accounts that can be invested in equities, another focal topic of this chapter.

Specifically, FR evaluate the desirability of moving from the current Social Security system to a privatized system of individual retirement accounts which are invested 60% in equities and 40% in bonds. Individuals contribute a fixed percentage of their wages to personal retirement accounts (PRAs) during their working years, which are assumed to be the continuous duration between age 21 and retirement at age 67. Various contribution (tax) rates are considered, including 4%, 6%, and

9%. Upon retirement, the cumulative value of their PRAs are used to purchase a variable annuity. FR model stock and bond returns as independently and identically distributed random variables, and conducted 10,000 stochastic simulations of bond and stock returns in order to calculate the cumulative value in the individual account at age 67, and the subsequent payoffs of the variable annuity between age 67 and the individual's death, which occurs sometime between age 67 and the maximum age of 100. They compared the distribution of retirement income streams from this PRA/variable annuity plan to a benchmark equal to the stream of benefits that this individual would receive under the current Social Security program.

If all the assets in the PRA were invested in risk-free bonds yielding 5.5%, individuals would only need to save 3.1% of their incomes to purchase an annuity stream equal to that promised under the current Social Security program, or about one sixth of the tax rate that the Office of the Actuary predicts is necessary to maintain the current pay as you go Social Security system in long run actuarial balance. To model the case where PRA balances are invested in a portfolio containing 60% equities and 40% (risky) bonds, FR assumed that the log returns on this portfolio would have a mean of 5.5% and a standard deviation of 12.5%. They simulated the cumulative value of the investment portfolio up until retirement at age 67 and then simulated the subsequent variable annuity streams that individuals would receive under the PRA system, comparing them to the retirement income stream an individual would receive under the current Social Security system. At a 6% contribution rate the median payment of the combined PRA/variable annuity plan at age 67 would be 2.14 times as large at the payment under the existing Social Security system. There is approximately a 10% chance that the PRA plan would lead to lower payments than the status quo, but less than a 1% chance that the payments from the variable annuity would be less than half of the benefits received under the status quo. Based on their evaluation of this simulated distribution of outcomes, FR conclude that

> "a pure defined contribution plan, with a saving rate equal to one third of the long-run projected payroll tax, invested in a 60:40 equity-debt Personal Retirement Account could provide a retirement annuity that is likely to be substantially more than the benchmark benefit while exposing the retiree to relatively little risk that the annuity will be less than the benchmark. Even this risk can be completely eliminated by a conditional guarantee plan that imposes only a very small risk on future taxpayers."

There is nothing mysterious in FR's the finding that the PRA plan generates substantially higher benefits from a contribution rate that is only one third as large as under the status quo. This result follows from the simple logic of compound interest. Abstracting from risk, it is easy to show that whenever there is a sufficiently long contribution horizon, a retirement plan that has a higher rate of return will be far more attractive than one that offers a lower rate of return. The plan with the higher return will generate higher retirement consumption streams for an equivalent contribution (savings or tax) rate, or require a smaller contribution rate to produce the same retirement consumption (benefit) stream, or both. Historically, the rate of return on Social Security contributions has fallen steadily from the extraordinarily high rates paid to the "startup generations" who were alive at the inception of the program in 1935 to less than 2% for the baby boomers and subsequent cohorts. Part of the decline in returns is due to the fact that the startup generations received large net transfers, which will effectively be paid via declining rates of return to subsequent generations. The other reason for the decline is the "demographic transition" which is manifested in part by the downward trend in the total fertility rate to just under 2 children per female, or approximately zero population growth abstracting from immigration. In steady state, the rate of return to a pay-as-you-go Social Security system is roughly equal to the sum of the growth in population plus the growth in real wage rates. It follows that if the rate of population and real wage growth is high relative to the return on bonds, then a pay-as-you-go system will seem more attractive than a privatized system. However the U.S. economy is now in a situation where the growth rate of the real wage base is significantly lower than the rate of return on government bonds, so a pay-as-you-go system seems unattractive relative to an individual account that earns the government bond rate or higher. This is essentially what FR's simulations have demonstrated, but with the added wrinkle that rates of return on the higher return PRA plan are risky, which implies that there is a small chance that realized returns in the PRA plan could be lower than the low asymptotic steady state rates of return earned under the status quo, which is financed mainly on pay-as-you-go basis.

4.2 Limitations of the Short Cut Approach to Policy Forecasting

There many limitations of the simulation approach to policy analysis, and the FR paper can be used to illustrate some of them. The first limitation is the subjective nature of the evaluation of the outcomes. Other analysts may look at the same distribution of outcomes and conclude that the PRA system imposes too much risk on investors. In particular, risk-averse individuals pay large sums of money to insure against low probability outcomes such as a fire burning down one's house or the risk of incurring catastrophic health care expenditures. So even though the probability that benefit streams under the PRA system will be substantially smaller than the status quo is fairly small, certain sufficiently risk-averse individuals might prefer the status quo to the PRA system. Although FR state that "we believe displaying the probability distributions of possible outcomes . . . is the best way to indicate the risks and rewards of alternative investment-based options", they do include a comparison of the expected discounted utilities for an individual at age 21 and at age 67 under the PRA plan and the status quo. The discounted utility of an individual at reference age a ($a = 21$ or $a = 67$) is given by

$$V_a = E\left\{\sum_{t=a}^{\tilde{T}} \beta^{(t-a)} u(\tilde{c}_t)\right\},$$

where $\tilde{T}$ is the random age of death, and $\tilde{c}_t$ is the random realized consumption at age t. By ignoring the utility of leisure, the endogenous labor supply decision, and other private savings decisions, their analysis simplifies considerably, allowing FR to evaluate discounted utility by simply averaging the realized discounted utilities using the realized incomes, taxes, and benefit levels from their 10,000 simulations. That is, they approximate V_a by the sample average $\hat{V}_a$ given by

$$\hat{V}_a = \frac{1}{N}\sum_{i=1}^{N}\sum_{t=a}^{\tilde{T}_i} \beta^{(t-a)} u(\tilde{c}_{it}),$$

where $N = 10,000$ is the number of simulations, $\tilde{T}_i$ is the date of death in simulation i, and $\{\tilde{c}_{it}\}$ is the simulated path of consumption in simulation i.

There is an obvious problem with assuming an arbitrary utility function $u(c)$, namely, different individuals may rank the PRA as more or less desirable than the status quo depending on their degree of risk aversion. FR used constant relative risk aversion utility functions, $u(c) = (c^\rho - 1)/\rho$, and tried various values of the coefficient of risk aversion ρ and the discount factor β. Not surprisingly, FR found that sufficiently highly risk averse individuals prefer the status quo to the PRA. However their calculations suggest an implausibly high degree of risk aversion is required in order for an individual to prefer the status quo to the PRA plan. There is no need to make subjective judgements about what level of risk aversion is empirically "implausible" since the appropriate functional form of the utility function and the degree of risk aversion is essentially an empirical issue that can be answered via econometric methods. However this approach leads us towards the more involved utility-based methods that we will describe in the next section. We note here that using empirically estimated utility functions may lessen but will not obviate the need for subjective judgements in policy evaluation exercises since most policies have distributional consequences for which subjective interpersonal utility comparisons cannot be avoided. So the problem of subjectivity is not unique to the simulation-based approach to policy evaluation, although it is fair to say that the nature of the approach requires the analyst to make a greater number of subjective judgements about the "desirability" of simulated outcomes than the most of approaches described in the next section.

A second limitation of the FR study is that it is uni-dimensional: it focuses essentially on only one risk facing an individual, stock market risk. FR do consider the many other risks individuals face including the risk of health problems and job loss during their working years that interrupts their ability to contribute to their PRA. If they included these risks, the PRA plan would not appear as attractive as it presently appears, since the interruptions in contributions would effectively reduce the realized return on the PRA relative to the status quo Social Security benefit, which is highly robust to fluctuations in working history due to the fact that the 5 lowest years of earnings are dropped in computing the AIME. These risk-sharing benefits of the current Social Security system can be substantial and are captured in the stochastic general equilibrium models considered in section 5.3. However short of solving a full-blown general equilibrium model, it is hard to see how the FR study could be extended to incorporate these extra risks unless one had access to a reliable probability model of labor force participation and earnings over the life cycle. Stochastic models of labor force earnings can be estimated via a variety of reduced-form approaches, see, e.g. Storesletten, Telmer, and Yaron (1999). Indeed, there a variety of new modeling efforts such as the MINT model and other microsimulation models (e.g. the LIFEPATHS mode of Statistics Canada, see Wolfson, 1995) that allow one to use reduced-form statistical methods to simulate individual-level stochastic processes governing fertility, marriage, divorce, labor force participation and earnings, retirement, and death to obtain distributions of various outcomes of interest under different policy scenarios. So in principle, the stochastic simulation approach appears to be quite flexible in allowing evaluation of a multidimensional set of outcomes.

However there are a number of important drawbacks to multidimensional simulation models that simulate multiple outcomes and risks simultaneously. The first drawback is that as the number of outcomes of interest increases (e.g. incomes, labor supply levels, marital states, and so forth in various years) the policy analyst is forced to evaluate potentially complicated multidimensional distributions of outcomes in order to make subjective comparisons between alternative policies. Although many people might agree with FR's claim of the self-evident superiority of the distribution of outcomes from the PRA plan relative to the status quo, one can imagine other more complicated cases where it is very difficult to achieve any consensus in subjective rankings of different policies based on a mass of simulation output. Even if individuals can come up with their own rankings, there might be considerable disagreement resulting from differences in the ways various analysts subjectively evaluate this simulation output. A second drawback of the multidimensional simulation approach is that many policies change the stochastic processes governing the simulated outcomes due to endogenous behavioral responses, a result of a problem known in the econometrics literature as the "Marschak-Lucas critique" that will be discussed in more detail in section 5.2. It is easy to illustrate how the Marschak-Lucas problem could arise in the FR model: if high equity returns lead to substantial accumulations in the PRA accounts in the FR analysis, individuals may be tempted to retire well before the age 67, reducing the ultimate size of the realized retirement accumulations (unless this reduction is offset by increased savings earlier an an individual's working career as suggested by Feldstein 1974). It is clear that allowing for endogenous determination of retirement age could substantially affect the results of their analysis, but there is no obvious way to determine a "hazard rate" for early retirement in this framework without solving the individual's dynamic programming problem for maximizing expected discounted utility. Thus, for many interesting policies, there may not be any reliable way to evaluate the policy without introducing a utility function and solving the individual's DP problem. Section 5.2 discusses DP models of the joint labor/leisure and consumption/savings decision.

A final limitation of the FR study illustrates an important problem common to many other studies that use the simulation approach, namely, that simulations can be extremely misleading if they focus only on a single cohort or group of individuals, ignore general equilibrium effects, or ignore changes in other taxes or benefits that need to be made so that policies under consideration satisfy short and long run budget constraints. In general, almost all policy changes impose gains and losses on different groups of individuals and it is extremely important not to lose sight of potential losses incurred by certain groups when focusing on the potential gains experienced by some other group. A misleading aspect of the FR analysis is that it does not account for the transition costs involved in moving from the status quo to the PRA plan. As most analysts recognize, there is an implicit debt (unfunded pension liability) to current beneficiaries and workers who paid Social Security taxes and expect to receive benefits under the status quo policy. If we reject the possibility that Social Security would renege on its obligation to current and future retirees, then to properly account for the risks and returns of moving to a privatized system like the PRA, the analysis needs to consider how these transition costs will be borne by current and future tax payers. If these costs were subtracted from the higher returns earned by the PRA accounts, it is clear that the FR analysis would result in a less optimistic conclusion about the gains to privatization.

Indeed, a number of recent analyses, including Geanakoplos, Mitchell and Zeldes (GMZ) (1998a) conclude that there is *no gain* to privatizing Social Security if individual accounts are invested in riskless securities such as government bonds. Even if the rate of return on government bonds is higher than the real internal rate of return in a pay-as-you-go Social Security system, the interest on "recognition bonds" (the expected present value of unfunded liabilities to current beneficiaries and contributors), completely offset the higher returns earned on the individual accounts. The present value of unfunded liabilities is substantial, in excess of $10 trillion dollars, or about twice the size of the explicitly recognized part of the national debt.[4] This estimate was taken from a previous study by Leimer (1994) that showed that the internal rate of return of the current Social Security system was initially very high (in excess of 20%) for cohorts born prior to 1896, who would have been eligible for benefits shortly after the start up for Social Security in 1935. These individuals received these high returns as a "startup windfall" at the initiation of the Social Security system: the first beneficiaries received a stream of Social Security benefits even though they paid little or no Social Security taxes. In fact, Leimer's results show that all birth cohorts up to 1936 received net transfers in the sense that the present value of the cohort's Social Security benefits exceeded the present value of its Social Security contributions. Even though benefits and taxes may diverge on a year to year basis, Social Security must obey a long run budget constraint that requires the sum of the present values of all net transfers to all past and future generations to equal zero. This long run budget constraint implies that the $10 trillion in net transfers to the "startup generations" born prior to 1936 must be by paid for by net taxes on generations born after 1936.

> "Privatizing the system would allow households to earn market returns on their social security contributions. But if those contributions were taxed just enough to keep the unfunded liability a constant fraction of GDP, then in the absence of uncertainty, extra market returns would be entirely dissipated. Future workers would not perceive any higher *net* investment returns than they would under the current social security system, because for every dollar of social security contributions, they would have to pay 29 cents in tax to meet the unfunded liability inherited from transfers from previous generations. (p. 45)

GMZ's calculations fail to value the additional output resulting from the higher long run capital stock that would result from moving from a pay-as-you-go to a privatized system. As we will see in section 5.3, the welfare gains resulting from higher savings and a higher capital stock in a fully-funded or privatized system can be substantial, although there may be a temporary reduction in welfare for the "transition generations" who are saddled with the dual burden of paying off the unfunded liabilities of the transition generations and saving for their own retirement at the same time. GMZ's conclusions also conflict with Feldstein (1998), who used similar calculations to derive the gains to privatizing Social Security that explicitly account for transition costs. Feldstein's formula for the present value of the gains to privatizing, PVG, is given by

$$\text{PVG} = U\left[\frac{r-\gamma}{\delta-\gamma} - \frac{r}{\delta}\right],$$

where U is the expected discounted unfunded Social Security liabilities, r is the riskless rate of interest (the rate of return on government bonds), γ is the growth rate of the economy (the sum of

[4] The $10 trillion figure is derived from Leimer's study. Other studies have arrived at lower estimates of the unfunded liability. For example, Duggan *et. al.* 1993 estimated that the net transfer to cohorts born from 1895 to 1992 was equal to $3.5 trillion in 1988 dollars.

the population growth rate plus the rate of growth of real wages), and δ is the "social discount rate". Notice that PVG > 0 only if three conditions hold, 1) $r > \gamma$, 2) $r > \delta$ and 3) $\gamma > 0$. However if we assume that the appropriate social discount rate is the risk free rate of interest, then $r = \delta$ and PVG $= 0$, in which case Feldstein's results are consistent with GMZ's conclusion that there are no gains to privatizing Social Security. However Feldstein uses a variety of arguments to suggest that the appropriate social discount rate is less than the risk-free rate of interest. "If considerations of risk are ignored, this implies that $\delta = (1 - \tau)r_N$ where τ is the marginal individual tax rate and r_N is the return after individual taxes but before individual taxes. With a relatively conservative estimate of $\tau = .2$ and with $r_N = 0.055$, this approach implies $\delta = 0.044$. If the real net return on government bonds is regarded as a more appropriate risk adjusted measure, $\delta = r_{GN} = 0.010$." (p. 25-26). Feldstein states that "experience in the U.S. since 1960 implies that $\gamma = 0.026$ and $r = 0.093$", but he also suggests that "the certainty equivalent rate of return that replaces the return to portfolio investors with the yield on government bonds is 6.4 percent." (p. 25).

Feldstein's real economic growth rates and rates of return are much higher than those considered in GMZ, which are closer to values used by the Social Security Actuary. GMZ assume that $\gamma = 0.012$ and $r = 0.023$. GMZ specifically criticize the approach of using high expected rates of return for projecting benefits of a privatization plan but discounting the expected benefits at a low risk-free rate: "calculations using an appropriate risky discount rate deviate considerably from those found in the literature, since all benefit payouts that depend on stock market returns must be discounted by a higher rate than the Treasury risk-free rate. In general, a money's worth measure that assumes high returns on stock but discounts by a risk-free rate will overstate the benefit of social security diversification, and the overstatement will be greater the more stock assume held in the social security accounts." (p. 59).

Regardless of whether risk-free or risk-adjusted discount rate is used, Feldstein finds that $r > \delta$ and $r > \gamma > 0$, which implies that PVG > 0. The higher r is relative to δ, the higher the gains to privatization. Thus, the simple logic of compound interest suggests that the gains to privatization will be even higher if one can invest in equities and take advantage of the *equity premium*, i.e. the excess in the expected return to equities relative to stocks. However, as usual there is a tradeoff between risk and return that needs to be evaluated. This has been done by Feldstein, Ranguelova, and Samwick (FRS) (1999), by extending the analysis in FR (1998) to account for transition costs in addition to uncertainty in returns. The analysis is very similar to FR (1998), but also borrows from the approach of Feldstein and Samwick (FS) (1998) which accounted for transition costs but abstracted from uncertainty. FRS find that accounting for transition costs does not radically affect the conclusions reached by either FR or FS. In particular, they find that "transitions to either a completely investment-based system or a mixed system that maintains current law benefits can be done with little additional saving in the early years (a maximum of three percent) and substantially lower combinations of taxes and savings deposits in the later years. The extra risk to retirees and/or taxpayers is relatively small, making investment-based plans preferable to a pure pay-as-you-go system for reasonable degrees of risk aversion."

GMZ also extend their analysis to allow for risky stock market investments that yield higher returns than the risk free rate. However they do not find the advantages to privatizing Social Security and investing in equities to be as clear-cut as FRS. The reason is that "if all households have access to stock investments of their own, then permitting equities in the individual accounts will have no effect on anyone's well-being. In effect, the stocks that workers buy for their individual social security accounts will be purchased from their own private portfolios. Their overall portfolios will end up absolutely unchanged." (p. 58). However GMZ recognize that by helping to "prefund" Social Security, privatization is likely to increase the long run capital stock and economic well-being. Further, the hypothesis that all households have access to stocks is empirically false: the most recent available data indicate tht fewer than half of all U.S. households have any equity holdings whatsoever, even indirectly via defined contribution pension holdings. [5] If there are a significant fraction of "constrained" households, then privatization could have have a beneficial impact since

> "the fundamental rationale for social security investment in the stock market rests on the existence of people who are currently constrained from holding equities. It is interesting to note that those who would benefit the most from social security investments in equity are probably the poor, since this group is least likely to hold stocks now. Quantifying the money's worth to a constrained household of a large movement into the stock market is more difficult. It is clear, however, that a discount rate higher than the risk free rate should be used in computing the money's worth of the stock payoffs. The reason is that as households gain more exposure to stocks, they would perceive their old age income as more and more at risk." (p. 32).

4.3 Using Options to Calculate the Value of Benefit Guarantees

A corollary to the problem of failing to fully account for gains and losses in policy simulation models is what Bazelon and Smetters (1999) have termed the problem of "super implicit debt". An example is the implicit cost of minimum benefit guarantees to Social Security beneficiaries. For example, in considering moving to a privatized system with individual accounts that can be invested in equities, such as the PRA plan considered in FR, then it is easy to see that if the government offers guarantee that benefits will not fall below a specific minimum benefit level, then future taxpayers necessarily bear the risk of paying for this guarantee in the event of poor stock market performance. To be fair, FR did consider the impact of the implicit minimum benefit guarantees in their simulations by computing the value of a social welfare function, a weighted sum of the expected discounted utilities for 80 birth cohorts who between ages 21 to 100 in a steady state after the PRA plan is fully phased in. A limitation of this calculation is that it does not consider the endogenous long run changes in saving and labor supply that result from such a change, but accounting for these feedbacks moves us toward a more complicated utility-based, general equilibrium analysis that we will consider in the next section. Below we will consider another shortcut approach to dealing with the problem of "super implicit debt" inherent in minimum benefit guarantees – the option-pricing approach that effectively uses observed market prices as certainty equivalents.

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[5] This situation is changing quickly, however. The huge stock market returns in recent years coupled with sharp decrease in costs in stock trading via the WWW and "electronic communication networks" has lead to a rapid rise in popularity of "day trading" by small investors that is rapidly making participation in the stock market more of a universal phenomenon in the U.S.

The option pricing approach is discussed in Smetters (1999). The discussion below repeats an example presented in Abel and Lucas (1999). The basic idea is to use a well developed theory of option pricing in finance to calculate the value of minimum benefit guarantees implicit in many social security reform proposals, and then use these values to calculate an adjusted cost of the program. A *call option* gives the holder the right to buy a stock (or a stock index) at a predefined exercise price. A *put option* gives the holder the right to sell a stock at a predefined exercise price. Thus, options can be used to completely offset the risk of investing in the stock market. For example, if you wanted to invest $100 in the stock market and obtain a certain return of 12% after one year, you could buy the stock for $100, and then buy a put option with an exercise price of $112 and sell a call option with an exercise price of $112, both with an exercise date one year in the future. One year later, if the stock price turned out to be less than $112 you could exercise the put and receive $112 for the stock. If the stock price is more the $112, then the owner of the call option would purchase the stock from you for $112. Either way you would have exactly $112 at the end of the year. Thus the combination of holding a long position of one stock and one put together with a short position of one call produces a guaranteed return of 12%. Assuming the risk free rate of return is 6%, the present value of such a portfolio is $\$112/1.06 = 105.66$. Thus, the implicit cost of the "insurance" that results in a perfectly certain return of 12% is $5.66. Using options in this way, one can value the implicit insurance provided by benefit guarantees. The idea is to assign taxpayers the "market price" of these guarantees, even though in practice the risk is not explicitly insured but rather "self-insured" via uncertain changes in future tax rates.

Abel and Lucas (1999) used this approach to evaluate the implicit cost to taxpayers of the Clinton administration's recent proposal to invest 20% of the Social Security Trust Fund in equities, while maintaining a guarantee that current Social Security benefits would remain unchanged. Assuming an expected return of 9% on equities, they calculated that the aggregate value of the benefit guarantee was $254 billion. [6] Smetters (1999) estimates that the Clinton Administration proposal is actuarially equivalent to increasing the payroll tax in 30 years by 0.8 percentage points in perpetuity, from the current 12.4% to 13.2%. Investing 40% of the Trust Fund in stocks is equivalent to a 2.1 percentage point rise in future tax rates.

The option pricing approach is an attractive way to estimate the value of the "super implicit debt" created by various benefit guarantees, but it has a number of important limitations. Since the government does not explicitly purchase this insurance by hedging in the stock market, but rather "self insures" this risk via stochastic adjustments to future tax rates, the calculated cost of the guarantee could overestimate or underestimate an individual's certainty equivalent valuation of this risk. Stated differently, many risk averse taxpayers would find the "insurance premium" necessary to insure a given percentage return to be too high, and will decide to be long in stock without incurring the cost to hedge this risk via purchases and sales of puts and calls. For these investors the insurance premium is higher than their certainty equivalent valuation of the risk. Other investors would find insurance premium to be relatively cheap since their certainty equivalent valuation of the risk is higher than the implicit insurance premium. Therefore ranking social security reform

[6] Their calculations presume that the Trust Fund is continually rebalanced to ensure that equities never constitute more than 20% of the Trust Fund.

proposals via money's worth measures that adjusting the expected present values of taxes for the estimated market cost of implicit benefit guarantees may not necessarily provide a correct social welfare ranking of the alternative proposals. Also, many proposals are rather vague about whether there are any minimum benefit guarantees: in practice most plans will lead to uncertain changes to future benefits and taxes and there is no clear way to value these risky changes in the social security rules via the standard Black-Scholes option pricing formula used to value simple puts and call options. In these more complicated and realistic situations, one may have no choice but to attempt to explicitly evaluate the risk via direct calculations of expected utility that account for the subjective probability distribution of uncertain future changes to the Social Security system. These calculations are not easy to do, but examples will be provided in section 5.

4.4 Pitfalls of Using Money's Worth Measures and Other Summary Statistics

We now turn to a consideration of other ways of summarizing the costs and benefits of different policies via relatively low dimensional "sufficient statistics" that are designed to capture the main welfare and behavioral impacts of various policies. A standard way of comparing alternative random sequences of cash flows that occur over a sequence of years is the *internal rate of return.* This is the discount rate that equates the expected present value of positive cash flows (benefits) to the expected present discounted value of negative cash flows (costs, taxes). In the case of Social Security, we can evaluate the internal rate of return of the existing Social Security by finding the discount rate that equates the expected prevent value of Social Security tax contributions to the expected present value of benefit payments. A large number of studies have carried out such calculations in recent years, including the recent study by Beach and Davis (1998a) that was discussed in section 3. In addition to the criticisms already noted, calculated internal rates of return do a poor job of accounting for risk since any policy that produces a mean-preserving spread on Social Security benefits and taxes will not affect the the internal rate of return. However it should be clear that mean-preserving spreads of taxes and benefits make risk averse individuals strictly worse off.

Despite these deficiencies, the IRR and other related "money's worth" measures (the discounted benefit to tax ratio and the net present value of Social Security benefits) have played a prominent role in the U.S. Social Security reform debate. For example, the Social Security Advisory Council (1997) scored three reform plans using money's worth measures and concluded that all three plans had higher money's worth than the status quo, with the implicit suggestion that most individuals would find these plans preferable to the status quo. Geanakoplos, Mitchell, and Zeldes (GMZ) 1998 provides a thorough analysis of some of the pitfalls that can arise from naive analyses using money's worth measures, with particular attention to the issue of whether it is possible to increase the returns to Social Security by increasing the Trust Fund or moving a privatized system with individual accounts. They show that ranking alternative reform proposals based on a simple money's worth measure such as the IRR or the net present value of benefits will generally not yield a correct welfare ranking: "In the most general situation, then, accurate money's worth numbers require a detailed knowledge of each household's preferences including its attitude towards risk. Since these preferences are generally not known, it might seem hopeless to derive a useful set of summary statistics that can be used for comparing different social security systems." (p. 23).

However they show that there are conditions under which rankings based on money's worth do yield valid welfare rankings: i.e. conditions under which all individuals would agree that a social security plan with a higher money's worth is preferable to one with a lower money's worth.

Unfortunately the conditions for this ranking to be valid are too restrictive to be relevant in practice. Indeed, their key "spanning" assumption (households can duplicate all social security income streams via securities traded in the marketplace) implies that there is no useful role for Social Security beyond providing a system of taxes and transfers that redistributes lifetime income. When spanning fails there are incomplete markets which Social Security can help to "complete". That is, when private markets don't offer individuals the opportunity to design their own preferred retirement, investment and insurance plans, the analysis of Eckstein, Eichenbaum and Peled (1986) suggests that Social Security can lead to welfare improvements by helping to fill in these missing markets. Actually, a safer statement is that Social Security can causes *changes* in welfare be helping to fill in missing markets, since an example discussed in section 5.3 shows that introducing an actuarially fair annuities market actually *reduces* welfare in a plausibly specified model. Examples of incomplete markets where Social Security is likely to have a strong effect include markets for annuities, disability, and health insurance. Unfortunately money's worth measures do not provide reliable measures for the practical case where markets are incomplete. GMZ conclude that "money's worth measures are well-suited to comparing benefits and costs for different income groups, and even different cohorts, under the same social security system. But the typical approaches do not fare well at making comparisons across different reform plans, primarily because they do not properly account for differences in risk and/or transition costs." (p. 46).

In section 5.3 we provide an example where a comparison of internal rates of return to Social Security contributions provides a misleading policy conclusion even when transition costs are accounted for. This example provides a stark illustration of the fact that at the aggregate level, a policy change (in this case, the creation of an actuarially fair annuities market) that leads to a higher IRR on Social Security contributions may actually result in a lower level of welfare for individuals in the economy.

4.5 Concluding Remarks about the Short Cut Approach

The main advantage of the simulation-based approach is that once SSA has a reliable probability simulation model, it is relatively easy to conduct stochastic simulations to study the implied distributions over a variety of different outcomes of interest. Stochastic simulation *per se* does not impose huge computational burdens: the approach is quite straightforward and could be implemented by SSA relatively quickly. Aside from the practical problems involved in subjectively assessing the desirability of different probability distribution for various outcomes implied by different policies, the key prerequisite for this approach is also its Achille's heel: it requires a probability model that accurately simulates individual behavior under the status quo and a range of hypothetical policies of interest. As we discuss in section 5.2, it is relatively easy to specify reduced-form probability models that can accurately simulate (observed) individual behavior under some historical policy regime for which there is sufficient data to reliably estimate observed behavioral relationships. However the Marschak-Lucas critique leads to the presumption that reduced-form models will not lead to accurate predictions of policy changes, especially those for which haven't occurred in the past. On the other hand if we want a fully behaviorally justified probability model that is more likely to predict policy changes accurately, we have few options except to work within a "closed" model that endogenously derives how policies affect the probability distributions affecting individual behavior such as via the structural DP or SGE approaches that will be described in the next section. The only other possibility is to assume that policy-induced changes to the probability distributions governing individual behavior are determined by some undefined, *ad hoc* process reflecting the analyst's "judgement" of how individuals will respond to various policies. In certain cases, such as Feldstein and Ranguelova's (1998) analysis of personal retirement accounts, policy changes can be modeled as changes in certain exogenously specified probability distributions, and endogenous behavioral and general equilibrium responses are ignored. However our critique of this example suggests that the assumption that there are no endogenous responses to policy changes can be very difficult to justify.

5. Longer Term Strategies for Incorporating Risk and Insurance in Policy Models

This section provides a "helicopter tour" of the large, rapidly growing academic literature on Social Security policy models. Collectively these models incorporate nearly all of the individual-level risks that section 3 listed as being relevant for policy analysis, as well as most of the various private, governmental, and non-governmental institutions and mechanisms individual have at their disposal to deal with these risks. Although some of these academic models could be used almost immediately with little or no modification for use in policy forecasting within SSA, most of the models considered in this section should be viewed as prototypes of models that SSA might consider as part of a longer term strategy for policy modeling. The reason is that many of the state-of-the-art methods are relatively untested in practical forecasting contexts, and SSA might regard these methods as too difficult to implement, or too experimental for use in the short term. However this section demonstrates that the existing academic literature already provides a powerful array of tools for constructing policy models that are likely to produce much more credible forecasts than the short-cut approach described in the previous section. Thus, the return to investing in these models as part of a longer term policy modeling strategy is likely to be very high.

We divide our review into three subsections: 1) "analytic models", 2) numerical dynamic programming models, and 3) numerical stochastic overlapping generations general equilibrium models. We briefly summarize the main points from each of these subsections in the paragraphs below, and encourage interested readers to read the full subsection for further details and examples.

Analytical models are relatively abstract and oversimplified idealizations of reality that are designed more in the interests of obtaining closed-form solutions (or clean characterizations of the properties of a solution) than for their empirical realism. Nevertheless the qualitative insights from these models have proven to be extremely important guides to our thinking about Social Security policymaking. The key advantage of analytic models is that they are *closed*, i.e. they endogenously derive the changes in individual behavior (in the case of partial equilibrium models), and the changes in the overall economy (in the case of general equilibrium models) resulting from changes in Social Security policy. We can think of individual behavior in game theoretic terms as being a *best reply* to the policy chosen by the government, which is initially modeled as a *Stackelberg leader.* Recent work on the political economy of Social Security is starting to relax the Stackelberg assumption that the government commits to a fixed policy for all future time periods. One strand of research has studied the impact of *political risk* of uncertain future policy changes (modeled as an exogenous stochastic process, see e.g. Diamond, 1994 and Bütler, 1998), and another strand is beginning to endogenizing the government's policy choices by accounting the government's incentive to respond to voter sentiment about the desirability of alternative policies (see, e.g. Conesa and Krueger, 1998, Rangel and Zeckhauser, 1999, Galasso, 1998, Boldrin and Alonso 1998, and Boldrin and Rustichini, 1997). Many of these endogenous behavioral changes on the part of individuals, firms, and the government would be difficult to predict without the assistance of an analytic model.

We have already summarized some of the important insights obtained from the first generation of deterministic analytic models of Social Security in section 2.1. The insights obtained from the second generation of stochastic analytic models that account for risk and various forms of insurance have had a profound effect on how economists think about Social Security, and could ultimately have an equally important practical impact on policy design. The main limitation of analytic models is their lack of empirical realism, and their lack of quantitative predictions. This limitation can be overcome by solving larger, more realistic versions of analytic models numerically using computers. This is the topic of subsections 5.2 and 5.3.

Subsection 5.2 reviews the literature on individual-level numerical dynamic programming (DP) models. The use of computers enables this literature to develop substantially more realistic models than possible using the analytic methods surveyed in subsection 5.1. It has also spawned a literature on econometric estimation and testing of dynamic models of sequential decision making under uncertainty, which enables us to test the validity of strong rationality hypotheses underlying analytic models. We discuss the pros and cons of this "structural" approach to econometrics relative to simpler reduced-form approaches which estimates behavioral relationships without presupposing any particular model of individual decision-making. We provide examples that show that even relatively simplified numerical DP models succeed in providing very good empirical models of individual behavior, and provide more accurate predictions of individuals' endogenous responses to policy changes than alternative reduced-form econometric models. We discuss the *Marschak-Lucas critique* that provides a theoretical presupposition for why this should be the case. We conclude with a brief review of the empirical literature that studies how Social Security affects individual decision-making. We find that DP models appear to provide very good empirical models of individual labor supply decisions and are quite useful for predicting the timing of retirement and the application for pension and Social Security benefits. However DP models that are designed to test the life-cycle consumption/saving hypothesis have not been as successful in explaining savings and wealth accumulation decisions and the puzzling finding of declining aggregate savings rates in the U.S. The big drawback of the current state of the art is that labor supply and consumption/savings decisions have been modeled separately, a potentially serious misspecification. We summarize a practical computational problems that explains why most researchers have done this, namely, the *curse of dimensionality* associated with solving increasingly comprehensive, detailed, and realistic DP specifications. One of the main ways to deal with the curse of dimensionality is to construct smaller partial models that consider only a subset of the universe of possible decisions and sources of uncertainty an individual faces. This has lead to the piece-meal approach of modeling certain aspects of the Social Security program in isolation. We conclude the section by discussing decisions that can be modeled separately from those that need to me modeled jointly in order to obtain accurate predictions of the behavioral and welfare impacts of policy changes.

A limitation of single-agent DP models is that they do not account for general equilibrium feedbacks that would permit a complete assessment of how Social Security affects individuals, firms, and the overall economy in both the short and long run. This is the topic of subsection 5.3, where we review the most ambitious class of computer simulation models, *stochastic overlapping generations, general equilibrium* (SGE) models. Computing solutions to SGE models is significantly more computationally demanding than solving individual-level DP models. Indeed, most algorithms for solving SGE models require repeated solution of individual DP problems as a subroutine of an "outer" equilibrium solution algorithm that searches over trial values of prices and quantities until values are determined that equate supply and demand in capital, labor, and financial markets, and government budget constraints and aggregate resource constraints are satisfied. If we want to choose values of the unknown parameters of the SGE model so that the simulated outcomes of the model "best fit" the corresponding observed outcomes in the economy, a further "do-loop" is required. For each trial value of these parameters the SGE model must be re-solved so that simulated values of the model's outcomes can be measured against observe outcomes according to some relevant measure of goodness of fit. This final loop presses the limits of current technology, so that computationally simpler *calibration methods* are typically used to specify unknown parameters of SGE models. The main limitations of SGE models arise from the curse of dimensionality involved in solving realistic version of these models that treat Social Security policies with a sufficient level of detail to be useful in policy analyses. Another related limitation is the lack of formal statistical tests of goodness of fit and forecast error uncertainty in these models resulting from the somewhat *ad hoc* and in-bred process of calibration. We conclude with some comments about policy issues for which general equilibrium feedbacks can be safely ignored from those where a failure to account for feedbacks would lead to misleading predictions and policy prescriptions.

5.1 Analytic Models

While it is not easy to draw a precise demarcation, analytic models are highly simplified, abstract, special-purpose single agent DP models and multiple agent SGE models that can either be solved analytically or via relatively simple "back of the envelope calculations" or via numerical methods that are not very demanding in terms of their cpu requirements. These models are intended to guide intuition rather than to provide quantitative predictions of the impact of different policies, an approach advocated by economists such as Martin Feldstein. Examples of this approach include Abel's (1998,1999) and Bohn's (1997, 1998a, 1999a,b) analyses of the impact of Social Security reform on financial markets, Eckstein, Eichenbaum and Peled's (1985) and Walliser's (1997) analysis of the welfare-enhancing role of Social Security in "filling in" for missing annuity markets and its effect on "crowding out" private annuity markets, Bohn's (1998b) and Shiller's (1999) analyses of the intergenerational risk sharing features of Social Security, Hopenhayn and Nicolini's

(1997) analysis of optimal unemployment insurance, Parson's (1996) model of optimal disability insurance, and Spiegel's (1998) model of endogenous stock price volatility in multiple security overlapping generations models. This section reviews some of these articles to give a flavor of this literature and some of the pros and cons of these types of models. In general, these models are valuable mostly for their *qualitative insights* and are not intended to provide quantitatively accurate policy predictions or recommendations.

Moral Hazard and Adverse Selection. One of the most important insights in the economic literature on risk and insurance in the past 3 decades was the realization that private information about individual characteristics and actions could lead to market failure due to problems of *adverse selection* and *moral hazard.* (see, e.g. Rothschild and Stiglitz, 1976 and Wilson, 1977). The high cost of private insurance in the annuity and medical care markets is well documented empirically (see, e.g. Walliser, 1997, 1998, Friedman and Warshawsky, 1988) and is one of the main theoretical rationales (along with paternalism and the redistribution) for the very existence of Social Security (Diamond, 1977). Eckstein, Eichenbaum and Peled (1985) built a simple overlapping generations model that formalized how a mandatory Social Security system, by forcing a mandatory pooling of risks as a common actuarily fair rate for the population as a whole, could lead to a pure Pareto improvement relative to private markets for annuities.

Second Best Outcomes and the Problem of Incentive-Compatibility. The subsequent literature on information economics and "incentive compatibility" showed that these same adverse selection and moral hazard problems could be hindering the effectiveness and increasing the cost of providing Social Security benefits. This is particularly the case with respect to the disability and unemployment insurance components of the Social Security program where moral hazard problems have long been recognized to be significant problems that increase the costs of the program. A related literature on optimal taxation and mechanism design (see, Diamond and Mirrlees, 1978) showed how the government could achieve second-best outcomes (i.e. social welfare maximizing outcomes subject to the constraints imposed by incomplete information) via relatively simple policies that provided incomplete insurance to enable *self-selection.* In the case of disability, the first-best solution under complete information would be to provide a worker full insurance, i.e. the worker would receive the same consumption level regardless of whether she was working or disabled. However if the government cannot observe disability status and individuals experience disutility to working, then full insurance is not incentive-compatible and too many people will want to apply for disability benefits. The Diamond and Mirrlees solution is to set the consumption level received by disability beneficiaries sufficiently lower than the net consumption level received by workers. The higher consumption level received by workers provides just enough incentive to induce all able-bodied individuals to work. Disabled individuals do receive a benefit, but it is substantially lower than what they would receive under the complete information solution — they bear the brunt of the "welfare costs" of incomplete information.

Optimal Disability Insurance. However subsequent work (Parsons, 1996) recognized that the government also has access to a *monitoring technology* i.e. it operates a disability award bureaucracy that provides noisy signals about whether an applicant is truly disabled. Parsons modeled the optimal structure of the disability program when the disability award system (e.g. the Disability Determiniation Services and and Administrative Law Judges, etc.) produce Type 1 and 2 errors (i.e.

they reject some truly disabled applicants and award benefits to some non-disabled applicants.) Parson's characterized an optimal "dual negative income tax" (NIT) benefit scheme that maximizes the *ex ante* expected utility of an individual in the population (prior to knowing disability status) subject to a resource constraint (equal to the production of the non-disabled fraction of the population). The optimal benefit structure involves, counter-intuitively, a substantial premium to individuals who are awarded disability benefits and decide to return to work. There is also a "welfare benefit" for individuals who don't work: this provides partial protection for individuals who apply for DI and are rejected but are truly disabled. This reward (similar in principle to the policy of allowing a DI recipient to keep their DI benefits during a trial work period) is required to provide the proper incentives for healthy individuals to work rather than to rely on disability.

In Parson's model the DI benefit is significantly larger than the welfare benefit, but the welfare benefit is smaller than the disability benefit in Diamond and Mirrlees model, a consequence of the fact that the monitoring technology tends to help the government screen truly disabled applicants. The existence of a monitoring technology causes Parson's dual-NIT solution to Pareto-dominate the Diamond-Mirrlees solution that ignored it. An unrealistic feature of Parson's dual NIT scheme is that 100% of the population has an incentive to apply for DI benefits (which was assumed to be costless in his initial model). An even better solution results from charging an application fee to apply for DI benefits. The application fee can be set in such a way that only truly disabled individuals have an incentive to apply for DI benefits, resulting in lower DI taxes for non-disabled workers and higher benefits for disabled awardees than under the dual-NIT system that didn't have an application fee. The main limitation of Parson's analysis is that is ignores the fact that the actual DI award process is a multi-stage "game" that allows applicants the option of appeal or re-application. The application and appeal process involves substantial delays, which might be interpreted as a sort of "in-kind" application fee. Also, Parson's ignored the substantial cost of running the huge DI bureaucracy, with over 15,000 employees at a cost of approximately 2% of total DI benefits (payroll tax receipts). Analysis of the impact of the proposed disability process reform (see, e.g. SSA, 1999) requires a more detailed model of the disability screening process, with multidimensional signals about health status and a dynamic model of individual's incentives to apply and appeal at various stages in the process. Empirical models of this sort are currently being developed (see, e.g. Benitez-Silva, *et. al.* 1999a,b).

Optimal Unemployment Insurance. Unemployment insurance is also subject to significant moral hazard problems. The U.S. unemployment insurance (UI) program has grown rapidly, with the fraction of covered workers increasing from 60% of the working population in 1950 to 90% in the 1980s, and UI benefits as a fraction of GDP reaching 0.4 percent by 1990. UI programs have been criticized, especially in European countries, for reducing incentives for an unemployed individual to return to work. On the other hand UI may provide a valuable source of insurance to risk averse workers who experience job losses, and if optimally structured, may help provide sufficient temporary liquidity to enable an unemployed individual to find a good match, reducing the costs of subsequent turnover. Determining the optimal structure of UI benefits involves a complicated balancing of the insurance benefits against moral hazard costs. Hopenhayn and Nicolini (HN,1997) provide a formal derivation of the optimal structure of UI benefits and taxes treated as a repeated principal-agent problem involving the unemployed worker (the risk-averse agent) and the government (the risk neutral principal) which cannot monitor the agent's search effort.

HN explicitly account for the dynamic nature of the optimal benefit structure, characterizing the optimal contract using recursive DP-like methods developed in the literature on dynamic mechanism design and repeated moral hazard (Phelan and Townsend, 1991 and Spear and Srivastava, 1987, Fernandes and Phelan, 1999). They consider unemployment tax/transfers of the form $\tau : h_t \to \{a_t, z_t\}$ where h_t is the individual's employment history at time t, a_t is the search effort of the agent, and z_t is the net transfer from the government to the individuals (a tax if negative). If the worker obtains expected discounted utility V under Social Security's existing UI policy (which involves a constant benefit profile for the first 26 weeks and zero thereafter), then the optimal UI policy minimizes $C(\tau)$ subject to $V(\tau) = V$, where $C(\tau)$ is the expected present value to the government of UI policy τ and $V(\tau)$ is the worker's expected discounted utility under τ.

HN show that the optimal benefit should decline monotonically with the duration of the unemployment spell in order to provide sufficient incentives for unemployed individuals to search for a new job, plus a tax rate once reemployed that increases with the length of the previous spell of unemployment. In a numerical illustration of a calibrated example, HN estimate a typical worker's expected utility under the status quo UI policy and then estimate the cost savings of adopting an optimal UI policy. They find that the savings from adopting an optimal UI benefit policy can be as large as 30%, depending on the level of other precautionary wealth of the agent, his degree of risk aversion, and the cost of job search.

Optimal Health Insurance. Of course, the market for medical insurance is also subject to severe informational and market failure problems. We noted in section 3 that over 40 million Americans have no form of health insurance, and the number is growing rapidly as firms discontinue the employee health plans in growing numbers. A review of the literature on health insurance would require a survey in itself and we will not attempt this here. We simply note here that due to the substantially more complicated nature of health insurance (involving non-standardized services whose quality is hard to verify and at least three agents, the insurer, the individual and the physician), makes it very difficult to model health care supply or demand, let alone characterize the structure of optimal health insurance contracts. Given these difficulties most of the work in the area of health care is empirical, with many exploratory data analyses.

There has been some pioneering initial work on the structure of optimal health care contracts by Ma and Riordan (1997), albeit in a highly simplified framework that ignores the role of a physician as an independent agent, under the assumption that the physician's interest are perfectly aligned with the patient's interest. Their model deals with the moral hazard problem of overutilization of health care services under standard insurance contracts because consumers do not internalize the full cost of the treatment. This analysis ignores moral hazard problems associated with imperfect monitoring of claims submitted physicians, hospitals, and other health care providers: there is anectdotal evidence as well as numerous newspaper articles reporting substantial levels of fraudulent Medicare and Medicaid claims, perhaps encouraged by the knowledge of SSA's overworked and sometimes poorly trained claims representatives who do not have the medical expertise to verify whether complicated claims from hospitals and doctors are valid. Given the magnitude of

Medicare spending, it is clear that there are substantial payoffs from research into managed care and other means of reducing fraud and moral hazard problems. The dramatic slow-down in the growth of Medicare costs last year may be an indication that recent policy changes designed to promote various forms of managed care as an alternative to traditional fee for service arrangement may be working. Overall, when we compare the complexity of the health care sector to the relatively primitive state of economic modeling of this part of the economy, it is likely that the highest short term returns will be obtained from additional data collection and empirical analyses, although the long term returns to investments in formal modeling of the health care sector could be very large.

5.2 Numerical Dynamic Programming Models

Even the very brief review in section 5.1 demonstrated the rich array of questions and issues that can be addressed using analytical models that incorporate risk via the expected utility framework. An important question about this approach from SSA's standpoint is whether the predictions of these often rather abstract and highly stylized models can be taken seriously as useful inputs to policy making in "the real world." Numerical dynamic programming models represent an alternative class of individual-level analytical models that use computers to solve for the strategies or *decision rules* that maximize an individual's expected discounted utility. The term "dynamic programming" (DP), introduced by Richard Bellman (1957), refers to a recursive approach for solving for optimal decision rules that constitutes the standard approach to solving these problems via both analytic and numerical methods. However there has been rapid growth in numerical methods for solving DP problems on digital computers (see, e.g. Rust, 1996). Computers allow us to formulate more detailed and realistic models of individual behavior since we are freed from the restriction of having to specify simple functional forms that permit closed-form solutions to the individual's optimization problem. The advent of sufficiently powerful hardware and software has enabled us to repeatedly solve trial versions of the DP problem in a process of searching for unknown parameters of individuals' beliefs and preferences to enable the predicted behavior from the DP model to "best fit" observed behavior using various measures of goodness of fit. Furthermore, optimal decision rules can be computed for alternative Social Security policies, constituting a precise quantitative prediction of how an individual would optimally respond to the new policy. It is also easy to use DP models to compute "certainty equivalent" valuations of a policy change, i.e. the fraction of the individual's wealth or income flow that they would need to pay (or be paid) to make them indifferent between the new policy and the status quo. This enables one to study the welfare and distributional consequences of policies in a relatively objective manner, quantifying the individual-level impacts in dollars rather than in "utils".

For concreteness, we briefly describe the DP method in the context of discrete time *Markovian decision theory.* The key variables entering this model are a vector of *state variables* s_t and a vector of *control variables* c_t. Examples of components of s_t include income, assets, hours of work, age, health status, family status, and indicators of pension status (eligibility for various types of Social

Security and pension benefits).[7] Examples of components of c_t include labor supply, consumption, and indicators of the decision to apply for Social Security or pension benefits. There is no significant loss of generality in modeling the evolution of various uncertain outcomes as a Markov process, higher orders of correlation in various state variables can be accounted by a variety of methods that retain the Markovian formulation at the expense of a higher dimensional state vector. Although it may be more realistic to think of this Markov process as evolving in continuous time, for data and computational reasons we will assume that it is a discrete time process. In practice annual time intervals are typically assumed, although for some policies (e.g. unemployment policy, or modeling disability application and appeal processes), monthly or even weekly time intervals might be necessary. However it is hard to imagine that SSA would require a model a model with finer time intervals for most of its policy forecasting needs.

The DP model is completed by specifying the individual's *beliefs* and *preferences*. Preferences are given by the utility function $u(s_t, c_t, \theta_1, \alpha)$, where θ_1 represents time-invariant parameters of the individual's utility function (relevant for the discussion of econometric estimation of DP models below) and α represents a vector of *policy parameters* that affect preferences. We do not index α with a subscript t to capture the Stackelberg assumption that the government commits to a fixed policy regime. This can be relaxed at the expense of allowing components of s_t to represent *policy variables* representing the state of the government's policy at time t. Examples of policy parameters include objective quantities such as tax rates and more subjective quantities such as parameters that affect the "stigma" of being in various states such as disability. Beliefs are represented by the transition probability density $p_t(s_{t+1}|s_t, c_t, \theta_2, \alpha)$ that also depends on a vector of parameters θ_2 (also included to motivate discussions of econometric estimation) and policy parameters α. It is easy to provide examples of how policy parameters can affect beliefs. For instance, parameters characterizing the levels and the bend points in the formula relating AIME to PIA affects an individual's beliefs about their future Social Security benefits. Another example would be parameters describing the conditional probability of being awarded DI benefits, or parameters affecting the distributions of the delays between application and award of benefits.

The method of dynamic programming amounts to calculating the *value functions* $\{V_t\}$ via the recursive formula known as *Bellman's equation* given by:

$$\begin{aligned} V_t(s) &= \max_{\{\delta_t\}} E\left\{ \sum_{j=0}^{\tilde{T}} \beta^j u_{t+j}(s_{t+j}, c_{t+j}, \theta) \middle| s_t = s, \theta, \alpha \right\} \\ &= \max_d \left[u_t(s, d, \theta_1, \alpha) + \beta \phi_t(s, d, \theta_2) \int V_{t+1}(s') p_t(ds'|s, d, \theta_2, \alpha) \right], \end{aligned} \tag{1}$$

[7] Note that as in Rust and Phelan (1997), having separate state variables that distinguish between labor force status and pension acceptance individuals obviates the need for arbitrary, subjective classifications of states such as "retirement". It is entirely possible for someone to apply for Social Security Old Age benefits and continue working, or to quit working and not apply for Social Security, etc. Different people will have different definitions of whether or not they are "retired" in these situations, but by focusing on objectively measurable states and decisions we avoid much of the arbitrariness inherent in the definition of retirement. Furthermore we avoid any presumption that retirement is an "absorbing state", since it is always a logical possibility to return to work.

where $\tilde{T}$ is the uncertain date of death of the individual and $\phi_t(s, d, \theta_2)$ is the conditional probability of survival from age t to $t + 1$ given (s, d). [8] The solution consists of the sequence of *optimal decision rules* $\{\delta_t\}$ which are the values of the control variables that maximize Bellman's equation:

$$\delta_t(s) = \underset{c}{argmax} \left[u_t(s, d, \theta_1, \alpha) + \beta \int V_{t+1}(s') p_t(ds'|s, d, \theta_2, \alpha) \right]. \quad (2)$$

The decision rule δ_t represents the *behavior* implied by the DP model and the value function V_t represents the individual's *welfare*. Thus, $c_t = \delta_t(s_t)$ represents the optimal decision that an individual should take in state s_t at time t and $V_T(s_t)$ represents the expected discounted utility over their remaining lifetime.

It is possible to turn generic DP models into behavioral econometric models using algorithms that estimate "structural parameters" θ characterizing an individual's beliefs and preferences (see, e.g. Rust, 1994). Examples of structural parameters include an individual's subjective discount factor, parameters affecting their willingness to trade-off consumption for leisure, parameters characterizing their mortality, etc. The estimation algorithm repeatedly re-solves the individual's DP problem until values of the structural parameters are found that enables the optimal behavior implied by the DP model to "best fit" observed behavior. There are a variety of different metrics of goodness of fit and associated estimation methods, including maximum likelihood. A likelihood function can be derived from the solution to the DP model by assuming that state variable is partitioned as $s_t = (x_t, \epsilon_t)$ where only x_t is observed by the econometrician and ϵ_t is treated as an unobservable from the standpoint of the econometrician. Under certain conditional independence assumptions one can derive a *conditional choice probability* $P_t(c_t|x_t, \theta)$ from the solution to the DP problem by "integrating out" the unobserved state ϵ_t

$$P_t(c_t|x_t, \theta) = \int I\{c_t = \delta_t(x_t, \epsilon, \theta)\} q(\epsilon|x_t) d\epsilon \quad (3)$$

and this conditional choice probability serves as the basis for maximum likelihood estimation of the unknown preference and belief parameters θ using the likelihood function $L(\theta)$ given by

$$L(\theta) = \prod_{i=1}^{N} \prod_{t=1}^{T_i} P_t(c_{it}|x_{it}, \theta) p_t(c_{it}|x_{i,t-1}, c_{i,t-1}, \theta_2), \quad (4)$$

where $\{x_{it}, c_{it}\}$, $t = 0, \ldots, T_i$, $i = 1, \ldots, N$ represent the observed states and decisions of a sample of N individuals where individual i is followed for T_i periods.

Policy analysis is conceptually straightforward within the DP framework. First we estimate the unknown structural parameters θ using observed data $\{x_{it}, c_{it}\}$ on individuals under some historical policy regime represented by the policy parameter vector α. Then to predict how

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[8] We omit the policy parameters α from ϕ_t on the assumption that the government policy does not directly affect mortality. However it is clear that government funded medical research has had a huge indirect effect on improving mortality, and it is not a stretch to think of other policy variables that SSA has control over (e.g. rules over who is eligible for Medicare and disability benefits) that has a much more direct impact on mortality. However so far, we are not aware of any studies that direct model the impact of policy on mortality.

behavior and welfare change under an alternative policy α' we simply re-solve Bellman's equation with α' substituted for α and using the estimates $\hat{\theta}$ for the unknown belief and preference parameters. The resulting decision rules $\{\delta_t(\cdot|\alpha')\}$ represent the DP model's prediction of how behavior will change under the new policy regime α'. The value functions $\{V_t(\cdot|\alpha')\}$ represent the DP model's predictions of how the individual's welfare will change under the new policy regime α'. If one of the state variables is wealth or income, then *certainty equivalent* valuations can be computed by solving for the change in wealth or income necessary to give the individual the same expected discounted utility after the policy change as they expected to receive prior to the policy change. Note that these certainty equivalent valuations will typically depend on the values of other state variables, and reflecting population heterogeneity: different people (as represented by different state vectors s_t) will be affected in different ways by any given policy change. The validity of these policy forecasts depend on the maintained hypothesis that the structural parameters are invariant to changes in the policy parameters, and that an individual's behavior is a "best response" to any given policy regime. That is, the individual behaves "as if" they had solved a dynamic programming problem with full knowledge of the values of all relevant policy parameters.

Clearly, the accuracy and reliability of quantitative predictions of numerical DP models depends on the validity of the key hypothesis underlying these and nearly all analytic models in economics, namely that individuals are *rational.* There are two aspects to this hypothesis. First we generally assume that individuals have *rational expectations,* i.e. they have full knowledge of the transition probability $p_t(s_t|s_{t-1}, c_{t-1}, \theta_2, \alpha)$ including all relevant policy parameters. In this context this implies that they are fully informed about the rules of the Social Security program and their beliefs about uncertain events such as death coincide with objective probability distributions that can be estimated from observed outcomes. Although it is possible we weaken the rational expectations assumption and allow individuals subjective beliefs to differ from the objective probability measure governing observable outcomes, identification of such models is extremely difficult. In simple terms there are generally many different combinations of beliefs and preferences that can rationalize the same observed outcomes, so to identify the model we generally invoke the strong identifying hypothesis of rational expectations. The second aspect of the rationality hypothesis is that *individuals behave optimally,* i.e. they behave "as if" they were maximizing the expected value of a discounted time separable utility function. Due to the identification problems noted above (see Rust, 1994 for details), the rationality hypothesis can be empirically tested only if one is willing to make some additional identifying assumptions about the functional forms of individuals' preferences and beliefs.

In summary, if the rationality hypothesis is correct, and the *a priori* specification of the parametric functional forms for preferences and beliefs are correct, then it is possible to correctly forecast the impact of arbitrary policy changes, even those for which there is no historical precedent. The impacts that can be analyzed via these "structural" econometric methods include changes in observable behavioral characteristics such as saving, labor supply, and the dates of application for Social Security benefits, as well as changes in non-observable features such as an individual's welfare. DP models constitute a subclass of structural models that are rich enough to model almost any problem involving individual sequential decision making under uncertainty. However they are not the only class of models that could be used for this purpose. We briefly review, and discard, two extensions to the DP approach below.

One class of models allows us to distinguish between choices involving risky outcome from choices of uncertain outcomes, i.e. where the decision-maker is not certain of all the parameters θ characterizing their preferences $u_t(c, s, \theta_1, \alpha)$ or beliefs $p_t(s'|s, c, \theta_2, \alpha)$. There is a well-developed literature on Bayesian decision theory where individuals have priors over the unknown parameters in the probability distributions governing uncertain outcomes. Individuals rationally update their beliefs via Bayes rule, but otherwise this theory is formally isomorphic to standard Markovian decision theory where agents are assumed to have complete knowledge of all probability distributions. Essentially the only change involved is to use the individual's posterior distribution in place of a known distribution over random outcomes. Other than substantially complicating the analysis, there is no clear evidence that suggests that use of Bayesian decision theory would significantly affect any major conclusions about Social Security policy that have been obtained in the existing literature. The predictions of DP models may be sensitive to specifications of individuals' beliefs, but this can usually be determined without resorting to Bayesian decision theory.

For similar reasons we also ignore the recent literature on non-Bayesian models of choice under uncertainty and choice under risk with non-expected utility and non-time separable specifications of preferences. While there is substantial experimental evidence that suggests that individuals do not behave in accordance with the expected utility model, there is no definitive alternative to the expected utility model that is analytically tractable and which succeeds in resolving a majority of the various experimental anomalies. Expected utility maximization of time separable preferences may appear highly restrictive, but if one has the freedom to choose preferences and beliefs arbitrarily, then it can be shown that virtually any type of behavior can be rationalized within this framework (see, e.g. Rust, 1994). Nearly all existing models of Social Security have adopted the expected utility framework, although a few recent exceptions have solved SGE models where non-expected utility preferences actually lead to a tractable analysis (e.g. Gertler, 1998 and Huang, Imrohoroglu and Sargent, 1997). These exceptions aside, the payoff to using more elaborate theories of choice under uncertainty appears to be lower than the payoff from developing richer models that account for other aspects of Social Security and other types of risks and decisions within the expected utility framework. As we will see, it is already quite challenging to construct realistic models of Social Security that account for the many risks individuals face and the variety of ways for coping with them within using the standard expected utility model.

The main drawback of the numerical dynamic programming approach to policy forecasting is the computational burden involved with solving increasingly realistic formulations of DP models, a problem Bellman referred to as the *curse of dimensionality,* which we will discuss in more detail below. However before we do this it is useful to consider the pros and cons of a much less computationally intensive alternative approach to policy forecasting, namely to extrapolate historical trends using a variety of *reduced-form models* estimated from a combination of individual-level panel data, cross-sectional data, and aggregate time series data. This is the approach that would generally be used to construct probability simulation model underlying the "short cut" approach to policy evaluation discussed in section 4. Reduced-form models have the advantage of being relatively simple to use and can be flexibly parameterized to approximate a wide variety of stochastic processes. Somewhat more computationally intensive non-parametric models can also be used to estimate these models. As a result, reduced-form models do not require a lot of strong maintained behavioral assumptions that numerical dynamic programming models require. However the validity of their forecasts does depend on a number of very restrictive assumptions, including *stationarity*. Any change in the historical "policy regime" induces a fundamental nonstationarity that generally rules out these methods for use in policy analysis. This is the essence of to the well-known "Marschak-Lucas critique" (Marschak, 1953, Lucas, 1973). This critique amounts to the simple observation that the stochastic process generating the data prior to the policy change is generally different than the stochastic process generating the data after the policy change. This is the reason why forecasts of reduced-form statistical methods generally cannot be relied upon to correctly forecast outcomes of policy changes. In some cases policy changes are sufficiently frequent that they can be treated as "regressors" within a reduced-form framework from which reliable predictions can be generated. However in the case of Social Security, most policy changes are infrequent or have no previous analogs, so the historical evidence is generally insufficient to enable one to predict how the stochastic process generating the data will change.

Of course, in most cases we view models as abstractions that are at best crude approximations to reality. The Marschak-Lucas critique ignores the possibility that a structural model could be misspecified. It is not obvious whether a misspecified structural model will necessarily forecast a policy change better than an *ad hoc* reduced-form statistical model. Thus, the problem reduces to a practical question of whether one obtains superior policy forecasts from flexible statistical models that do not attempt to exploit any *a priori* knowledge of the problem or our knowledge of human behavior, versus what often amount to highly simplified structural models that impose considerable *a priori* assumptions about rationality and optimization. We cannot settle these issues here, except to note that in a number of specific examples including the problem of predicting how retirement behavior is affected by changes in retirement pension incentives, relatively simple parametric structural models have provided substantially more accurate forecasts than *ad hoc* reduced-form models. For examples see Rust, (1994) and Lumsdaine, Stock and Wise (1993).

5.3 Numerical Stochastic Overlapping Generations General Equilibrium Models

Numerical SGE models are descendants of the 55 period deterministic overlapping generations models pioneered by Auerbach and Kotilikoff (1987), generalized to incorporate various forms of uncertainty. Within the last five years increasingly comprehensive versions of SGE models have been formulated that incorporate multiple decisions and types of uncertainty and fairly detailed representations of Social Security policy (see, e.g. Storesletten, Telmer and Yaron 1999). The models we describe in this section are among the most ambitious policy models that have been solved and simulated in academic research. Some of these models are sufficiently realistic to be taken seriously in policy analysis. They demonstrate that it is now feasible to provide detailed quantitative evaluations of both the short and long run general equilibrium feedbacks and welfare effects of a range of policy issues of current interest such as increasing the level of Social Security Trust Funds or privatizing Social Security via creation of individual accounts. These models provide both long-run steady-state forecasts as well as detailed calculations of the transition dynamics that move the economy from an existing steady state to a new steady state following a change in policy or in demographic variables such as birth rates or mortality rates (Huang, Imrohoroglu and Sargent 1997, Denardi, Imrohoroglu and Sargent, 1998). The latter papers trace out how aggregate economic quantities and the welfare of different cohorts evolve on a period by period basis in response to anticipated policy and demographic changes. We describe an example of a SGE model in some detail in order to make our analysis of the strengths and weaknesses of this approach more concrete. We then provide a brief overview of other recent contributions to this literature. We conclude this section with a discussion of some of the limitations of current generation SGE models, and discuss the circumstances under which a failure to account for general equilibrium feedbacks is likely to lead to misleading policy forecasts and policy prescriptions.

Although there are many very promising models that we could have chosen to illustrate the SGE approach, we chose the model by Storesletten, Telmer and Yaron, "The Risk-Sharing Implications of Alternative Social Security Arrangements" (STY,1999) because it provides a particularly detailed analysis of specific policy reforms advocated by the 1996 Social Security Advisory Council. As we noted in the introduction, one of the important goals of this chapter was to review models that have the capability to analyze these specific types of policy questions. To provide some context for STY's analysis, recall that our review of the literature on deterministic overlapping generations models in section 2.1 suggested that most deterministic models have difficulty finding a useful role for Social Security other than serving as a redistributive tax/transfer program. The general conclusion of the deterministic literature is that either Social Security is irrelevant (if Ricardian equivalence holds), or if it does have an effect (due to binding liquidity constraints or the existence of corner solutions with zero intended bequests) rational individuals would prefer abolishing Social Security and have the government implement a non-distortionary system of lump-sum transfers to redistribute lifetime income. If the existence of Social Security is tied to paternalistic reasons (i.e. public short-sightedness in preparing for retirement), then the general conclusion is that it is better to run it as a fully funded system than as a pay-as-you-go system since the former leads to higher long run savings and a larger capital stock, which increases consumption and overall welfare. Social Security also reduces welfare via distortionary taxation, by taking away income from young individuals during their working years when they would like to borrow against future income to increase current consumption. Because of liquidity constraints, it is believed that many young workers are at a corner solution involving zero savings except for the implicit savings via their mandatory Social Security tax contributions. In this situation, increases in the Social Security tax rate generally lowers lifetime utility (see, e.g. Hubbard and Judd, 1987).

The main drawback of deterministic models is that they are unable to properly evaluate the many potentially valuable risk-sharing features of Social Security, such as its ability to "fill in" for poorly functioning annuities markets. The absence of annuities markets forces individuals to accumulate extra wealth to self-insure against the possibility they will live longer than expected. To the extent Social Security can be viewed as an actuarially fair annuity, it enables individuals to guarantee a higher stream of consumption in old age without the "overaccumulation" of assets that is required in a world without Social Security and actuarially fair private annuities markets. This leads to the possibility that individuals would be better off under a mandatory actuarially fair pay-as-you-go Social Security system than they would be under a privatized system, even though aggregate capital accumulation under the latter system might be greater. As we noted in section 2, this result was suggested by the analytical model of Eckstein, Eichenbaum and Peled (1986), however their model ignored the general equilibrium feedbacks on capital accumulation which subsequent models, including STY's model, have addressed.

There is also a question as to the extent to which individuals might value a progressive redistributive Social Security tax and transfer system as a type of "insurance" against lifetime earnings risk. It is clear that *ex post* a high income/high ability person would prefer to "opt out" of Social Security, whereas a low income/low ability person may prefer the status quo Social Security system to a privatized system. But from the *ex ante* perspective of an individual who is unsure whether they will be born into a rich or poor family, or have a low or high "ability endowment", a pay-as-you-go Social Security system might provide greater insurance than a privatized system where individual accounts are more directly proportional to lifetime earnings histories.

The SGE model developed by STY leads to important new insights into these issues. It also provides a detailed quantitative comparison of how the U.S. economy would be affected by various proposals described in the Advisory Council on Social Security (1996), including the "Personal Security Account" (PSA) plan. This is a hybrid that combines aspects of the current largely pay-as-you-go Social Security system with the Personal Retirement Account (PRA) plan analyzed in Feldstein and Ranguelova, (1998). Under the PSA plan the long run tax rate would remain the same as under the status quo OASI system, 12.4%. However 5 percentage points of this tax would be invested in personal retirement accounts, and the remaining 7.4% tax rate would fund a scaled-down pay-as-you-go Social Security system that pays $410 per month regardless of contributions. Further, 100% of Social Security benefits would be treated as taxable income. In order to cover the transition costs of paying the unfunded liabilities to contributors under the current system, the PSA plan also includes a supplemental tax of 1.5% until 2070.

STY model these issues using a stochastic overlapping generations model where individuals are "born" at age 22, work until retirement at age 65, and live at most to age 100. Individuals can die prior to age 100 according to mortality hazards observed for U.S. females in 1991. All individuals have identical constant relative risk averse utility functions, $u(c) = (c^\rho - 1)/\rho$ with $\rho = -1$, and maximize expected discounted utility with subjective discount factor $\beta = 1.011$, which corresponds to a negative subjective discount rate. STY model the risk of labor earnings as follows: an individual i of age a works an exogenously specified amount of hours per period given by

$$log(n_{ia}) = \kappa_a + \alpha_i + z_{ia} + \epsilon_{ia}, \tag{5}$$

where κ_a is an age-specific constant included to enable the model to capture the age-earnings profile, α_i is a individual-specific "random effect" realized at birth, and z_{ia} and ϵ_{ia} are time varying shocks designed to provide a "reduced-form" account of factors such as job lob, health problems and so forth that may temporarily interrupt an individual's labor supply trajectory. They assume that $\{\epsilon_{ia}\}$ represents transitory shocks which are independently and identically distributed (*IID*) whereas $\{z_{ia}\}$ follows a first order Markov process given by

$$z_{ia} = \omega z_{i,a-1} + \eta_{ia} \tag{6}$$

where $\{\eta_{ia}\}$ are *IID* shocks. Thus, the STY model incorporates two basic types of risk: mortality risk and earnings risk. There are three different types of earnings risk: 1) persistent individual differences in ability (or labor "endowment") accounted for the α_i random effects, 2) serially correlated shocks to labor supply accounted for by the $\{z_{ia}\}$, and 3) transitory shocks to labor supply represented by the $\{\eta_{ia}\}$. STY used econometric methods (exactly identified generalized methods of moments estimation) to choose the parameters of this parameterization of the stochastic process of labor earnings $y_{ia} = wn_{ia}$ that matched observed moments (means, covariances, etc.) of labor earnings in the Panel Study on Income Dynamics (PSID).

The final individual-specific state variables, are non social security wealth w_a and "Social Security wealth" s_a^{α}. The latter variable is a scalar summary of the cumulative Social Security contributions of an individual of age a under various alternative policies α, including $\alpha =$ psa (the PSA plan) and $\alpha =$ pg a pay-as-you-go Social Security system. s_a^{α} is updated according to the following scheme,

$$s_a^{\alpha} = \begin{cases} s_{a-1}^{\alpha} r_{\alpha} + min(\tau_{\alpha} n_a w, \overline{s}^{\alpha}) & a \leq 65 \\ s_{65}^{\alpha} & a > 65 \end{cases} \tag{7}$$

where $\overline{s}_a$ denotes a government-mandated floor on annual Social Security contributions – a form of insurance against years in which labor earnings are very low. r_{α} denotes the rate of return to Social Security contributions under policy α. This is equal to the real rate of growth in the wage base when $\alpha =$ pg and equals the real rate of return on capital when $\alpha =$ psa. Social Security benefits are a nonlinear function of contributions given by

$$b^{\alpha}(s_a^{\alpha}) = \begin{cases} 0 & a \leq 65 \\ max(\underline{b}^{\alpha}, d_{\alpha}(s_{65}^{\alpha})) & a > 65 \end{cases} \tag{8}$$

where $\underline{b}^{\alpha}$ denotes a minimum benefit level, and d_{α} is a concave function relating Social Security contributions to benefit payments about the minimum benefit level. In the case $\alpha =$ pg, the d_{α} function can be thought of as an approximation to the relationship between AIME and PIA. Wealth evolves according to the standard budget equation

$$w_{a+1} = w_a(1+r) - \tau_k w_a r + n_a w(1 - \tau_l - \tau_{\alpha}) + b^{\alpha}(s_a^{\alpha})(1 - \tau_l) - c_a, \tag{9}$$

where τ_k is the tax rate on interest earnings, τ_l is the tax rate on wages, and τ_{α} is the Social Security tax rate (which may be different under a pay-as-you-go system than under the PSA plan). The individual's "state" at age a can be summarized by the 3-dimensional vector (z_a, w_a, s_a) where z_a is the serially persistent shock to labor supply at age a, w_a denotes accumulated (non-social security) wealth at age a, and s_a denotes the accumulated Social Security contributions discussed above. Since labor supply is given by the exogenous process in equation (5), and everyone is assumed to retire at age 65, the individual's only choice variable is how much to consume, c_a. The Bellman equation for this problem is given by:

$$V_a(z_a, w_a, s_a) = \max_{c_a} \left[u(c_a) + \beta\phi_a \int V_{a+1}(z_{a+1}, w_{a+1}, s_{a+1}) p(z_{a+1}, s_{a+1} | z_a, s_a) \right], \tag{10}$$

where ϕ_a is the survival probability for a person of age a and where increases in c_a result in 1 for 1 reductions in w_{a+1} due to the budget constraint in equation (9). The Bellman equation is solved via backward induction from the maximal lifespan, age 100. As we wil see, the DP problem must be repeatedly solved in an inner loop of an outer algorithm that searches for equilibrium values of endogenously determined quantities such as aggregate capital and labor and wages and interest rates. Thus, the feasibility of this approach depends on the feasibility of rapidly solving individuals' DP problems as noted in section 5.2.

Aggregate output Y_t is generated from a Cobb-Douglas production function, $Y_t = Z_t K_t^{\theta} L_t^{1-\theta}$, where K_t is the aggregate capital stock and L_t is the aggregate labor supply, and Z_t is a term that can be thought of as capturing technological progress or "knowledge capital", and is assumed to grow as a constant rate of $(1+\lambda)$ per period. The population in this economy is assumed to grow at a constant rate of $(1+n)$ per period. Thus, the overall rate of growth of the economy is $(1+\gamma) = (1+n)(1+\lambda)$. There is also a government that spends an aggregate amount G on items other than Social Security, and issues an aggregate amount of bonds B that are held constant as a fraction of GNP, and thus grow at rate γ.

Definition: An *equilibrium* for the stochastic overlapping generations economy consists of market clearing wages and interest rates, and a set of value functions $\{V_a\}$, $a = 21, \ldots, 100$ satisifying:

1. Wages and interest rates are equal to the marginal product of labor and capital, respectively:

$$\begin{aligned} w &= \partial Y / \partial L \\ r &= \partial Y / \partial K - \delta \end{aligned} \tag{11}$$

   where δ is the depreciation rate of capital.

2. Individuals behave optimally, i.e. $\{V_a\}$, $a = 21, \ldots, 100$ solves Bellman's equation (10).

3. Markets clear and aggregate quantities are the sum (integral) over individuals in the economy with respect to the population distribution μ, the joint (stationary) distribution of the ages, labor supply shocks (both persistent and transitory), and wealth levels and social security contribution levels.

$$\begin{aligned} K + B &= \int (w_a + s_a^{\text{psa}}) d\mu \\ L &= \int n_a d\mu \\ Y = Z K^{\theta} L^{1-\theta} &= \int c_a d\mu + (K' - K) + \delta K \end{aligned} \tag{12}$$

4. The government budget constraint is satisfied:

$$G + (r - \gamma) B = \int (\tau_k r w_a + \tau_l w n_a) d\mu + E \tag{13}$$

   where the second term on the left hand side of (13) is net interest cost on the government debt, the integral on the right hand side of (13) is total revenue from taxes on capital and labor income, and E is revenue from government estate tax, equal to 100% of the wealth of any individual who dies.

5. The pay-as-you-go component of the Social Security program is balanced period-by-period

$$\int(\tau_{\text{pg}} w n_a + \tau_l b_a^{\text{pg}}) d\mu = \int b^{\text{pg}}(s_a^{\text{pg}}) d\mu \tag{14}$$

An equilibrium to the SGE model is computed as follows. Initial values for G and B are specified, along with guesses for tax rates that satisfy the government budget constraint (13) and values of w and r that satisfy equilibrium in the market for labor and capital given in (11). Then the individual's DP problem is computed via the Bellman equation (10), and from this solution the stationary distribution μ of individuals' ages, idiosyncratic labor shocks, and wealth levels can be computed. Using μ, aggregate capital, labor supply and output can be calculated via (12). The initial guesses for tax rates, w and r are then updated via a quasi-Newton algorithm designed to solve the system of nonlinear equations (11), (12), (13) and (14). Thus, the SGE model requires repeated solutions of a DP problem that is nested within an outer equilibrium solution algorithm, which in this case is simply a nonlinear equation solver. Since it may take hundreds or thousands of trial evaluations of the DP problem until equilibrium wages, interest rates, and tax rates are found, it is clear that the DP problem must be solved very efficiently (in a matter of minutes) for the SGE approach to be computationally feasible.

With the ability to compute equilibria for different policy regimes, the only remaining detail is to specify a way of comparing welfare losses/gains across different regimes. STY define a certainty equivalent measure of the welfare impact of a policy change by solving for an age-invariant proportional increase or decrease in per period consumption that equates the expected discounted utility under some alternative policy to the expected discounted utility that an individual would receive under the status quo. This certainty equivalent will depend on the initial state of the individual when this calculation is made (e.g. age, wealth levels, and the realized values for the various shocks to labor supply), so STY solve for the certainty equivalents for all possible combinations of this initial state and then compute an average certainty equivalent value by integrating the state-dependent certainty equivalents with respect to the stationary distribution μ.

STY computed equilibria for several different policy regimes, measuring welfare changes relative to the status quo as noted above. Their idealization of the status quo (SQ) policy regime is intended to approximate the current U.S. Social Security system, but without the Trust Fund. Thus, STY assumed that the Trust Fund balance is zero and that Social Security is run as a pure pay-as-you-go system. They parameterized the benefit function $b^{\text{pg}}(s_a^{\text{pg}})$ in equation (8) to approximate the benefits payable under the current Social Security rules. They assumed that 25% of Social Security benefits are taxable at the ordinary income tax rate, τ_l, and set values for the minimum benefit level $\underline{b}^{\text{pg}}$ and the maximum Social Security tax $\overline{s}^{\text{pg}}$ to approximate the actual values of \$572 per month and \$61,750 per year, respectively. When they solved for the Social Security tax rate τ_{pg} that satisfies the budget balance condition in equation (14), they obtained a rate of $\tau_{\text{pg}} = .1092$ for the SQ policy regime which is reasonably close to the actual OASI tax rate of 12.4%. They chose the parameters of the PSA plan to approximate the plan detailed in the 1996 Advisory Council Report. They did this by setting τ_{psa}, the tax rate that finances the individual accounts in the PSA plan, to be $\tau_{\text{psa}} = .05$, and assumed that these individual accounts would earn interest at the equilibrium interest rate r calculated in equation (11). The accumulated value in these individual accounts are assumed to be paid out as a lump-sum distribution at age 65. The PSA plan also contains a scaled-down version of a pay-as-you-go Social Security system that pays a flat benefit of $410 per month to all retirees regardless of income or wealth. They solved for the payroll tax rate that balances the budget of the pay-as-you-go component of Social Security and obtained $\tau_{\text{pg}} = .0513$, so that the total tax rate under the PSA policy regime amounts to 10.13%. Finally STY consider the radical policy option of abandoning the pay-as-you-go component of Social Security altogether and letting individuals rely completely on their individual accounts, a policy regime that they describe as "privately provided pensions" (PP). In the PP policy regime the Social Security payroll tax is set to zero, and individuals have complete discretion about how much of their income to save for their retirement each period. It is important to note that STY assume there are no private annuity markets, so individuals are constrained to consuming a fraction of their remaining wealth during each year of retirement. However STY do evaluate a version of the PP scenario where there is an actuarily fair annuity market. This leads to an interesting estimate of the potential welfare gains to "filling in" a "missing market".

Initially STY ignored Social Security's unfunded pension liabilities, and calculated equilibria and welfare under new long-run steady states for the PP and PSA regimes under the implicit assumption that SSA reneges on its obligations to existing retirees under the SQ policy regime. They find welfare gains equal to 0.9% and 7.3% of consumption, respectively, for the PP and PSA regimes. The PP economy is dynamically efficient with an equilibrium interest rate of $r = 0.0096$ that is less than the sum of the rate of growth of the economy, $\gamma = 0.025$ (equal to the sum of the 1% population growth rate and a 1.5% rate of growth in real wages). The dynamic inefficiency is partially a result of the assumption that $\beta > 1$ (which implies that individuals value future utility more than current utility), and partially a result of the substantially larger precautionary savings that individuals undertake in the PP economy due to the lack of a redistributive Social Security system and the absence of private annuity markets. Altogether, these factors cause the aggregate capital stock to be nearly twice as high under the PP policy regime than under the SQ regime. This is the reason why the welfare gain under the PSA plan is so much larger than the PP plan.

In all subsequent calculations STY carefully treat the issue of how to account for Social Security's obligations to current beneficiaries and contributors in the aftermath of a policy change to a new policy regime. They assume that Social Security issues an amount of debt D equal to the expected discounted value of the unfunded liabilities under the SQ policy regime. Once this extra "Social Security debt" is accounted for, the welfare calculations are rather different: individuals would be willing to pay 3.7% of per period consumption to adopt the PP regime, and 4.0% of per period consumption to adopt the PSA regime. The fact that the welfare gain is *larger* once we account for the Social Security debt seems non-sensical. However note that it has been known since Diamond's (1965) analysis that government debt "crowds out" private capital accumulations, lowering the aggregate capital stock. When there is is dynamic inefficiency, as there is in the case of the PP economy prior to issuance of Social Security debt, then issuing additional debt actually results in a welfare gain. Indeed, the issuance of Social Security debt causes capital stock to fall by 30%, increasing the before tax rate of return r to 3%, which exceeds the 2.5% rate of growth of the economy. Note that in the case of the PSA plan, there is implicit "Social Security debt" due to the fact that the PSA plan contains a pay-as-you-go component, which is also predicted to crowd out private capital accumulation in a manner similar to explicit government debt. This crowding out implies that the equilibrium for the PSA regime is dynamically efficient even in the absence of explicit Social Security debt, so it follows that issuing additional Social Security debt has the expected effect of reducing the welfare gains of the PSA plan from 7.3% to 4.0% of per period consumption.

An interesting feature of STY's analysis is their ability to decompose the change in welfare into four components: 1) general equilibrium effects (i.e. the overall effect of the policy on aggregate capital accumulation and market clearing prices), 2) taxation effects (i.e. reductions in the incentive to work and accumulate capital due to distortionary taxation of capital and labor), 3) incomplete market effects (i.e. the effect of the policy on individuals' access to actuarially fair annuities, and 4) risk sharing effects (i.e. the effect of redistributive Social Security taxes and transfers on the welfare of different individuals in the economy). Under the PP plan, the total welfare gain of 3.7% of per period consumption equals the sum of a 6.8% welfare gain due to general equilibrium effects and a 3.1% welfare loss due to the other effects, including a 1.6% welfare loss due to reduced income risk sharing under a privatized system, a 0.8% welfare loss due to removing Social Security as substitute for missing annuity markets, and a 0.7% welfare loss due to distortions caused by increased capital tax revenues on interest earnings on individuals' retirement savings.

> "The main message of this decomposition is simple. The lion's share of the welfare gain associated with social security reform derives from the general equilibrium effects. As we demonstrate explicitly below, this is a manifestation of the fact that, as a whole, society saves more under the PP or PSA arrangements, leading to lower interest rates, a higher capital stock, and a higher level of aggregate output and consumption. Income risk sharing effects are also important as evidenced by the 1.6% loss associated with the the PP alternative, whereas effects directly attributable to the provision of annuities and capital income tax distortions play a relatively minor role." (STY, 1999, p. 24).

> "The primary force driving these welfare gains is a kind of externality associated with retirement savings. Social Security provides a participant with an imperfect annuity. When that annuity is removed — either completely or partially — individuals save more during their working lives in order to insure against the possibility of outliving their resources during retirement. The collective effect of this increase in savings, something which is external to each individual's choice problem, is an increase in aggregate capital, output and consumption. This increase in aggregate resources lies at the heart of the welfare gains we uncover." (STY, 1999, p. 31).

A final, interesting policy experiment that STY study is the impact of perfect annuity markets on welfare under the SQ, PSA and PP policy regimes. *Ceteris paribus* the addition of a perfect annuities market should make all individuals better off, since it provides an additional option for hedging against risk. Paradoxically STY find that the addition of perfect annuities markets *reduces* welfare under each of the three policy regimes. The reason for the welfare reduction is the "savings externality" noted above:

> "We argue that this finding — that the provision of annuities can reduce welfare — is not unlike a classic set of results from the literature on general equilibrium with incomplete markets: the endogenous nature of the set of investment opportunities generates an externality which can make changes in market structure welfare decreasing. Our example of this is stark in that it abstracts from privately provided (imperfect) annuities which are, to some extent, available in actual financial markets. Nevertheless, it makes a point which is often overlooked in the debate on social security reform: that the savings response to a change in the system can very much depend on how the availability of annuities is altered. Our results suggest that the quantitative magnitude of this response is substantial." (STY, 1999, p. 31).

It is also interesting to note that a "money's worth" measure, the internal rate of return on social security contributions, provides a completely misleading indicator of the welfare change resulting from the addition of annuity markets. For example, the internal rate of return on total contributions under the PSA plan is 3.7% without complete annuity markets versus 4.2% with complete annuity markets. The higher IRR suggests that individuals should be better off with complete annuity markets, but the discussion above shows that individuals are actually worse off, and the higher IRR is due to the fact that marginal product of capital necessarily increases when there is less capital relative to the exogenously determined aggregate labor supply in this economy.

Imrohoroglu, Imrohoroglu and Joines (1998) provide a survey of other recent computational SGE models of Social Security. There is no need to repeat that survey here, although, we do briefly discuss papers by Huang, Imrohoroglu and Sargent (HIS,1997) and De Nardi, Imrohoroglu and Sargent (DIS,1998) since they deal with important issue of transition dynamics in moving from the status quo to an alternative policy regime, an issue that STY and most previous work in this literature have abstracted from.[9] HIS study transition dynamics in an economy where birth rates and mortality rates are time-invariant, and the main non-stationarity results from the anticipated consequences of an initially unanticipated policy change and the subsequent fully anticipated transition to a new steady state. They consider two cases, a "small open economy case" where the interest and wage rates r and w are exogenously determined, and a "closed economy case" where r and w are determined endogenously from the marginal product of capital and labor, respectively, similar to the procedure described for STY. They compute two different policy experiments describing how the economy responds to a change from a pay-as-you-go to a fully funded Social Security system. In the first experiment the government suddenly terminates Social Security and issues "recognition bonds" equal to the present value of the unfunded liabilities under the pay-as-you-go regime. This debt is fully retired over a 40 year transition period to the new steady state. In the second experiment Social Security benefits are untouched, but the system is funded by building up a Trust Fund over a

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[9] Although original computational SGE models in Auerbach and Kotlikoff (1987) did explicitly calculate transition dynamics, these calculations were simplified by the fact that the models were deterministic so that it was only necessary to compute paths for the key aggregate quantities. When uncertainty is incorporated in the model, we have a form of heterogeneity in terms of different realized outcomes for uncertain variables in the model. It is then necessary to describe the evolution of the *distributions* of these uncertain quantities, which is a much more difficult computational task. The initial stochastic SGE models of Social Security such as Hubbard and Judd (1987) and as Imrohoroglu, Imrohoroglu and Joines (1995) showed that it was possible to incorporate various types of uncertainty, but at the cost of abstracting from transition dynamics. To our knowledge the HIS and DIS papers are the first SGE models to explicitly account for transition dynamics.

40 year transition period at a sufficient rate that all benefits can be paid from interest earnings on the Trust Fund by the end of the transition period. These experiments are performed in a model where individuals live for 65 years, with the interpretation that an individual is "born" at age 20, retires at age 65, and lives at most until age 85. The main modeling innovation is the use of non-expected utility linear-quadratic preferences that delivers linear decision rules that simplify computation and aggregation considerably while allowing for a form of risk-sensitivity that does not satisfy the standard version of certainty equivalence of standard linear-quadratic expected utility models. This allows the model to capture a precautionary savings motive, and an increase in the within-cohort variance in consumption spending as the cohort ages. These preferences are described recursively via a generalized form of the Bellman equation (10):

$$V_a = -\frac{1}{2}(\pi c_a - \xi_a)^2 + \beta \phi_a \frac{2}{\sigma} log \left[E \left\{ exp \left(\frac{\sigma V_{a+1}}{2} \right) \middle| I_a \right\} \right]. \tag{15}$$

where I_a denotes information available at age a, ϕ_a is the survival probability at age a, and ξ_a can be regarded as a "target consumption level" at age a.

Under experiment 1, consumption decreases for the first 20 years of the transition, reflecting the initial transition costs involved in saving for individual retirement and paying the interest and principal on the recognition bonds that cover Social Security's unfunded obligations. After 40 years aggregate consumption levels are the same as they were pre-transition, and by 100 years after the policy change, the capital stock has risen by 40%, the labor income tax rate decreases from 34% to 14%, and consumption levels asymptote to a level 9.8% higher than prior to the transition. However during the 40 year transition period, the income tax must be raised to 38% to pay off the entitlement debt, equal to 2.7 times real GDP. Under experiment 2, aggregate consumption immediately drops by 2.5%, representing the extra taxes that are collected to build up the Trust Fund, but thereafter consumption levels steadily rise, asymptoting to a level 8.4% higher than prior to the transition. All cohorts born 25 years or more after the transition gain from the change to a fully funded Social Security whereas the first 25 cohorts born after the date the policy is announced have a lower lifetime utility.

HIS quantified the welfare gains associated with the two reform plans as follows. First they computed the present value of additional wealth required to make the individuals along a transition path indifferent between the reform or remaining under the status quo pay-as-you-go system. Then they computed the annuity equivalent value of this certainty equivalent wealth measure, and then expressed it as a fraction of GDP at the initial stationary equilibrium under the status quo Social Security policy. The privatization plan yields welfare gains of 1.3% of GDP for the small open economy scenario and 2.0% of GDP under the closed economy scenario. They found larger gains to preserving the defined benefit and simply building up the Trust Fund, equal to 2.1% of GDP under the small open economy scenario and 2.8% under the closed economy scenario. The reason the policy of building up the Trust Fund delivers larger welfare gains than the policy of privatizing Social Security is due to "the scheme's public provision of insurance both against life-span risk and labor income volatility." (p. 7). They conclude that while welfare of transition generations falls on average during the 40 year transition period, these policies "redistribute enough of the permanent gains from future to current generations to induce a majority of each cohort to assent to the transition." (p. 8).

It is interesting to contrast HIS's conclusion about the welfare gains to privatization with the conclusion obtained from the "short-cut" approach to the analysis of transition costs by Geanakoplos, Mitchell and Zeldes (GMZ) (1998a,b) discussed in section 4.2. Recall that their analysis lead them to conclude that there is no gain to privatizing Social Security since the cost of paying off the entitlement debt completely offsets the gains from the higher returns earned in privatized accounts or by investing Trust Fund balances in equities. In HIS's analysis, equilibrium interest rates actually fall in the new steady states (a simple consequence of the increased steady state capital stocks). If we were to use these lower rates of return in GMZ's calculations, then it would appear that their analysis leads to the conclusion that privatization leads to a clear welfare loss. Note also that GMZ do not assume that the "recognition bonds" are ever retired, but instead are continually refloated as a constant fraction of GDP. In HIS's analysis, the recognition bonds are paid off in a relatively short span of 40 years. If we account for the cost of paying off a principal balance of 2.7 times GDP, this would be an additional factor that would lead GMZ type of short-cut analysis to conclude that privatization involves a clear welfare loss. How is it that HIS are able to find a net welfare gain to policies of privatization or fully funding Social Security net of all transition costs? The reason is fundamentally due to the general equilibrium feedbacks that the short-cut analyses ignore. The long run build up in capital stock leads to higher consumption and welfare levels that are correctly accounted for within the SGE model but which are ignored by the short-cut approaches.

We conclude our survey of SGE models with a brief review of one final paper, "Projected U.S. Demographics and Social Security" by De Nardi, Imrohoroglu and Sargent (DIS) (1998), since it illustrates how SGE models can account for nonstationarities in survival probabilities and demographic patterns, including the "demographic shift" to higher dependency ratios in the next century as the baby boom generation approaches retirement. [10] This is an important issue confronting SSA and individuals, since unfavorable demographic shifts make the current pay-as-you-go system is unsustainable (at current tax rates and benefit levels), increasing the "political risk" that major changes will be made to the system, possibly including "radical reform" such as privatization. The Social Security Actuary projects a doubling in the dependency ratio (the ration of Social Security beneficiaries to tax payers) between 1997 and 2050. The less favorable demographic patterns effectively increase the transition costs involved in various Social Security reform proposals, which may invalidate conclusions obtained from previous SGE models on the desirability of privatizing or building up the Social Security Trust Fund. On the other hand, a number of unpleasant adjustments must be made even if we stick to the status quo pay-as-you-go system. Some SGE models such as Cooley and Soares (1996) predict that the rise in tax rates or reductions in benefit levels need keep a pay-as-you-go system in long run balance will lead to its abandonment. Boldrin and Rustichini (1998) develop a similar model, but show that a pay-as-you-go system can be an equilibrium political outcome even though the system will eventually collapse with probability 1 due to a sufficiently prolonged decline in the birth rate.

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[10] The paper is noteworthy since it also introduces several methodological innovations including modeling consumption and labor decisions jointly within a linear-quadratic specification of preferences, and allowing for a bequest motive.

DIS consider 6 experiments involving relatively minor changes to the structure of a status quo simliar to those that have been considered in recent policy discussions. These changes are designed to restore long run fiscal balance following the demographic transition but without altering the fundamentally pay-as-you-go character of the Social Security system. The fiscal adjustments include an increase in the payroll tax rate on labor earnings, the introduction of a consumption tax, various combinations of benefit reductions and tax increases, and a final experiment designed to increase the linkage of benefits to cumulative earnings while also adjusting the tax rate on labor income. The outcomes of the six experiments are summarized below:

1. In experiment 1, SSA uses a rise in the payroll tax rate to balance the system, increasing it from 29% to 53% between 2000 and 2060. Over this period the amount of labor supplied falls by 19%, capital stock falls by 5% and output falls by 14%.

2. In experiment 2 the government uses a consumption tax to balance the system and the outcomes are also better than in experiment 1: the consumption tax rises from 6% to 29% between 2000 and 2060, the amount of labor supplied falls by 17%, the capital stock rises by 14% and output falls by 6%.

3-4. Experiments 3 and 4 postpone the retirement age to 68 and then increase the labor tax rate (experiment 3) or the consumption tax rate (experiment 4) to finance the remaining burden. Postponing the retirement age necessitate smaller tax increases: the labor tax need only rise to 45% by 2060 in experiment 3 (compared with 53% in experiment 1) and the consumption tax only rises to 22% (compared to 29% in experiment 2). The lower tax rates lead to lower reductions in the amount of labor supplied (falling 14% in experiment 3 and 12% in experiment 4), but GDP falls by slightly more in experiment 3 than in experiment 1 (7.4% vs. 6.6%), but slightly less in experiment 4 than in experiment 2 (3% vs. 6%).

5. In experiment 5 Social Security benefits are taxed and the labor income tax is raised to finance the residual burden. The results are similar to the use of a consumption tax as in experiment 2. For example, the amount of labor supplied falls by 14%, capital stock rises by 17% and output falls by 4%.

6. In experiment 6 there is a stronger linkage between retirement benefits and past earnings in order to reduce the perception that Social Security contributions are a pure tax and reduce the resulting distortion in labor/leisure choices. The results from experiment 1 are somewhat better than experiment 6: the payroll tax rate only rises to 51%, labor input falls by 11%, the capital stock rises by 2% and output falls by 6.6%.

DIS conduct a welfare comparison of these six experiments by measuring the fraction of initial wealth that makes a person indifferent between experiment j and experiment 1. They conclude that

> "Essentially all future generations are better off under Experiments 2-6 relative to Experiment 1. In fact, when we compute an overall welfare measure by properly taking into account the welfare gains and losses of all generations, weighing them by their (time-varying) population shares and discounting the future gains and losses by the net real interest rate, Experiments 2, 3, 4 and 6 deliver an overall welfare gain, whereas experiment 5 yields an overall welfare loss. Experiment 2 produces a welfare improvement of 7% of GDP (at the initial steady state) relative to Experiment 1. Experimental 3, 4 and 6 yield overall welfare gains of 18.7%, 21.8% and 32.4% of GDP, respectively. Experiment 5 produces an overall welfare loss of 2.2% relative to Experiment 1. This reflects the domination of the welfare losses of the currently alive generations over the gains of the future generations." (DIS, 1998, p. 13)

Our review of several recent SGE models suggests that some of these models are now sufficiently realistic that they can be useful inputs to the evaluation of a range of policy issues of interest to SSA. These models are especially useful for evaluating "radical" policy reforms such as privatization of Social Security or making the transition to a fully funded system where general equilibrium feedbacks are likely to be substantial. We conclude this section by discussing a number of limitations of SGE models that could lead to reservations about using existing versions of these models "off the shelf" for quantitative forecasting. We also provide a speculative discussion of policy issues where general equilbrium feedbacks appear to be less important, and for which simpler partial equilibrium models could provide accurate policy forecasts.

The main drawback of SGE models is the computational burden involved in solving them. The computational problems arise from the need to re-solve individual agent DP problems repeatedly as an "inner loop" within a zero-finding "outer loop" algorithm that searches for values of prices, wages, and interest rates that clear the market, and values of tax rates and benefit levels that satisfy government budget constraints. Although it is now feasible to solve an SGE a relatively small number of times in order to evaluate various policy scenarios, it is infeasible to solve most of these models hundreds or thousands of times. This is what would be required to econometrically estimate the unknown parameters of SGE models, where a "third loop" would be added to solve the SGE mode for various trial values of its unknown parameters until values were found that enable the predictions of the SGE model to "best fit" observed outcomes according to a well-defined metric. Instead, SGE models are *calibrated* via an unspecified informal procedure for selecting the unknown parameters so that the model's predictions "best fit" observed data according to an implicit but typically undefined metric. The current state of the art in the academic literature on calibration is an *ad hoc* combination of the somewhat in-bred process of "borrowing" most of the model parameters (e.g. coefficients of risk aversion, or the parameters of a Cobb-Douglas production function) from previous calibration studies, and then selecting a small number of remaining parameters in an attempt to match the model's predictions to reality. The criterion used to specify "best fit" is often unclear in calibrated models, and we currently lack a rigorous statistical theory that could be used to evaluate their goodness of fit and the degree of uncertainty in their predictions. This lacunae is due mostly to computational problems but also due to lack of an appropriate statistical theory. For example there are difficult unresolved issues about how to include unobservables in these models. Unobservables are needed to avoid problems of "statistical degeneracy", i.e. how to deal with observed outcomes that that have probability zero of occurring in the SGE model. Even setting aside computational problems, there is no theory of econometric inference in general equilibrium models, and statistical methods for conducting estimation and inference are still largely undeveloped. For a more detailed description of the process of calibration and its problems see Hansen and Heckman, 1998, and Srinivasan and Whalley, 1998.

As a result of these inferential problems, it is not yet possible to rigorously test the validity of SGE models (i.e. the implicit rationality or equilibrium assumptions) and assess their predictive accuracy. Similar to DP models, the main way to assess the credibility of SGE models for use in policy forecasting is via informal "out-of-sample" predictive tests. Further, the "forecasts" of many SGE models are best viewed for their qualitative features rather than the realism of their quantitative predictions. Even among models that are intended to generate realistic quantitative forecasts, there are many difficult issues pertaining to the appropriate metric for ranking the accuracy of alternative SGE models that we are unable to resolve here. To help diversify "forecast risks" SSA might want to rely on a "portfolio" of forecasts from different models rather than attempting to identify a single "best" model. In spite of these difficulties, we believe that SGE models can be a very important tool for SSA, even if some models are best employed for qualitative predictions, and and even if, among quantitatively oriented SGE models, it isn't yet possible to scientifically and objectively quantify the uncertainty we have about their predictions.

The remaining limitations of SGE models from the standpoint of their use in policy forecasting at SSA concern their failure to incorporate various risks, aspects of reality, and features of the Social Security program. These limitations are largely related to the "curse of dimensionality" associated with solving the DP problem for more realistic formulations of individuals' decision problem, as discussed in section 5.2. We simply list several of the most important limitations which are relevant to addressing policy issues of interest to SSA. One key limitation is the failure to account for stochastic macro shocks such as the effect of an oil shock or a stock market crash. The production technologies and rates of return on assets in current generation SGE models are deterministic. None of these models allows for the possibility of stock market "bubbles", which is a focus of concerns about privatization and investing Trust Fund assets in equities. The failure to incorporate stochastic macro shocks limits the usefulness of these models for studying the role of Social Security as a device for intergenerational sharing of aggregate risks. This type of risk-sharing is tangentially addressed in some of the studies reviewed above (e.g. the De Nardi *et. al.* 1998 paper shows how different cohorts share the burden of a perfectly anticipated demographic shock) but at present there is no SGE model can address the question of whether Social Security can provide a welfare enhancing transfer mechanism to help out a cohort that suffered the consequences of a sustained stock market crash or depression, which Blinder (1988) ascribed as one of the reasons motivating the introduction of Social Security in 1935.

Another limitation is the lack of detail on firm behavior. Most models abstract from modeling firms: the "firm" is synonymous with single aggregate Cobb Douglas production function that earns zero profits and pays out all revenue to workers and capital owners at competitive rates equal to the marginal product of labor and capital, respectively. With the exception of a few studies such as Walliser (1997), there has been few attempts to model the markets for insurance or annuities, or to model why firms offer fringe benefits such as health insurance or private pensions. Information asymmetries that lead to moral hazard and adverse selection problems in insurance markets have not been modeled at the same level of detail as the analytic approaches surveyed in section 5.1.

Incomplete markets are modeled only to the extent that certain markets are exogenously specified to exist or not to exist, but the pattern of available markets and contracts such as pensions are not allowed to emerge endogenously as a competitive outcome. Thus, the current generation of SGE models is unable to address the important question of the extent to which Social Security "crowds out" pensions, annuities and private insurance contract.

Another limitation worth noting is the failure to model labor supply and consumption decisions jointly in the individual's DP problem (the De Nardi, *et. al.* 1998 model is an exception). Instead labor supply is typically treated as an exogenous process, with a fixed retirement date as in the Storesletten, *et. al.* paper. The latter paper allows for exogenous random variation in pre-retirement labor supply, in which case the dichotomous treatment of labor and consumption is slightly less objectionable, but the importance of jointly modeling labor supply, retirement and savings decisions has been recognized since Feldstein (1974). In particular, labor supply is an important mechanism for dealing with risk, at least for healthy, productive workers. If savings turn out to be lower than expected the individual can delay retirement. The additional complexities and unexpected results from modeling consumption, labor supply and retirement as jointly endogenous decisions has already been discussed in section 5.2.

Finally, most SGE models abstract from "political risk" of changes in the Social Security system, and government policy is typically treated as exogenously specified, although recent specifications have endogenized policy formation via simple median voter models of the political economy of social security policymaking. Even remaining within the standard framework for policy analysis where the government is modeled as a "Stackelberg leader" that can commit to any given policy, we are still far from the point of being able to apply mechanism design theory in order to systematically search for welfare maximizing or cost minimizing social insurance systems subject to information and incentive constraints. In view of all this, it should come as no surprise that we are quite far from developing a "grand unified model" of social insurance for reasons that have already been discussed in section 5.2.

A useful direction for work in the near term is to determine policy issues where it might be reasonable to abstract from general equilibrium feedbacks and thereby avoid the complexities inherent in solving SGE models. Our survey suggests that general equilibrium feedbacks cannot be safely ignored for fairly radical changes to the Social Security system such as privatization or changing from a pay-as-you-go system to a fully funded system. However it is likely that there are questions for which equilibrium feedbacks are second order. One example might be the issue of investing the Trust Fund in equities. If we believe that most individuals can undertake offsetting changes in their private portfolios and that the U.S. is increasingly a small player in a global equity market, then it seems that impact on the equity premium of investing the Trust Fund in equities would be second order and might be safely ignored in policy analyses similar to what was done in the Feldstein, Ranguelova and Samwick (1999) study discussed in section 4.3. It is hard to determine in advance of actually solving an SGE model whether general equilibrium feedbacks are likely to be important, but common sense and intuition are likely to be good guides. This is standard practice in academic models where certain variables are assumed to follow exogenous stochastic processes even though it is possible to argue that on a grand scale "everything is endogenous." We think it is emminently reasonable to try to reduce the computational burdens underlying SGE models by identifying certain processes such as equity returns, trends in fertility, mortality, marriage and divorce that can be reasonably treated as exogenous stochastic processes, at least to a first approximation.

6. Conclusions

This chapter has surveyed a very rapidly growing literature on academic and non-academic policy models that account for various types of risk as well a several private and public mechanisms that individuals have at their disposal for dealing with these risks. One can get some appreciation for the speed at which this literature is developing by noting that over three quarters of the extensive list of citations are books or papers that have been written or published in the last three years. In order to put this survey in some perspective, it is useful to revisit the final recommendation of the Panel on Retirement Income Modeling (PRIM) at the National Academy of Sciences concerning the correct strategy for model development

> "Relevant agencies should consider the development of employer models and a new integrated individual-level microsimulation model for retirement income-income-related policy analysis as important long-term goals. Construction of such models would be premature until better data, research knowledge, and computational methods are available. To respond to immediate policy needs, agencies should use limited, special-purpose models with the best available data and research findings to answer specific policy questions." (Citro and Hanushek, 1997, p. 9).

Since the time of this report was written there have been a very significant changes in circumstances that affect how one views the kinds of tradeoffs agencies such as SSA are facing. The government is no longer in a severe budget deficit and government agencies have benefited from increased funding and the possibilities it affords for taking a longer range view of how they fulfill their mandates. In particular SSA has embarked on a very ambitious program of investing a significant amount of resources on both short and long term model development and on improved liaisons with the academic community. We view this as a very positive development and hope that it will continue. SSA should bear a greater burden of funding academic research and data collection on aging and social insurance issues that has been previously shouldered primarily by NSF and NIH. We have argued that the social returns to these investments are very high. Although the increasing funding levels are encouraging, we feel that the absolute level of SSA's spending on research and data gathering is still too low.

The large budget deficits and the pessimistic atmosphere for research funding in the early to mid 1990s may have colored the PRIM's views about the feasibility of model development. While the PRIM's basic recommendation is still valid, this chapter has offered a considerably more optimistic view about the prospects for the modeling in light of the rapid progress in the last several years. Although this chapter has had relatively little to say about employer models, we do agree that modeling firm behavior is critical for capturing many of the key risks facing individuals. Firms provide job opportunities, pensions, health insurance, and a variety of types of private insurance contracts that can compliment the goals of Social Security in providing a stronger safety net for all American citizens. If we continue to ignore firm behavior, we run the risk that public policies designed to insure against more types of risk may inadvertently "crowd out" firms, possibly even reducing the overall set of options at individuals' disposal.

It should come as no surprise that there is a fundamental trade-off between the amount invested in developing a policy forecasting model and the credibility of its policy forecasts. However a crash investment program designed to develop the most sophisticated possible modeling framework is not warranted. Instead, we recommend an evolutionary approach that begins in the short-term with the short-cut strategy of modifying existing microsimulation models to evaluate distributional consequences of risky outcomes implied by alternative policies via stochastic simulation. We do this with some hesitation since our analysis exposed some important dangers involved in using short-cut approaches to policy evaluation. We provided several examples that demonstrated how the short-cut approach can leads to misleading policy conclusions — at least conclusions that are opposite to the ones we would reach using calibrated stochastic overlapping generations models that allow us to quantify endogenous changes in welfare and general equilibrium feedbacks. In intelligent hands, it is possible for the short-cut approach to produce relatively accurate and credible policy forecasts. However various consumers of these forecasts (including Congress, the media, and the general public) should be fully apprised of their inherent limitations and pitfalls.

Even though the short-cut approach is much simpler than the longer term strategies discussed in section 5, there are a number of short term challenges involved in fully implementing it to analyze different aspects of risk. A major problem concerns how to evaluate simulated output, since it will be difficult to rank the desirability of different policies based on "eye-ball" examination of simulated data sets. It will be important to develop new ways to present these simulations graphically via the assistance of summary welfare measures including some of the simplified expected utility and money's worth calculations described in section 3. The other major problem concerns how to forecast the impacts of policy changes. The initial generations of short-cut models will employ reduced-form behavioral relationships that will require a substantial number of *ad hoc* adjustments based on the SSA's judgement as to how the historical behavioral relationships will change in response to new policies. Considerable judgement will be required in order to forecast responses by firms and longer term general equilibrium feedbacks in the overall economy. It will be quite a challenging task to make these adjustments in a way that the resulting "judgemental forecasts" from the model are transparent, justifiable, and credible. However in the short term this rather *ad hoc* process of judgemental forecasting using short-cut modeling approaches to incorporating risk and private insurance mechanisms is probably the best we can hope for.

As a longer term strategy, SSA should continue to invest heavily in developing and improving its analytical capabilities which will make it less costly for it to implement an array of special purpose, state-of-the-art academic models such as those surveyed in section 5. This will allow it to evaluate and improve the forecasts of its microsimulation models by comparing its judgemental forecasts of changes in key behavioral relationships to the forecasts of state-of-the-art academic models. Wherever possible it should attempt to incorporate these models as modules or "subroutines" in its microsimulation model in order to reduce the role of subjective judgement and the reliance on "guessitimates" in policy-forecasting.

Rapidly improving computer hardware, combined with improved algorithms and theoretical breakthroughs that have revealed classes of problems for which it is possible to break the curse of dimensionality have resulted in substantial improvments in DP and SGE models, enabling them to capture an increasing number of risks and aspects of Social Security with a fair amount of detail and realism. Some of these models are now sufficiently realistic and accurate that they can be taken seriously for policy forecasting purposes. Despite the empirical success of certain structural DP models, the behavioral assumptions underlying most DP and SGE models are still a long way from being empirically justified. There many unresolved empirical puzzles connected with savings and wealth accumulation, and we are still not at the point where we can solve and empirically estimate the full life-cycle model that handles both the labor/leisure and consumption/savings decisions simultaneously. Even focusing on the end of the life-cycle, we are still years away from being able to solve a reasonably complete DP model that incorporates the key components of Social Security, private pensions, and private insurance contracts with an adequate level of detail to be useful to evaluate many policy questions of interest to SSA. None of the existing DP or SGE models has track record in policy forecasting that would enable us to determine whether they are really more accurate than existing methods, and in the short term computation and data constraints still make it prohibitively difficult and expensive to formulate and solve a wide range of more limited academic models that SSA might be interested in using for policy evaluation. In particular we are decades away from developing a single comprehensive “grand unified” stochastic overlapping general equilibrium model of Social Security which could simultaneously handle all of the key risks and private insurance mechanisms listed in section 3. If we are interested in the general equilibrium effects of certain policies, we must be willing to work with relatively coarse descriptions of Social Security policy in order to obtain a tractable SGE model.

However it is possible that a “patchwork” of DP and SGE models covering different parts of the Social Security program at different levels of detail could be an extremely useful complement to help determine the right adjustments for endogenous behavioral and general equilibrium responses within a larger scale reduced-form policy simulation model developed according to the short cut approach discussed in section 4. The key unresolved question is whether the proposed evolutionary approach that gradually upgrades an initial “short cut” model will ultimately result in something that resembles the grand unified SGE model that could provide an integrated treatment of the key risks facing individuals and the private mechanisms for dealing with them. It is possible that a patch work approach of providing “behavioral upgrades” to individual modules of an initially non-behavioral, non-equilibrium microsimulation model will result in a model that produces incoherent, internally inconsistent forecasts. If this is the case, then it may eventually be better to abandon this approach and begin developing a new consistently formulated overlapping generations general equilibrium model from scratch. This is a question that is probably best left to the future, since continued rapid improvement in technology will eventually enable academics to develop increasingly comprehensive and realistic SGE models which can be compared to the outcome of the evolutionary approach we are recommending here. In any event, since it is not feasible to develop a sufficiently realistic and detailed SGE a model given current technology, our recommendation to begin with the short-cut approach seems to be the only feasible path to follow in the short term.

In the final analysis, the recommendations in this chapter for the best strategy for incorporating rish and insurance in Social Security policy models is not radically different from the recommendation of the Panel on Retirement Income Modeling quoted above.

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