

CGE Modelling Social Security Reforms*

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Abstract

The paper reviews CGE models that have dealt with social security issues during the last two decades. After introducing the benchmark model from Auerbach and Kotlikoff (1987), we consider the impact of the demographic transition on international capital markets and national wages. Then the discussion focusses on optimal funding and optimal progressivity of social security and concludes with some possible directions for future research.

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1 Introduction

I'm deeply honored to participate in this symposium celebrating Leif Johansen's contribution to the development of CGE models. As a Ph.D. student I developed a static multi-country, multi-sectoral general equilibrium model which was applied to the problem of tax harmonization in the European Union. At that time I was quite aware that my own work is based on Leif Johansen's doctoral dissertation which was published as *A Multi-Sectoral Study of Economic Growth* in 1960 (and later in a second edition in 1974). In my own dissertation I did not follow the so-called "Johansen-method" of solving a system of non-linear equations by log-linearization but applied instead a variant of Scarf's numerical algorithm for finding the equilibrium. Nowadays Scarf's algorithm is quite antiquated since many computational tools are available to solve nonlinear equation systems efficiently. However, even after half a century, the economic structure of many applied models is still very similar to Leif Johansen's pathbreaking work.

Since my dissertation I have changed my research agenda from static multi-sectoral to dynamic one-sector growth models with overlapping generations dealing with social security issues. With the exception of Samuelson (1958) and Diamond (1965) overlapping generation models were hardly discussed up to the early 1980s, so it is not surprising that (at least to my knowledge) none of Leif Johansen's work is directly connected to this specific class of models. Nevertheless, since Leif Johansen showed a lifelong interest in the use of long-term models as a guide for practical problems in macroeconomic planning, I'm quite sure that he would have liked the studies I will discuss. Due to the demographic transition, social security has become an extremely important area of economic policy. In the recent past dynamic CGE models have highlighted the economic consequences of the ongoing and upcoming demographic transition. They have assessed the sustainability of many existing pension schemes and indicated the need for dramatic policy reforms. Even in Norway, a country where public finances look impressively solid due to its large petroleum revenues and an ambitious pre-funding strategy, fiscal policies seem not to be sustainable in the long-run. Consequently, since Steigum (1993) dynamic CGE models are used to evaluate the macroeconomic, the distributional and the insurance and efficiency effects of alternative policy options. Currently, Statistics Norway applies modern variants of its MSG model (which was initiated by Leif Johansen) to welfare state and pension reform issues, see Holmøy and Stensnes (2008).

In my discussion I will not present a survey of the literature¹ but concentrate on three central issues: The impact of population ageing, the privatization and the progressivity of social security. I will explain how CGE models are applied to analyze these questions and how model structures, results and policy conclusions have changed over time. My intention is not to present

¹ For recent surveys of the literature see Fehr and Thøgersen (2009) and Fehr (2009).

projections for the future path of the economy or definite answers for policy practice, but to show how institutional assumptions shape the assessment of economic problems. In my opinion this is the main advantage of CGE models. They can go beyond theoretical models and analyze practical policy issues in very complex institutional settings which require to evaluate different economic effects quantitatively. My discussion will focus on numerical models in the tradition of Auerbach and Kotlikoff (1987). For this reason the next section describes the general structure of this approach. Then I discuss the policy issues mentioned above before I conclude with some (personal) notes on expected future developments.

2 The Auerbach-Kotlikoff model

Alan Auerbach and Larry Kotlikoff developed their dynamic life-cycle simulation model (henceforth the AK model) in the early 1980s.² Whereas CGE models at that time were typically static in nature, they were the first who integrated a dynamic optimization procedure and solved for the transition path between steady states. The original AK model distinguishes between 55 overlapping generations (representing ages 21 to 75), the preference structure of a “newborn” agent who just enters the labor market is represented by a time-separable, nested CES utility function:

$$U = \frac{1}{1 - \frac{1}{\gamma}} \sum_{j=1}^{55} \delta^{j-1} \left[c_j^{1-\frac{1}{\rho}} + \alpha \ell_j^{1-\frac{1}{\rho}} \right]^{\frac{1-\frac{1}{\gamma}}{1-\frac{1}{\rho}}}, \quad (1)$$

where c_j and ℓ_j denote consumption and leisure, respectively. The parameters δ, ρ, γ and α represent the time preference rate, the intra- and intertemporal elasticity of substitution, and the leisure preference, respectively. “Newborn” agents maximize their utility function (1) subject to the intertemporal budget constraint

$$\sum_{j=1}^{55} [(1 - \ell_j)h_j w - c_j - \Gamma_j](1+r)^{1-j} + \sum_{j=j_R}^{55} p_j(1+r)^{1-j} = 0, \quad (2)$$

where w and r denote the pre-tax wage and return on savings, respectively, h_j defines the efficiency (or human capital) of the agent at age j and Γ_j represent the individual tax liabilities including social security contributions. Finally, p_j represent the payments from the pension program at age j after retirement at age j_R . Of course, agents are restricted in their leisure consumption by their time endowment which is normalized to unity, i.e. $\ell_j \leq 1$. At corner solutions, where the time constraint bites, a shadow price of labor is computed to make the corner solution satisfy the first-order condition. The optimization problem for households already alive at the time the policy reform is implemented is very similar. Such agents optimize

² Kotlikoff (2000) provides a nice insight on the origins of this approach.

consumption in the remaining years of their life taking into account accumulated assets in their respective budget constraint. The utility function (1) and the budget constraint (2) already highlight the central assumptions of the original model. First, agents are rational and each agent faces a certain life span of 55 years, he enters the labor market at the fixed age of 21 when he is already endowed with an exogenous and certain age-specific productivity profile h_j . At the end of the working career, the government-specified age of initial benefit receipt j_R is important for the labor market exit decision. Second, the original model abstracts from a family context, i.e. it has a purely individual perspective and neglects a bequest motive and inheritances or other private intergenerational transfers. Third, agents face no liquidity constraints, i.e. they might accumulate debt during young age which they pay back later in life. Forth, wages and interest rates are non-stochastic. Consequently, the model does not distinguish between different financial assets with alternative risk-return profiles. Fifth, there is only one consumption good so that any disaggregation of the consumption structure and the production sector is disregarded. Finally, individual variables are only indexed by age, there is no disaggregation within a cohort according to country of origin, income class or sex. Consequently, the model can not address distributional issues between countries and/or within a generation.

On the other hand, the model is able to replicate the tax and social security system in quite some detail by the specification of individual tax payments and pension benefits. With respect to the social security system we can specify the pension function as follows

$$p_j = \lambda \Psi_1(\bar{y}) + (1 - \lambda) \Psi_2(y_1, \dots, y_{j_R}) \quad j \geq j_R \quad (3)$$

where \bar{y} and y_j define the average labor income of a specific year and the (annual) income of a household at age j , respectively. The functions $\Psi_i(\cdot)$ convert income into pension benefits and λ measures the degree of progressivity, i.e. whether the replacement rate of the pension system is either constant or decreasing with rising income. If $\lambda = 0$ then pension benefits depend on individual income (i.e. contributions) alone and the replacement rate is the same for all income levels. Alternatively, only a certain number of best income years counts (as in the USA or in Spain) or the whole working career is taken into account (as in Germany or in Sweden). If $\lambda = 1$ benefits are flat, i.e. they are independent of former contributions and the replacement rate decreases with rising income. If $\lambda > 1$ even benefits decrease with rising labor income. The function $\Psi_1(\cdot)$ is a pure replacement rate whereas $\Psi_2(\cdot)$ computes the individual social security wealth and models the (possible non-linear) relationship between social security wealth and pension benefits.

In general equilibrium, a continuum of households interacts on labor and capital markets in order to determine real wages and returns to capital. The former equates labor demand by firms to labor supplied by households; the latter equates capital demand by firms and public debt to total desired asset holdings of households. Typically, the government runs an unfunded

pension system, so that contributions from workers finance the benefits of pensioners. In addition, the government may also provide a public consumption good that is financed by taxes and public debt. Of course, the public budget has to be balanced intertemporally.

Since at the end of each period the oldest cohort alive dies, the remaining lifetime is varying across cohorts living in a specific year. Consequently, fiscal reforms have a different impact on the budget constraints of current and future cohorts (who enter the labor market after the reform year). Typically, the initial long run equilibrium is calibrated to represent the existing fiscal system. After a policy reform is announced or enacted, the model computes a transition path to the new long run equilibrium. Given the model's solution, researchers are able to evaluate the transitional growth effects for the macro-economy as well as the distributional consequences of the considered reform for different current and future generations.

In order to understand the economic implications of the model, it is useful to keep in mind that the basic effects of alternative pension financing schemes persist as in the stylized theoretical models mentioned above. Due to the absence of lifespan uncertainty, bequest motives and liquidity constraints, individuals can perfectly provide for their old-age consumption by means of private saving. Consequently, a mandatory individualized funded pension program would only replace private savings with saving in the public pension fund but would have no real effects in the economy. On the other hand, a pay-as-you-go financed pension program works similar as public debt. It crowds out capital and redistributes resources from young and future generations towards the elderly. Consequently, a move from an unfunded towards a funded program will always increase the capital stock in the economy and redistribute resources from current towards future generations.

Of course, these results depend on the simplifying assumptions made above. In principle, it is no problem to include non-rational decision making, endogenous human capital formation and retirement, family relations and bequest motives, labor income and life span uncertainty, liquidity constraints and intra-generational heterogeneity. The following discussion will show that some of these assumptions affect the results derived from these models quite substantially.

3 Population ageing and factor markets

Due to decreasing birth rates and increasing life expectancy, almost all industrialized countries are confronted with a dramatic ageing of the population. Despite positive migration rates, the number of workers will decrease since already in the near future fewer youngsters will enter the labor market while at the same time the baby boom cohorts of the 1960s will enter retirement.

Table 1 documents some important key figures of the population in selected countries which

Table 1: Dynamics of global ageing

Country	Total fertility (children per woman)			Life expectancy (at birth, both sexes comb.)			Dependency ratio (age 60+/age 15-59)		
	1950-05	2000-05	2045-50	1950-05	2000-05	2045-50	1950	2000	2050
USA	3.45	2.04	1.85	68.9	78.3	83.3	20.7	26.0	49.3
Germany	2.16	1.35	1.69	67.5	78.7	84.4	23.5	37.9	82.4
France	2.73	1.88	1.85	67.1	79.5	86.6	26.5	34.2	63.6
Italy	2.36	1.26	1.74	66.3	80.2	85.4	19.6	39.8	82.5
UK	2.18	1.70	1.85	69.2	78.5	84.1	24.9	34.5	52.6
Japan	3.00	1.30	1.60	62.1	82.1	87.2	13.5	37.5	99.1
Norway	2.60	1.80	1.85	72.7	79.4	85.2	22.5	31.6	54.7
China	6.11	1.77	1.85	40.8	72.0	79.3	12.7	15.5	57.9
India	5.91	3.11	1.85	37.9	62.0	73.3	9.4	11.5	31.5

Source: United Nations (2010), medium variant.

highlight the differences and the similarities of national population dynamics. As shown in the last three columns, the dependency ratio (measured as the ratio of 60-years old and elderly to 15-59-years old) has already increased during the last fifty years and will increase much more dramatically in the next half century. Japan, Italy and Germany will experience the strongest increase over the whole period 1950-2050, France is somewhere in a middle position while the demographic transition will be much less severe in the USA, the UK and Norway. Note that dependency ratios also increase in fast growing Asian economies, China will experience the strongest relative increase of all countries considered in the next 50 years. Table 1 also reveals that fertility rates differ significantly even between western countries which in turn explains the differences in the population dynamics. While the US fertility rate is currently almost at reproduction level, Germany, Italy and Japan have extremely low fertility rates while France, Norway and the UK are somewhere in the middle. Based on past experience, the projections of the UN for the future even seem overly optimistic for the three low-fertility countries. With lower future fertility rates, future dependency ratios will even further increase there. Due to specific population control programs and the fast economic and social progress, China and India have also experienced a dramatic decline in fertility and a rise in longevity. While the dependency ratio has hardly changed in the past, one can expect a strong increase in the future in these countries.

It is quite clear that the ongoing and upcoming demographic transition will have a significant impact on the economy of all industrialized countries. Of course, the most direct connection between population structure and economy is given by the pay-as-you-go financed social security systems in these countries. If the number of contributors decreases while at the same time the number of beneficiaries increases, these systems become unsustainable so that contribution rates have to increase or benefit levels have to fall. But population ageing will also affect factor

markets whereas the direction of this effect is not so clear. While the (national) supply of workers and capital will decrease, it is uncertain how the demand for primary factors will change in an ageing society. It is also ambiguous how international capital markets are able to neutralize future capital shortages in developed economies. This is where dynamic CGE models which feature the demographic transition come to the front.

3.1 Closed economy studies

Auerbach and Kotlikoff (1985) already present calculations which quantify the impact of population ageing for the government and the macroeconomy in the US. Since they apply the original model discussed above, it is useful to highlight their central results. Table 2 reports the computed impact of population ageing on saving rates and factor prices in an economy without social security.

Table 2: Ageing and capital deepening

Year	Dependency ratio (age 60+ / age 20-59)	Saving rate (in %)	Wage index	Interest rate (in %)
0	16.3	7.6	1.00	9.9
50	28.6	3.0	1.10	7.3
110	37.0	-1.5	1.11	7.1

Source: Auerbach and Kotlikoff (1985: 158).

The key figures of the original steady state which features a 3 percent population growth rate are stated in Period 0. Dependency ratio and saving rate are quite realistic for the US in the 1950s, wages are normalized to unity and the gross interest rate is calibrated to approximately 10 percent. Starting in period 1 the population growth rate decreases to zero and remains at this level. As a consequence, the dependency ratio increases slowly and doubles after roughly one hundred years.³ The decline in the number of young savers causes a dramatic fall in the saving rate which even turns negative during the transition (and will be zero in the long run). At the same time wages rise and interest rates gradually fall throughout the transition reflecting the decline in the supply of workers and the increase in capital per worker. The association of capital deepening with lower population growth is hardly surprising. Already Solow's (1956) growth model with its Keynesian saving behavior yielded this result. The authors also simulate the same demographic transition in a model that includes a pay-as-you-go financed social security system with a replacement rate of 60 percent and an initial age of benefit receipt of 65. Increasing social security contributions lowers net wages, which dampens in turn the reaction

³ Note that this is quite close to the actual US transition reported in Table 1.

of labor supply, savings and factor prices. When benefits are cut (or the retirement age is raised) the payroll tax rate increases less and the amplitude of the factor price reaction increases again. Consequently, the inclusion of social security dampens the quantitative implications for factor prices but the general direction still remains valid.

Auerbach, Kotlikoff, Hagemann and Nicoletti (1989) include utility from leaving bequest and present similar calculations where they compare the demographic transitions in the US, Japan, Sweden and Germany. In the following years the original model was further extended in various directions. Chauveau and Loufir (1997) combine age-specific survival probabilities and uncertain life spans with a perfect annuity market. De Nardi, Imrohoroğlu and Sargent (1999) include life-span risk and income shocks and model the US medicaid and medicare programs in detail. Fehr (2000) distinguishes various productivity (i.e. human capital) profiles within a specific cohort while Hirte (2001) also considers the German unemployment and health care system. Börsch-Supan, Ludwig and Winter (2006) present a multi-country model with detailed demographic projections for seven world regions (France, Germany, Italy, Rest-EU, USA/Canada, Rest-OECD, Rest-World) in order to analyze the impact of ageing on capital flows and the world interest rate. Finally, Krueger and Ludwig (2007) also consider idiosyncratic labor income uncertainty in a multi-country model with global ageing.⁴ All these approaches basically confirmed the basic intuition of capital deepening which provides at least some potential silver lining on the dark horizon since higher real wages would broaden the tax base and thereby increase tax revenues.

However, despite all these adjustments of the original model structure, ageing hardly changes the individual consumption, saving and bequest behavior and mainly affects the macroeconomy through aggregation. For this reason Kotlikoff, Smetters and Walliser (2007) extend the original approach in various directions in order to generate a direct effect from ageing on life-cycle behavior. They allow for intra-cohort heterogeneity and introduce a much more detailed mapping of the demographic process. During their child-bearing years, agents give birth each year to fractions of children. This means of finessing marriage and family formation permits to incorporate changes through time in age-specific fertility rates and the family structure. In addition, Kotlikoff et al. (2007) also assume that agents care about their children's utility when the latter are young and, as a consequence, make consumption expenditures on behalf of their children. Therefore, the model replicates the hump in the consumption profile that appears during child-rearing years in the actual data. As previous studies, Kotlikoff et al. (2007) also include utility from leaving bequest and realistic mortality probabilities for agents. However, agents fail to annuitize their assets in old age. Consequently, agents gradually reduce their consumption in old age due to the uninsurable lifespan uncertainty and leave desired and undesired bequests to their children when they die. While agents die at different ages and have

⁴ Adema, van Groezen and Meijdam (2009) discuss the literature on ageing and international capital markets.

children of different ages, their heirs also inherit at different ages. Agents who were born when their parents were young receive inheritances later in their life than do their younger siblings. Finally, they provide a more detailed mapping of the US fiscal institutions and simulate the model from non-steady state initial conditions. Table 3 reports their results for the baseline path without social security reform.

Table 3: Ageing and capital shallowing

Year	Dependency ratio (age 60+ / age 20-59)	Saving rate (in %)	Wage index	Interest rate (in %)
2000	20.3	4.6	1.00	7.5
2050	37.5	1.5	0.93	9.5
2100	42.6	2.7	0.90	10.3

Source: Kotlikoff, Smetters and Walliser (2007: 258).

Quite surprisingly, they find that ageing will lead to capital shallowing, rather than capital deepening over the course of the century. According to their simulation, the real wage per unit of effective labor will be 7 percent lower in 2050 and 10 percent lower in 2100 than it is today. The results which turn out to be quite robust are due to the interplay of three model characteristics: Ageing directly affects individual behavior, the presence of other government programs induces dramatic tax hikes and effective labor supply increases by a productivity growth of 1 percent. The tax increase reduces disposable income of workers so that they save less while at the same time effective labor decreases much less.⁵

3.2 Open economy studies

The multi-region model of Fehr, Jokisch and Kotlikoff (2004, 2008a) featuring the US, the EU and Japan builds directly on Kotlikoff et al. (2007). Besides the explicit provision for immigration, the demographic transition at the national level and the household decision problem are modelled in a very similar fashion. However, the ageing processes of the three countries are now interlinked via the international capital market, so that international capital flows dampen the factor price effects of the closed economy. Again, ageing increases the world interest rate and decreases real wages in all three countries significantly.

Finally, in order to account for the impact of the growing Asian economies, Fehr, Jokisch and Kotlikoff (2008b) also include China and India in their model. These countries not only fea-

⁵ Note that neither tax increases nor productivity growth can generate capital shallowing alone. Already Auerbach, Kotlikoff, Hagemann and Nicoletti (1989: 103) included productivity growth (even at a higher rate), but still obtained capital deepening. De Nardi, İmrohoroğlu and Sargent (1999) even included productivity growth and other fiscal institutions in the US without generating capital shallowing.

ture much higher saving rates (due to forced saving and deferred ageing) but also have an abundance of low-skilled workers. The model distinguishes five consumption goods and a changing consumption demand structure over the life cycle. Due to imperfect substitutability between low-, medium- and high-skilled workers the changing population structure affects the structure of consumption demand and the production structure so that wages of different skill classes change differently.⁶ Table 4 compares the world economy without and with the two Asian countries.

Table 4: The impact of China and India on international factor markets

	3-region model				5-region model			
	Wage rates			Interest (in %)	Wage rates			Interest (in %)
	low	middle	high		low	middle	high	
2005	1.05	3.04	5.96	11.9	1.00	2.99	5.83	12.7
2010	1.06	3.08	6.02	11.5	0.98	3.03	5.87	12.4
2030	1.04	3.08	5.95	11.7	0.84	3.13	6.37	10.9
2050	0.99	2.98	5.87	12.7	0.75	3.24	7.16	9.1

Source: Fehr, Jokisch, Kotlikoff (2008b).

In the 3-region model on the left side of Table 4 we again observe capital shallowing as was already discussed above. However, the model's predictions are dramatically altered when China and India are added to the picture on the right side. Even though especially China is ageing rapidly (see Table 1), the saving behavior, growth rate, and fiscal policies of both countries are currently very different from those of developed countries. Therefore, these countries might eventually become the developed world's savior with respect to its long-run supply of capital and long-run general equilibrium prospects, if successive cohorts of Chinese and Indians continue to save like current cohorts, if the Asian governments can restrain growth in expenditures, and if their technology and education levels ultimately catch up with those of the West and Japan. Table 4 also reveals that population ageing and globalization does not only reduce world interest rates but also increases significantly the skill premium for high-skilled workers. This might be a major problem for industrialized countries in future decades.

Of course, the anticipated demographic transition raised concerns about the long-term financial sustainability of the existing social security systems. Consequently, most of the models discussed above also simulated various policy reform options designed to dampen the expected increase in contribution rates. The following two sections focus on two particular issues of this discussion: Whether the phase-down or complete phase-out ("privatization") of social security generates efficiency gains and whether benefits within the unfunded system should be linked

⁶ Alternatively, Rojas (2005) assumes that productivity increases with work experience and young and old workers are imperfectly substitutable. Ageing then directly affects the supply of high- and low-skilled workers.

to former contributions.⁷

4 Efficiency gains from social security privatization?

Feldstein (1996) points out two central gains from a shift from an unfunded social security to a privatized funded program: On the one side, since such a reform would increase capital accumulation, people would gain since the real return on capital is higher than the implicit return of the social security system. On the other hand, such a reform would reduce the deadweight loss caused by the payroll tax. He even argues that

"... it is possible to design a transition to a funded program that leaves each generation better off than it would be with the existing program."

Feldstein (1996: 12)

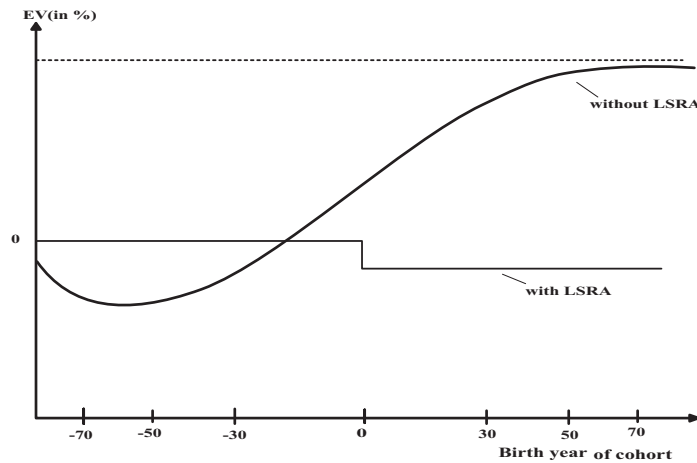
There is reason to believe that Feldstein's (1996) argumentation is overly optimistic. Already Breyer (1989) shows that the transition towards a funded system generates no efficiency gains in a model with fixed labor supply. Sinn (2000) demonstrates that the difference in the explicit and implicit returns of capital and social security simply reflects the burden of the implicit debt accumulated at the introduction of the unfunded system. A move towards funding would therefore just convert implicit debt to explicit debt and implicit taxes to explicit taxes without generating any economic gains for cohorts. However, there still remains the question whether the reductions in labor supply distortions could generate enough efficiency gains so that all transitional cohorts could be compensated at least in principle. During the last decade various dynamic CGE models were applied to answer that question.

Before we discuss the details it is useful to explain the structure of policy experiments and the compensation mechanism applied to isolate economic efficiency. Given a transition path which reflects a specific social security policy, a reform is announced or enacted and the economy enters a new transition path. Given the two possible paths of the economy it is no problem to compute the welfare changes for different cohorts living at the introduction of the reform and in future periods. Figure 1 represents the intergenerational welfare effects of such a typical simulation run. The horizontal axis shows the different cohorts, while the vertical axis reports the welfare changes (typically computed as equivalent variation and measured in percent of remaining lifetime resources) after the reform. The reform is enacted in year 0 and cohorts are either born before, in or after the reform year.

The graph "without LSRA" shows that the considered reform reduces the welfare of currently working and already retired cohorts, whereas cohorts currently younger than 20 years old and

⁷ For a comprehensive discussion of pension reform issues see Lindbeck and Persson (2003).

Figure 1: Intergenerational Welfare and Efficiency Effects of Policy Reforms



future cohorts realize welfare gains. The dotted horizontal line indicates that the considered reform generates welfare gains that are higher for future than for current generations. If the transition is ignored, the welfare effects of the reform would be considered to be very positive. However, most cohorts alive in the reform year are hurt by the reform. This is ignored by a purely long-run analysis, but a comprehensive evaluation of the reform also has to take such intergenerational distribution effects into account. Once the winners and losers from a reform are identified, the logical next step is to find out whether the winners can compensate the losers. Are the long-run welfare gains in Figure 1 only due to transitional welfare losses or does the reform produce an overall efficiency gain? Auerbach and Kotlikoff (1987) have introduced the so-called "Lump-sum redistribution authority" (LSRA) to answer that question. In a third run the reform is simulated with lump-sum transfers and taxes from the LSRA so that existing generations after the reform end up at their pre-reform welfare level. Newborn and future cohorts pay lump-sum taxes to or receive transfers from the LSRA in order to balance the LSRA budget intertemporally. In order to facilitate a comparison of efficiency- and welfare effects, LSRA payments are distributed across newborn and future cohorts so that they experience identical welfare gains or losses after compensation. In the example of Figure 1, the LSRA pays lump-sum transfers to cohorts older than 20 years and levies lump-sum taxes on younger cohorts in the reform year. Since taxes on younger cohorts are not sufficient to finance the transfers to older cohorts, the LSRA levies lump-sum taxes on newborn- and all future cohorts. These LSRA payments dominate welfare gains due to the reform, so that newborn- and future cohorts realize an identical welfare loss after compensation (see the graph "with LSRA"). This welfare loss reflects the aggregate efficiency effect of the policy reform under consideration. As indicated by Figure 1, the long-run welfare change without compensation is generally an ineffective indicator of the aggregate efficiency consequences of the reform.

4.1 Privatization in models with perfect markets

Seidman (1986) already carried out some numerical simulations where social security was phased-out partially in the US. However, this general equilibrium model featured exogenous labor supply and the considered policy reforms did not fully honor the claims of existing pensioners. Pareto experiments and efficiency calculations are only interesting with variable labor supply. Kotlikoff (1996, 1998) presented probably the first studies that simulated alternative privatization policies for the U.S. and compared the resulting efficiency consequences. Applying the original model discussed in section 2 (i.e. no demographic transition and no intra-cohort heterogeneity), the initial study analyzed the complete phase-out of the US social security system with alternative financing assumptions. The initial steady state features a 20 percent income tax used to finance public consumption and an unfunded social security system with a 12 percent payroll tax rate where benefits equal 75 percent of average wages earned during the previous working periods. Privatization involves an immediate elimination of the payroll tax and a 45-year phaseout of social security benefits starting after 10 years. As a consequence, all retirees collecting benefits at the time of the reform (i.e. those between ages 66 and 75) receive all benefits they have been promised. The following 45-year phaseout period ensures that all workers alive at the time of the reform receive some social security benefits when they retire. Table 5 compares the welfare and efficiency effects of three privatization scenarios: The “base case” assumes no marginal tax-benefit linkage and uses income taxes to finance the declining social security benefits. The scenario “tax-benefit linkage” assumes that people believe initially that each dollar contributed to social security provides a future benefit of equal amount in present value.⁸ Finally, the scenario “consumption taxation” again neglects a tax-benefit linkage but finances the transitional benefit payments via consumption taxes.

Table 5: Welfare and efficiency effects of social security privatization (I)^a

Age in reform year/birth year	Base case		Tax-benefit linkage		Consumption taxation	
	Welfare	Efficiency	Welfare	Efficiency	Welfare	Efficiency
74	-0.12	0.00	-0.24	0.00	-4.71	0.00
45	-1.84	0.00	-3.06	0.00	-1.19	0.00
30	-0.17	0.00	-1.26	0.00	1.81	0.00
20	1.19	0.93	0.31	-3.14	3.55	4.45
10	2.38	0.93	1.39	-3.14	5.07	4.45
∞	9.67	0.93	8.89	-3.14	10.79	4.45

^aExpressed as a percentage change in initial remaining lifetime resources.

Source: Kotlikoff (1996: 17), Table 5.

As one would expect, in all three scenarios considered privatization of social security redis-

⁸ Of course, the actual return of social security contributions is much lower!

tributes from initial generations towards future ones. With consumption taxation redistribution is stronger than with income taxation and with an initial tax-benefit linkage all cohorts considered are worse off compared to the base case. When compensation is provided to initial generations, newborn and future generations end up in the base case with a utility gain of 0.9 percent of initial resources. This aggregate efficiency gain may seem small compared with the long-run uncompensated welfare gain of 9.7 percent, but it indicates a significant scope for a potential Pareto improvement. The efficiency gains in the base case are due to the reduction of labor supply distortions. In the second scenario, privatization results in a significant efficiency loss of 3.1 percent. With full tax-benefit linkage, social security contributions do not distort labor supply in the initial steady state. Consequently, the shift towards income taxes after privatization now increases labor supply distortions. Finally, efficiency gains increase if consumption taxes are used to finance the transitional benefits in the third scenario of Table 5. In the overlapping generations framework, consumption taxation encompasses a one-time, nondistortionary wealth tax so that labor supply distortions decrease, see Auerbach and Kotlikoff (1987: 77f.).

Kotlikoff (1998) reiterates these simulations assuming initial and transitional progressive income taxation and different phaseout periods. In the following years Kotlikoff, Smetters and Walliser (1998, 1999) extend the original model and distinguish twelve lifetime income classes within each cohort in order to study the intragenerational impact of alternative privatization schemes. As one could imagine, different income classes are affected quite differently by specific privatization policies so that these studies try to find a privatization strategy which combines an efficiency and a distributional improvement. Finally, as already mentioned above, Kotlikoff, Smetters and Walliser (2007) also account for the demographic transition in the US. They compute the welfare consequences of alternative pre-funding schemes but do not compute efficiency effects. Similar studies are also carried out for European countries. Fehr (2000) and Hirte (2001) consider the German pension system, Fehr and Steigum (2002) concentrate on reforms in Norway while Beetsma, Bettendorf and Broer (2003) analyzed the Dutch system to name just a few.

Summing up the studies discussed so far, one can conclude that funding may yield a potential Pareto improvement as long as the old unfunded system did not already comprise a tight tax-benefit linkage. However, one should be careful to agree too early with Feldstein's (1996) claim which was cited above. After all, all these studies assume perfect markets and full rationality of households. Therefore, they completely disregard various reasons for having a social security system in the first place. Apart from distributional reasons, the introduction of a mandatory system was motivated with reference to market failure in financial and insurance markets and by the fact that individuals are myopic. Consequently, simulation models should reflect missing markets for lifetime annuities and insurance against income shocks as well as individuals

that apply hyperbolic discounting, see Lindbeck and Persson (2003: 77) or Diamond (2004: 4). The efficiency effects of some recent studies which introduce such features in numerical models will be discussed in the following.⁹

4.2 Privatization in models with imperfect markets

De Nardi, İmrohorođlu and Sargent (1999) as well as Fuster, İmrohorođlu and İmrohorođlu (2007) simulate the elimination of social security applying a model with idiosyncratic labor income and life-span uncertainty. Whereas the former study considers the demographic transition, the latter one focusses on optimal decisions within a family context in order to account for informal insurance provisions. Both studies compute the welfare consequences of privatization but do not provide efficiency calculations.¹⁰ Nishiyama and Smetters (2007) provide the first study achieving that in a stochastic CGE model. They simulate a stylized phased-in 50-percent privatization of the US social security system in a model with variable labor supply. The benefits of households aged 65 or older in the reform year are not affected by the reform. Benefits decrease linearly for younger households, so that cohorts aged 25 or younger in the reform year receive only half of their traditional benefits when they turn 65. As in previous studies with idiosyncratic uncertainty, the considered reform reduces not only labor supply distortions but also the insurance provision of the social security system. Consequently, to isolate the overall efficiency effects, the authors introduce LSRA transfers and taxes in a separate simulation. The reform is first simulated in an economy without income uncertainty. As one would expect, the results show a clear redistribution from the elderly and middle-aged (i.e. younger than 65 years) cohorts towards younger and future-born cohorts. After compensating the welfare losses of the elderly, the study finds efficiency gains from privatization that amount to \$18,100 (in 2001 growth-adjusted dollars) per household. Therefore, the loss in annuity provision is overcompensated by reduced labor market distortions and increased liquidity of younger households. Next, the reform is simulated with idiosyncratic labor income uncertainty. Table 6 reports the welfare changes (i.e. without compensation) and the efficiency effects (i.e. with compensation payments) for different cohorts and income classes.

In the long run, welfare gains from partial privatization range from \$76,300 for low-income

⁹ İmrohorođlu, İmrohorođlu and Joines (1995) were probably the first who examined the optimality of alternative social security arrangements in a framework where social security provides insurance against income and longevity risk. However, their analysis is constrained to steady states. Krueger (2006) and Fehr (2009) survey other models in this direction.

¹⁰ Huang, İmrohorođlu and Sargent (1997) aggregate the wealth-equivalent welfare gains and losses of all cohorts along the transition path and then convert the aggregate into an annuity value that is expressed as a fraction of the initial equilibrium GDP. However, the aggregate of individual welfare changes measures efficiency only incompletely since households are not compensated.

Table 6: Welfare and efficiency effects of social security privatization (II)^a

Age in reform year/birth year	Welfare effects for selected income classes				Efficiency effects
	Class 1	Class 3	Class 5	Class 8	
79	-0.2	-0.2	-0.3	-0.5	0.0
60	-22.6	-29.7	-37.5	-57.1	0.0
40	-27.6	-46.0	-75.8	-130.7	0.0
20	-5.4	-7.4	-11.2	-22.4	0.0
0	34.3	37.0	38.4	30.7	-2.4
∞	76.3	84.1	91.3	91.2	-2.4

^a Expressed in 1000 \$ of year 2001.

Source: Nishiyama and Smetters (2007: 1700), Table IX.

households to \$91,200 for top-income households. The higher gains for rich households simply reflect the redistributive features of the US social security system. Similar figures are also reported by the studies discussed above that compute only the long-run consequences of social security reforms. However, these gains are mainly due to income redistribution, since elderly cohorts at the time of the reform realize significant welfare losses due to higher income- or consumption taxes that are required to finance the existing pension claims. Table 6 shows that 60-year olds at the time of the reform lose between \$22,600 and \$57,100 per household. If the LSRA is introduced and all existing generations at the time of the reform are compensated by transfers, then each household that enters the economy in the reform year or later has to pay \$2,400 to service the debt of the LSRA. In other words, the partial privatization of the US social security system does reduce economic efficiency because the (positive) insurance effects against lifespan and income risk dominate the distortionary effects on labor supply and losses from increased borrowing constraints.

Fehr, Habermann and Kindermann (2008) reach a similar conclusion for the German social security system. In contrast to the U.S. system, benefits in the German system are strongly linked to former contributions; i.e. $\lambda = 0$ in (3). While this institutional feature minimizes labor supply distortions, it also reduces insurance provision against income shocks. In addition, the numerical model accounts for significant borrowing constraints and compares economies populated by either rational or hyperbolic consumers. In the model privatization of the German pension system is accomplished by simply eliminating the further accumulation of pension wealth. After the reform, existing pension claims are financed by time-invariant payroll taxes, and the intertemporal budget of the general government is balanced by consumption taxes. Consequently, the burden is smoothed across current and future generations with endogenous public debt. The reform reduces payroll taxes by 8 percent and consumption taxes by roughly 3.5 percent, since higher savings for old age boost income-tax revenues. Due to the immediate decrease in consumption taxes, already retired cohorts benefit from the reform. Middle-aged

cohorts lose (since the tax share of contributions was below the payroll tax) and future generations win (due to lower payroll taxes). Table 7 compares the aggregate efficiency effects of this experiment for both economies. In order to isolate both the impact of labor market distortions and the insurance and liquidity effects on aggregate efficiency, we simulate the privatization experiment in a small open economy with alternative assumptions about tax progressivity, lifetime uncertainty, as well as liquidity constraints. In each simulation we adjust the respective interest rate so that the capital-output ratio always remains constant.

Table 7: Efficiency effects of social security privatization (III)^a

Scenario	Progressive tax system	Uncertain lifetime	Liquidity constraints	Consumers	
				rational	hyperbolic
(1)	yes	yes	yes	-0.57	-1.78
(2)	no	yes	yes	-0.54	-1.46
(3)	no	no	yes	0.68	0.22
(4)	no	no	no	0.18	0.05

^aExpressed as a percentage change in initial remaining lifetime resources.

Source: Fehr, Habermann and Kindermann (2008: 898), Table 6.

Scenario (1) features the benchmark assumptions with a progressive tax system, an uncertain lifespan and binding liquidity constraints for low-income households at young ages. Similar to Nishiyama and Smetters (2007), we find that social security privatization in Germany would reduce economic efficiency by 0.57 percent of lifetime resources. Since social security represents a commitment technology when individuals are myopic, the efficiency loss due to privatization increases to 1.78 percent in economies with hyperbolic consumers.

In scenario (2) we assume a proportional income tax of 10 percent in the initial equilibrium, so that both the income insurance effect of the tax system and the labor supply distortions are reduced. Since both effects neutralize each other, aggregate efficiency is hardly affected. In scenario (2), the reported aggregate efficiency losses are mainly due to the elimination of longevity insurance, which overcompensates (positive) liquidity effects. Consequently, in scenario (3) we eliminate the longevity insurance of social security by simulating the model with a certain lifespan of 80 years. Now, reported efficiency gains are solely due to liquidity effects and tax distortions, and the difference between scenarios (3) and (2) roughly captures the provision of longevity insurance by the pension system. Consequently, the (implicit) longevity insurance amounts to approximately 1.1 percent and 1.7 percent of remaining resources for rational and hyperbolic consumers respectively. Hyperbolic consumers especially benefit from this insur-

ance since they value their very old age consumption much higher than rational consumers.¹¹ Finally, scenario (4) simulates the model with unrestricted borrowing in the initial equilibrium. The difference between scenarios (4) and (3) captures the efficiency gains that are due to reduced liquidity constraints after privatization. Liquidity effects are especially important in stochastic economies in which young poor agents expect to climb up to higher income levels in the future. In the benchmark calibration, pension privatization would reduce borrowing constraints, which in turn translates into an efficiency gain of roughly 0.5 percent of aggregate resources. Since hyperbolic consumers regret their consumption behavior at young age later in their life, borrowing constraints serve as a commitment device for them. The elimination of social security reduces this commitment technology, consequently aggregate efficiency gains from reduced borrowing constraints are smaller in economies with hyperbolic consumers. Finally, note that the remaining aggregate efficiency effects of simulation (4) are rather small. This could be explained by the fact that the existing German pension system features a tight tax-benefit linkage (i.e. $\lambda = 0$ in equation (3)). In principle, it would be no problem to go one step further and construct an additional scenario in which the elimination of the paygo pension system is completely neutral.¹² In such a scenario, privatization perfectly converts implicit taxes, savings and debt into their explicit counterparts by a one-time reduction of the contribution rate, but has no impact on the output and welfare of current and future generations, see Fenge (1995) for a theoretical discussion of this result. Fehr and Kindermann (2010) compare pension privatization with tax-favored retirement accounts in economies with rational and hyperbolic consumers. Since savings in retirement accounts are illiquid before retirement they also may represent a commitment technology for short-sighted consumers. Nevertheless, the results confirm the basic intuition that the unfunded pension system provides an important insurance and commitment technology which overcompensates the (negative) liquidity effects. Therefore we conclude this section that Feldstein (1996) was wrong after all. Pension privatization should not be promoted on efficiency grounds. The pension system provides an important commitment technology for short-sighted consumers and an insurance mechanism in a world with imperfect insurance markets. If the reduction of labor supply distortions is considered the policy objective, it could be achieved without social security privatization if policy reforms are implemented which increase the tax-benefit linkage. Therefore, the next section discusses the optimal tax-benefit linkage in a world where the pension system may also provide insurance against income risk.

¹¹ Of course, this rather significant amount is also due to the fact that the model abstracts from a bequest motive. Fehr and Kindermann (2010) include the latter and simulate privatization with and without annuitized accounts in order to quantify the longevity insurance. In this case, the value of the longevity insurance is reduced to roughly 0.5 percent of remaining lifetime resources.

¹² More specifically, such a scenario would require age-specific payroll taxes after the reform, and no capital-income taxation for future interest income from pension debt.

5 Should social security be progressive?

The previous section indicated already that instead of implementing a radical funding policy, marginal tax rates on labor supply could also be reduced by simply tightening the link between benefits received and contributions paid within the pay-as-you-go system. Recently, countries such as Sweden and Italy have followed such a reform strategy and introduced so-called notional defined contribution (NDC) systems. In order to strengthen the link between contributions and benefits, the former are registered on individual accounts and generate a yield which is related to the growth rate of real wages. After retirement future benefits are computed in an actuarially fair fashion given the pension assets accumulated in the accounts, see Palmer (2002). Due to the individual proportionality between contributions and pensions, intra-cohort redistribution is avoided and the labor-leisure distortion is reduced to the (unavoidable) difference between the interest rate and the growth rate of the economy.

The move towards NDC systems is supported by results of CGE simulation studies which indicate substantial efficiency gains from a tighter tax-benefit linkage. For example, Fehr (2000) alters the linkage of the German pension system while Kotlikoff (1998) simulates privatization policies with alternative initial tax-benefit linkages in the US system. However, one has to keep in mind that these studies consider a deterministic world where only the labor supply distortions matter. But if income is uncertain, a tight tax-benefit linkage also reduces the risk-sharing properties of the pension system, since all fluctuations in earnings are carried forward towards retirement. In order to improve the insurance provision of the pension system it may be optimal to increase labor market distortions and reduce the tax-benefit linkage. Fehr and Habermann (2008) analyze the optimal progressivity of the German pension scheme in an economy with idiosyncratic income and lifespan uncertainty and liquidity constraints. Individual preferences on goods and leisure consumption are represented by a time-separable, nested CES utility function which follows Epstein and Zin (1991) in order to separate risk aversion from intertemporal substitution. The benchmark calibration assumes a coefficient of relative risk aversion (η) of 4 and generates an uncompensated wage elasticity of labor supply of -0.03 and a compensated elasticity of 0.3. These figures are in line with empirical estimates for Germany. When people die with positive assets, the (accidental) bequests are distributed within a cohort proportional to current productivity. The initial equilibrium features the perfect linkage of the German system (i.e. $\lambda = 0$ in equation (3)), then we increase the flat benefit fraction λ and compute the resulting aggregate efficiency consequences. When the fraction of flat benefits increases, individuals experience a (positive) insurance effect, a (negative) incentive effect due to rising labor supply distortions and a (negative) liquidity effect since precautionary savings can be reduced

so that liquidity constraints bite stronger.¹³ Table 8 reports the compensated welfare changes for alternative flat-benefit fractions for specific preference structures and institutional settings.

Table 8: Efficiency effects of social security progressivity^a

	λ					
	0.25	0.50	0.75	1.00	1.25	1.50
Benchmark	0.61	1.04	1.28	1.33	1.31	1.18
Risk-neutral preferences	-0.17	-0.38	-0.64	-0.97	-1.39	-1.91
No liquidity constraints	0.94	1.76	2.36	2.70	2.78	2.53
Proportional income tax	0.88	1.55	2.04	2.33	2.44	2.37
Uniform bequest	0.49	0.86	1.06	1.10	0.97	0.69

^aExpressed as a percentage change in initial remaining lifetime resources.
Source: Fehr and Habermann (2008), Table 6 and Table 8.

The first line considers the benchmark calibration. As one can see, the insurance effect always dominates the labor supply and liquidity effect as long as pensions are positively related to the wage level. For $\lambda > 1$ pensions fall with rising wages and the additional labor supply distortions and rising liquidity constraints dominate the marginal insurance effects. Consequently, the first line shows an efficiency gain which rises with the flat-benefit level until $\lambda = 1$ and decreases afterwards. The next line reports the aggregate efficiency consequences of risk-neutral preferences (i.e. $\eta = 0$), which of course are mainly due to labor supply distortions. As one would expect, efficiency losses are now increasing with the progressivity of the system. Next, we assume again risk averse individuals and remove the borrowing constraints in the third line of Table 8. Consequently, the reported figures show the insurance and labor supply effect. Efficiency gains are therefore always higher than in the respective benchmark simulation.

Of course, the optimal progressivity of the pension system also depends on other institutional arrangements in the economy that may provide risk sharing. If, for example, the tax system or the bequest distribution provide for more (less) risk sharing, the required insurance provision of the pension system is reduced (increased). Consequently, the last two lines of Table 8 report the aggregate efficiency gains when we change some institutional arrangements. When the government levies a proportional income tax of 10 percent in the initial equilibrium, the insurance gains and the optimal progressivity of the pension system increases compared to the benchmark, since the tax system is now less redistributive.¹⁴ Finally, we return to the progres-

¹³ Fehr and Habermann (2008) also introduce a basic allowance for contributions in order to improve liquidity, but this is not considered in the following.

¹⁴ Note, however, that progressive income taxes and a progressive social security system are not equivalent. While the former offers insurance against fluctuations in annual earnings the latter offers insurance against fluctuations in lifetime earnings, see Diamond (2004: 12) for a further discussion.

sive tax system but assume that bequests are distributed within a generation independent of actual productivity. Since now bequests offer a partial insurance against income shocks, the insurance gains from pension progressivity are dampened and liquidity constraints are less binding compared to the benchmark economy.

I do not think that these results suggest that the German pension system should be radically changed towards a flat benefit system. But they strengthen again the central point that labor supply distortions should not be the only policy target. Numerical results from CGE studies clearly indicate that social security may provide a quantitatively important insurance role in an uncertain world. As it seems, these (positive) insurance effects may even dominate the (negative) labor supply and liquidity effects for a wide range of parameter values in the standard model. Consequently, I can only agree with Assar Lindbeck and Mats Persson who claim that

"... growing reliance on quasi-actuarial and actuarially fair systems, which in themselves do not encompass any systematic intra-generational redistributive elements, makes it even more imperative to maintain a safety net to prevent poverty in old age." Lindbeck and Persson (2003: 109)

6 Extensions and future research

During the last two decades many attempts have been made to analyze social security issues in dynamic CGE models with overlapping generations. I do not claim that I have covered this enormous literature. Instead the paper is selective and has tried to concentrate on central issues which are important for the social security reform process in many countries. Thereby I have stayed within the framework of the Auerbach and Kotlikoff (1987) approach. Of course, it is no problem to extend the economic structure further and include features such as endogenous human capital, growth, borrowing constraints and retirement. However, these extensions do not really change the central qualitative conclusions derived in the previous sections. Efficiency gains from social security privatization are highly unlikely as soon as the models account for market imperfections and non-rational individual behavior. In addition, a progressive structure with at least some flat benefit fraction seems to be optimal in order to provide intragenerational risk sharing even in a world with a progressive income tax system.

For the future, I expect especially two directions for fruitful further research. First, the role of the family as a disaggregated decision unit and insurance device should be further explored. Kotlikoff and Spivak (1981) already have demonstrated that the family can provide an insurance against longevity risk. Some recent numerical models consider explicitly family formation and dissolution and account for the implicit insurance provision. For example, in Fuster, İmrohoroğlu, and İmrohoroğlu (2007) parents and children are linked by two-sided altruism so that

the intergenerational redistribution induced by public policy is (at least partly) neutralized by *intervivos* transfers and bequests. In addition, borrowing constraints are less binding so that social security mainly provides an insurance against uninsurable "labor ability" shocks at birth. While they find that a transition towards a funded system is beneficial for the majority of individuals considered, an overall assessment of the privatization via efficiency calculation is not provided. Future work may distinguish between husband and wife who jointly determine their marriage, labor supply, home production and fertility decisions. In such a framework the risk sharing properties of social security may be dampened or intensified, depending on the assumptions of the model structure.

Introducing aggregate risk in capital markets will be a second important venue for future CGE models that deal with social security issues. While theoretical papers already indicate the potential beneficial effects from intergenerational risk sharing, quantitative research has only started to analyze the role of social security in such a framework. Krueger and Kubler (2006) simulate a model with nine overlapping generations where aggregate productivity shocks affect the return from capital and the wage rate independently. Without social security, there exists no risk sharing between young and old generations. Consequently, it may be optimal to have a low-yielding paygo program in an optimal portfolio, if welfare gains from intergenerational risk sharing dominate the welfare losses due to the long-run crowding-out of the capital stock. They are able to show that in a small open economy social security may improve long-run welfare if individuals are very risk averse. However, in a closed economy the crowding-out effect of the capital stock always seems to dominate the improved risk sharing. While in the model of Krueger and Kubler (2006) hedging against aggregate risk was very indirect, Olovsson (2010) explores a direct mechanism to transfer aggregate risk across generations. In his three-period model pension benefits are either indexed to wages or to capital returns. The long-run consequences are compared to an equilibrium which reflects the existing US social security system and to a *laissez-fair* equilibrium without social security. It turns out that the economies with highly volatile pension benefits may in fact neutralize the crowding-out of the capital stock and improve long-run welfare significantly compared to the existing social security system. However, the elimination of social security would still yield the highest long-run welfare gains. Therefore, the quantitative results of these initial papers indicate that in the long-run the benefits from intergenerational risk sharing will not dominate the cost from intergenerational redistribution. However, what is still missing is an efficiency evaluation of labor supply distortions and benefits from intergenerational risk sharing. If the latter dominate the former, the efficiency case for social security would be even further strengthened.

References

- Adema, Y., B. van Groezen and L. Meijdam (2009): Population ageing and the international capital market, Netspar Panel paper 15, Tilburg University.
- Auerbach, A.J. and L.J. Kotlikoff (1985): Simulating alternative social security responses to the demographic transition, *National Tax Journal* XXVIII (2), 153-168.
- Auerbach, A.J. and L.J. Kotlikoff (1987): *Dynamic fiscal policy*, Cambridge, Cambridge University Press.
- Auerbach, A.J., L.J. Kotlikoff, R.P. Hagemann and G. Nicoletti (1989): The economic dynamics of an ageing population: The case of four OECD countries, *OECD Economic Studies* 12, 97-130.
- Beetsma R., L. Bettendorf and P. Broer (2003): The budgeting and economic consequences of ageing in the Netherlands, *Economic Modelling*, 20, 987-1013.
- Börsch-Supan, A., A. Ludwig and J. Winter (2006): Ageing, pension reform and capital flows: A multi-country simulation model, *Economica* 73, 625-658.
- Breyer, F. (1989): On the intergenerational pareto efficiency of pay-as-you-go financed pension systems, *Journal of Institutional and Theoretical Economics* 145, 643-658.
- Chauveau, T. and R. Loufir (1997): The future of public pensions in the seven major countries, in: P. Broer and J. Lassila (eds.), *Pension policies and public debt in dynamic CGE models*, Heidelberg, Physica-Verlag, 16-73.
- De Nardi, M., S. İmrohoroğlu and T.J. Sargent (1999): Projected U.S. demographics and social security, *Review of Economic Dynamics* 2, 575-615.
- Diamond, P. (1965): National debt in a neoclassical growth model, *American Economic Review* 55, 1126-1150.
- Diamond, P. (2004): Social security, *American Economic Review* 94(1), 1-24.
- Epstein, L.G. and S.E. Zin (1991): Substitution, risk aversion, and the temporal behavior of consumption and asset returns: An empirical analysis, *Journal of Political Economy* 99, 263-286.
- Fehr, H. (2000): Pension reform during the demographic transition, *Scandinavian Journal of Economics* 102(3), 419-443.
- Fehr, H. (2009): Computable stochastic equilibrium models and their use in pension- and ageing research, *De Economist* 157, 359-416.

- Fehr, H. and C. Habermann (2008): Risk sharing and efficiency implications of progressive pension arrangements, *Scandinavian Journal of Economics* 110, 419-443.
- Fehr, H., C. Habermann and F. Kindermann (2008): Social security with rational and hyperbolic consumers, *Review of Economic Dynamics* 11, 884-903.
- Fehr, H., S. Jokisch and L.J. Kotlikoff (2004): The role of immigration in dealing with developed world's demographic transition, *FinanzArchiv* 60, 296-324.
- Fehr, H., S. Jokisch and L.J. Kotlikoff (2008a): Fertility, mortality, and the developed world's demographic transition, *Journal of Policy Modeling* 30(3), 455-473.
- Fehr, H., S. Jokisch and L.J. Kotlikoff (2008b): Dynamic globalization and its potentially alarming prospects for low-wage workers, NBER Working Paper No. 14527, Cambridge, December 2008.
- Fehr, H. and F. Kindermann (2010): Pension funding and individual accounts in economies with life-cyclers and myopes, *CESifo Economic Studies* 56(3), 404-443.
- Fehr, H. and E. Steigum (2002): Pension funding reforms in a small open welfare state, in: A. Fossati and W. Wiegard (eds.), *Policy evaluation with computable general equilibrium models*, London and New York, Routledge, 232-248.
- Fehr, H. and Ø. Thøgersen (2008): Social security and future generations, in: R. Brent (ed.), *Handbook on Research in Cost-Benefit Analysis*, Cheltenham, Edward Elgar, 417-454.
- Feldstein, M. (1996): The missing piece in policy analysis: Social security reform, *American Economic Review Papers and Proceedings* 86(2), 1-14.
- Fenge, R. (1995): Pareto-efficiency of the pay-as-you-go pension system with intragenerational fairness, *FinanzArchiv* 52, 357-363.
- Fuster, L., A. İmrohoroğlu, and S. İmrohoroğlu (2007): Elimination of social security in a dynastic framework, *Review of Economic Studies* 74, 113-145.
- Hirte, G. (2001): *Pension policies for an aging society*, Tübingen, Mohr Siebeck.
- Holmøy, E. and K. Stensnes (2008): Will the Norwegian pension reform reach its goals? An integrated micro-macro assessment, Discussion paper No. 557, Research Department, Statistics Norway.
- Huang, H., S. İmrohoroğlu and T. J. Sargent (1997): Two computations to fund social security, *Macroeconomic Dynamics* 1, 7-44.
- İmrohoroğlu, A., S. İmrohoroğlu and D.H. Joines (1995): A life cycle analysis of social security, *Economic Theory*, 6, 83-114.

- Kotlikoff, L. (1996): Privatization of social security: How it works and why it matters, in: J. Poterba (ed.), *Tax Policy and the economy* 10, Cambridge MA, MIT Press, 1-32.
- Kotlikoff, L. (1998): Simulating the privatization of social security in general equilibrium, in: M. Feldstein (ed.), *Privatizing social security*, Chicago and London, University of Chicago Press, 265-311.
- Kotlikoff, L.J. (2000): The A-K OLG model: Its past, present, and future, in: G.W. Harrison, S.E.H. Jensen, L.H. Pedersen and T.F. Rutherford (eds.), *Using dynamic general equilibrium models for policy analysis*, Amsterdam, North-Holland, 13-52.
- Kotlikoff, L.J., K.A. Smetters and J. Walliser (1998): The economic impact of privatizing social security, in: H. Siebert (ed.), *Redesigning social security*, Tübingen, Mohr Siebeck, 327-349.
- Kotlikoff, L.J., K.A. Smetters and J. Walliser (1999): Privatizing social security in the United States - Comparing the options, *Review of Economic Dynamics* 2, 532-574.
- Kotlikoff, L.J., K.A. Smetters and J. Walliser (2007): Mitigating America's demographic dilemma by pre-funding social security, *Journal of Monetary Economics* 54(2), 247-266.
- Kotlikoff, L.J. and A. Spivak (1981): The family as an incomplete annuities market, *Journal of Political Economy* 89(2), 372-391.
- Krueger, D. (2006): Public insurance against idiosyncratic and aggregate risk: The case of social security and progressive income taxation, *CESifo Economic Studies* 52, 587-620.
- Krueger, D. and F. Kubler (2006): Pareto improving social security reform when financial markets are incomplete? *American Economic Review* 96(3), 737-755.
- Krueger D. and A. Ludwig (2007): On the consequences of demographic change for rates of return to capital, and the distribution of wealth and welfare, *Journal of Monetary Economics* 54(1), 49-87.
- Lindbeck, A. and M. Persson (2003): The gains from pension reform, *Journal of Economic Literature* XLI, 74-112.
- Nishiyama, S. and K. Smetters (2007): Does social security privatization produce efficiency gains? *Quarterly Journal of Economics* 122(4), 1677-1719.
- Olovsson, C. (2010): Quantifying the risk-sharing welfare gains of social security, *Journal of Monetary Economics* 57(3), 364-375.
- Palmer, E. (2002): Swedish pension reform - How did it evolve, and what does it mean for the future? in: M. Feldstein and H. Siebert (eds.), *Social security pension reform in Europe*, Chicago and London, University of Chicago Press, 171-205.

- Rojas, J.A. (2005): Life-cycle earnings, cohort size effects and social security: A quantitative exploration, *Journal of Public Economics* 89, 465-485.
- Samuelson, P.A. (1958): An exact consumption-loan model of interest, with or without the social contrivance of money, *Journal of Political Economy* 66, 467-482.
- Seidman, L.S. (1986): A phase-down of social security: The transition in a life-cycle growth model, *National Tax Journal* XXXIX, 97-107.
- Sinn, H.W. (2000): Why a funded pension system is useful and why it is not useful, *International Tax and Public Finance* 7, 389-410.
- Solow, R. (1956): A contribution to the theory of economic growth, *Quarterly Journal of Economics* 70(1), 64-95.
- Steigum, E. (1993): Accounting for long-run effects of fiscal policy by means of computable overlapping generations models, in: S. Honkapohja and M. Ingberg (eds.), *Macroeconomic modelling and policy implications*, Amsterdam, Elsevier, 45-71.
- United Nations (2010): *World population prospects: The 2008 revision*, April 12, 2010, <http://esa.un.org/unpp>.