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ABSTRACT

AN ASSESSMENT OF THE VALUE-ADDED TAX, USING COMPUTATIONAL GENERAL EQUILIBRIUM MODEL WITH OVERLAPPING GENERATIONS

By

Jae-Jin Kim

Auerbach and Kotlikoff (1983) found that a consumption taxation would lead to long-run welfare gains, at the expense of the cohorts that are elderly during the transition. Their model has no bequests, and no government transfers. However, bequests explain a large portion of the capital stock, and transfer payments make up a large fraction of the income of the elderly. The inclusion of bequests and transfer payments may affect the results substantially, since they can significantly alter the wealth profile of the elderly. We have incorporated these important factors into a computational general equilibrium model of the United Stated economy and tax system. Our model has bequests, a realistic profile of government transfers, a labor/leisure choice, and a number of other features, including a detailed treatment of the many components of the tax system. Taken together, these factors help to produce a fairly flat wealth profile over the life cycle, which is much more realistic than the extremely humped wealth profiles of Auerbach and Kotlikoff. Our main result is that a consumption tax may lead to welfare gains for all cohorts, including the elderly.

Dedicated to

My father, You-Kyung Kim
My mother, Bong-Sup Shim

My father-in-law, Tae-Young Kim
My mother-in-law, Bong-Soon Lim

My aunt, Choon Sup Shim
My aunt, Ha Sup Shim

My wife, Hye-Kyung
My daughter, Tae-Won

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Chapter 1

INTRODUCTION

1.1. Introduction

The question of whether consumption or income is the appropriate tax base is an important one with a long history of study. Henry Simons (1938) was an eloquent advocate of income taxation, while consumption taxation has been advocated by such distinguished economists as Irving Fisher (1942) and Nicholas Kaldor (1957).

There are two different ways to tax consumption. One method involves indirect taxation, with, for example, a general sales tax or value-added tax (VAT). The second method involves taxing consumption directly by allowing a deduction for saving from the income tax base. The latter approach is sometimes called "personal consumption taxation."

Since the Second World War, value-added taxes have become standard in the European Community, and similar structures have been adopted in recent years in Japan, Canada, and New Zealand. The U.S. Treasury Department's *Blueprints for Basic Tax Reform* (1977) advocated a personal consumption tax. A VAT has not yet been adopted in the United States, nor has the U.S. moved fully toward personal consumption taxation. Nevertheless, it seems unlikely that the debate will end soon. For example, the Chairman of the House Ways and Means Committee, Bill Archer, has advocated the adoption of a national consumption tax.

Besides this tax proposal, there are several other proposals for alternative federal taxes. Senators Pete Domenici (R-N. M.) and Sam Nunn (D-Ga.) proposed the USA (or unlimited saving account) Tax. It levies an 11% VAT on all businesses. It allows exemptions of $17,600 for a family of four. There is a full tax credit for payroll tax payments for both personal and business taxes. It has graduated tax rates for the personal tax, starting at 19% and rising to 40%. Robert Hall and Alvin Rabushka of the Hoover Institution have proposed a 19% flat tax on all businesses, with the deduction of wages and pension contributions from the tax base along with material costs and capital investments. House Majority Leader Richard Armey (R-Texas) and Senator Richard Shelby (R-Ala.) proposed a 20 percent flat tax rate with a $31,400 exemption for a family of four. David Bradford has proposed an X-tax which is similar to Hall-Rabushka, but with graduated tax rates on household wage income to raise progressivity. In this study, I consider the effects of adopting a uniform VAT or national sales tax in the United States. In my simulations, the revenues from this tax will be used to lower the marginal income tax rates.

1.2. Review of the Literature

In a two-period model of consumption choice with no labor supply decision, a consumer chooses between present and future consumption. In this model, a consumption tax has an efficiency advantage over an income tax, since the consumption tax does not generate a substitution effect. Feldstein (1978) shows that this argument neglects the effect of taxes on the individual's choice between leisure and consumption. Since the individual consumes three distinct goods (*i.e.*, first-period leisure, first-period consumption, and second-period consumption), the choice between an income tax and a consumption tax will depend upon the complementarity among all three goods.

In response to the limitations of two-period models, three types of simulation model were developed in the late 1970s and 1980s: the family of "GEMTAP" models, infinite-horizon models, and overlapping-generations life-cycle models.

Summers (1981) studies intertemporal taxation using a simulation model with overlapping generations of life-cycle consumers. Summers's model has no bequests, no labor/leisure choice, no uncertainty, and no borrowing constraints, and there is perfect foresight. Also, the structure of utility is extremely simple, with additively separable, isoelastic utility functions. He takes an entirely different approach from the previous studies, *i.e.*, he chooses parameter values from a variety of sources rather than calibrating them based on real data. This approach generates large estimates of the saving elasticity, which range as high as 3.71. Thus, it is not surprising that he finds very large welfare gains from moving to a consumption tax. Summers explains the high savings elasticities in terms of a "human wealth effect".[1] It should also be emphasized that Summers only looks at steady states. This means that he ignores the possibility of losses during the transition to a new tax regime.

1 When the net rate of return goes up as a result of a change in tax policy, the present value of lifetime wealth goes down. The consumer is now poorer, and reduces his first-period consumption. Thus, saving increases.

Starrett (1982, 1988) points out that the Summers model implies unusual swings in the pattern of consumption. He also shows that some of Summers's parameterizations are associated with highly unrealistic capital/labor ratios for the economy. He suggests two changes in the Summers formulation to control the large saving elasticities. The first change introduces a minimum required level of consumption. The second involves "big-ticket items", that lead to a change in the desired consumption path once these changes are made. Following the suggestion of Starrett, I incorporate minimum required consumption level in my model, in an effort to reduce the intertemporal responses to a more realistic level.

Auerbach and Kotlikoff (1983, 1987) expand this approach by focusing on transition and intergenerational distribution issues. They examine how dynamic tax policy changes such as a change in the tax rate on saving can shift the overall burden of taxes from one generation to another, using assumptions similar to Summers'. They find that the shift to consumption taxation would lead to large long-run welfare gains. However, the large long-run gains come at the cost of harming the cohorts that are old at the time of the policy change. This is explained partly in terms of the inelastic behavior of the old in a simple life-cycle model with no bequests.[2] Auerbach and Kotlikoff find that it is very difficult (but theoretically possible) to establish tax rates that will benefit all age groups.

Fullerton, Shoven, and Whalley (1983) use the "GEMTAP" model, in which infinitely-lived consumers make repeated choices between present and future consumption. Thus, consumption is only affected by current income, not by lifetime wealth. However, the strength of this model is that it can be calibrated precisely to any desired intertemporal elasticity. The welfare gains from the adoption of a full consumption tax are on the order of one percent of wealth, when the transition is evaluated explicitly. These results are broadly similar for savings elasticities between 0.0 and 0.4.

Goulder, Shoven, and Whalley (1983) consider the effect of adopting four alternative forms of VAT in the United States. These include income-type VATs and consumption-type VATs, on both destination and origin bases. Some believe the destination-based VAT in Europe restricts trade, since exports leave Europe tax-free but imports are taxed as they enter. Thus, they have prompted the discussion of adopting VAT in the United Stated for reasons of international competitiveness reason. However, the results of Goulder, Shoven, and Whalley show that foreign trade concerns regarding destination- versus origin-based taxes do not provide a legitimate reason for the United States to introduce a VAT, but a broadly based VAT may lead to welfare gains.

Ballard and Goulder (1985) explore how consumers' expectations can influence the attractiveness of adopting a personal consumption tax in the United States. Using the infinite-horizon model, they find that the welfare gain from adopting a consumption tax is reduced by about ten percent when moving from myopia to a great deal of foresight.

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[2] When each cohort begins and ends its life with zero capital, it must be true that cohorts are dissaving rapidly late in life. Thus, such dissaving is penalized by the consumption tax.

Ballard and Shoven (1987) use the GEMTAP model to examine the efficiency properties of introducing a VAT in the United States. They compute the efficiency-equity trade-off offered by a VAT, using a computational general equilibrium (CGE) model of the U.S. economy and tax system. Their contribution to the literature is the introduction of Stone-Geary inner nest in the consumer utility functions. This closes off a portion of each consumer's income, and thus reduces the overall degree of responsiveness of consumption choice. They consider three types of VAT: an ideal consumption-type VAT, an ideal income-type VAT, and a more politically realistic 'mean European VAT'.[3] However, my model has the same marginal tax rate for all commodities.

In addition to looking at three types of VAT, Ballard and Shoven perform simulations reducing the income tax using additive replacement and multiplicative replacement, which are two different ways in which the income tax could be scaled. They find that the simulation results are very sensitive to the manner of replacement. Additive replacement means additive changes to the marginal income tax rate, *i.e.*, the same number of percentage points is subtracted from (or added to) each household's marginal income tax rate. With multiplicative replacement, each household's marginal tax rate is multiplied by a constant, so that equal government revenue yield is achieved. When tax increases are necessary for equal revenue yield, additive replacement is more efficient. However, when tax reductions are necessary for equal yield, multiplicative replacement is more efficient. The simulation results of Ballard and Shoven show that,

[3] The primary distinguishing characteristics of the European VATs are the consumption base, the destination base, and differentiated rate structure. See Aaron (1981) and Cnossen (1982) for a discussion of rate structures of the European VATs.

even though rate differentiation does reduce the regressiveness of the VAT somewhat, the VATs are generally regressive, and that rate differentiation is not a very efficient way to redistribute income. Although their results are interesting, they cannot look at some important issues such as the intergenerational distribution.

Ballard, Scholz, and Shoven (1987) study three types of consumption-based tax: an ideal flat consumption VAT, a stylized European VAT, and a progressive expenditure tax. They find that the adoption of a flat consumption-based equal-revenue-yield VAT leads to modest welfare gains in the aggregate. For their central-case simulations, they have larger welfare gains when multiplicative replacement rather than additive replacement is used. This fact reminds us that the method of tax replacement can be just as important as the tax policy change itself. Although rate differentiation like that of the European VATs reduces its regressivity on the VAT, it leads to substantial reductions in the welfare gains at the same time. Thus, there is a trade-off between equity and efficiency.

Ballard, Scholz, and Shoven also consider the welfare effects of replacing the corporate income tax with these three types of VAT. This replacement produces fairly substantial welfare gains, regardless of the type of replacement for equal revenue yield. The attractiveness of the policies ultimately depends on what kind of a social welfare function is used. Their results show that a Benthamite would favor all three types of VAT, while a Rawlsian would advocate a differentiated VAT with additive replacement, or the progressive expenditure tax with either additive or multiplicative replacement.

Finally, their sensitivity analysis says that a greater saving elasticity always leads to larger welfare gains, as expected.

Feldstein and Krugman (1990) use a simple three-good, two-period model to explore the international trade effects of a VAT. They show that the widespread belief that VATs give the traded goods sectors of countries with VATs an advantage over the corresponding sectors of countries that rely on income taxation, is incorrect. They argue that a VAT may improve competitiveness in the short run by offering less bias against saving than an income tax, and this tends to improve the trade of balance, other things being equal. However, an offsetting effect is that, a VAT tends to be levied more heavily on traded goods, thus reducing rather than increasing the size of a country's traded-goods sector. Thus, on balance, we have an uncertain effect on a nation's net exports in the short run. However, in the long run, imports may increase in excess of exports as a result of the accumulation of foreign investment. Feldstein and Krugman conclude that the common belief that a VAT is a kind of disguised protectionist policy is based on a misunderstanding.

Jorgenson and Yun (1990) use an infinite-horizon model with an intertemporally additive utility function to evaluate the impact of the Tax Reform Act of 1986 on U.S. economic growth. They find that the welfare gain from moving to a consumption tax from an income tax is much larger than the gain from the Tax Reform Act of 1986. However, since the infinite-horizon models are usually characterized by a very large intertemporal responsiveness, we must be careful in interpreting the welfare results of these simulation models. In addition, since these models abstract from the simultaneous existence of many generations of different ages, they can not consider intergenerational issues.

1.2.1. The Role of Bequests

Many of the models discussed above leave out intergenerational issues, which are important for many reasons. At this point, I will discuss some of the empirical literature on bequests.

Using cross-section Social Security data, Mirer (1979) finds that the wealth of the aged does not decrease during their lifetimes, and adds that "Precautionary, bequest, or other motives must be taken into account if the theory is to explain the wealth holding behavior of persons toward the end of their lives." White (1978) uses a simulation approach, and finds that the simple life-cycle theory without bequests cannot explain the total amount of observed aggregate personal saving. Her simulated values of aggregate saving represent no more than about 60 percent of the observed values.

Kotlikoff and Summers (1981) estimate historic age-earnings and age-consumption profiles. These profiles are combined with data on rates of return to calculate a stock of life-cycle wealth. They compare this stock of life-cycle wealth with aggregate wealth holdings in the United States, to see whether any intergenerational transfers occur. They conclude that the simple life-cycle theory of saving with no intergenerational transfers is a very poor description of the process of capital accumulation in the U.S. economy. In other words, intergenerational transfers are responsible for a sizable amount of wealth accumulation in the U.S..

Gale and Scholz (1994b) conclude that *inter vivos* transfers and bequests may account for about 51 percent of net wealth accumulation. This implies that an overlapping-generations model will have great difficulty in capturing the stylized facts of the economy, unless it incorporates intergenerational transfers in an explicit way.

In fact, without bequests, consumers are born with no capital and die without leaving any capital. If the model is to generate a large capital stock (like the one actually observed), this requires consumers to save a tremendous amount early in life, followed by very rapid dissaving late in life. Thus, we observe a very steep wealth profile during their working years, and a very rapid decrease in wealth during the retirement period. This fact leads to the widely-publicized results of Auerbach and Kotlikoff that the move to consumption taxation would lead to large welfare gains at the cost of harming the cohorts that are elderly at the time of the policy change.

1.3. Plan for this Research

In the GEMTAP model, the consumer makes a choice in every period between present and future consumption. Thus, the model is basically an infinitely repeated two-period model. The advantage of this model is that it can be calibrated to any desired intertemporal elasticity. However, it is not attractive theoretically, since consumers make their decisions subject to a constraint on current income, rather than an entire lifetime wealth stream. It also ignores issues of intergenerational distribution.

In infinite-horizon models, such as those of Jorgenson-Yun and Ballard-Goulder (1985), a single consumer maximizes the utility from an infinite stream of consumption, subject to an infinite stream of wealth. This type of model tends to produce an unrealistically large saving elasticity, which will tend to lead to overstated welfare gains. In addition, since these models abstract from the simultaneous existence of many generations of different ages, they cannot consider intergenerational issues.

An overlapping generations life-cycle model is attractive because it can explore intergenerational issues. However, it does not necessarily remove the possibility of very high intertemporal elasticities.

The purpose of my dissertation is to build a model that not only addresses the intergenerational issues that first came to our attention with Auerbach and Kotlikoff, but also overcomes some of the problems of that model. First of all, I want to lower the elasticity, so that the overall size of the intertemporal responses is reasonable. Just as important, however, I want to deal with one of most widely-publicized results of Auerbach and Kotlikoff, the story that the elderly are badly hurt during the transition period in the movement from an income tax to a consumption tax. Since Auerbach-Kotlikoff do not incorporate either bequests or government transfers, they generate unusual wealth profiles. All of the evidence (*e.g.*, White, Mirer, Kotlikoff-Summers, Gale and Scholz) shows that wealth profiles are fairly flat. Thus, I want to incorporate bequests and government transfers in order to create flatter, more realistic wealth profiles.

Since the purpose of my model is to improve on some of the problems of Auerbach and Kotlikoff, it is worthwhile to compare the major differences between two models. Table 1 shows the differences between my model and that of Auerbach and Kotlikoff.

Table 1. Difference Between My Model and Auerbach and Kotlikoff's

	A-K (1983)	A-K (1987)	My Model
$\bar{\delta}$	No	0.25	0.4
$\bar{\sigma}$	1	0.8	0.8
ρ	0.02	0.015	0.01
Foresight	Perfect Foresight	Perfect Foresight	Myopia
Bequests	No	No	Yes
Government Transfers	No	No	Yes
Labor/leisure Choice	No	Yes	Yes
C^*	No	No	Yes

$\bar{\delta}$ =Intertemporal Elasticity of Substitution Between Consumption and Leisure
$\bar{\sigma}$ =Intratemporal Elasticity of Substitution Between Consumption and Leisure
ρ =The Rate of Time Preference
C^*=Minimum Required Consumption Level

Chapter 2

DESCRIPTION OF THE SIMULATION MODEL

2.1. Model Structure

2.1.1. The Household Sector

We assume that, in every period, aggregate consumption, saving, and labor supply are derived from the intertemporal optimizing behavior of individual generations. Each generation or cohort has an economic life of 55 years (for example, from age 21 through age 75), and a new cohort is "born" each period (one period is five years).[4] Thus, in any period, there are 11 cohorts of different ages making household decisions.

Households derive utility from consumption, leisure, and bequest-giving. The utility function for any given cohort takes the following additively separable form:[5]

$$(1) \qquad \mathrm{U} = \frac{1}{\delta}\sum_{t=1}^{T}\frac{1}{(1+\rho)^{t-1}}\left\{\left(C_t - C^{*}\right)^{\sigma} + \alpha\left(H^{*} - H_t\right)^{\sigma}\right\}^{\frac{\delta}{\sigma}} + \frac{1}{\delta}\frac{1}{(1+\rho)^{T}}b^{1-\delta}B_T^{\delta}.$$

In the above expression, t is the period, T is the index for the last period of life, C_t is consumption in period t, C^{*} is minimum required consumption[6], H^{*} is potential labor

[4] Auerbach and Kotlikoff also assumed an economic lifetime of 55 years. However, they calculate equilibria every year. The assumption of a five-year period reduces computational expense, without sacrificing a great deal of information.

[5] This kind of intertemporal additively separable utility function is used by virtually all researchers in the field. However, it should be emphasized that it is not used primarily because of realism, but because it is tractable. Lifetime utility functions of this sort can be found in Ballard (1983), Auerbach and Kotlikoff (1983), and Ballard and Goulder (1987). The bequest formulation is discussed in Blinder (1974).

time, and H_t is labor supply in period t. Thus, leisure in period t, which we call $\hat{H}_t$ or l_t, is defined as $H^* - H_t$. The parameter ρ is the rate of time preference.[7] The parameter $\sigma \equiv 1 - 1/\bar{\sigma}$, where $\bar{\sigma}$ is the elasticity of substitution between C and l in a given period. The parameter $\delta \equiv 1 - 1/\bar{\delta}$, where $\bar{\delta}$ is the elasticity of substitution between bundles of C and l across periods. To maintain dynamic consistency, the elasticity of substitution between consumption/leisure bundles and bequests is also $\bar{\delta}$. The distribution parameter α influences the intensity of demand for leisure at given relative prices.

B_T is the bequest left at the end of year T.[8] The parameter b determines the strength of the bequest motive. When b is zero, individuals derive no benefits from bequest-giving. Thus, since length of life is assumed to be known with certainty, such that accidental bequests are ruled out, the consumers will not leave any bequests when $b=0$. The larger the value of b, the more bequests individuals leave, thus the greater the fraction of lifetime resources left by individuals to succeeding generations. This type of

6 Note that, even though I include C* (minimum required consumption level) in the model, it does not mean that tax base is changed.

7 We assume that ρ is constant, in order to maintain dynamic consistency in the sense of Strotz (1955-1956).

8 We assume certain date of death, as Auerbach and Kotlikoff did, but others relax this assumption. We also assume that all bequests come at end of life. We abstract from gifts *inter-vivos.* Gale and Scholz (1994b) distinguish between intended transfers and unintended transfers using the 1983-86 Survey of Consumer Finances. Their estimate shows that intended transfers (*i.e.*, *inter-vivos transfers*) account for at least 20% of net worth. Their results show that bequests account for an additional 15% of net worth. Thus, intergenerational transfers account for at least 35%, and probably around 50% of net worth. We collapse *inter vivos* gifts into bequests in our model.

bequest theory has been used, for example, by Blinder (1974). However, it should be noted that other plausible explanations for bequests have been proposed.[9]

Each cohort maximizes utility subject to an intertemporal wealth constraint. Suppressing taxes for expositional convenience, we can write the lifetime wealth constraint as:

$$(2) \qquad P_{K_1} K_1 + \sum_{t=1}^{T} \left\{ W_t'\left(H^* - l_t\right) + TR_t + IN_t - P_t C_t \right\} d_t - P_{B_T} B_T d_T = 0 ,$$

where P_{K_1} is the current price of a unit of nonhuman capital, K_1 is the current capital endowment, W' is the hourly wage, TR is transfers, and IN represents inheritances. The variable P_t refers to the price index for consumption, which is a weighted average of the price of specific consumption goods purchased in the given period. The discounting operator for period t, d_t, is defined by

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9 Davies (1981) takes the importance of bequests as given, and attempts to explain why bequests take place. He suggests that consumers do not gain utility from bequests, but rather that they are forced to leave accidental bequests as a result of the lack of well-functioning annuities markets. He finds that uncertainty about length of life can indeed depress consumption if the intertemporal substitution elasticity is sufficiently small. Bernheim, Shleifer, and Summers (1985) suggest that bequests are a device by which parents manipulate the behavior of their children. Barro (1974) regards bequests as arising from the intertemporal utility maximization decision of intergenerationally altruistic individuals. Such individuals maximize a utility stream which includes the utilities of their immediate descendants as well as themselves. Wolfe and Goddeeris (1987) emphasize uncertainty about future health status as a possible additional reason for accidental bequests. Kotlikoff (1986) shows that uncertain health expenditures represent a strong motive for saving. However, this motive may be greatly influenced by the availability of private insurance and the presence of government programs such as Medicaid. Hubbard, Skinner, and Zeldes (1995) find that the presence of asset-based means-tested social insurance leads to a non-monotonic relationship between wealth and consumption for lifetime low-income families, which is inconsistent with the orthodox life-cycle model. They suggest that a properly specified life-cycle model with precautionary saving and social insurance can explain the heterogeneity in motives for saving. Carroll and Samwick (1992) provide some evidence that wealth is higher for consumers with greater income uncertainty. They find that the pattern of precautionary saving is more consistent with the "buffer-stock" models of saving, in which consumers hold wealth to buffer consumption against near-term fluctuations in income, and are far less concerned about uncertainty in lifetime income than in the standard model.

$$d_t \equiv \begin{cases} \dfrac{1}{\prod_{s=1}^{t-1}(1+r_s)} & ,\forall t > 1 \\ 1 & ,\ t = 1 \end{cases} .$$

where r_s is the expected rate of return between period s and period $(s+1)$. Equation (2) thus states that the sum of current non-human wealth and the present value of prospective lifetime labor income, transfers, and inheritances must equal the present value of consumption plus bequests.

We can write the labor supply constraint as:

(3) $$\left(H^{*} - l_t\right) \geq 0 \ \text{ for all } t .$$

Equation (3) states that the labor supply cannot be negative in any period.

Each cohort has a given endowment of potential labor time $\left(H^{*}\right)$, which is allocated to working and leisure: $H^{*} = H_t + l_t$. The value of H^{*} is constant over the lifetime of a given cohort. The hourly wage $\left(W_t'\right)$ can be written as

(4) $$W_t' = W_t e_h \ ,$$

where W_t is the prevailing wage per unit of effective labor, and e_h is the ratio of effective labor to labor hours for a cohort of age h. The labor efficiency ratio $\left(e_h\right)$ changes over the lifetime of a given cohort, reflecting changes in skills as a result of experience and age.

Some key aspects of the solution to the consumer's lifetime utility maximization will be discussed here. Details are provided in part 1 of the Appendix. The consumer's choice variables are consumption (C_t) and leisure $\left(l_t, \text{or } H^* - H_t\right)$ in each period, and the size of the bequest (B_T). We can form the Lagrangean function by combining equations (1), (2), and (3):

$$(5)\ L = \frac{1}{\delta}\sum_{t=1}^{T}\frac{1}{(1+\rho)^{t-1}}\left\{\left(C_t - C^*\right)^{\sigma} + \alpha_t\left(H^* - H_t\right)^{\sigma}\right\}^{\frac{\delta}{\sigma}} + \frac{1}{\delta}\frac{1}{(1+\rho)^{T}}b^{1-\delta}B_T^{\delta}$$
$$+\lambda\left[P_{K_1}K_1 + \sum_{t=1}^{T}\left\{W_t'\left(H^* - l_t\right) + TR_t + IN_t - P_tC_t\right\}d_t - P_{B_T}B_Td_T\right]$$
$$+\lambda\left\{\sum_{t=1}^{T}\mu_t\left(H^* - l_t\right)d_t\right\} ,$$

where λ is the Lagrange multiplier and represents the marginal utility of lifetime resources, and the μ_t's are the Kuhn-Tucker multipliers on the constraints on labor supply.

Taking the first-order conditions for consumption and leisure, and rearranging, gives us the following expressions:

$$(6)\qquad \frac{1}{(1+\rho)^{t-1}}\left(\hat{C}_t^{\sigma} + \alpha_t l_t^{\sigma}\right)^{\frac{\delta}{\sigma}-1}\hat{C}_t^{\sigma-1} = \lambda P_t d_t \ ,$$

and

(7) $$\frac{1}{(1+\rho)^{t-1}}\left(\hat{C}_t^{\sigma}+\alpha_t l_t^{\sigma}\right)^{\frac{\delta}{\sigma}-1}\alpha_t l_t^{\sigma}=\lambda\left(W_t'+\mu_t\right)d_t\ .$$

Equation (6) indicates that the marginal utility of consumption at time t must equal the marginal cost of consumption, and equation (7) shows that the marginal utility of the leisure must equal its marginal opportunity cost.

Dividing (6) by (7) and arranging, we solve for l_t (leisure in period t) as a function of consumption in period t and various parameters:

(8) $$l_t=\hat{C}_t\xi_t\ ,$$

where $\xi_t=\left(\dfrac{W_t'+\mu_t}{\alpha_t P_t}\right)^{\frac{1}{\sigma-1}}$.

Substituting (8) into (6) and manipulating terms gives us:

(9) $$\hat{C}_t=\lambda^{\frac{1}{\delta-1}}P_t^{\frac{1}{\delta-1}}\left(\frac{(1+\rho)}{\prod_{s=1}^{t-1}(1+r_s)}\right)^{\frac{1}{\delta-1}}\left(1+\alpha_t\xi_t^{\sigma}\right)^{\left(1-\frac{\delta}{\sigma}\right)\left(\frac{1}{\delta-1}\right)}.$$

Dividing (9) for period t by (9) for period (t-1) yields:

$$(10) \qquad \frac{\hat{C}_t}{\hat{C}_{t-1}} = (1+\eta_t)\left(\frac{P_t}{P_{t-1}}\right)^{\frac{1}{\delta-1}}\left(\frac{1+\alpha_t\xi_t^\sigma}{1+\alpha_{t-1}\xi_{t-1}^\sigma}\right)^\psi ,$$

$$\text{where } \begin{cases} \eta_t = \left(\dfrac{1+\rho}{1+r_{t-1}}\right)^{\frac{1}{\delta-1}} - 1, \text{ i.e., the reference growth rate of consumption,} \\ \text{and} \\ \psi = \left(1-\dfrac{\delta}{\sigma}\right)\left(\dfrac{1}{\delta-1}\right) = \left(\dfrac{\sigma-\delta}{\sigma}\right)\left(\dfrac{1}{\delta-1}\right) = \dfrac{\sigma-\delta}{\sigma(\delta-1)} . \end{cases}$$

By recursively applying (10) over successive periods and manipulating, we can express $\hat{C}_t$ in terms of $\hat{C}_1$ and the parameters of the problem:

$$(11) \qquad \hat{C}_t = \hat{C}_1\Omega_t ,$$

$$\text{where } \Omega_t = \left\{\left(\frac{P_t}{P_1}\right)(1+\rho)^{t-1}d_t\right\}^{\frac{1}{\delta-1}}\left(\frac{1+\alpha_t\xi_t^\sigma}{1+\alpha_1\xi_1^\sigma}\right)^\psi .$$

Equation (11) represents an optimal consumption path. Once the optimal $\hat{C}_1$ is known, we can obtain an optimal consumption path conditional on expected prices and interest rates.

Differentiating the Lagrangean function with respect to bequests (B_T) yields:

$$(12) \qquad \frac{1}{(1+\rho)^T} b^{1-\delta} B_T^{\delta-1} = \lambda P_{B_T} d_T ,$$

which indicates that the marginal utility of the bequest must equal its marginal opportunity cost. Rearranging (6) gives us:

(13) $$\lambda = \frac{1}{P_T d_T} \frac{1}{(1+\rho)^{T-1}} \left(\hat{C}_T^{\sigma} + \alpha_T l_T^{\sigma} \right)^{\frac{\delta}{\sigma}-1} \hat{C}_T^{\sigma-1}.$$

Substituting (8) and (11) into (13) and rearranging terms yields the following expression:

(14) $$\lambda = \left((1+\rho)^{T-1} P_T d_T \right)^{-1} \left(1 + \alpha_T \xi_T^{\sigma} \right)^{\frac{\delta}{\sigma}-1} \left(\hat{C}_1 \Omega_T \right)^{\delta-1}.$$

Substituting (14) into (12) and rearranging terms gives us an expression for the optimal bequest in terms of discretionary consumption in the base period:

(15) $$B_T = b\phi \hat{C}_1 \Omega_T ,$$

$$\text{where } \phi = \left(\frac{(1+\rho) P_{B_T}}{P_T} \right)^{\frac{1}{\delta-1}} \left(1 + \alpha_T \xi_T^{\sigma} \right)^{\frac{\delta-\sigma}{\sigma(\delta-1)}}.$$

Equation (15) implies that bequests are equal to zero when the bequest intensity parameter (b) is zero, and that bequests increase with b. Although equation (15) suggests a linear relationship between bequests and b, this is not the case, since higher values of b entail lower discretionary consumption. (We have to reduce consumption in order to leave a larger bequest.)

Substituting (11) into (8), we have

(16) $$l_t = \hat{C}_1 \Omega_t \xi_t \ .$$

From equation (11), we have

(17) $$C_t = C^{*} + \left(C_1 - C^{*}\right)\Omega_t \ .$$

Substituting (11), (15), (16), and (17) into (2), and rearranging terms, gives us an initial optimal consumption:

(18) $$C_1 = C^{*} + \frac{P_{K_1} K_1 + \sum_{t=1}^{T} \left\{ \left(W_t' + \mu_t\right) H^{*} + TR_t + IN_t - P_t C^{*} \right\} d_t}{\sum_{t=1}^{T} \Omega_t \left\{ \left(W_t' + \mu_t\right) \xi_t + P_t \right\} d_t + P_{B_T} b \phi \Omega_T d_T} \ .$$

In the above equation, first-period consumption $\left(C_1\right)$ is linearly homogeneous in lifetime resources (initial wealth plus the present value of lifetime potential labor time, transfers, and inheritances). Equations (18) and (10) imply that, for given lifetime resources and prices, a lower *b* indicates higher consumption at each point in time.

Once we get the initial equilibrium consumption level ($\hat{C}_1$), we can calculate an equilibrium consumption path according to (11). By substituting this equilibrium consumption path into (8) and the leisure constraint, we can get the equilibrium leisure path and thus the equilibrium labor path:

$$(19)\qquad \begin{cases} C_t = C^* + (C_1 - C^*)\Omega_t \\ l_t = (C_t - C^*)\xi_t \\ H_t = H^* - l_t \ . \end{cases}$$

From equation (10), the rate of consumption growth is negatively related to the growth rate of prices (P_t / P_{t-1}) and positively related to the interest rate (r_t) and to the growth rate in the real wage. In the steady-state, $P_t = \overline{P}$ and $r_t = \bar{r}$, and the consumption growth equation becomes:

$$(20)\qquad \frac{\hat{C}_t}{\hat{C}_{t-1}} = (1+\overline{\eta})\left[\frac{1+\alpha_t \xi_t^{\sigma}}{1+\alpha_{t-1}\xi_{t-1}^{\sigma}}\right]^{\psi},$$

where the steady-state reference growth rate of consumption ($\overline{\eta}$) is:

$$(21)\qquad \overline{\eta} = \left(\frac{1+\rho}{1+\bar{r}}\right)^{\frac{1}{\delta-1}} - 1 .$$

Thus, lower values for time preference (ρ) or higher values for the intertemporal elasticity of substitution ($\bar{\delta}$), which is inversely related to δ, imply a steeper consumption profile in the steady state. Although the growth rate of aggregate consumption is a constant in the steady state, the growth rate of individual consumption is not. Individual consumption growth will depend positively on the hourly wage, W_t' (or $W_t e_h$), and this in turn will vary over one's lifetime according to changes in e_h. These variations imply that the bracketed component of equation (20) will not be constant over time. Thus the growth rate of individual consumption changes over the lifetime.

From (8), leisure is related to discretionary consumption according to:

$$l_t = \left(C_t - C^*\right)\left(\frac{W_t' + \mu_t}{\alpha_t P_t}\right)^{\frac{1}{\sigma-1}} .$$

Thus, with σ<1, leisure in period *t* is positively related to P_t and negatively related to W_t'. The optimal labor path (H_t) is negatively related to P_t and positively related to W_t', since $H_t = H^* - l_t$.

2.1.2. The Production Sector

The structure of the production submodel is similar to that of the GEMTAP model of Fullerton, Shoven, and Whalley. (The reader may refer to Ballard *et al.* (1985) for detail.) This model includes 19 profit-maximizing industries, which produce value added with capital and labor. In addition, a portion of the output of each of the 19 industries is used as intermediate input. Each industry uses labor and capital in a constant elasticity of substitution (CES) value-added function. The industries also use the outputs of other industries through a matrix of fixed input-output coefficients.

Since each industry purchases outputs from other industries, the output of a given industry meets both final demand and the intermediate goods demands of industry. Each of the 19 industries creates a producer good that can be used as an intermediate input, or can be transformed into 17 consumer goods and one capital investment good that are demanded directly by households. The goods classification of the consumer expenditure data is different from the classification of the outputs of the production sectors. Thus, the 19 goods produced by industry do not correspond to the commodities purchased by consumers. To accommodate these different classifications, we convert these 19 producer goods into 18 consumer goods by a fixed-coefficient "Z" matrix. The 18 goods include 17 consumption categories, plus one "savings/investment good", which is a composite of the producer goods that are used in the investment process. The 19 producer goods and the 17 consumer goods other than saving are listed in Table 2.

2.1.3. The Foreign Sector

For each of the 19 producer goods, we specify foreign export demand and import supply functions. These functions incorporate parameters that determine constant price elasticities of import supply and export demand:

$$(22) \qquad \begin{cases} M_i = M_i^0 (P_{Mi}^w)^{\theta} & 0 < \theta < \infty, \quad i = 1, \ldots, 19, \\ E_i = E_i^0 (P_{Ei}^w)^{\nu} & -\infty < \nu < 0, \quad i = 1, \ldots, 19. \end{cases}$$

where M_i and E_i are import demand and export supply, M_i^0 and E_i^0 are constants, P_{Mi}^w is the world price of imports, P_{Ei}^w is the world price of U.S. exports, and θ and ν are the price elasticities of import supply and export demand. These equations imply that the i^{th} commodity can be both imported and exported.

Table 2. Classification of Industries and Consumer Expenditures

	Producer Goods (Industries)		Consumer Goods (Expenditure Categories)
1.	Agriculture, forestry, and fisheries	1.	Food
2.	Mining	2.	Alcohol
3.	Crude petroleum and gas	3.	Tobacco
4.	Contract construction	4.	Household food and utilities
5.	Food and tobacco	5.	Shelter
6.	Textile, apparel, and leather	6.	Furnishing
7.	Paper and printing	7.	Application
8.	Petroleum	8.	Apparel
9.	Chemicals, rubber, and plastics	9.	Public transportation
10.	Lumber, furniture, stone, clay, and glass	10.	New and used cars, fees and maintenance
11.	Metals, machinery, instruments, and miscellaneous manufacturing	11.	Cash contributions and personal care
12.	Transportation equipment and ordnance	12.	Financial services
13.	Motor vehicles	13.	Reading and entertainment
14.	Transportation, communications, and utilities	14.	Household operations
15.	Trade	15.	Gasoline and motor oil
16.	Finance and insurance	16.	Health care
17.	Real estate	17.	Education
18.	Services		
19.	Government enterprises		

The model allows for the phenomenon of *crosshauling*, which means that a given commodity can be both exported and imported. There can be many reasons for this phenomenon. Armington (1969) asserts that foreign commodities are qualitatively different from domestic goods. This imperfect substitutability is often referred to as the Armington assumption. In this model, however, we explain crosshauling by reference to geography and transportation costs.[10]

In order to close the system and solve the general equilibrium model, we add the trade balance constraint:

(23) $$\sum_{i=1}^{19} P_{Mi}^{w} M_i = \sum_{i=1}^{19} P_{Ei}^{w} E_i \ .$$

If we substitute equation (22) into equation (23), we have

(24) $$\sum_{i=1}^{19} P_{Mi}^{w} M_i^0 \left(P_{Mi}^{w}\right)^{\theta} = \sum_{i=1}^{19} P_{Ei}^{w} E_i^0 \left(P_{Ei}^{w}\right)^{v} .$$

We define the relationship between U.S. and world prices through an exchange rate term, e, as

(25) $$\begin{bmatrix} P_{Ei}^{US} = eP_{Ei}^{w} \\ P_{Mi}^{US} = eP_{Mi}^{w} \ . \end{bmatrix}$$

The model is, of course, a real model and has no financial exchange rate variable, but the use of this construct enables us to write foreign import supply and export demand as

[10] Ballard *et al.* (1985) give an example: "It may be perfectly sensible for the United States to export Alaskan oil to Japan and at the same time import the identical product through ports on the East Coast and the Gulf of Mexico, given the cost of delivering Alaskan oil to the eastern United States."

functions of U.S. prices rather than of world prices. U.S. prices are determined endogenously in the model. If we substitute these prices into (24) and rearrange terms, we have:

$$(26) \qquad e = \left(\frac{w_2}{w_1}\right)^{\frac{1}{\nu-\theta}},$$

$$\text{where} \quad \left[\begin{array}{l} w_1 = \sum_{i=1}^{19} \left(P_{Mi}^{US}\right)^{\theta+1} M_i^0 \\ w_2 = \sum_{i=1}^{19} \left(P_{Ei}^{US}\right)^{\nu+1} E_i^0 . \end{array}\right.$$

Finally, substituting equations (25) and (26) into equation (22), gives

$$(27) \qquad \left[\begin{array}{l} M_i = M_i^0 \left(P_{Mi}^{US}\right)^{\theta} \left(\frac{w_2}{w_1}\right)^{\frac{\theta}{\theta-\nu}} \\ E_i = E_i^0 \left(P_{Ei}^{US}\right)^{\nu} \left(\frac{w_2}{w_1}\right)^{\frac{\nu}{\theta-\nu}} . \end{array}\right.$$

Note that w_1 and w_2 are themselves functions of U.S. import and export prices. Equations (27), thus, can be thought of as foreign import supply and export demand functions, written as functions of U.S. prices, and incorporating zero trade balance.

I treat the foreign trade activity of the United States in a simple manner, so as to close the model: We do not deal with capital flows (*i.e.*, while the economy in this model is open to balanced international flows of goods and services, it is not open to international capital flows). However, as foreign trade has increased rapidly as a fraction of GNP and capital markets have become more international for the last few decades, there has been growing interest in open-economy models for analyzing the effect of changes in tax policies. Several studies have investigated the effects of international capital flows in the context of general-equilibrium tax models.[11] Second, I do not differentiate between commodities on the basis of origin (*i.e.*, we do not employ the assumption of Armington (1969)).

Despite these simplifying assumptions, foreign trade has an effect on the model. Foreign trade introduces a difference between the aggregate demands of consuming groups in the United States (broadly defined to include business investment and government purchases) and the demands for products faced by U.S. domestic industries. The demand for U.S. exports by foreigners has a negative price elasticity, while the supply of imports to the United States has a positive price elasticity. The relative prices of traded goods are determined endogenously in the model. Trade balance is assured, since the export demand and import supply functions satisfy budget balance.

2.1.4. The Government Sector

General Features:

The model represents in detail the taxation, production, consumption, and transfer roles of the government. In the base case, the model generates a steady-state growth path.

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[11] Goulder, Shoven, and Whalley (1983) found that the allowance for international capital service flows can either greatly increase the efficiency gain of a tax policy in the case of corporate tax integration, or turn a significant gain to a large loss as we move to a consumption tax. Their results indicate that the evaluation of domestic tax policy is very sensitive to the functioning of international capital markets. Goulder (1989) pointed out that, for a small open economy, subsidizing saving would not increase welfare as most of the increased saving will spill into the foreign capital market. The nation thus will lose revenue without augmenting its own capital. He found that the welfare effects of investment subsidies are muted, since some of the returns from the additional capital will be paid to foreign investors. His results depend, in part, upon his use of an infinite-horizon model, which tends to give large intertemporal welfare effects.

Relative prices remain constant through time, and all outputs and aggregate incomes grow at the growth rate of the overall economy. In addition, government spending, tax revenue, government deficits, and government debt all remain in constant proportion to GNP. In the revised case, we maintain the same growth of government debt as in the base case, but examine the effects of changing the configuration of tax rates, while holding the profiles of real government spending and bond issue fixed.[12]

We divide government activities into three broad categories: general government activities, government enterprises, and transfer payments.

1) General Government Activities: Government offers some goods and services to the public, free of charge. These goods and services may be true public goods, or they may be private in nature. Expenditures by government, other than those for public enterprises, are an element of final demand. These expenditures include payments for capital and labor services and purchases of industry outputs. We model the government as if it were a single consumer, with a Cobb-Douglas utility function defined over all 19 producer goods, capital, and labor.[13] These government expenditures do not enter the utility functions of consumers as public goods. When tax rates are changed for a simulation, an alternative source of tax revenue is changed, so that government

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[12]The model of bonds and debt used in this study is essentially the same as that described in a paper by Goulder (1985), which allows for alternative government financing and contains the overlapping-generations features described in this paper. With the exception of the treatment of bond issuance and debt, the modeling of government is similar to that in Ballard, Fullerton, Shoven, and Whalley (1985), and in Ballard and Goulder (1987).

[13]We do not really claim that government is a Cobb-Douglas consumer. The main purpose of this assumption is to allow for some responsiveness to output price changes. In any case, it does not greatly affect the results of the model when we simulate the effects of the structural tax reforms. We simply use the government utility function, and the corresponding expenditure function, to hold constant the government's revenue in real terms. Thus, what is important is the concept of equal-revenue-yield equilibrium.

expenditures are held constant in real terms, and the government budget remains in balance. Consequently, we only need to be concerned with changes in consumer utility when we want to calculate the total welfare change from some policy.

2) Government Enterprises: Government produces certain goods and services that are sold in private markets. The government enterprises (*e.g.*, postal services and some utilities) provide the goods and services subject to user charges, even though the charges may not cover costs. The model treats government enterprises as an industry (number 19); thus it operates like the other private industries. It uses primary factors and intermediate inputs and earns zero economic profits. This industry receives a large subsidy, such that its output is sold substantially below cost. This means that the effective output tax rate for government enterprises in the model is negative.

3) Transfer Payments: The government makes redistributive transfer payments directly to consumers in a lump-sum fashion in each period. We use data for Social Security, Supplemental Security Income, Food Stamps, Aid to Families with Dependent Children, and other welfare programs to determine the amount of transfers payments. These transfers are held constant in real terms during simulations, using a Laspeyres price index.

The government collects taxes on capital, labor, outputs, income, intermediate goods purchases, and consumer purchases. The government uses its revenue to make transfer payments to consumers, and to subsidize government enterprises. The government uses the remaining revenues to buy producer goods at the prices of P_i

(i=1,...,19), to buy labor at the gross-of-tax price, $P_L\left(1+t_L^G\right)$, and to buy capital at the gross-of-tax price, $P_K\left(1+t_K^G\right)$.

Since the gross-of-tax capital price in the private sector equals the marginal product of capital, a capital flow from the public to the private sector would imply (possibly large) welfare gains, which would lead to the miscalculation of the welfare effects of distorting taxes. Therefore, we assume that the entire government sector faces a price for capital that is equal to $P_K(1+\Phi)$, where Φ is the weighted-average tax rate on capital used in industry. Then, if the industry tax rates were to change, the government's price would change accordingly. The new price of capital faced by the government would be P_K (1 + the new weighted average industry tax rate). Thus, capital would not flow from the government to the private sector.

The model is calibrated to generate a steady-state growth path in the base (or status quo) case. Relative prices remain constant through time, and all outputs and aggregate incomes grow at the rate of growth of the overall economy. In addition, base-case government spending, tax revenues, government deficits, and government debt all remain in constant proportion to GNP. In revised-case (or policy change) simulations, we maintain the same growth of government debt as in the base case, but alter the configuration of taxes.

Model Treatment of Taxes:

The model incorporates each of the major taxes in the United States. In Table 3, I outline the ways in which these are modeled. My goal is to assess the entire system of distortionary taxes. Therefore, the disaggregated treatment of production is important, since it allows us to consider intersectoral as well as intertemporal distortions.

Table 3 U.S. Taxes and Their Treatment in the Model

	Tax	Treatment
1	Corporate taxes (including state and local) and corporate franchise taxes	*Ad valorem tax* on use of capital services by industry
2	Property taxes	*Ad valorem tax* on use of capital services by industry
3	Social Security taxes, unemployment insurance taxes, and workmen's compensation taxes	*Ad valorem tax* on use of labor services by industry
4	Motor vehicles taxes	*Ad valorem tax* on use of motor vehicles by producers
5	Retail sales taxes	*Ad valorem tax* on purchases of producer goods
6	Excise taxes	*Ad valorem tax* on output of producer goods
7	Other indirect business taxes and non-tax payments to government	*Ad valorem tax* on output of producer goods
8	Personal income taxes (including state and local)	Linear function for each consumer; 30% of saving currently tax sheltered

The treatment of each tax in the model reflects certain assumptions about the tax system. We combine the corporate and property taxes to produce an overall tax rate on capital income originating in each industry. One important feature of this model is the personal factor tax, which is designed to capture the different proportion of each sector's capital income subjected to full personal income taxation. This proportion will differ across industries, depending on variations in dividend/retention policies and differences in the amount of unincorporated capital which qualifies for the investment tax credit. At the industry level, capital income is taxed at rate τ, the overall capital-weighted average marginal income tax rate.[14] In order to derive the amount of "personal factor tax" in each industry, we calculate the parameter f_i (the fraction of the i^{th} industry's payment for capital). When all capital taxes are subtracted from capital income, we have net income to capital.[15] The effective tax rates that we use in this model are the ratios of all capital taxes to net capital income in each industry. Since the effective tax rate is defined as taxes relative to <u>net</u> capital income, rather than to the more common use of <u>gross</u> income, the rates can exceed unity. The average tax rate on capital income at the industry level is .97, which corresponds to a tax rate on gross capital income of just under 50%.

1) The Corporate Tax: We follow the tradition of Harberger (1962, 1966), who treated the corporate tax as a partial factor tax, even though this has been the subject of active debate.[16] We follow Harberger's procedure of treating the corporate tax as an *ad valorem* tax on capital, with average and marginal tax rates the same. As a result, differences in capital income tax rates cause capital to be misallocated across industries.

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[14]This feature captures the favorable treatment of industries with a high proportion of retained earnings, industries that receive large amounts of noncorporate investment tax credits, and the housing industry. However, it leads to distortion of the interindustry capital allocation.

[15]Net income to capital is equal to the gross income to capital, minus corporate and property taxes, minus the personal factor tax, where the personal factor tax is $CAP_i \tau f_i$ (gross income to capital minus corporate and property tax). τ is capital-weighted average of the consumers' marginal tax rates. CAP_i is the Capital payments from the i^{th} industry, net of corporate and property taxes. f_i is the proportion of the i^{th} sector's CAP_i that is subject to the personal income tax.

[16]For instance, Stiglitz (1973) points out that, if all marginal investments by firms are debt-financed, the corporate tax operates as a lump-sum tax. Gravelle and Kotlikoff (1989) explore the misallocation of capital between corporate and noncorporate firms within the same sector. Their results show that the coexistence of corporate and noncorporate capital in the same sector makes the distortion larger. They find a high elasticity of incorporation with respect to tax parameter changes in their model. However, Gordon and MacKie-Mason (1990) find that

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In addition, the corporate tax affects savings decisions, since savers who acquire corporate equity pay these taxes indirectly on the return to their savings. Through the tax treatment of depreciation and the investment tax credit, we have a pattern of tax rates by industry which is highly discriminatory.

The advantage of this approach is that it replicates the tax revenue that is actually observed in the economy. The weakness, however, is that it abstracts from the details of the tax system such as the investment tax credit, depreciation, differences in tax rates, and property tax.

While our model bases incentives to invest on average tax rates, the ***cost-of-capital approach*** bases incentives to invest on marginal tax rates, and it indicates that marginal tax rates may not be the same as average tax rates. In other words, while the Harberger model uses average tax rates measured for existing assets, the cost-of-capital approach uses marginal tax rates for the incremental uses of capital, since the concept of the tax on a new investment is preferred as a measure of the incentive to invest.

Fullerton and Henderson (1989) use a cost-of-capital approach to measure the incentives to invest in each combination of asset, sector, and industry. Their model encompasses inter-asset, inter-sectoral, and inter-industry distortions into a single general equilibrium model of the U.S. tax system. They find that intersectoral distortions are much smaller than those in Harberger-type models, such as the model of Fullerton,

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this elasticity of incorporation is small, which casts doubt upon the validity of the Gravelle-Kotlikoff model.

Shoven, and Whalley. In contrast, interasset distortions dominate the two other misallocations.

Fullerton and Gordon (1983) take account of uncertainty, the flexibility of corporate financial policy, and inflation in the cost-of-capital framework. They argue that recipients of capital income receive benefits which largely compensate them for the taxes they pay, and often more than compensate them. These recipients are able to reduce some of the risk in the return on their investments by transferring it to the government through risky tax revenue. They find that corporate tax integration actually reduces welfare, because the welfare gains of lessening tax distortions through integration are more than offset by the welfare losses resulting from raising tax rates on labor income to replace the lost revenue, and because the government no longer provides this insurance.

However, Bulow and Summers (1984) challenge this, by dividing the riskiness of an investment into "income risk" (*i.e.*, variation in the return from capital goods) and "capital risk" (*i.e.*, variation in the price of capital assets). They argue that most of the risk borne by owners of corporate capital pertains not to income risk (which is hedged by the corporate income tax), but to capital risk (which is not hedged by the corporate income tax). Therefore, the Fullerton-Gordon story does not work well.[17]

Ballentine (1987) points out that all of the studies with cost-of-capital calculations are incomplete in modeling the tax system. Those studies usually take account of the investment tax credit, depreciation schedule, indexing, dividend deduction, corporate and personal marginal tax rates, and property taxes. However, they omit multiperiod accounting rules, industry-specific incentives, international tax charges, and many other aspects that are difficult to model.

The advantage of the cost-of-capital approach is that it is more consistent with microeconometric theory, and it captures some important details of the tax system. The disadvantage is that it neither gets the revenue correct nor captures the extreme complexity of the tax system, as mentioned above by Ballentine (1987).[18]

2) The Property Tax: We treat this as a differential tax on capital by sector (similarly to the corporate tax). This falls most heavily on residential housing, but structures in other capital-using industries in the economy are also liable for the tax. As with the corporate income tax, both static and dynamic distortions occur.

3) The Income Tax: We specify income taxes as linear functions of income with a negative intercept and a single positive marginal tax rate. Although each consumer faces a constant marginal tax rate, the average tax rate increases with income due to the negative intercepts. Thus, this model captures the fact that U.S. tax system is progressive, although it does not capture the details of the graduated tax rate structure. We do not model many of the deductions and exemptions that exist in the U.S. tax system. The key distortions caused by the income tax have to do with factor supply decisions. It is widely recognized that the income tax distorts labor supply. In addition, the supply of new capital through saving is affected by the double taxation of saving, although these effects are partially offset by the tax treatment of pensions and housing.

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[17]See Slemrod (1982, 1983) for further details.

We assume that 30% of saving is sheltered in this way.[19] In addition to distorting factor-supply decisions, the income tax also has important features which distort choices among industries and commodities. The most prominent of these is the preferential treatment of housing that results from the absence of tax on the imputed income of owner-occupied housing. This is compounded by the preferential treatment for capital gains on houses.

4) Sales and Excise Taxes: We model sales and excise taxes as consumer purchase taxes on the 17 consumer goods. The average tax rates are about 5.2% in this model, and rates for most goods are reasonably low. Consumer sales taxes have a variety of effects. Even if the sales tax system covers all commodities evenly, it still distorts labor supply decisions. Additional distortions come from the nontaxation of food and services in most States. Also, the specific excises on alcohol, tobacco, and gasoline are discriminatory in our model, since we treat them (along with sales taxes) as *ad valorem* taxes.

5) The Social Security Payroll Tax: We model Social Security payroll taxes as *ad valorem* taxes on the use of labor services by industry, and we treat Social Security benefits as lump-sum transfers.

The tax rate on labor for each industry is derived by taking payroll taxes and other contributions as a proportion of labor income. The tax rate on capital for each industry is obtained by taking three components - the corporate income tax levied by the federal government, corporate franchise taxes levied by the state governments, and property taxes

[18]As an example of how the cost-of-capital approach can give unusual results, see Fullerton and Rogers (1993).

levied at the state and local levels. We use capital income as the tax base for all three taxes, even though the legal tax bases for the latter two are capital stock and capital assets, respectively.[20]

The labor tax rate used by government $\left(t_L^G\right)$ is based on Social Security and railroad retirement taxes paid by the government and its employees. When the government pays these taxes on its use of labor, it pays the taxes to itself. Consequently, the income effects cancel out. However, the price effects measure correctly the opportunity cost to government of hiring additional labor.

The capital tax rate used by government $\left(t_K^G\right)$ is more disputable. Governments in the U.S. pay neither corporate income taxes nor property taxes. If we were to model t_K^G as only the personal tax on that capital income, the government's tax rate on K would be substantially less than the private sector's tax rate. The benchmark equilibrium would imply a misallocation of capital in favor of government use. Any reduction in the capital taxes faced by the private sector would imply reallocation flows from the government sector to the private sector.

19This assumption is based on calculations using the 1976 Flow of Funds Accounts.

20Even though we use capital income net of all taxes to reflect the use of capital in each industry, we should note that measuring the industrial use of capital services by capital income is not the only method available. See Kendrick (1976) and Jorgenson and Sullivan (1981).

Chapter 3

DATA AND PARAMETERS

Several important aspects of our model are shared by the GEMTAP model described in Ballard *et al.* (1985). The data set used in that model contains valuable information on industry interactions and taxes. However, the original GEMTAP model (which was based on 1973 data) consisted of 12 infinitely-lived consumers, and thus could not address the intergenerational issues that concern us here. A fundamental challenge in the development of the model used here was to link consistently an overlapping-generations treatment of households with the detailed and disaggregated data from the GEMTAP model.

3.1. New Data

The basic source of the data is Karl Scholz (1987). Scholz's original data set provides information for 14 consumer groups, which are distinguished on the basis of their incomes in 1983. I begin by aggregating them into a single consumer group. Then, I re-divide them into 11 groups, which are distinguished by age.

It is necessary to make some adjustments to create a data set for inheritances and government transfers. The bequest left by one cohort is assumed to be divided among the 11 cohorts that are alive during the next period. Therefore, we need to calculate the proportions of total bequests that are received by the next 11 cohorts. We derive these proportions based on Consumer Expenditure Survey data showing the value of bequests received per year. The aggregated version of the 1972-1973 data was issued by the Bureau of Labor Statistics. These values are reported in per-household terms in Table 4. We also need the proportions of government transfers that are received by the different cohorts at a given time. These proportions are derived from Michigan Panel Studies of Income Dynamics Survey data (PSID, 1973). These data were collated by Charles Becker, and reported in Fullerton, Shoven, and Whalley (1980). These values are reported in per household terms in Table 5.

However, the problem is that the data are from the real world, which does not conform neatly to the structure of my steady-state model. So, I need to adjust the data so that I can use them in my model. Here are two ways to approach this problem.

Table 4. Inheritances Per Household, 1973 (in dollars)

	Age of Head						
Income Class	18-24	25-34	35-44	45-54	55-64	65+	**SUM**
$0 - $4,000	151	49	0	18	4	30	252
$4,000 - $7,000	60	21	7	27	193	74	382
$7,000-$10,000	99	204	15	14	133	132	597
$10,000-$15,000	87	62	38	25	117	124	453
$15,000-$25,000	0	98	186	165	123	606	1,178
$25,000+	0	191	456	272	418	364	1,701
SUM	397	625	702	521	988	1330	4,563

Table 5. Public Transfers Per Household, 1973 (in dollars)

	Age of Head						
Income Class	18-24	25-34	35-44	45-54	55-64	65+	**SUM**
$0 - $4,000	462	1,124	1,530	1,152	1,004	1,683	6,955
$4,000 - $7,000	178	875	1,444	980	1,114	2,476	7,067
$7,000-$10,000	157	210	917	906	876	2,487	5,553
$10,000-$15,000	54	101	397	462	501	2,627	4,142
$15,000-$25,000	5	7	87	178	238	2,320	2,835
$25,000+	11	145	49	99	46	1.077	1,427
SUM	867	2,462	4,424	3,777	3,779	12,670	27,979

3.1.1. Bequest and Transfer Proportions Without Demographic Adjustment

While the age of the youngest group in Table 4 and Table 5 is between 18 and 24, the youngest cohort in my model is between 20 and 24. Thus I multiply the first column of Table 4 and Table 5 by 5/7 to get the data that conform to the data set of my model. Since the model's cohorts are 5 years apart rather than 10 years apart, I average the above data for every group except the youngest one to get the inheritance and transfer amounts for my model. Table 6 and Table 7 show the adjusted inheritances and transfers per household.

Except for the youngest age group in Table 6 and Table 7, I divide the total of inheritances and transfers for each of the ten-year cohorts into two equal pieces, so that they conform to the five-year cohorts of my model. Table 8 shows the results of these manipulations.

Table 6. Adjusted Inheritances Per Household, 1973 (in dollars)

	Age of Head						
Income Class	20-24	25-34	35-44	45-54	55-64	65+	SUM
$0 - $4,000	108	49	0	18	4	30	252
$4,000 - $7,000	43	21	7	27	193	74	382
$7,000-$10,000	71	204	15	14	133	132	597
$10,000-$15,000	62	62	38	25	117	124	453
$15,000-$25,000	0	98	186	165	123	606	1,178
$25,000+	0	191	456	272	418	364	1,701
SUM	284	625	702	521	988	1330	4,563

Table 7. Adjusted Public Transfers Per Household, 1973 (in dollars)

	Age of Head						
Income Class	20-24	25-34	35-44	45-54	55-64	65+	SUM
$0 - $4,000	330	1,124	1,530	1,152	1,004	1,683	6,955
$4,000 - $7,000	127	875	1,444	980	1,114	2,476	7,067
$7,000-$10,000	112	210	917	906	876	2,487	5,553
$10,000-$15,000	39	101	397	462	501	2,627	4,142
$15,000-$25,000	4	7	87	178	238	2,320	2,835
$25,000+	8	145	49	99	46	1.077	1,427
SUM	620	2,462	4,424	3,777	3,779	12,670	27,979

Table 8. Adjusted Inheritances and Transfers Per Each Age Group

AGE	Inheritances	Transfers
20-24	284	620
25-29	312	1,231
30-34	313	1,231
35-39	351	2,212
40-44	351	2,212
45-49	260	1,889
50-54	261	1,888
55-59	494	1,889
60-64	494	1,890
65-69	665	6,335
70-74	665	6,335
TOTAL	**4,450**	**27,732**

Table 9 shows the actual bequest and transfer proportions I use in my model. This table shows that most inheritances and government transfers are received later in life.

Table 9. Proportions of Inheritances and Transfers

AGE[a]	INPROP[b]	TRPROP[c]
1	0.064	0.022
2	0.070	0.044
3	0.070	0.044
4	0.080	0.080
5	0,080	0.080
6	0.058	0.068
7	0.058	0.068
8	0.111	0.069
9	0.111	0.069
10	0.149	0.228
11	0.149	0.228
TOTAL	1.000	1.000

[a]AGE = Period of life. Each period is five years in length, so that the 11 periods of life cover a total of 55 years. When AGE=1, the cohort has just entered the model, and the cohort's last period of life occurs when AGE=11.

[b]INPROP = the proportion of the total bequest that is received by each of the 11 living cohorts in the benchmark.

[c]TRPROP = the proportion of total government transfers that is received by each of the 11 living cohorts in the benchmark.

3.1.2. Bequest and Transfer Proportions With Demographic Adjustment[21]

First, Table 10 shows that the number of households (*NH*) of each age group is irregular, while I assume that the population grows steadily at the rate of (1+*G*), where *G* = 0.267562984.[22] If we use *NH* of the oldest age group as the base, *NH* of the other groups should grow by (1+*G*), starting at 13881 (which is *NH* of the oldest age group) keeping the proportion of *NH* within each age group constant.[23]

Table 10. Number of Households (in thousands)

	Age of Head						
Income Class	18-24	25-34	35-44	45-54	55-64	65+	SUM
\$0 - \$4,000	1,239	1,202	810	1,153	1,815	6,059	12,278
\$4,000 - \$7,000	1,451	1,676	1,096	1,290	1,644	3,589	10,746
\$7,000-\$10,000	1,354	2,505	1,497	1,568	1,629	1,629	10,182
\$10,000-\$15,000	1,266	4,619	3,101	2,990	2,484	1,345	15,805
\$15,000-\$25,000	494	3,640	3,886	4,025	2,483	879	15,407
\$25,000+	54	683	1,318	1,904	1,079	380	5,418
SUM	5,858	14,325	11,708	12,930	11,134	13,881	69,836

I multiply 13881 by (1+*G*), raised to various powers to calculate the total number of households in each age group which I have to use in my model:

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21 Note that, even in this case, the population growth rate is constant over time. We just apply this fixed population growth rate to derive bequests and transfers proportions across cohorts in each period.

22 The economy is on a balanced growth path if the capital endowment grows at the same rate as the effective labor force. G is a steady-state growth rate and the endowment of labor must grow at this rate to be on a balanced growth path. G=0.022284497 for one year, G=0.121064355 for five years, and G=0.267562984 for ten years. See Ballard, Fullerton, Shoven, and Whalley (1985) for further information.

Generation 2: $13881(1+G)^1 = 17595$ where G = 0.267562984
Generation 3: $13881(1+G)^2 = 22303$ where G = 0.267562984
Generation 4: $13881(1+G)^3 = 28270$ where G = 0.267562984
Generation 5: $13881(1+G)^4 = 35834$ where G = 0.267562984
Generation 6: $35824(1+G)^1 = 40172$ where G = 0.121064355

For generation 6, G is 0.121064355 rather than 0.267562984 because we need to calculate the number of households whose age is between 20 and 24. We multiply the first column of Table 10 by 40172/5858, the second column by 35834/14325, *etc.*, in order to calculate *NH* which I can actually use in my steady-state model. Table 11 shows this adjusted *NH* within each age group, when we take into account the demographic change.

Table 11. Adjusted *NH* Within Each Age Group (in thousands)

	Age Group					
Income Class	20-24	25-34	35-44	45-54	55-64	65+
$0 - $4,000	8,497	3,007	1,956	1,989	2,868	6,059
$4,000 - $7,000	9,950	4,193	2,646	2,225	2,598	3,589
$7,000-$10,000	9,285	6,266	3,615	2,705	2,574	1,629
$10,000-$15,000	8,682	11,554	7,488	5,157	3,926	1,345
$15,000-$25,000	3,388	9,105	9,383	6,943	3,924	879
$25,000+	370	1,709	3,182	3,284	1,705	380
SUM	40,172	35,834	28,270	22,303	17,595	13,881

We multiply both the adjusted inheritances per household (Table 6) and public transfers per household (Table 7) by these adjusted numbers of households (Table 11), to get the total inheritances and transfers for each income and age group (Table 12 and Table 13). If we add up the last row of the Tables 12 and 13, we can get the total

[23]Allowing irregular demographics would be an interesting and important extension of this model. See chapter 3 of Ballard (1983) and chapter 11 of Auerbach and Kotlikoff (1987) for

inheritances and transfers which are $15,856,868 and $80,369,858 each. We divide each figure for inheritances and transfers by these total inheritances and transfers, to get the proportion of inheritances and transfers that is received by each income class/age group cell. Table 14 and Table 15 show the inheritance and transfer proportions for each income and age group.

Table 12. Total Inheritances for Each Income and Age Group (in $thousands)

	Age Group					
Income Class	20-24	25-34	35-44	45-54	55-64	65+
$0 - $4,000	917,676	147,343	0	35,802	11,472	181,770
$4,000 - $7,000	427,850	88,053	18,522	60,075	501,414	265,586
$7,000-$10,000	659,235	1,278,264	54,225	37,870	342,342	215,028
$10,000-$15,000	538,284	716,348	284,544	128,925	459,342	166,780
$15,000-$25,000	0	892,290	1,745,238	1,145,595	482,652	532,674
$25,000+	0	326,419	1,450,992	893,248	712,690	138,320
SUM	2,543,045	3,448,717	3,553,521	2,301,515	2,509,912	1,500,158

Table 13. Total Transfers for Each Income and Age Group (in $thousands)

	Age Group					
Income Class	20-24	25-34	35-44	45-54	55-64	65+
$0 - $4,000	2,804,010	3,379,868	2,992,680	2,291,328	2,879,472	10,197,297
$4,000 - $7,000	1,263,650	3,668,875	3,820,824	2,180,500	2,894,172	8,886,364
$7,000-$10,000	1,039,920	1,315,860	3,314,955	2,450,730	2,254,824	4,051,323
$10,000-$15,000	338,598	1,166,954	2,972,736	2,382,534	1,966,926	3,533,315
$15,000-$25,000	13,552	63,735	816,321	1,235,854	933,912	2,039,280
$25,000+	2,960	247,805	155,918	325,116	78,430	409,260
SUM	5,462,690	9,843,097	14,073,434	10,866,062	11,007,736	29,116,839

further discussion.

Table 14. Proportion of Inheritances for Each Income and Age Group

	Age Group					
Income Class	20-24	25-34	35-44	45-54	55-64	65+
$0 - $4,000	0.057	0.009	0	0.002	0.001	0.011
$4,000 - $7,000	0.026	0.006	0.001	0.004	0.032	0.017
$7,000-$10,000	0.042	0.081	0.003	0.002	0.022	0.014
$10,000-$15,000	0.034	0.045	0.018	0.008	0.029	0.011
$15,000-$25,000	0	0.056	0.110	0.072	0.030	0.034
$25,000+	0	0.021	0.092	0.056	0.045	0.009
SUM	0159	0.218	0.224	0.144	0.159	0.096

Table 15. Proportion of Transfers for Each Income and Age Group

	Age Group					
Income Class	20-24	25-34	35-44	45-54	55-64	65+
$0 - $4,000	0.035	0.042	0.037	0.029	0.036	0.127
$4,000 - $7,000	0.016	0.046	0.048	0.027	0.036	0.111
$7,000-$10,000	0.013	0.016	0.041	0.030	0.028	0.050
$10,000-$15,000	0.004	0.015	0.037	0.030	0.024	0.044
$15,000-$25,000	0	0.001	0.010	0.015	0.012	0.025
$25,000+	0	0.003	0.002	0.004	0.001	0.005
SUM	0.068	0.123	0.175	0.135	0.137	0.362

Since the age groups are 5 years apart in my model, rather than 10 years, I average the above data for every age group except the youngest, to get the inheritance and transfer proportions for my model. Table 16 presents the proportions I use for inheritances and transfers when we take into account the demographic change.

Table 16. Proportions of Inheritances and Transfers

AGE[a]	INPROP[b]	TRPROP[c]
1	0.159	0.068
2	0.108	0.062
3	0.110	0.061
4	0.112	0.088
5	0.112	0.087
6	0.072	0.068
7	0.072	0.067
8	0.080	0.068
9	0.079	0.069
10	0.049	0.182
11	0.047	0.180
TOTAL	1.000	1.000

[a]AGE = Period of life. Each period is five years in length, so that the 11 periods of life cover a total of 55 years. When AGE=1, the cohort has just entered the model, and the cohort's last period of life occurs when AGE=11.

[b]INPROP = the proportion of the total bequest that is received by each of the 11 living cohorts in the benchmark.

[c]TRPROP = the proportion of total government transfers that is received by each of the 11 living cohorts in the benchmark.

We put Table 9 and Table 16 together so that we can easily compare the difference in inheritances and transfers proportions between the two cases. Table 17 shows these results. Figure 1 tells us that inheritances are heavily concentrated later in life in case 1, while they are heavily concentrated early in life in case 2, since we assume that the population grows steadily across cohorts. However, we do not observe such a big difference in proportions of transfers in general. Figure 2 shows these differences.

Figure 1. Proportions of Inheritances

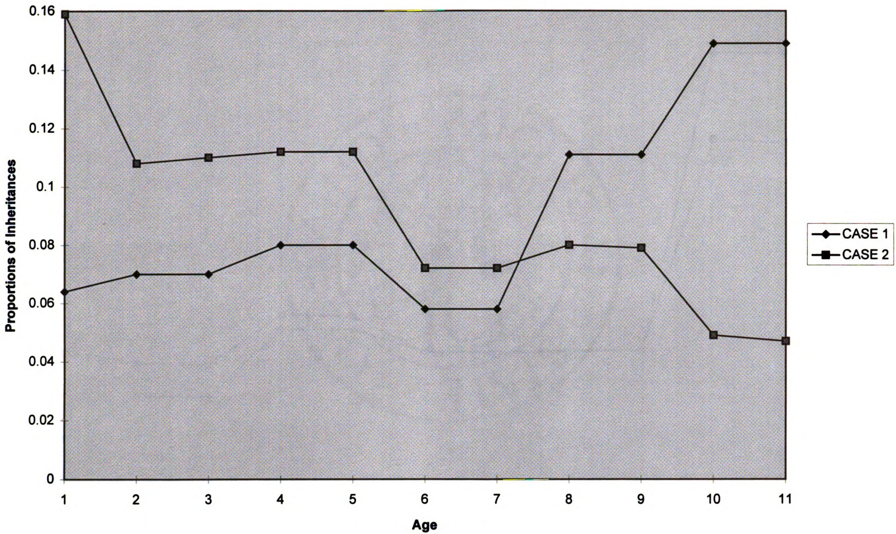

Figure 2. Proportions of Transfers

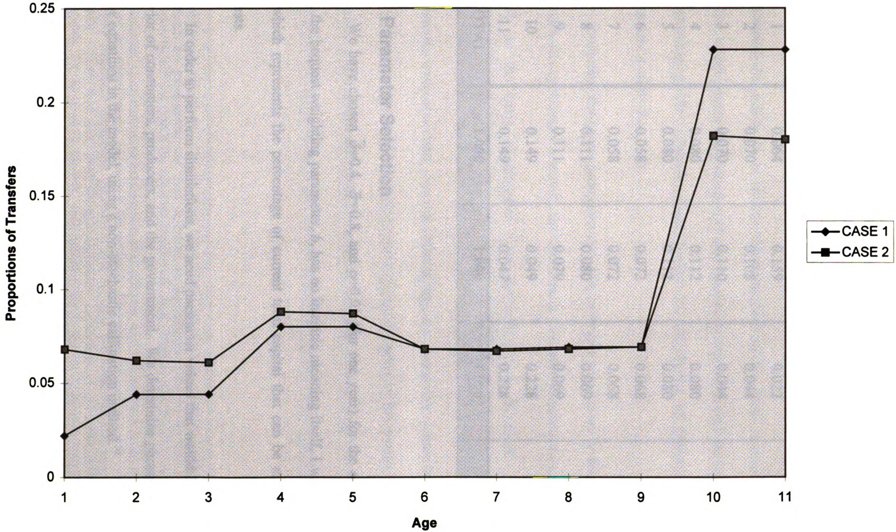

Table 17. Proportions of Inheritances and Transfers in Both Cases

AGE	Inheritances		Transfers	
	CASE 1	CASE 2	CASE 1	CASE 2
1	0.064	0.159	0.022	0.068
2	0.070	0.108	0.044	0.062
3	0.070	0.110	0.044	0.061
4	0.080	0.112	0.080	0.088
5	0.080	0.112	0.080	0.087
6	0.058	0.072	0.068	0.068
7	0.058	0.072	0.068	0.067
8	0.111	0.080	0.069	0.068
9	0.111	0.079	0.069	0.069
10	0.149	0.049	0.228	0.182
11	0.149	0.047	0.228	0.180
TOTAL	1.000	1.000	1.000	1.000

3.2. Parameter Selection

We have chosen $\bar{\delta}$=0.4, $\bar{\sigma}$=0.8, and ρ=0.01 (for one year) for the central case. Since the bequest weighting parameter, *b*, has no intrinsic meaning itself, I will focus on *BK*, which represents the percentage of current total capital that can be explained by bequests.

In order to perform simulations, we need parameter values that would describe the behavior of consumers, producers, and the government. We determine parameter values for the equations in the model, using a non-stochastic calibration method.[24]

[24]An alternative procedure would be to estimate the parameters of the model econometrically. Unfortunately, our model is much too large to be estimated as an econometric system of

The assumptions that producers minimize cost and receive zero economic profits allow us to choose the values of the production function parameters. Similarly, the assumption that households maximize their utility subject to a budget constraint has implications that allow us to choose the parameters of the inner nest of the utility function, which govern the allocation of aggregate consumption in each period among the 17 consumer goods. Similar logic applies to the choice of parameters in the government's utility functions.

Even after the above procedures, we still have free parameters to determine. To deal with this problem, we specify the consumer's elasticity of substitution parameters $(\bar{\sigma}, \bar{\delta})$ on the basis of estimates from the econometric literature. Thus, the parameterization procedures involve, first, selecting certain parameters from outside econometric estimates, and, second, identifying the remaining parameters for the overlapping generations of life-cycle households, on the basis of the restrictions implied by the two requirements discussed in the paragraphs that follow. (A detailed description of this procedure is explained in part 1 of the appendix: we offer only a sketch here.)

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simultaneous equations. On the other hand, if we were to use single-equation methods to estimate the parameters, and then calculate an equilibrium solution for the economy, the solution would not match the adjusted benchmark data. Mansur and Whalley (1984) say that the deterministic calibration method that we use for large-scale general equilibrium models has weaknesses, since it requires preselection of elasticities, and it does not provide any basis for a test of the specification, because it fits perfectly the single data point used. They consider whether stochastic estimation procedures can be used for small-scale general equilibrium models. They find that, even though stochastic estimation of complete models may be infeasible for large-scale models, time-series econometric estimation appears feasible for smaller-scale variants. Jorgenson (1984) estimates the parameters of nonlinear general equilibrium models using econometric methods. Thus he makes some progress in this direction.

1. Replication Requirement:

In the first period of the base case, the integrated model must generate an equilibrium solution that matches the Scholz data (1987). In particular, the aggregate labor supply, wage income, capital income, consumption, and saving that emerge from the overlapping-generations model must be identical to the aggregate labor demand, wage payments, capital income payments, consumption, and saving contained in the GEMTAP data set.

2. Balanced-Growth Requirement:

In the base case, the model must generate a steady-state growth path.

3.2.1. Parameterization of the Elasticities of Substitution

The parameters of $\overline{\sigma}$ and $\overline{\delta}$ are set exogenously. Friend and Blume (1975), examining portfolio decisions, suggest that $\overline{\delta}$ is less than or equal to 0.5. Summers (1982) favored a value for $\overline{\delta}$ of around 0.33, and Ghez and Becker (1975) estimate that $\overline{\delta}$ should be at most 0.28. Hall (1988) finds that $\overline{\delta}$ is indistinguishable from 0. Hansen and Singleton (1983) and Weber (1970, 1975), however, call for values equal to or greater than 0.5 for $\overline{\delta}$.

It is important to recognize, however, that the choice of $\overline{\delta}$ (the intertemporal elasticity of substitution between consumption and leisure) cannot be made independently of the choices of other parameters, especially $\overline{\sigma}$ (the elasticity of substitution of substitution between consumption and leisure in any period) and b (the bequest parameter). Moreover, even for seemingly reasonable values for $\overline{\delta}$, models of this type can generate unrealistically large saving elasticities.[25] This is because of the "human wealth effect". From equation (8), we know that leisure decreases as well when consumption decreases. Thus, not only does the consumer buy fewer goods, but he also works more and earns more labor income. These two effects can generate very large saving elasticities. In our simulation model, we want to use values for $\overline{\sigma}$ and $\overline{\delta}$ that are reasonably in line with those from the econometric literature. However, we are also mindful of the need for implied elasticities of behavioral response to be reasonable. Equation (21) indicates that the steady-state reference growth rate of consumption $(\overline{\eta})$ is determined by δ, ρ, and $\bar{r}$. We have chosen $\overline{\delta}$=0.4, $\overline{\sigma}$=0.8, and ρ=0.01 (for one year) for the central case. These exogenous parameters imply a value of approximately 0.0129 for $\overline{\eta}$ for one year, and 0.0664 for five years.

3.2.2. Parameterization of the Leisure Intensity

Given these parameter values taken exogenously from outside econometric estimates, it is necessary to define the leisure intensity parameter (α_i) and benchmark endowment of labor time and capital for each of the 11 cohorts alive in the benchmark year (first equilibrium period). This must be done in a way that assures that both the replication and balanced-growth requirements are satisfied. The problem is tractable by the assumption of balanced growth and the fact that the utility-function parameters of all cohorts are specified to be the same. Under these circumstances, in the steady state, the pattern across time of a given cohort's consumption (or leisure) will be closely linked to

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[25] Auerbach and Kotlikoff (1983) produced the bizarre results that the immediate effect of an unanticipated switch to a consumption tax is an increase in the saving rate from 10% to about 42%.

the pattern across cohorts of consumption (or leisure) at a given point in time. In other words, in a steady state, we can infer information about individual profiles on the basis of cross-section information. In the case of consumption, the following relationship must hold in the steady state:

$$(28) \qquad C_{n-t,1} = \frac{C_{n,t+1}}{(1+g)^t}.$$

Thus, the total consumption of cohort *n-t* (born *t* years before cohort *n*) in period 1 $\left(C_{n-t,1}\right)$ must be the same as the total consumption of cohort *n* in period *t*+1 $\left(C_{n,t+1}\right)$, adjusted for the growth rate of population (*g*). Thus, for purposes of calibration, equation (28) allows the expression of the behavior of all cohorts in terms of the behavior of a single representative cohort. Once the paths of consumption and leisure for the representative cohort are identified, one can determine fairly directly the benchmark endowments of labor time and capital for all cohorts alive in that period, because these endowments are translations of the representative cohort's endowments at different points in time.

3.2.3. Parameterization of the Labor Efficiency Ratio (e_h)

The "human capital earnings function" of Mincer (1970, 1974), in which earnings are expressed as a quadratic in potential experience, has been one of the most widely-accepted empirical specifications in economics. Mincer expresses the natural logarithm of earnings per hour, week, or year as a linear function of the number of years of school completed and as a quadratic function of years since leaving school (or potential work experience). The quadratic in experience has been adopted very widely, since most researchers believed that it provides a reasonable approximation to the actual earnings profile. Since the pioneering work by Mincer, several studies have been done on this subject.[26]

Murphy and Welch (1990) found that, in spite of its widespread acceptance, the quadratic human capital earnings function provides a poor approximation of the true empirical relationship between earnings and experience. They noted that the standard quadratic function in experience understates early career earnings growth by about 30% - 50%, and overstates midcareer growth by 20% - 50%. They suggest that a quartic specification provides a reasonably good approximation to the "true" earnings function. The model used here incorporates exogenous values for e_h based on a quartic function estimated by Murphy and Welch:

(29) $$e_h = e^x \ ,$$

[26]Oaxaca (1973) included a quadratic experience variable in the wage equation, in accordance with the post schooling investment model of human capital formation as developed by Johnson (1970) and Mincer (1970). His study indicates that e_h follows a hump-shaped pattern over the life-cycle, rising over most of economic life but falling in the last portion. Welch (1979) added an early career spline to experience and experience squared, to explain the evidence that early career wage growth is more rapid for those with more schooling. This splined experience coefficient generally implies more rapid growth in earnings during the early years of the career than can be captured in the experience quadratic alone.

where $$x = b_1 + b_2 h + b_3 h^2 + b_4 h^3 + b_5 h^4 \ .$$

I use b_1 = -0.465218, b_2 = 0.584478, b_3 = -0.1319, b_4 = 0.014343, and b_5 = -0.000624.

Chapter 4

SIMULATION RESULTS

4.1. Solution Process

Since the original raw data are taken from many different sources, they are not mutually consistent, so that quantities supplied are not equal to quantities demanded. However, to generate counterfactual simulations, we must begin with a consistent benchmark equilibrium data set, where quantities demanded equal quantities supplied for every good and factor. Thus, we first make a series of consistency adjustments for the 1983 data set. Given this equilibrium data set and any exogenously specified parameters, we use the nonstochastic calibration techniques to determine the remaining parameters. This calibration process ensures that the model replicates the 1983 data set in the absence of any policy change. Dynamic calibration procedures further ensure that, in a base-case sequence, the economy is on a steady-state, balanced growth path.

In the solution process, several equilibrium conditions must be met. In each period, demand must equal supply for every good and factor, and tax revenues plus net revenue from bond sales must equal government expenditures. The model is solved in each period, using the tâtonnement algorithm developed by Kimbell and Harrison (1986). An initial guess is made regarding the current price of labor services, the price of capital services, and tax rates. Based on these values and expectations of future prices, each cohort determines lifetime wealth and the optimal path of consumption, leisure, and saving. If excess demand is found in any factor market, prices are adjusted, and iterations are continued until no excess demand is found. Thus, equilibrium is achieved when total factor demands equal total factor supplies, and the government budget is balanced. I calculate equilibria over 31 successive periods, spaced five years apart. I employ the assumption of myopic expectations regarding prices.[27]

4.1.1. Base Case

With this consistent data set and parameters, we are ready to perform simulations. In the base-case simulation, the model replicates the original Scholz (1987) data set, and it produces a steady-state growth path. Various data on prices and quantities from the base-case simulation are saved and used later in comparisons with the data from a revised-case simulation. The revised-case simulation is based on the same behavioral parameters, but with a different configuration of taxes. Figure 3 shows the labor supply profile of a newcomer cohort for various values of *BK*, when C^{*}=0% in the case of no demographic adjustment. As we increase the *BK* value, we have a smaller increase in labor supply early in life, and the consumer retires later in life. This shape of labor supply profile depends on the quartic earnings function of Murphy and Welch (1990). All of these profiles show a slow decrease in labor supply for 25-30 years, even though we observe a sharp drop of labor supply after retirement in reality. However, we have to

[27]Ballard and Goulder (1985) and Ballard (1987) discuss the effects of future price expectations, in an infinite-horizon model and in the GEMTAP model. They show that the differences between perfect foresight and myopia are not very large. However, Auerbach and Kotlikoff (1987) and Judd (1985) show that the nature of expectations may be important if an announcement effect is involved, or if the policy change is only temporary. However, in this dissertation, I concentrate exclusively on permanent, unanticipated policy changes, so that

admit that any simulation model of this kind cannot duplicate the true labor supply profile exactly.

4.1.2. Revised Case

For the revised-case simulation, we specify a tax policy that replaces a portion of the current income tax with a 10% uniform VAT.[28] My analysis here takes a differential incidence approach.[29] As we change a tax policy, the level of government exhaustive expenditure is held constant in real terms. If government expenditures are to remain unchanged, and if we are to maintain budget balance, we have to alter some tax rates to maintain equal government revenue yield. In the experiments performed here, a 10% uniform value-added tax is instituted, and the revenue from this tax is used to lower the marginal income tax rates.

4.2. Results in the Aggregated Model

It has long been asserted that a move toward consumption taxation would result in welfare gains in the aggregate. Auerbach and Kotlikoff (1983) did indeed find long-run welfare gains, using a perfect-foresight general equilibrium simulation model. However,

announcement effects are not relevant. I plan to incorporate perfect foresight in a future version of the model.

28Consumption taxation can be accomplished either by taxing consumption itself (as with a VAT we consider here) or by offering deductions for saving within the income tax (as studied by Fullerton, Shoven, and Whalley (1983)). However, the latter treatment has problems in the transition: First, consumers may have other assets that can simply be transferred into their qualified accounts to avoid taxation without actually undertaking any saving. Second, the present system has a ceiling on the amount that can be deducted in any one year. Thus, if consumers plan to save more than the ceiling, the government would lose revenue without providing any marginal incentive to save. Empirical evidence suggests that these problems are very substantial. See Gale and Scholz (1994a) and Engen and Gale (1993).

29See Musgrave (1959) for different ways of calculating tax incidence.

the Auerbach-Kotlikoff model, with no bequests, produces unrealistic wealth profiles.[30] In addition to this, their model has no labor/leisure choice[31] and no government transfer payments. The presence of transfer payments may affect the results, since it can significantly alter the consumption profile of the elderly.

I have built these important factors into my model. Thus, my model has bequests, a labor/leisure choice, and a "realistic"[32] profile of government transfers. I also use a Stone-Geary form of the instantaneous utility function in order to control the intertemporal elasticities. Taken together, these factors help to produce a fairly flat wealth profile, which is much more realistic than the extremely humped wealth profiles of Auerbach and Kotlikoff. We get different results depending on the inheritance and transfer proportions we use in the calibration process. Thus, I report two results, one without demographic adjustments of the inheritance and transfer profiles, and the other with demographic adjustment.

4.2.1. Case Without Demographic Adjustment

In this case, I use the original data on the number of households (*NH*) of each age group as they are, even though they are irregular and do not conform to the assumption of constant population growth in my model.

30See Seidman (1984) and Ballard (1990). See also Mirer (1967), White (1978), and Kotlikoff and Summers (1981) for discussion of this problem.

31However, in another paper, Auerbach, Kotlikoff, and Skinner (1983) do include a labor/leisure choice in the model.

32It means that the elderly receive more transfers than the young. We derive the transfer profile from data on the government transfers from the Michigan Panel Studies of Income Dynamics (PSID, 1973).

In the revised-case simulation, we replace a portion of the current income tax with a 10% uniform VAT, and compare the results with various data on prices and quantities saved in the base-case simulation. We begin with a model that is similar to that of Auerbach and Kotlikoff, in that bequests are zero and there is no minimum required level of consumption.

Table 18 shows that, when BK=2%[33] and C^{*}=0, each cohort dissaves in the first period of its economic life, and turns to rapid increases in saving until the fourth of the five-year periods of the life. Thereafter, saving begins to drop. Finally, saving goes negative in the seventh period and beyond. Because of these huge swings of the saving profile, the elderly are harmed during the transition as we move toward greater reliance on consumption taxation, which is the result of Auerbach and Kotlikoff.

Table 18. Newcomer Cohort's Saving Profile When C*=0 ($billions/5 year period)

T	*BK*=2%	*BK*=15%	*BK*=25%	*BK*=50%	*BK*=70%
1	-105.0	-109.7	-113.6	-124.4	-135.4
2	650.6	593.9	551.0	458.9	396.2
3	1041.1	965.8	909.0	787.3	704.6
4	1227.3	1169.2	1125.2	1028.0	956.2
5	967.5	953.4	941.9	907.5	865.8
6	357.3	424.8	474.3	561.6	586.4
7	-510.0	-301.3	-145.5	162.3	320.5
8	-967.8	-871.7	-796.4	-558.8	-249.6
9	-1411.4	-1258.1	-1137.4	-845.3	-608.0
10	-462.2	-254.9	-91.1	305.0	624.4
11	-680.2	-509.2	-372.4	-39.5	225.5

33Even though it is possible to run simulations for a wide variety of values of *BK*, I have encountered some numerical problems in calibrating the model when *BK*=0% which is the same case as the model of Auerbach and Kotlikoff. In this model with a labor/leisure choice, we use the leisure intensity parameter (α) to achieve calibration. The α parameter is very sensitive, and it has not been possible to calibrate the model when *BK*<2%. However, *BK*=2% is low enough that we can compare these results with those of Auerbach and Kotlikoff. I did run the simulation successfully when *BK*=0% in the case with demographic adjustment.

While there is wide consensus among economists that intergenerational transfers explain a large portion of total wealth accumulation, there is no clear consensus about the exact proportion of total wealth accumulation that can be explained by bequest. Kotlikoff and Summers (1981) divide total wealth into life-cycle wealth and transfer wealth. They come to the result that transfer wealth can explain from 46% to 80% of the total wealth accumulation, depending on definitions and methodology. Modigliani (1988) says that the reported evidence indicates that the share of wealth received does not exceed 25% of the total wealth. Reviewing six types of evidence concerning the importance of intergenerational transfers to savings, Kotlikoff (1988) finds that intergenerational transfers play a very important and dominant role in U.S. wealth accumulation. Recently Gale and Scholz (1994b) conclude that *inter vivos* transfers and bequests may account for about 51% of net wealth accumulation.

Figure 4A shows that, as BK increases, we have a flatter and flatter profile of wealth. In other words, we observe smaller and smaller swings in savings, as bequests become more important in the model. When BK=70% and C^{*}=0, we observe less rapid saving early in life, and less rapid dissaving later. Saving is even positive in the last two periods. This result is actually not unusual considering some of the empirical studies.[34]

The adoption of a VAT or a national sales tax leads to capital deepening, and thus to a decrease in the relative price of capital services over time. As we can see in Table

[34]Mirer (1979) found that wealth tends to increase with age after adjusting for intercohort differences in wealth at retirement. Bernheim (1986) found that a large portion of singles as well as couples continue to accumulate wealth after retirement.

19, the *K/L* ratio starts at 0.243 and eventually increases to 0.282[35] when *BK*=2%, as capital deepening occurs. This amounts to a 16% increase in the *K/L* ratio. Even though we increase *BK*, the eventual steady-state *K/L* ratio is the same in each case, and it converges so fast because the elasticities are high.

As the *K/L* ratio changes, the prices of capital and labor services also change accordingly. For example, Table 20 shows that, when *BK*=2% and *C**=0, the price of capital services (which was 1.0 in the base case) increases to 1.065 in the first period,[36] but it decreases to 0.926 in the final period as capital deepening occurs. When *BK*=70% and *C**=0, the price of capital increases to 1.036 in the first period, but it decreases to 0.929 in the last period. If we take a look at Figures 4B, 5B, and 6B, we find that the rental price of capital fluctuates a lot before it converges to a new steady-state level. This happens mainly because we assume myopia in my model. If we assume perfect foresight in my model, the rental price of capital may not fluctuate as much as a result of a policy change.

Auerbach and Kotlikoff (1983) find that the shift to consumption taxation would lead to large long-run welfare gains at the cost of harming the cohorts that are old at the time of policy change. Auerbach, Kotlikoff and Skinner (1983) come to a similar result: They find that a consumption tax offers efficiency gains, chiefly due to the replacement

[35]Capital here is being measured in terms of service flows. Since capital service flows are only a fraction of the value of the capital stock, these numbers for capital/labor ratios are much smaller than those reported elsewhere. However, there is no fundamental conceptual difference between the different numbers.

[36]This can be explained by Summers' Human Wealth Effect. The present value of human wealth decreases as the interest rates goes up when we adopt a VAT. Then consumers would want to consumer less, and enjoy less leisure. Consequently, labor supply increases, and this pushes up the relative price of capital services in the first period.

of large marginal tax burdens on the relatively inelastic elderly. However, they acknowledge that, since their model does not incorporate a number of important factors which might influence saving behavior (*e.g.*, bequest, risk, *etc.*), the results must be regarded with some caution.

The simulation results of my model with bequests confirm their caution. As we can see in Figure 4D, when bequests are this large, even the cohorts that are elderly during the transition have welfare gains. Figure 4D shows that, as *BK* increases, the elderly are hurt less and less, and finally, every generation including the elderly is better off for a reasonably large value of *BK*. From Figures 4D, 5D, and 6D, we can tell that this result is valid for various values of C^*.

Auerbach and Kotlikoff (1983) find that the equivalent variation for cohorts living in the new long-run equilibrium under the consumption tax is 2.32% of the lifetime resources. In my model, when C*=0 and *BK*=2%, which is close to their case, I observe a 1.6% increase in welfare as a proportion of lifetime resources for the cohorts in the new steady-state equilibrium. Figures 4D, 5D, and 6D tell us that these values increase as we increase the *BK* value. For example, the welfare gains in the new steady-state is about 1.92% of lifetime resources when C*=0 and *BK*=50%, and it rises to 2.06% when C*=0 and *BK*=70% in my model. We also observe that the long-run welfare increase becomes smaller as we increase the C* value. For example, the welfare increase is about 1.92% when C*=0% and *BK*=50%, 1.81% when C*=10% and *BK*=50%. The welfare gains are smaller than those of Auerbach and Kotlikoff (1983).

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This can be explained by two factors: First, as I incorporate minimum required consumption and bequests into the model, consumer behavior becomes less elastic with respect to the policy change. Second, my model assumes a more realistic policy change, *i.e.*, we begin with a model with taxes on incomes, consumer purchases, capital use, labor use, outputs, and bequests. We then introduce a 10% uniform VAT on top of existing sales and excise tax and reduce income tax rates, while maintaining all of the other features of the model's treatment of taxes. Auerbach and Kotlikoff assume that the model starts with a complete income tax and no other taxes and then they replace it with a complete consumption tax. Another factor is that, in calculating the welfare change as a proportion of lifetime resources, I use a definition of lifetime resources that differs from the definition of Auerbach and Kotlikoff. In my model, the lifetime resources are defined as initial wealth plus the present value of lifetime labor time (excluding leisure), plus transfers, and inheritances.

There are several ways to define the lifetime resources. For example, we can either include or exclude leisure in the definition of lifetime resources. Here, I exclude leisure. There are some legitimate reasons to exclude leisure in the definition of lifetime resources in my model: First, the amount of leisure is chosen in an arbitrary way in most models of this kind. In my model, the calibration procedures are such that the amount of leisure is very large in most simulations. This makes the value of the welfare change as a proportion of lifetime resources so small that it is very hard to give any economic meaning to the number. Second, we exclude leisure in the definition of lifetime resources, so that it will be possible to compare our results with any model with no lab

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labor/leisure choice. (Later, I intend to develop a model with no labor/leisure choice. In this case, of course, leisure will not be included in the definition of lifetime resources.)

However, Auerbach and Kotlikoff include leisure in their definition of lifetime resources. They say (1987, p.74);

> "One measure of these utility differences is the equivalent percentage increase in full lifetime resources (assets plus the present value of earnings based on *working full time*) needed in the original income tax regime to produce each cohort's realized level of utility under the specified alternative tax regimes."

In the initial steady-state of Auerbach and Kotlikoff model, about 51% of lifetime resources are spent on leisure. Since the denominator of my model is smaller than that of Auerbach and Kotlikoff, the welfare change as a proportion of lifetime resources in my model will be bigger than that of their model, *ceteris paribus*. Thus, the true difference in the welfare change as a result of the policy change between my model and their model is actually bigger than it would appear, based on these figures.

I have performed some sensitivity analysis with respect to changes in C^* (the minimum required level of consumption) and BK. The results are reported in Figure 4A to Figure 6D. As we increase C^*, the intertemporal responsiveness decreases. However, the pattern of the wealth profile, the present value of the welfare change, the path of the rental price of capital, and the equivalent variation as a proportion of lifetime resources are quite similar. For a low value of BK with C^*=0%, I have results that are similar to those of Auerbach and Kotlikoff (1983). However, with a reasonably large value of BK, every cohort has welfare gains for various values of C^*, even though the elderly have smaller welfare gains than the younger or future cohorts.

This can be explained by two factors: First, since the elderly have less dissaving, they are penalized less by the move toward consumption taxation. Second, even though the policy change leads to capital deepening, and thus to a decrease in the relative price of capital services over time, initially it leads to an increase in the price of capital services, which helps to increase the welfare of the elderly (who have more capital income than labor income). For example, in the first period, the rental price of capital increases to 1.065 when BK=2% and C^{*}=0 (relative to a base-case value of 1.0), and 1.036 when BK=70% and C^{*}=0. The reason for the increase in the price of capital services is as follows: When we adopt a VAT, we use the revenue to decrease the income tax rates. As a result, the net-of-tax interest rate goes up, and the present value of human wealth decreases. Then, consumers in the model desire to consume less, and to enjoy less leisure. Consequently, labor supply increases, and this pushes up the relative price of capital services in the first period.[37] As we increase C^{*}, we can reduce the intertemporal elasticities. For each value of C^{*}, the rental price of capital fluctuates less as BK increases.

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[37]Another effect we may consider is that the reduction in consumption and leisure induce more investment demand. Since investment goods are relatively labor intensive, the demand for labor increases, leading to an increase in the price of labor. However, the fact that the price of capital services increases in the first period means that the labor supply effect (which increases the price of capital services) is greater than this labor demand effect (which decreases the price of capital services).

Figure 3. Labor Supply Profile of Newcomer Cohort When C=0%, without Demographic*

Figure 3. Labor Supply Profile of Newcomer Cohort When C*=0%, without Demographic Adjustment, Aggregate Model

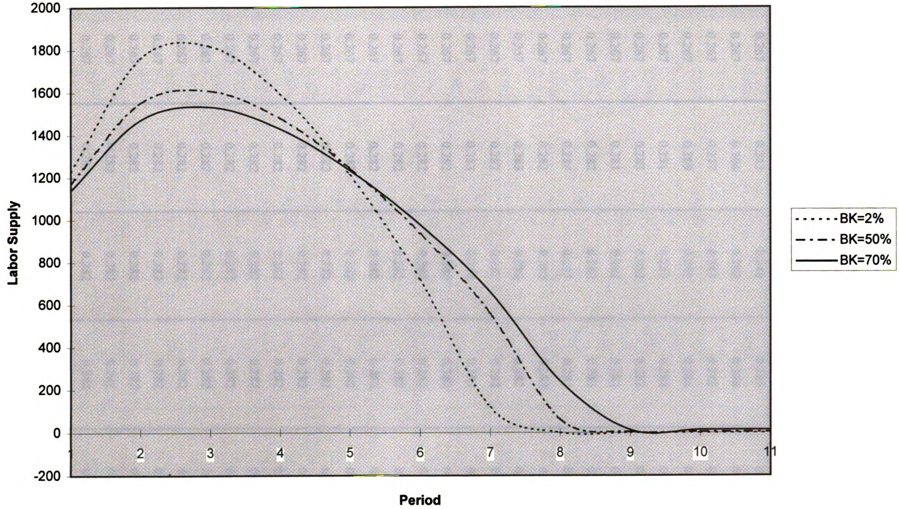


Table 19. Aggregate K/L Ratio When C^*=0, No Demographic Adjustment, Aggregate Model

T	BASE CASE	REVISED CASE			
		BK=2%	*BK*=25%	*BK*=50%	*BK*=70%
1	0.267	0.243	0.248	0.249	0.251
2	0.267	0.306	0.292	0.288	0.284
3	0.267	0.277	0.283	0.282	0.282
4	0.267	0.289	0.285	0.286	0.285
5	0.267	0.281	0.283	0.284	0.285
6	0.267	0.283	0.282	0.283	0.283
7	0.267	0.281	0.281	0.282	0.283
8	0.267	0.282	0.282	0.281	0.282
9	0.267	0.284	0.283	0.281	0.282
10	0.267	0.282	0.282	0.282	0.282
11	0.267	0.283	0.282	0.282	0.282
12	0.267	0.282	0.282	0.282	0.282
13	0.267	0.283	0.282	0.283	0.282
14	0.267	0.282	0.282	0.282	0.282
15	0.267	0.282	0.282	0.282	0.282
16	0.267	0.282	0.282	0.282	0.282
17	0.267	0.282	0.282	0.282	0.282
18	0.267	0.282	0.282	0.282	0.282
19	0.267	0.282	0.282	0.282	0.282
20	0.267	0.282	0.282	0.282	0.282
21	0.267	0.282	0.282	0.282	0.282
22	0.267	0.282	0.282	0.282	0.282
23	0.267	0.282	0.282	0.282	0.282
24	0.267	0.282	0.282	0.282	0.282
25	0.267	0.282	0.282	0.282	0.282
26	0.267	0.282	0.282	0.282	0.282
27	0.267	0.282	0.282	0.282	0.282
28	0.267	0.282	0.282	0.282	0.282
29	0.267	0.282	0.282	0.282	0.282
30	0.267	0.282	0.282	0.282	0.282
31	0.267	0.282	0.282	0.282	0.282

Table 20. Real Rental Price of Capital in Revised Case When $C^*=0$, No Demographic Adjustment, Aggregate Model

T	BK=2%	BK=25%	BK=50%	BK=70%
1	1.065	1.047	1.043	1.036
2	0.858	0.895	0.910	0.921
3	0.944	0.924	0.927	0.927
4	0.907	0.917	0.918	0.919
5	0.930	0.925	0.922	0.921
6	0.924	0.926	0.926	0.924
7	0.930	0.929	0.928	0.927
8	0.927	0.929	0.930	0.929
9	0.921	0.925	0.930	0.930
10	0.928	0.927	0.927	0.928
11	0.924	0.927	0.928	0.929
12	0.927	0.927	0.928	0.929
13	0.925	0.927	0.929	0.930
14	0.926	0.927	0.928	0.929
15	0.925	0.927	0.929	0.929
16	0.926	0.927	0.929	0.929
17	0.926	0.927	0.929	0.929
18	0.926	0.927	0.929	0.929
19	0.926	0.927	0.929	0.929
20	0.926	0.927	0.929	0.929
21	0.926	0.927	0.929	0.929
22	0.926	0.927	0.929	0.929
23	0.926	0.927	0.929	0.929
24	0.926	0.927	0.929	0.929
25	0.926	0.927	0.929	0.929
26	0.926	0.927	0.929	0.929
27	0.926	0.927	0.929	0.929
28	0.926	0.927	0.929	0.929
29	0.926	0.927	0.929	0.929
30	0.926	0.927	0.929	0.929
31	0.926	0.927	0.929	0.929

Figure 4A. Wealth Profile of Newcomer Cohort When C*=0, without Demographic Adjustment, Aggregate Model

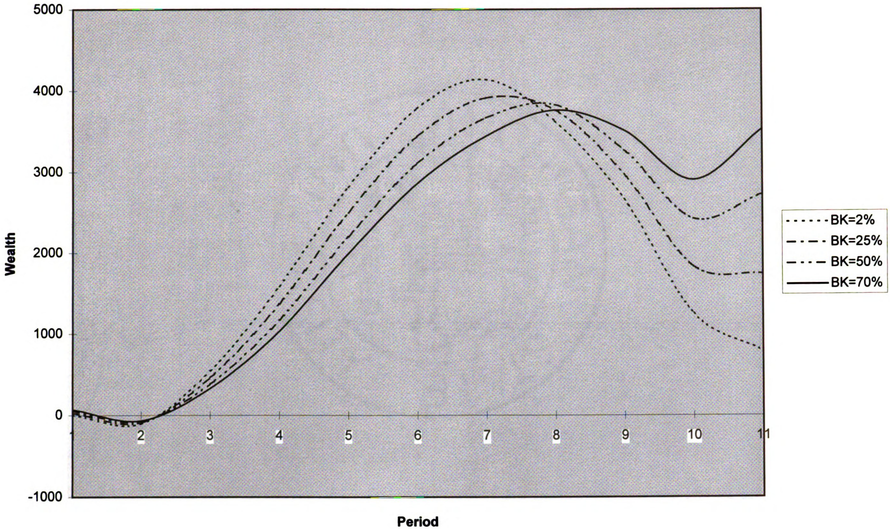


Figure 4B. Rental Price of Capital When C*=0, without Demographic Adjustment, Aggregate Model

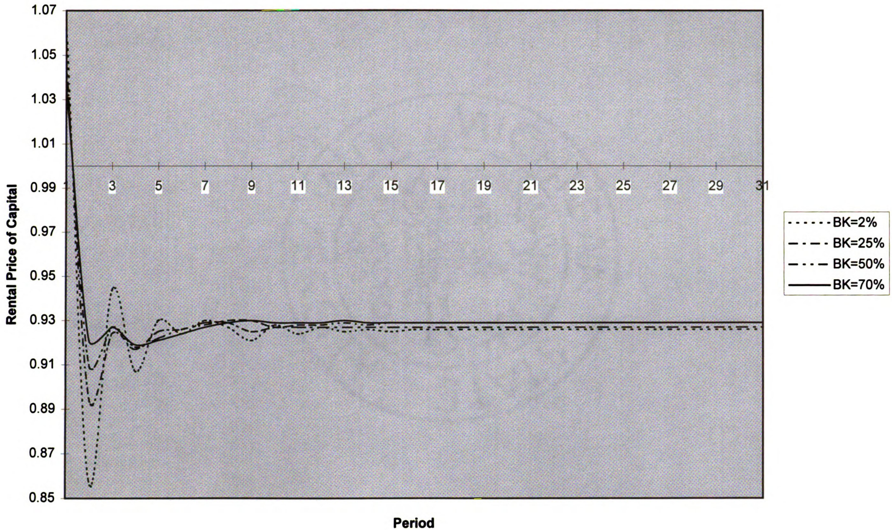


Figure 4C. Present Value of Equivalent Variation When C*=0, without Demographic Adjustment, Aggregate Model

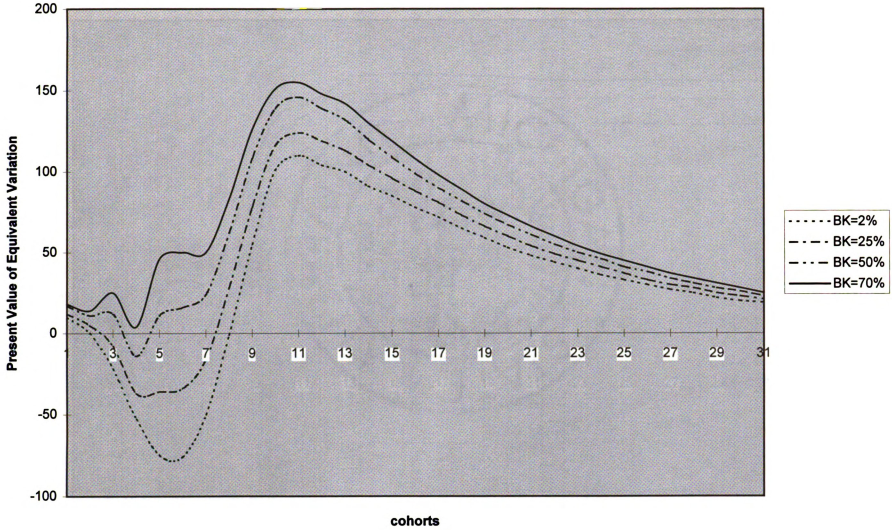


Figure 4D. Equivalent Variation as Proportion of Lifetime Resources When $C^*=0$, without

Figure 4D. Equivalent Variation as Proportion of Lifetime Resources When C*=0, without Demographic Adjustment, Aggregate Model

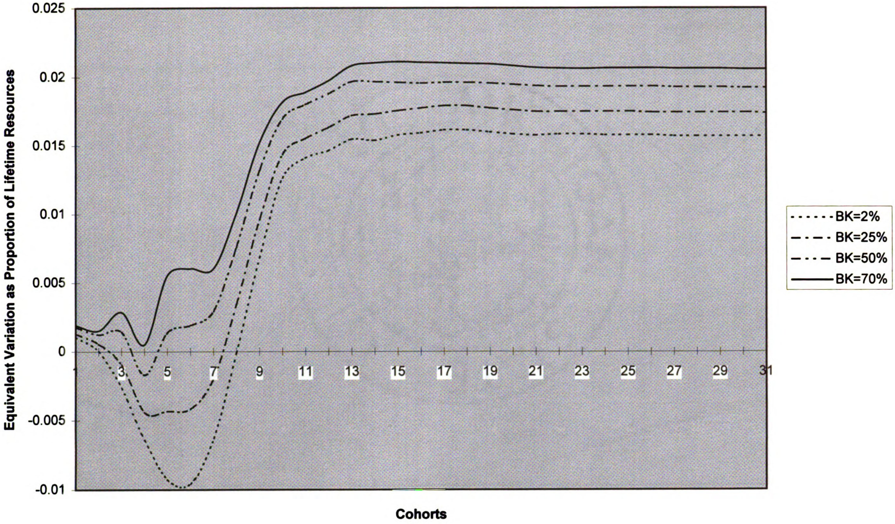


Figure 5A. Wealth Profile of Newcomer Cohort When C*=10%, without Demographic Adjustment, Aggregate Model

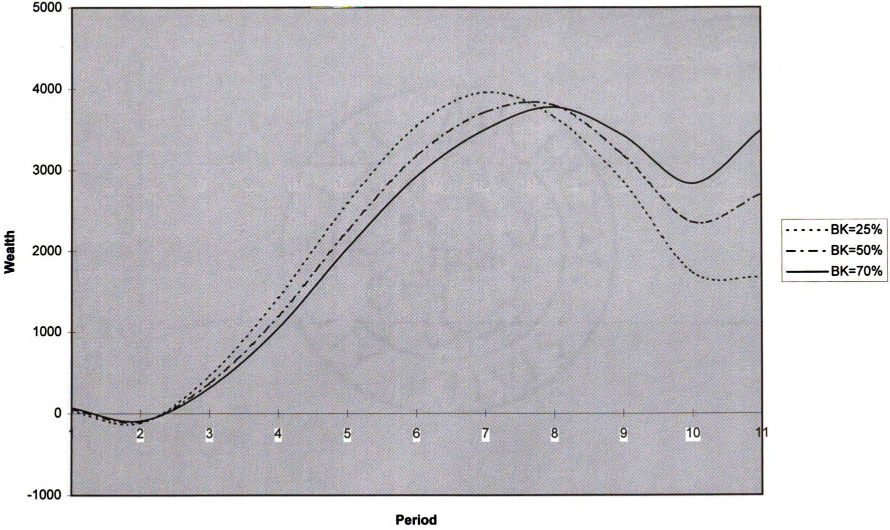


Figure 5B. Rental Price of Capital When C*=10%, without Demographic Adjustment, Aggregate Model

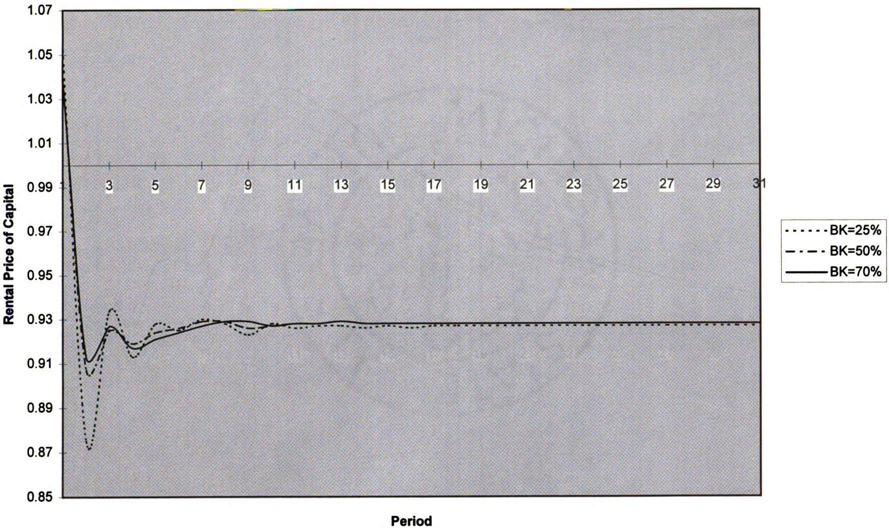


Figure 5C. Present Value of Equivalent Variation When C*=10%, without Demographic Adjustment, Aggregate Model

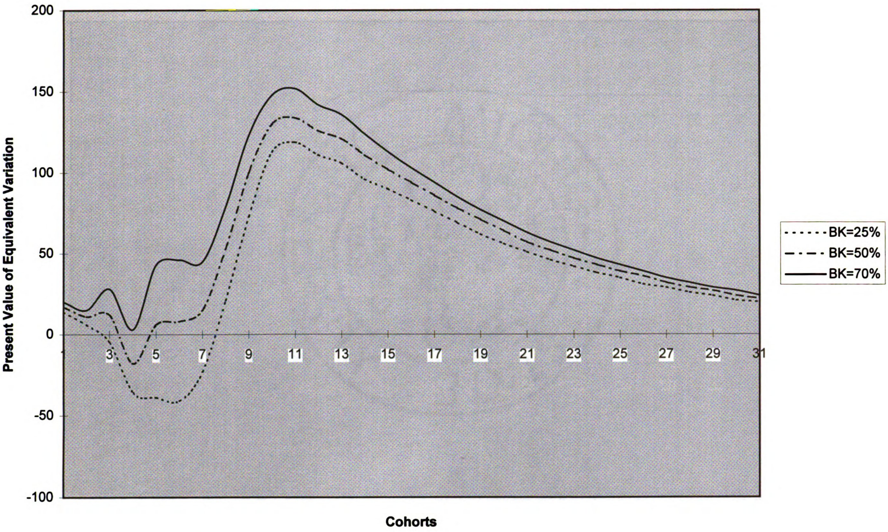


Figure 5D. Equivalent Variation as Proportion of Lifetime Resources When C*=10%, without Demographic Adjustment, Aggregate Model

Figure 6A. Wealth Profile of Newcomer Cohort When C^*=20%,

Figure 6A. Wealth Profile of Newcomer Cohort When C*=20%, without Demographic Adjustment, Aggregate Model

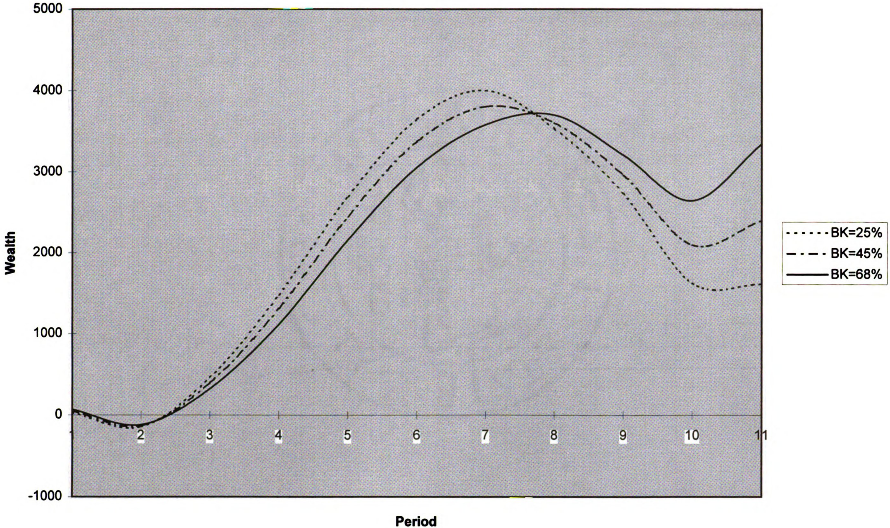


Figure 6B. Rental Price of Capital When C=20%, without Demographic Adjustment,*

Figure 6B. Rental Price of Capital When C*=20%, without Demographic Adjustment, Aggregate Model

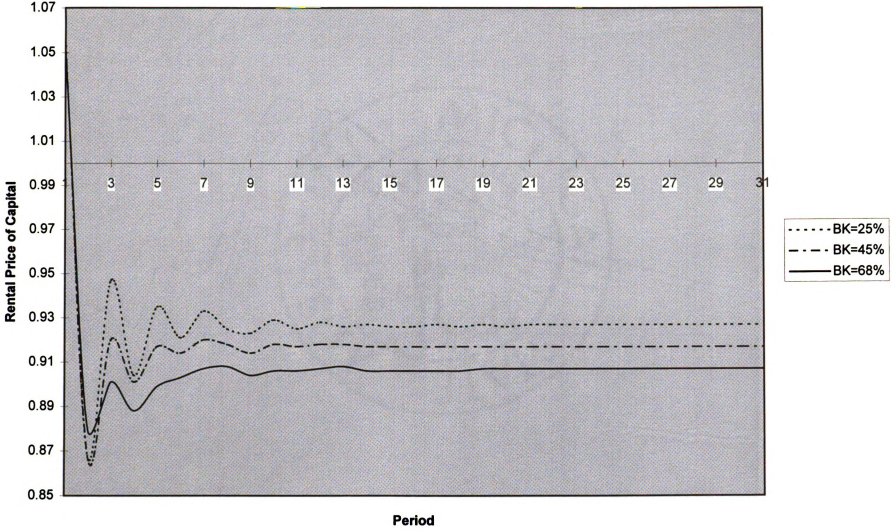


Figure 6C. Present Value of Equivalent Variation When C*=20%, without Demographic Adjustment, Aggregate Model

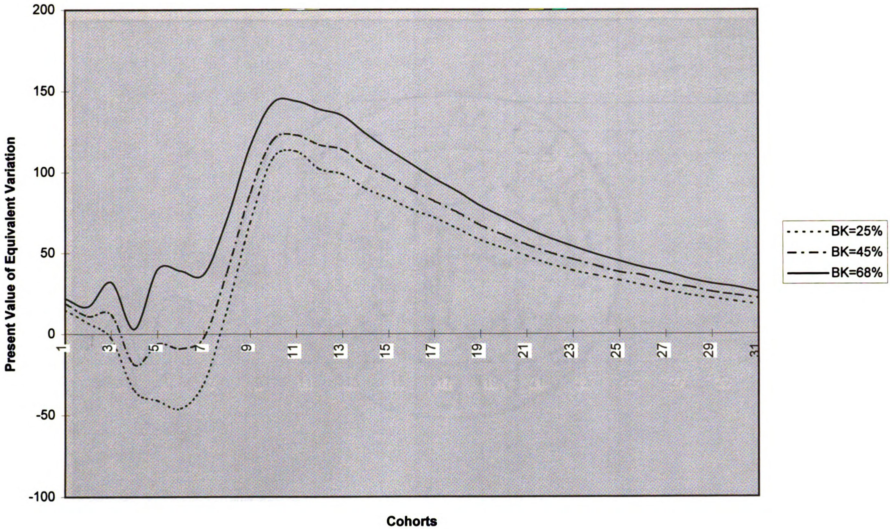
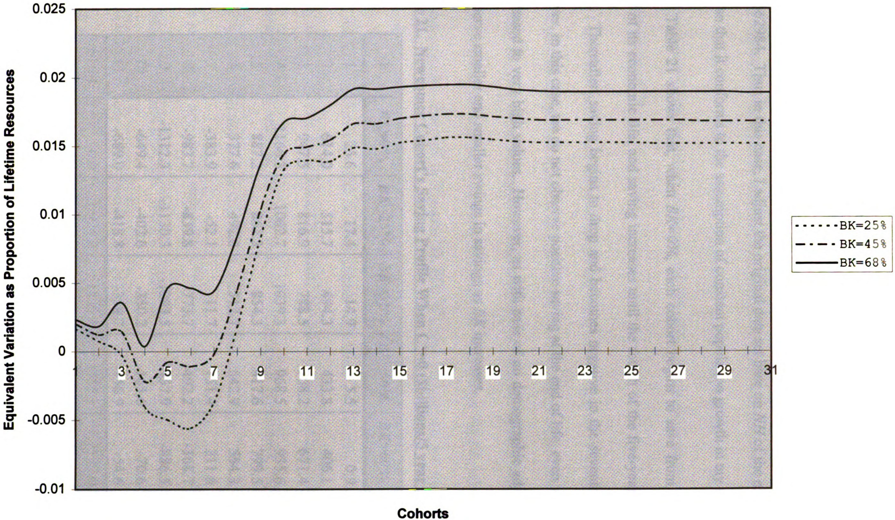


Figure 6D. Equivalent Variation as Proportion of Lifetime Resources When C*=20%, without Demographic Adjustment, Aggregate Model



4.2.2. Case With Demographic Adjustment

The number of households (*NH*) of each age group in the original data is irregular while I assume that the population grows steadily at the rate of (1+*G*), where G = 0.267562984. Thus in this case, I adjust the original data set base on *NH* of the oldest age group so that it conforms to the assumption of constant population growth in my model.

Table 21 shows that, when *BK=0%*, each cohort begins to save from the first period of its economic life, and saving increases until the fourth of the five-year periods of life. Thereafter, saving begins to drop and becomes negative in the seventh period. However, in this case, we do not observe positive saving at the end of life, even when *BK* is increased to very high values. However, as with case of no demographic adjustment, we observe smaller and smaller swings in savings as *BK* increases.

Table 21. Newcomer Cohort's Saving Profile When C*=0 ($billions/5 year period)

T	*BK*=0%	*BK*=25%	*BK*=31%	*BK*=50%	*BK*=60%
1	25.6	17.4	14.9	5.5	0.9
2	614.0	515.7	494.3	433.8	406.1
3	947.5	816.9	788.5	708.2	671.4
4	1166.3	1062.7	1039.3	968.5	935.6
5	887.2	862.3	854.3	817.6	799.5
6	377.6	492.8	512.7	542.9	554.3
7	-383.9	-52.1	11.7	151.4	211.6
8	-983.7	-839.8	-773.7	-492.2	-368.7
9	-1312.3	-1130.3	-1093.5	-957.9	-886.5
10	-649.4	-402.6	-350.2	-165.6	-70.6
11	-689.0	-418.8	-358.7	-156.9	-54.6
SUM	0.0	924.2	1139.6	1855.3	2199.0

In this case, we also observe capital deepening. Table 22 shows that the *K/L* ratio decreases to 0.254 in the first period, and eventually increases to 0.281 when *BK*=0%. This amounts to a 10.6% increase in the *K/L* ratio. Table 23 shows that the real rental price of capital also changes in this case, and reaches almost the same level in the final period. However, we observe smaller fluctuations of the capital price for the first few periods compared with former case. Figures 7B, 8B, 9B, and 10B show these results for different values of C*.

I have also performed the same sensitivity analysis with respect to changes in *C** and *BK*, and the results are reported in Figures 7A to 10D. The results are similar to those from the case of no demographic adjustment. As Figures 7C, 8C, 9C, and 10C show, we see less fluctuation of the welfare change as we increase the *BK* values. The same thing can be observed in Figures 7D, 8D, 9D, and 10D, where we express the welfare change as a proportion of lifetime resources.

As in the former case with no demographic adjustment, we observe smaller and smaller welfare gains as we increase C*. While we observe larger welfare increases as we increase the *BK* value in the case with no demographic adjustment, we observe <u>smaller</u> welfare increases in this case as we increase the *BK* values. We have 1.6% welfare gains in the new steady state when C*=0% and *BK*=0%, but only 1.0% welfare gains when C*=0% and *BK*=50%. When C*=30% and *BK*=50%, we have 0.76% welfare gains in the new steady state. Therefore, the effect of *BK* on the long-run welfare gains depends on the profile of transfer payments and bequests over the life cycle.

In all cases, I find that a move toward consumption taxation leads to long-run welfare gains. However, my results in the transition are somewhat different from those of Auerbach and Kotlikoff. I find that the losses to the elderly become smaller and smaller when we increase the *BK* values. (In some cases, the elderly actually gain.) The big difference between the case with demographic adjustment and the case without demographic adjustment is that we do not observe positive welfare gains for all cohorts in the case with demographic adjustment, even when we increase the *BK* values to very high levels.

By comparing the simulation results of this case with those of no demographic adjustment, I find that we have different results depending on the bequest and transfer proportions we are using in this model, although, in my opinion, the results with no demographic adjustment are more realistic. Although we do not observe such a big difference in the proportion of transfers between the two cases, we observe a big difference in the proportion of inheritances between the two cases. As we observed in Figure 1, with demographic adjustment, inheritances are more heavily distributed in early life. In reality, however, inheritances are bunched up in the later years of life. To tell which case is more realistic, I run simulations with demographic adjustment for transfers, but with no adjustment for inheritances. I find that the results are more close to the case without demographic adjustment for either transfers or inheritances. Thus we know that the basic difference in the results between the two cases comes from the proportion of inheritances which are heavily concentrated in early life in the case with demographic adjustment.

I also believe that bequests are large. Therefore, the results with *BK* much higher than zero are most believable. Some of these yield the result that all cohorts gain. Some do not. However, all have the result that, with a higher value of *BK*, the losses of the elderly become substantially smaller.

Table 22. Aggregate K/L Ratio When $C^*=0$, with Demographic Adjustment, Aggregate Model

T	BASE CASE	REVISED CASE			
		BK=0%	*BK*=25%	*BK*=50%	*BK*=60%
1	0.267	0.254	0.249	0.252	0.253
2	0.267	0.278	0.286	0.281	0.279
3	0.267	0.282	0.286	0.283	0.283
4	0.267	0.284	0.287	0.284	0.284
5	0.267	0.284	0.285	0.284	0.284
6	0.267	0.283	0.283	0.283	0.283
7	0.267	0.282	0.282	0.282	0.282
8	0.267	0.281	0.282	0.281	0.282
9	0.267	0.281	0.283	0.281	0.281
10	0.267	0.281	0.283	0.281	0.282
11	0.267	0.282	0.283	0.282	0.282
12	0.267	0.282	0.283	0.281	0.282
13	0.267	0.281	0.283	0.281	0.282
14	0.267	0.281	0.283	0.281	0.282
15	0.267	0.281	0.283	0.281	0.282
16	0.267	0.281	0.283	0.281	0.282
17	0.267	0.281	0.283	0.281	0.282
18	0.267	0.281	0.283	0.281	0.282
19	0.267	0.281	0.283	0.281	0.282
20	0.267	0.281	0.283	0.281	0.282
21	0.267	0.281	0.283	0.281	0.282
22	0.267	0.281	0.283	0.281	0.282
23	0.267	0.281	0.283	0.281	0.282
24	0.267	0.281	0.283	0.281	0.282
25	0.267	0.281	0.283	0.281	0.282
26	0.267	0.281	0.283	0.281	0.282
27	0.267	0.281	0.283	0.281	0.282
28	0.267	0.281	0.283	0.281	0.282
29	0.267	0.281	0.283	0.281	0.282
30	0.267	0.281	0.283	0.281	0.282
31	0.267	0.281	0.283	0.281	0.282

Table 23. Real Rental Price of Capital in Revised Case When $C^*=0$, with Demographic Adjustment, Aggregate Model

T	*BK*=0%	*BK*=25%	*BK*=50%	*BK*=60%
1	1.022	1.041	1.031	1.028
2	0.934	0.911	0.927	0.932
3	0.925	0.917	0.925	0.925
4	0.921	0.914	0.921	0.921
5	0.922	0.919	0.923	0.922
6	0.925	0.924	0.926	0.925
7	0.927	0.926	0.929	0.927
8	0.930	0.927	0.931	0.930
9	0.930	0.924	0.931	0.930
10	0.929	0.924	0.929	0.929
11	0.929	0.924	0.929	0.928
12	0.928	0.925	0.929	0.928
13	0.929	0.925	0.929	0.928
14	0.928	0.925	0.929	0.928
15	0.929	0.925	0.929	0.928
16	0.929	0.924	0.929	0.928
17	0.929	0.925	0.929	0.929
18	0.929	0.925	0.929	0.929
19	0.929	0.925	0.929	0.929
20	0.929	0.925	0.929	0.929
21	0.929	0.925	0.929	0.929
22	0.929	0.925	0.929	0.929
23	0.929	0.925	0.929	0.929
24	0.929	0.925	0.929	0.929
25	0.929	0.925	0.929	0.929
26	0.929	0.925	0.929	0.929
27	0.929	0.925	0.929	0.929
28	0.929	0.925	0.929	0.929
29	0.929	0.925	0.930	0.929
30	0.929	0.925	0.930	0.929
31	0.929	0.925	0.930	0.929

Figure 7A. Wealth Profile of Newcomer Cohort When C*=0, with Demographic Adjustment, Aggregate Model

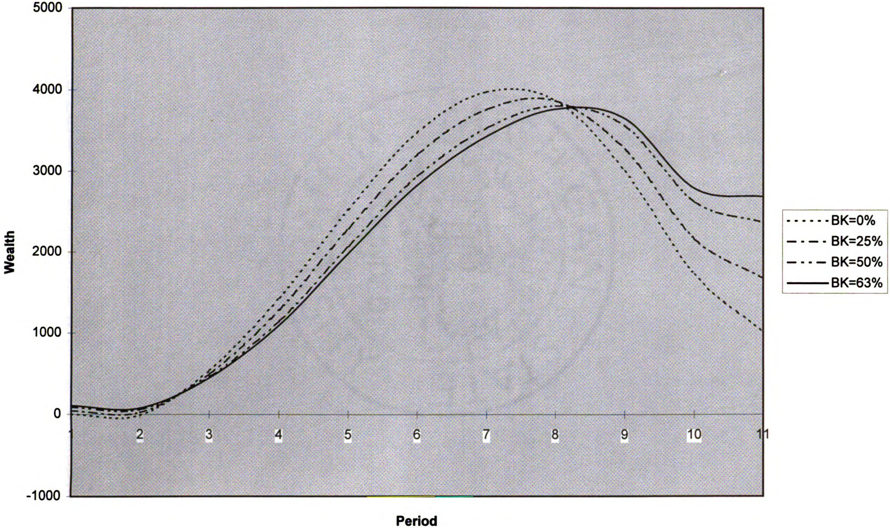


Figure 7B. Rental Price of Capital When C*=0, with Demographic Adjustment, Aggregate Model

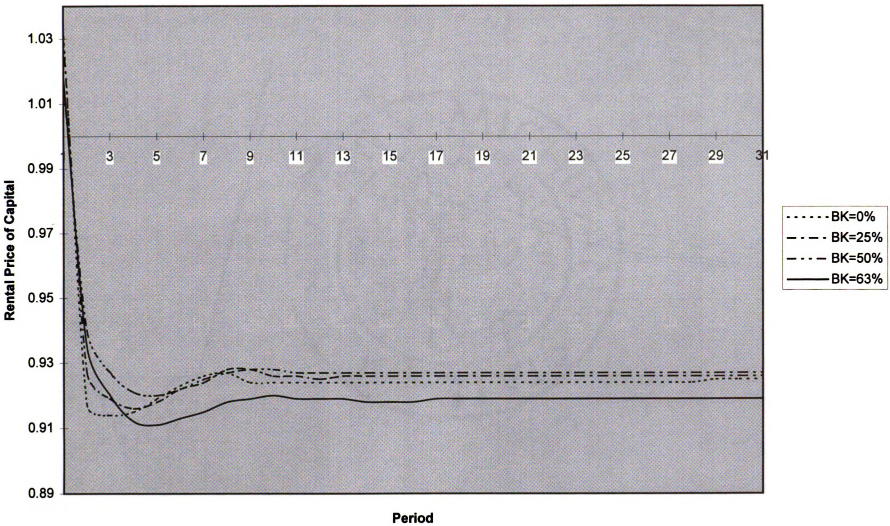


Figure 7C. Present Value of Equivalent Variation When C*=0, with Demographic Adjustment, Aggregate Model

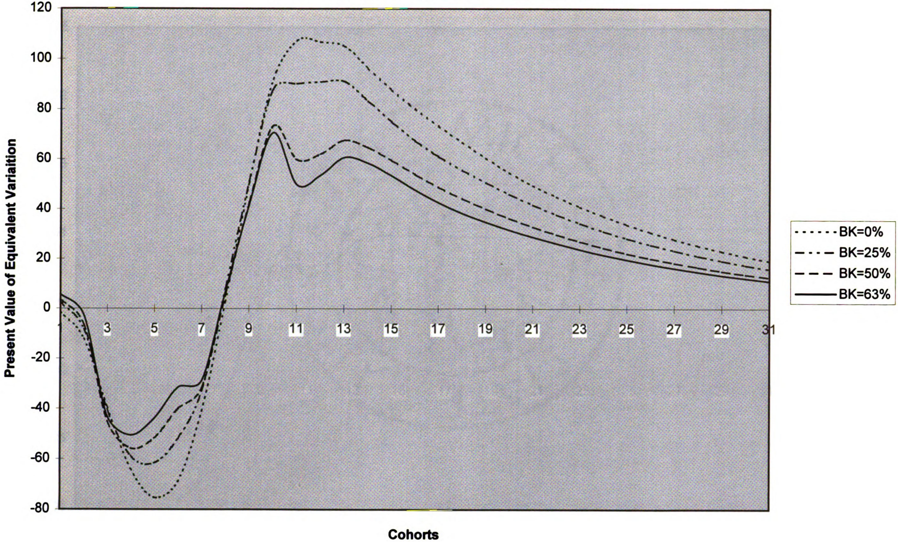


Figure 7D. Equivalent Variation as Proportion of Lifetime Resources When C*=0, with Demographic Adjustment, Aggregate Model

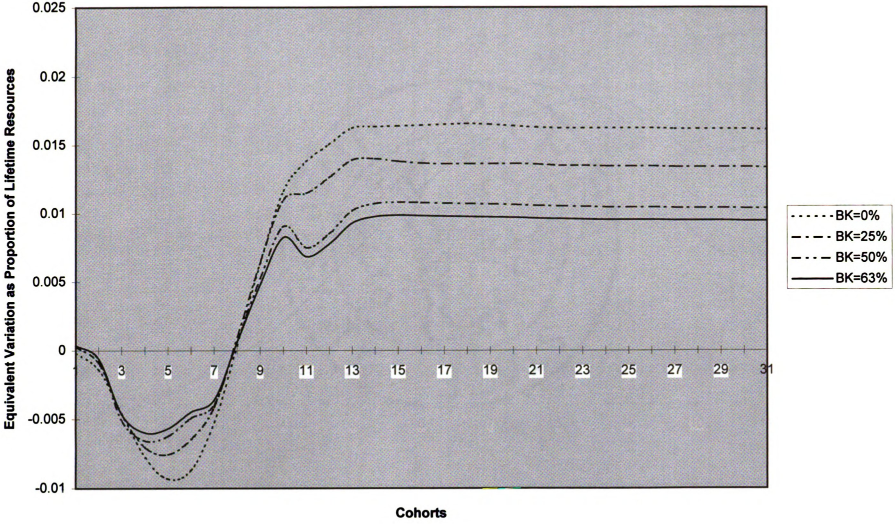


Figure 8A. Wealth Profile of Newcomer Cohort When C*=10% with Demographic Adjustment, Aggregate Model

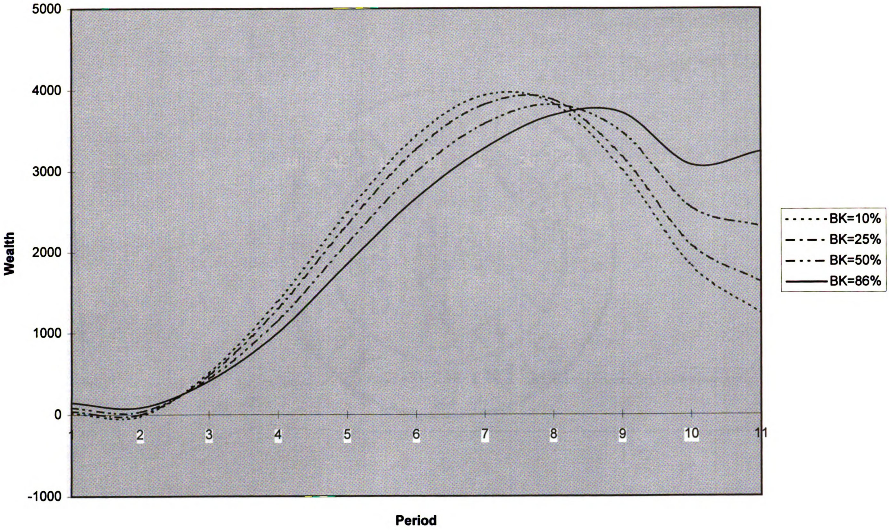


Figure 8B. Rental Price of Capital When C*=10%, with Demographic Adjustment, Aggregate Model

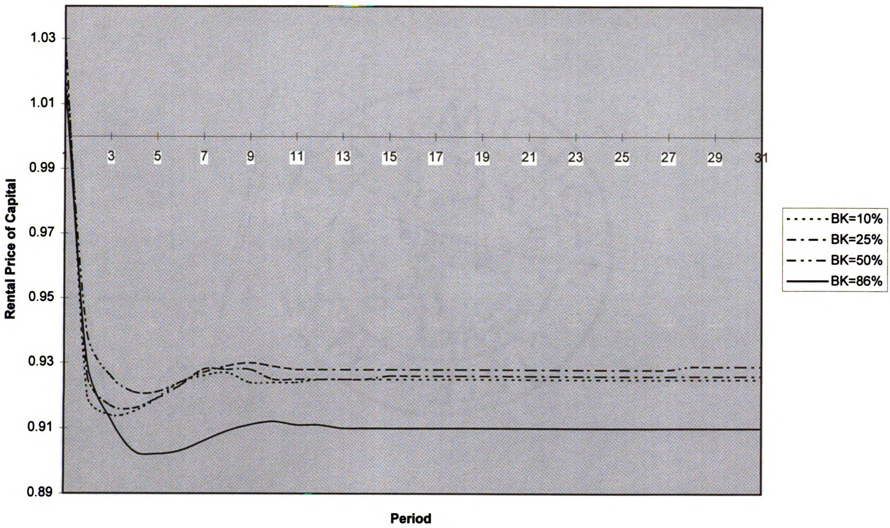


Figure 8C. Present Value of Equivalent Variation When C^{*}=10%,

Figure 8C. Present Value of Equivalent Variation When C*=10%, with Demographic Adjustment, Aggregate Model

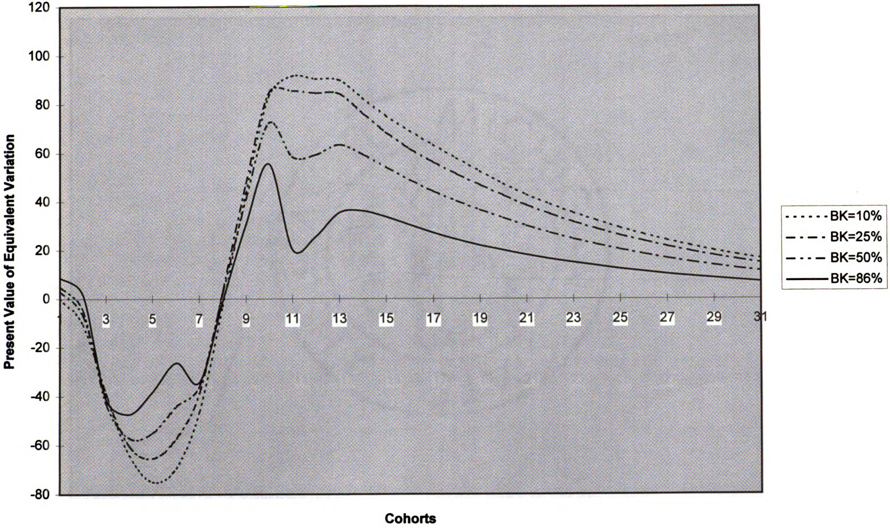


Figure 8D. Equivalent Variation as Proportion of Lifetime Resources When C*=10%, with Demographic Adjustment, Aggregate Model

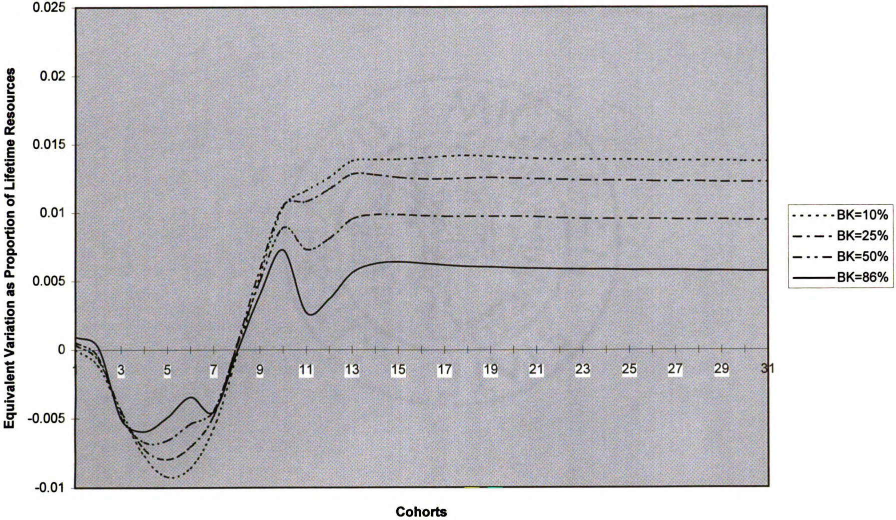


Figure 9A. Wealth Profile of Newcomer Cohort When C*=20%, with Demographic Adjustment, Aggregate Model

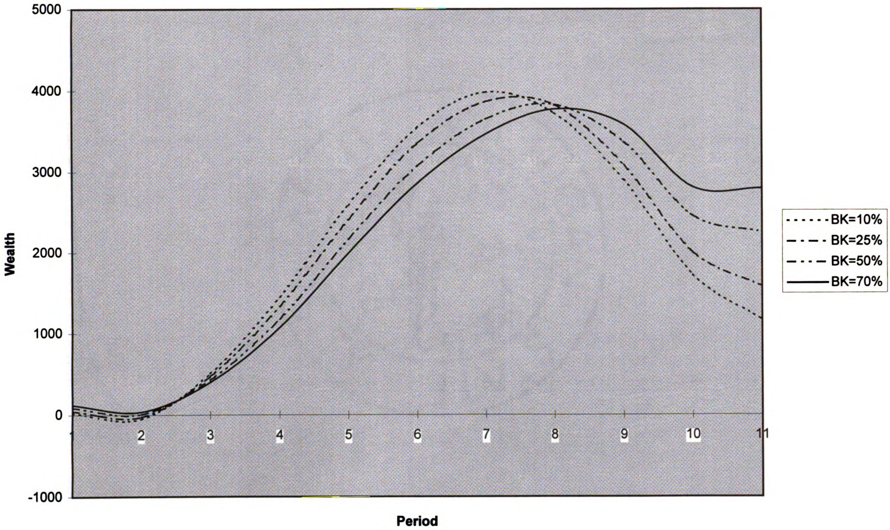


Figure 9B. Rental Price of Capital When C*=20%, with Demographic Adjustment, Aggregate Model

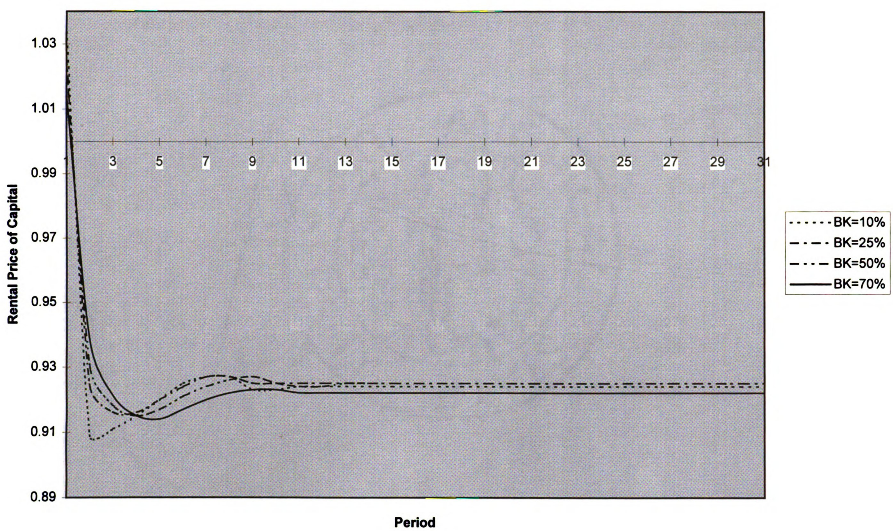


Figure 9C. Present Value of Eqivalent Variation When C*=20%, with Demographic Adjustment, Aggregate Model

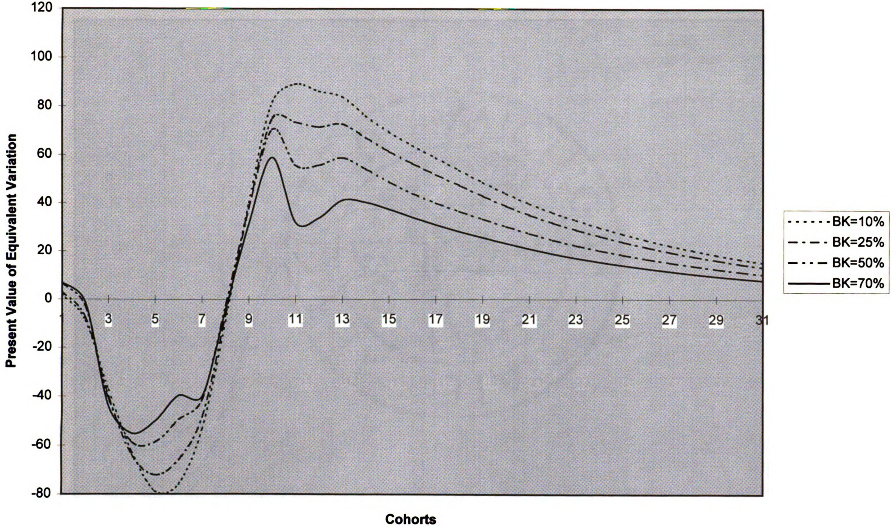


Figure 9D. Equivalent Variation as Proportion of Lifetime Resources When c*=20%, with Demographic Adjustment, Aggregate Model

Figure 10A. Wealth Profile of Newcomer Cohort When C*=30%, with Demographic Adjustment, Aggregate Model

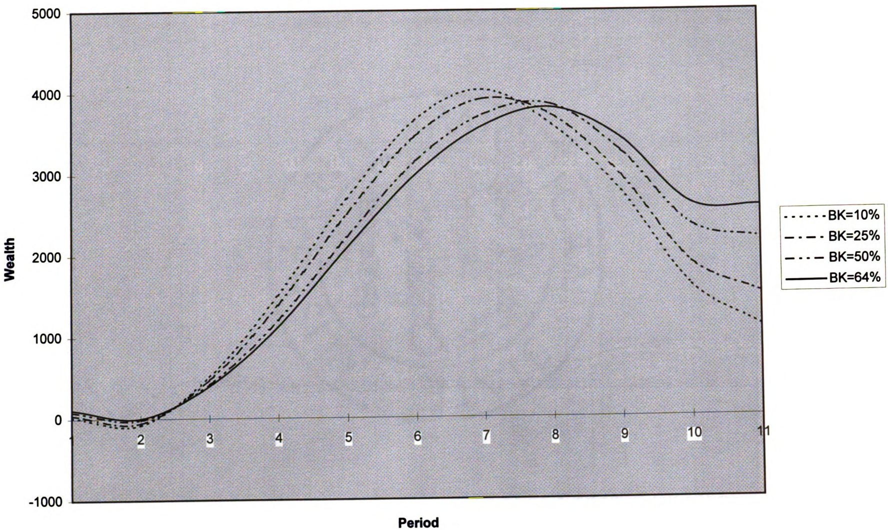


Figure 10B. Rental Price of Capital When C*=30%, with Demographic Adjustment, Aggregate Model

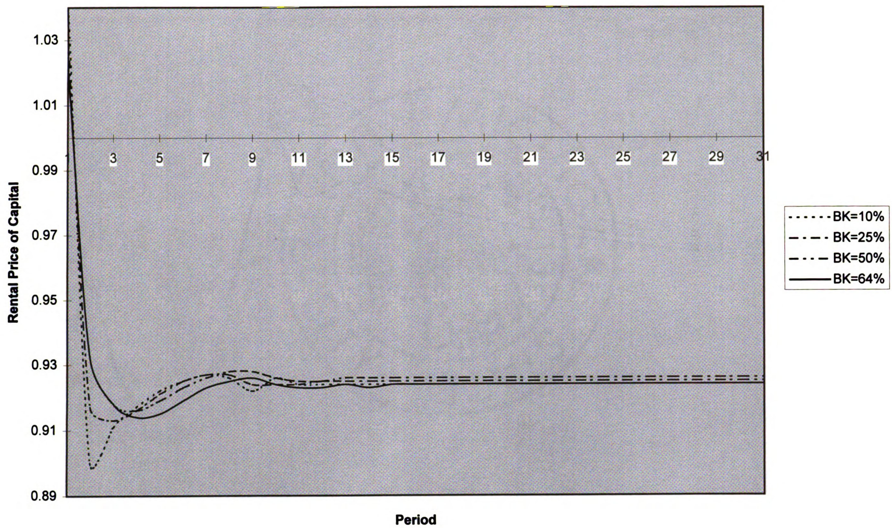


Figure 10C. Present Value of Equivalent Variation When C*=30%, with Demographic Adjustment, Aggregate Model

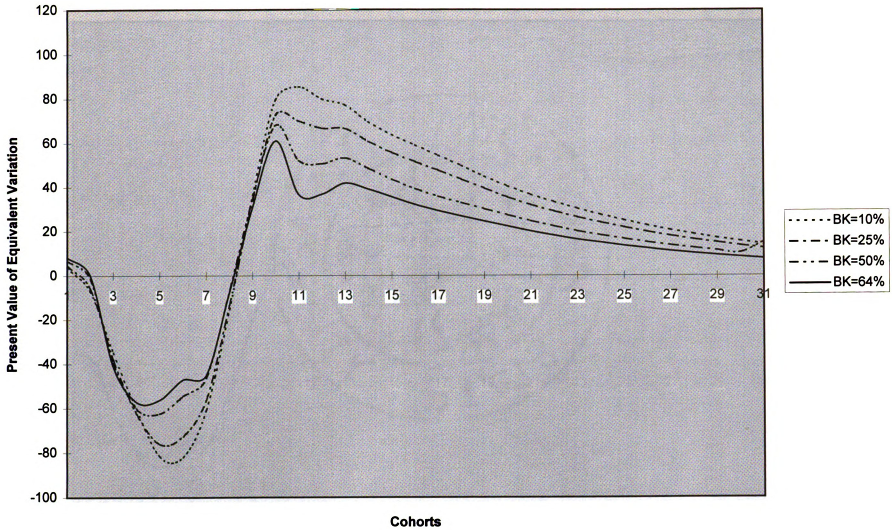
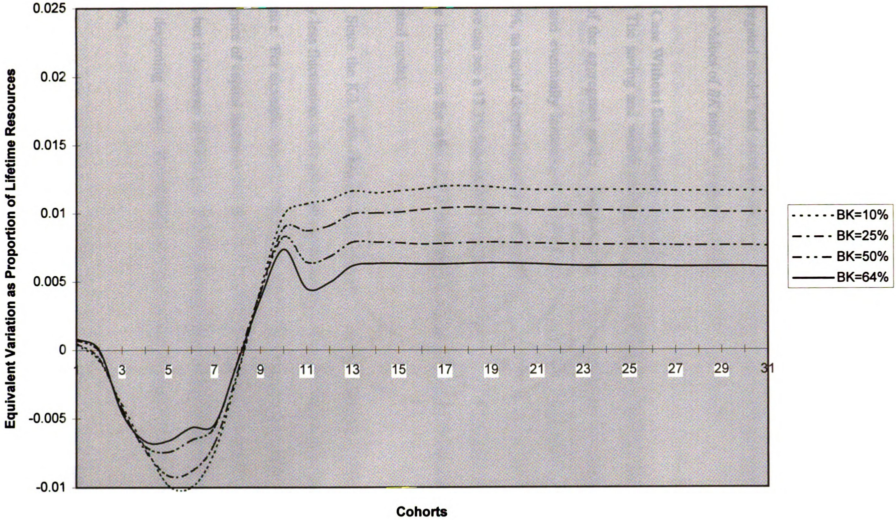


Figure 10D. Equivalent Variation of Lifetime Resources When C*=30%, with Demographic Adjustment, Aggregate Model



4.3. Results in the Disaggregated Model

As Table 2 shows, I disaggregate this model into 19 sectors and 18 consumer goods in this case, and run the simulations again. I run several simulations for the disaggregated model, and compare these results with those of the aggregated model for the same values of *BK* and *C**, to see the effects of VAT on each sector.

4.3.1. Case Without Demographic Adjustment

The saving and wealth profiles from the disaggregated model are the same as those of the aggregated model. Table 24 shows that the aggregate *K/L* ratio starts at 0.250 and eventually increases to 0.280 in the disaggregated model when *C**=0 and *BK*=50%, as capital deepening occurs. This amounts to a 12.0% increase in the *K/L* ratio, while we can see a 13.3% increase in the aggregated model. For various values of *C** and *BK*, the increase in the ratio of *K/L* is smaller in the disaggregated model than in the aggregated model.

Since the K/L ratio changes somewhat less in the disaggregated model, we see slightly less fluctuation in the price of capital services. In Table 25, we can observe this difference. For example, when *C**=0 and *BK*=50% in the disaggregated model, the real rental price of capital increases to 1.027 (vs. 1.043 in the aggregated model) in the first period, but it decreases to 0.933 (vs. 0.929 in the aggregated model) in the final period as capital deepening occurs. This difference is also shown in Figure 11A for *C**=0 and *BK*=70%.

Figures 11B and 11C show the difference in the welfare change between the disaggregated model and the aggregated model. When C*=0% and *BK*=70%, we have

2.06% welfare gains as a proportion of lifetime resources in the aggregated model. When the same parameters are used in the disaggregated model, we have 1.89% welfare gains. For various values of C* and *BK*, we do not observe any big difference in welfare change between the aggregated and disaggregated model. This is not a surprising result, because I have assumed a uniform VAT on 19 production sectors. If we levy a differentiated VAT on each sector, we would expect to see a bigger difference in the welfare change between the aggregated model and the disaggregated model.

4.3.2. Case With Demographic Adjustment

Generally speaking, we observe almost the same results in this case as in the case of the disaggregated model without demographic adjustment. The results are reported in Tables 26 and 27, and also in Figures 12A, 12B, and 12C. However, in this case, we do not observe much overshooting in the rental price of capital for various values of *C** and *BK*. The capital service price converges more quickly, without much fluctuation, to the new steady state than in the aggregated model.

Since there are only a consumption good and an investment good in the aggregated model, there is no relative price change among goods, even when factor prices change. However, in the disaggregated model, relative prices of the consumption goods can change, since each price is a weighted average of the prices of the 19 goods. In the revised case with the disaggregated model, there is a big shift of investment toward contract construction (*4th* industry) and metals, machinery, instruments, and miscellaneous manufacturing (*5th* industry). This leads to a price change of these two industries.

However, as we can observe in figure 11A, 11B, 11C, 12A, 12B and 12C, there is only a small change between the results of the disaggregated model and those of the aggregated model. Thus, the disaggregated model does not tell us a great deal more about the dynamics of this model.

Table 24. Aggregate K/L Ratio without Demographic Adjustment, Disaggregated Model

T	C*=0 and BK=50%		C*=10% and BK=50%	
	Aggregated	Disaggregated	Aggregated	Disaggregated
1	0.249	0.250	0.250	0.250
2	0.288	0.290	0.288	0.291
3	0.282	0.279	0.283	0.279
4	0.286	0.283	0.285	0.282
5	0.284	0.281	0.283	0.280
6	0.283	0.280	0.282	0.280
7	0.282	0.280	0.282	0.279
8	0.281	0.279	0.282	0.280
9	0.281	0.280	0.283	0.281
10	0.282	0.280	0.282	0.280
11	0.282	0.280	0.282	0.280
12	0.282	0.280	0.282	0.280
13	0.282	0.280	0.282	0.280
14	0.282	0.280	0.282	0.280
15	0.282	0.280	0.282	0.280
16	0.282	0.280	0.282	0.280
17	0.282	0.280	0.282	0.280
18	0.282	0.280	0.282	0.280
19	0.282	0.280	0.282	0.280
20	0.282	0.280	0.282	0.280
21	0.282	0.280	0.282	0.280
22	0.282	0.280	0.282	0.280
23	0.282	0.280	0.282	0.280
24	0.282	0.280	0.282	0.280
25	0.282	0.280	0.282	0.280
26	0.282	0.280	0.282	0.280
27	0.282	0.280	0.282	0.280
28	0.282	0.280	0.282	0.280
29	0.282	0.280	0.282	0.280
30	0.282	0.280	0.282	0.280
31	0.282	0.280	0.282	0.280

Table 25. Real Rental Price of Capital without Demographic Adjustment, Disaggregated Model

T	C*=0 and BK=50%		C*=10% and BK=50%	
	Aggregated	Disaggregated	Aggregated	Disaggregated
1	1.043	1.027	1.040	1.026
2	0.910	0.903	0.907	0.900
3	0.927	0.934	0.925	0.932
4	0.918	0.924	0.919	0.925
5	0.922	0.930	0.924	0.930
6	0.926	0.932	0.926	0.932
7	0.928	0.933	0.929	0.933
8	0.930	0.934	0.929	0.933
9	0.930	0.934	0.926	0.931
10	0.927	0.932	0.927	0.932
11	0.928	0.933	0.928	0.932
12	0.928	0.933	0.928	0.932
13	0.929	0.933	0.929	0.933
14	0.928	0.933	0.928	0.932
15	0.929	0.933	0.928	0.932
16	0.929	0.933	0.928	0.932
17	0.929	0.933	0.928	0.932
18	0.929	0.933	0.928	0.932
19	0.929	0.933	0.928	0.932
20	0.929	0.933	0.928	0.932
21	0.929	0.933	0.928	0.932
22	0.929	0.933	0.928	0.932
23	0.929	0.933	0.928	0.932
24	0.929	0.933	0.928	0.932
25	0.929	0.933	0.928	0.932
26	0.929	0.933	0.928	0.932
27	0.929	0.933	0.928	0.932
28	0.929	0.933	0.928	0.932
29	0.929	0.933	0.928	0.932
30	0.929	0.933	0.928	0.932
31	0.929	0.933	0.928	0.932

Table 26. Aggregate K/L Ratio with Demographic Adjustment, Disaggregated Model

T	C*=0 and BK=0%		C*=30% and BK=50%	
	Aggregated	Disaggregated	Aggregated	Disaggregated
1	0.251	0.251	0.254	0.254
2	0.284	0.286	0.279	0.281
3	0.286	0.283	0.285	0.283
4	0.286	0.283	0.286	0.282
5	0.285	0.281	0.285	0.282
6	0.283	0.281	0.283	0.280
7	0.282	0.280	0.282	0.280
8	0.282	0.280	0.281	0.280
9	0.283	0.281	0.281	0.280
10	0.283	0.281	0.282	0.280
11	0.283	0.281	0.282	0.280
12	0.283	0.281	0.282	0.280
13	0.283	0.281	0.282	0.280
14	0.283	0.281	0.282	0.280
15	0.283	0.281	0.282	0.280
16	0.283	0.281	0.282	0.280
17	0.283	0.281	0.282	0.280
18	0.283	0.281	0.282	0.280
19	0.283	0.281	0.282	0.280
20	0.283	0.281	0.282	0.280
21	0.283	0.281	0.282	0.280
22	0.283	0.281	0.282	0.280
23	0.283	0.281	0.282	0.280
24	0.283	0.281	0.282	0.280
25	0.283	0.281	0.282	0.280
26	0.283	0.281	0.282	0.280
27	0.283	0.281	0.282	0.280
28	0.283	0.281	0.282	0.280
29	0.283	0.281	0.282	0.280
30	0.283	0.281	0.282	0.280
31	0.283	0.281	0.282	0.280

Table 27. Real Rental Price of Capital with Demographic Adjustment, Disaggregated Model

T	C*=0 and BK=0%		C*=30% and BK=50%	
	Aggregated	Disaggregated	Aggregated	Disaggregated
1	1.033	1.018	1.023	1.013
2	0.917	0.909	0.932	0.921
3	0.914	0.921	0.918	0.922
4	0.915	0.923	0.916	0.924
5	0.919	0.927	0.919	0.926
6	0.923	0.929	0.923	0.929
7	0.926	0.931	0.926	0.931
8	0.927	0.931	0.928	0.932
9	0.924	0.928	0.928	0.932
10	0.924	0.929	0.926	0.930
11	0.924	0.929	0.925	0.930
12	0.924	0.929	0.925	0.930
13	0.924	0.929	0.926	0.930
14	0.924	0.929	0.926	0.930
15	0.924	0.929	0.926	0.930
16	0.924	0.929	0.926	0.930
17	0.924	0.929	0.926	0.930
18	0.924	0.929	0.926	0.930
19	0.924	0.929	0.926	0.930
20	0.924	0.929	0.926	0.930
21	0.924	0.929	0.926	0.930
22	0.924	0.929	0.926	0.930
23	0.924	0.929	0.926	0.930
24	0.924	0.929	0.926	0.930
25	0.924	0.929	0.926	0.930
26	0.924	0.929	0.926	0.930
27	0.924	0.929	0.926	0.930
28	0.924	0.929	0.926	0.930
29	0.925	0.929	0.926	0.930
30	0.925	0.929	0.926	0.930
31	0.925	0.929	0.926	0.930

Figure 11A. Rental Price of Capital When C*=0 and BK=70%, without Demographic Adjustment

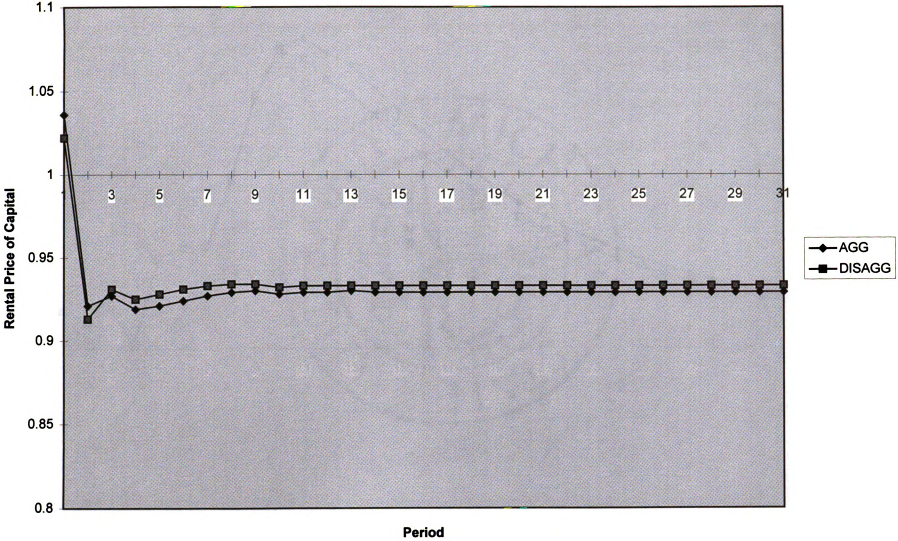


Figure 11B. Present Value of Equivalent Variation When C*=0 and BK=70%, without Demographic Adjustment

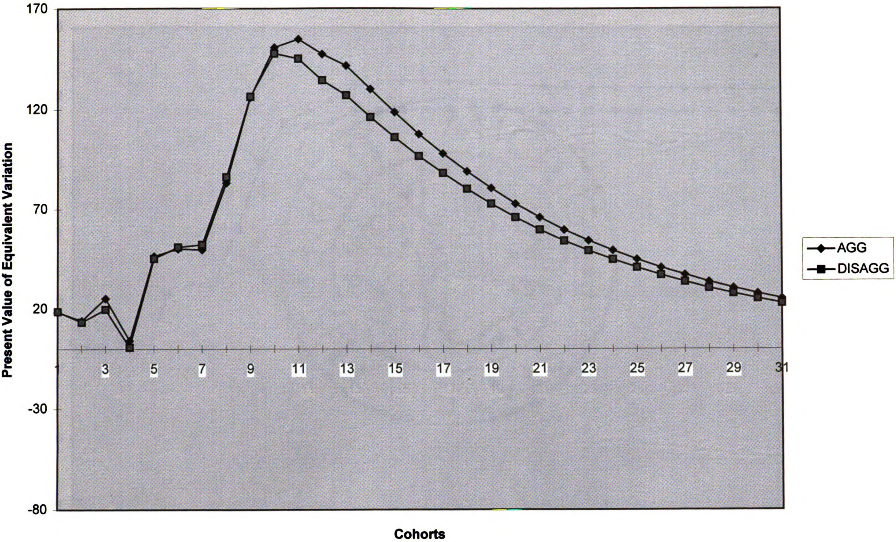


Figure 11C. Equivalent Variation as Proportion of Lifetime Resources
When C*=0 and BK=70%, without Demographic Adjustment

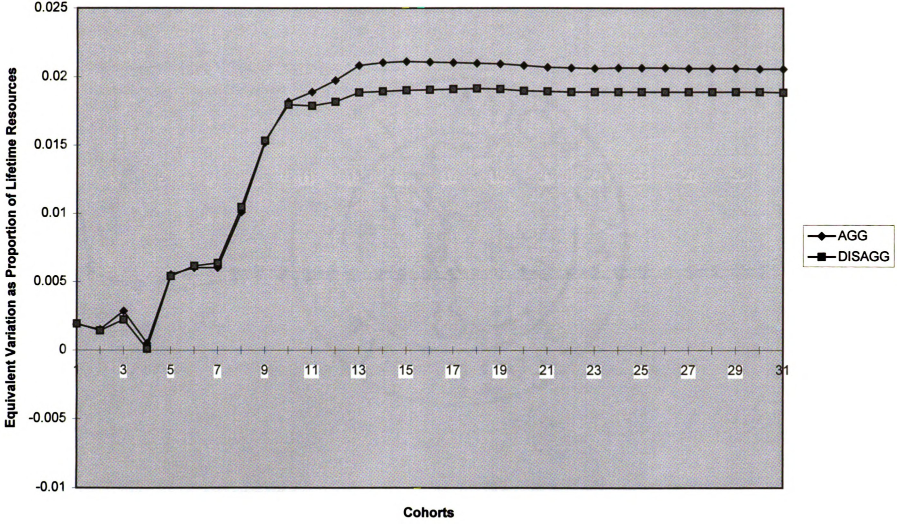


Figure 12A. Rental Price of Capital When C*=0 and BK=50%, with Demographic Adjustment

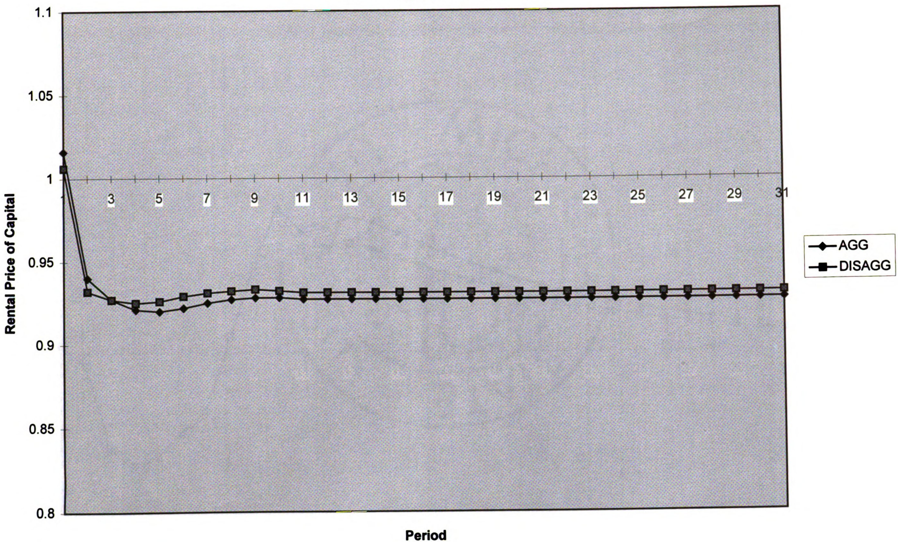


Figure 12B. Present Value of Equivalent Variation When C*=0 and BK=50%, with Demographic Adjustment

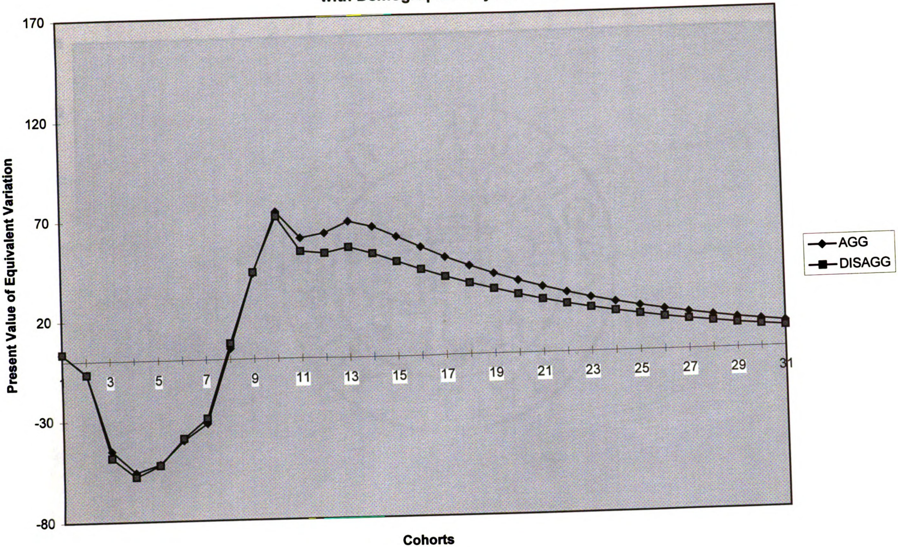
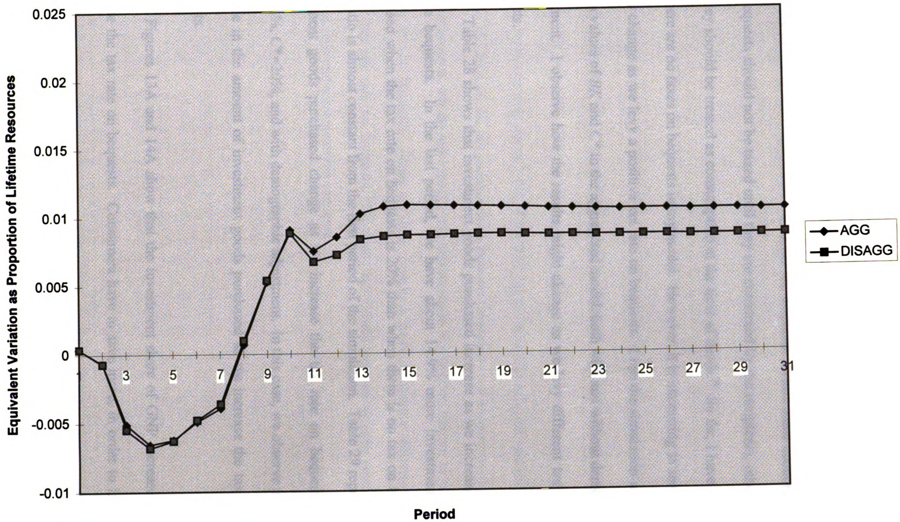


Figure 12C. Equivalent Variation as Proportion of Lifetime Resources when C*=0 and BK=50%, with Demographic Adjustments



4.4. Results When Tax on Bequests Is Positive

One of the issues of shifting to a consumption tax is how to tax bequests and gifts. There are pros and cons on whether we should tax bequests. While some economists say that bequests should not be taxed until they are consumed by the recipients, others argue that they should be treated as consumption at the time of death.[38] So far, I have assumed that there are no taxes on bequests in my model. However, it is interesting to see how the results change as we levy a positive tax rate on bequests. I run the simulation model for certain values of *BK* and *C** in the aggregated model, both with and without demographic adjustment. I observe how the results might change as we levy different tax rates on bequests.

Table 28 shows that investment goods purchased increase as we increase the tax rate on bequests. In the last period, we have about 14.9% more investment goods purchased when the tax rate on bequests is 20% than when there is no tax on bequests. This ratio is almost constant from the first period of the simulation. Table 29 reports how investment goods purchased change as we increase the tax rate on bequests when *BK*=50%, *C**=20%, and with demographic adjustment. In this case, we observe a smaller increase in the amount of investment goods purchased as we increase the tax rate on bequests.

Figures 13A and 14A show that the investment share of GNP increases as we increase the tax rate on bequests. Consumers have to save more, in order to leave the

[38] See Bradford (1984) and Aaron and Galper (1985) for further discussion. This debate turns on distributional and administrative issues, more than on efficiency issues.

same amount of bequests as the tax on bequests increases.[39] Figures 13B and 14B show how the equivalent variation as a proportion of lifetime resources changes as we change the tax rate on bequests. We do not observe a big difference in the welfare change as we levy a positive tax on bequests. For example, in the case of no demographic adjustment, if the tax on bequests is 0%, we have welfare gains of 1.92% of lifetime resources in the long-run when C*=0, *BK*=50%. If we increase the tax rate on bequests to 10%, we have long-run welfare gains of 1.87%. Thus, the effect of the estate tax on the welfare change is small in the long run. In addition, the effect is small in the short run, as shown in Figures 13B and 14B. This result can be explained by the fact that tax revenue from bequests makes up only about 1.4% of the total tax revenue when the tax rate on bequests is 10%. As long as the tax revenue from bequests explains such a small portion of the total tax revenue, we do not expect a big difference in the welfare change as we levy a positive tax on bequests. Since we only observe a small efficiency difference as we change the tax rate on bequests, the estate tax debate appears to turn primarily on distributional and administrative concerns.

[39]However, this is not a Barro/Ricardian model, because we assume that the households derive utility from their own consumption, leisure, and bequests, not from those of their descendants.

Table 28. Investment Goods Purchased When C*=20%, BK=50%, with No Demographic Adjustment, Aggregated Model

T	Btax=0	Btax=5%	Btax=10%	Btax=15%	Btax=20%
1	1915	1914	1915	1914	1914
2	1275	1385	1494	1603	1711
3	1564	1628	1688	1754	1818
4	1623	1698	1765	1840	1909
5	1834	1904	1965	2036	2102
6	2069	2145	2211	2288	2359
7	2342	2427	2500	2586	2666
8	2655	2751	2836	2933	3025
9	2988	3099	3197	3310	3416
10	3275	3404	3518	3650	3774
11	3697	3839	3965	4110	4248
12	4149	4309	4452	4617	4771
13	4688	4865	5022	5203	5374
14	5225	5427	5606	5812	6006
15	5869	6092	6291	6520	6735
16	6570	6822	7045	7303	7545
17	7365	7646	7896	8184	8456
18	8253	8569	8845	9173	9478
19	9257	9611	9925	10288	10630
20	10380	10777	11130	11537	11921
21	11639	12083	12479	12936	13366
22	13043	13542	13986	14499	14982
23	14624	15183	15681	16255	16797
24	16393	17020	17579	18223	18830
25	18379	19082	19707	20429	21110
26	20603	21391	22092	22902	23665
27	23098	23981	24768	25676	26531
28	25895	26885	17766	28784	29744
29	29029	30139	31128	32269	33345
30	32543	33788	34896	36179	37482
31	36483	37879	39121	40556	41908

Table 29. Investment Goods Purchased When C*=20%, BK=50%, with Demographic Adjustment, Aggregated Model

T	Btax=0	Btax=5%	Btax=10%	Btax=15%	Btax=20%
1	1724	1699	1696	1700	1698
2	1487	1530	1577	1627	1674
3	1533	1571	1611	1653	1694
4	1647	1687	1727	1769	1810
5	1820	1862	1905	1950	1993
6	2053	2097	2143	2192	2238
7	2328	2375	2426	2480	2531
8	2641	2694	2751	2812	2870
9	2982	3042	3108	3178	3244
10	3309	3380	3455	3535	3611
11	3699	3778	3868	3953	4039
12	4151	4240	4335	4436	4533
13	4662	4761	4867	4980	5087
14	5224	5335	5453	5580	5700
15	5857	5981	6113	6255	6390
16	6568	6705	6854	7013	7164
17	7361	7517	7683	7861	8031
18	8251	8425	8612	8812	9002
19	9250	9445	9655	9879	10092
20	10370	10590	10825	11076	11316
21	11626	11872	12136	12418	12687
22	13034	13309	13605	13921	14222
23	14611	14921	15252	15607	15944
24	16380	16727	17093	17496	17876
25	18363	18752	19168	19614	20038
26	20586	21022	21489	21988	22464
27	23079	23567	24090	24650	25184
28	25873	26420	27006	27635	28233
29	29005	29619	30277	30981	31652
30	32517	33205	33942	34731	35484
31	36453	37224	38051	38936	39780

Figure 13A. Investment Share of GNP When Cratio=0%, BK=50%, and No Demographic Adjustment

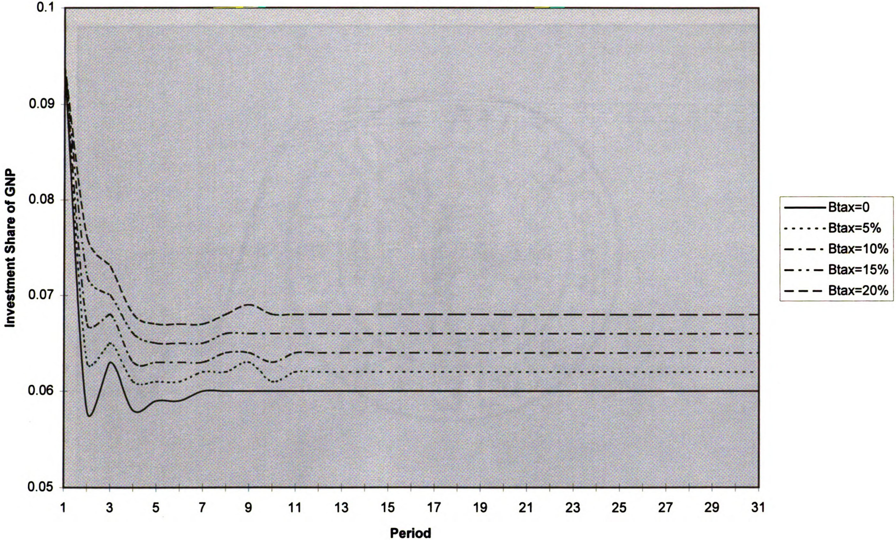


Figure 13B. Equivalent Variation as Proportion of Lifetime Resources When C*=0%, BK=50%, and No Demographic Adjustments

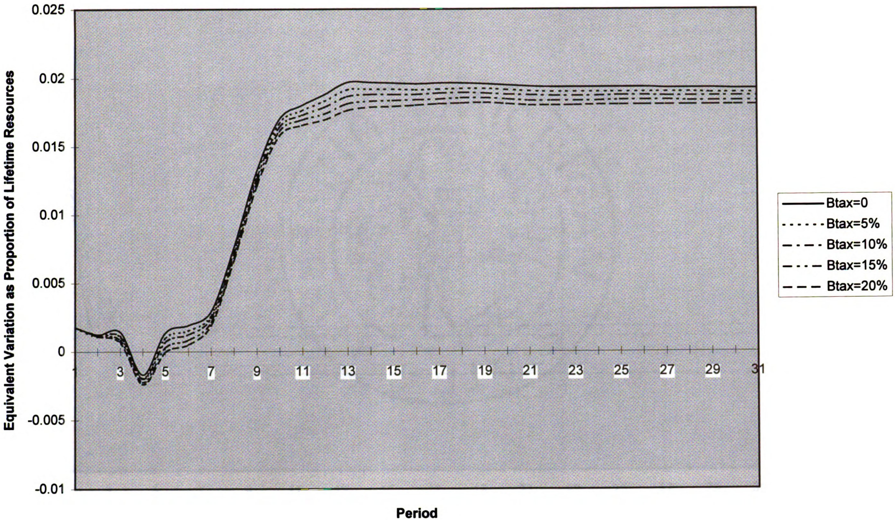


Figure 14A. Investment Share of GNP When C*=20% BK=50%, and With Demographic Adjustment

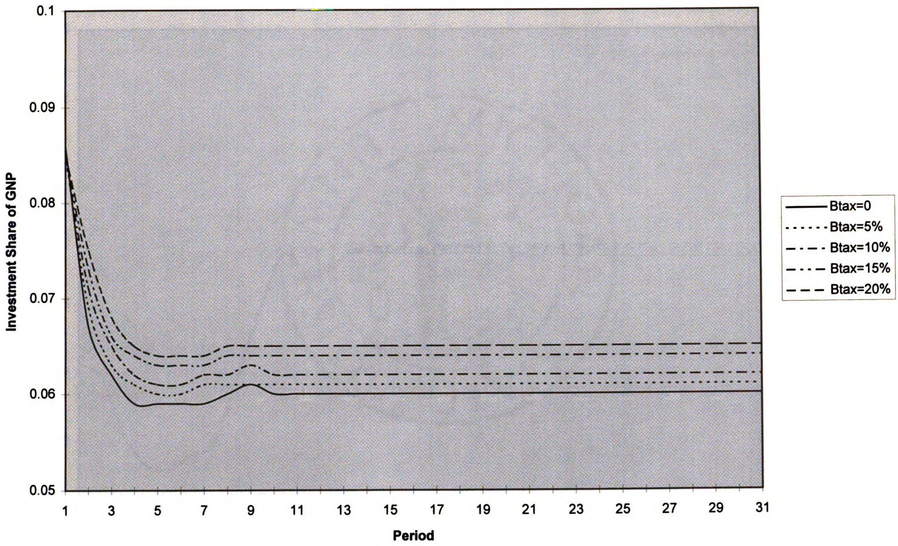
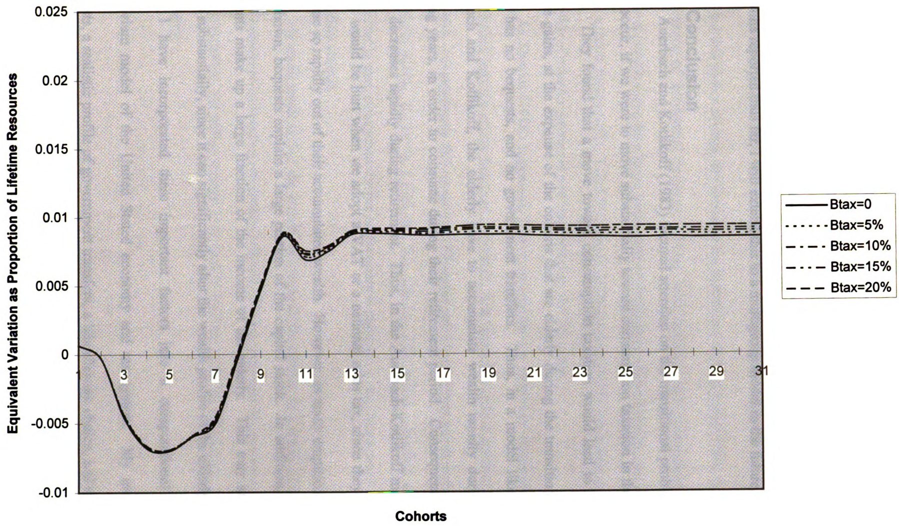


Figure 14B. Equivalent Variation as Proportion of Lifetime Resources When C*=20%, BK=50%, and with Demographic Adjustment



Currently, I am using a steady-state model, in order to be more comparable with the work of others. However, I am interested in doing some work with non-steady-state models in the future. Although I have only one group per cohort in the model to generate the results reported thus far, I will extend this to a multigroup model in the future.

4.5. Conclusion

Auerbach and Kotlikoff (1983) focused attention on the transitional problems that could occur, if we were to move substantially toward consumption taxation in the United States. They found that a move toward consumption taxation would lead to long-run welfare gains, at the expense of the cohorts that are elderly during the transition. Their model has no bequests, and no government transfers. Thus, in a model like that of Auerbach and Kotlikoff, the elderly have to accumulate wealth rapidly during their working years, in order to consume during their retirement period. Consequently, their wealth decreases rapidly during retirement. Thus, in the Auerbach-Kotlikoff model, the elderly would be hurt when we adopt a VAT or a national sales tax, since they have to consume so rapidly out of their accumulated wealth. However, as many empirical studies have shown, bequests explain a large portion of the capital stock. In addition, transfer payments make up a large fraction of the income of the elderly. This may affect the results substantially, since it can significantly alter the wealth profile of the elderly.

I have incorporated these important factors into a computational general equilibrium model of the United Stated economy and tax system. My model has bequests, a realistic profile of government transfers, a labor/leisure choice, and a number of other features, including a detailed treatment of the many components of the tax system. Taken together, these factors help to produce a fairly flat wealth profile, which is much more realistic than the extremely humped wealth profiles of Auerbach and Kotlikoff. As a result, it is sometimes possible for all cohorts to have welfare gains from a move toward greater reliance on consumption taxation. Even when all cohorts do not gain from this policy change, the losses to the elderly are still mitigated when we assume the presence of substantial bequests. Thus, both bequests and government transfer payments (which make up a large proportion of the income of the elderly), are important factors to have these results. I find that these results are sensitive to the assumption about the profile of transfer payments and bequests over the life cycle.

As Starrett (1988) suggested, I have incorporated a minimum required level of consumption into the utility function. However, this factor has only a modest effect on the results. I disaggregate this model into 19 sector and 18 consumer goods and I run the simulations again. However, I find that this also has little effect. Another surprising result I find is that, even when the tax on bequests is positive, it only has a small effect on the welfare change.

My main result is that the transition losses to the elderly as a result of the move toward consumption taxation are greatly reduced. Under some sets of parameters that are not unreasonable, the policy change may lead to welfare gains for all cohorts, including the elderly.

APPENDIX

APPENDIX

This appendix relies on an appendix to Ballard and Goulder (1987). However, my model has some nice features that their model lacks. Even though their model has bequests in it, the bequest parameter was always set to zero during their simulations. However, my model has positive bequests and I add a minimum required consumption to control the intertemporal elasticities. I also add a positive labor supply constraint to their model. While bequests and government transfers are assumed to be distributed evenly across cohorts in their model, I use realistic bequest and transfer proportions across cohorts based on the real data. I use a quartic specification of human capital earnings based on Murphy and Welch (1990) to derive the labor efficiency ratio (e_h). Ballard and Goulder, however, use the quadratic human capital earnings function of Oaxaca(1973). As shown by Murphy and Welch, the quartic function describes actual earnings profiles much more accurately than does the quadratic.

1. SOLUTION OF HOUSEHOLD'S MAXIMIZATION PROBLEM

Let $\hat{C}_t = C_t - C^*$[40] and $\hat{H}_t (= l_t) = H^* - H_t$.

[40]David Starrett (1982) first suggested that a Stone-Geary formulation of the instantaneous utility or felicity function would be useful in studying the behavior of life-cycle consumers.

$$\text{where}\begin{cases} C_t = \text{consumption at year } t, \\ C^* = \text{minimum consumption level}, \\ \hat{H}_t(=l_t) = \text{leisure}, \\ H_t = \text{amount of labor supply, and} \\ H^* = \text{potential labor time given endowment.} \end{cases}$$

The utility function for any given cohort takes the following additively separable form:

$$\text{(1-1)} \quad \mathrm{U} = \frac{1}{\delta}\sum_{t=1}^{T}\frac{1}{(1+\rho)^{t-1}}\left\{\left(C_t - C_t^*\right)^{\sigma} + \alpha_t\left(H^* - H_t\right)^{\sigma}\right\}^{\frac{\delta}{\sigma}} + \frac{1}{\delta}\frac{1}{\left(1+\rho\right)^{T}}b^{1-\delta}B_T^{\delta},$$

$$\text{where}\begin{cases} T \text{ is the index for the final year of life,} \\ l_t \text{ is leisure at year } t, \\ B_T \text{ is the bequest left at the end of year } T, \\ \bar{\delta} \text{ is the elasticity of substitution between bundles of } C \text{ and } l \text{ across periods,} \\ \delta \equiv 1 - \frac{1}{\bar{\delta}}, \\ \bar{\sigma} \text{ is the elasticity of substitution between } C \text{ and } l \text{ in a given period,} \\ \sigma \equiv 1 - \frac{1}{\bar{\sigma}}, \\ \rho \text{ is the rate of time preference,} \\ \alpha \text{ is the leisure intensity parameter, and} \\ b \text{ is the bequest parameter.} \end{cases}$$

The intertemporal wealth constraint is:

$$\text{(1-2)} \qquad P_{K_1}K_1 + \sum_{t=1}^{T}\left\{W_t'\left(H^* - l_t\right) + TR_t + IN_t - P_tC_t\right\}d_t - P_{B_T}B_Td_T = 0,$$ [41]

[41]Taxes have been suppressed for notational convenience. Inclusion of taxes is straightforward.

$$\text{where} \begin{bmatrix} P_{K_1} \text{ is the price of initial nonhuman capital,} \\ K_1 \text{ is the initial capital endowment,} \\ W_t' \text{ is the wage rate for period } t, \\ H_t \text{ is the hours worked for period } t, \\ TR_t \text{ is transfers for period } t, \\ IN_t \text{ is inheritances for period } t, \\ P_t \text{ is the price index for consumption for period } t, \\ d_t \text{ is the discounting factor for period } t, \text{ defined below, and} \\ P_{B_T} \text{ is the price of bequest for period } t. \end{bmatrix}$$

and

(1-3) $$W_t' = W_t e_h \ ,$$

$$\text{where} \begin{bmatrix} W_t \text{ is the prevailing wage per unit of effective labor for period } t \\ e_h \text{ is the ratio of effective labor to labor hours for a cohort of age } h. \end{bmatrix}$$

The intertemporal labor supply constraint is:

(1-4) $$\left(H^{*} - l_t\right) \geq 0 \ \text{ for all } t,$$

Finally,

We assume that bequests are all given at end of life.

$$d_t \equiv \begin{cases} \dfrac{1}{\prod_{s=1}^{t-1}\left(1+r_s\right)} & ,\forall\, t > 1 \\ 1 & ,\ t = 1 \ . \end{cases}$$

From expressions (1-1), (1-2), and (1-4), we can write the Lagrangean function for the consumer's maximization problem as

$$(1\text{-}5)\quad L=\frac{1}{\delta}\sum_{t=1}^{T}\frac{1}{(1+\rho)^{t-1}}\left\{\left(C_t-C^{*}\right)^{\sigma}+\alpha_t\left(H^{*}-H_t\right)^{\sigma}\right\}^{\frac{\delta}{\sigma}}+\frac{1}{\delta}\frac{1}{\left(1+\rho\right)^{T}}b^{1-\delta}B_T^{\delta}$$

$$+\lambda\left[P_{K_1}K_1+\sum_{t=1}^{T}\left\{W_t'\left(H^{*}-l_t\right)+TR_t+IN_t-P_tC_t\right\}d_t-P_{B_T}B_Td_T\right]$$

$$+\lambda\left\{\sum_{t=1}^{T}\mu_t\left(H^{*}-l_t\right)d_t\right\}\ ,$$

where λ is the Lagrange multiplier and represents the marginal utility of lifetime resources, and μ_ts are the Kuhn-Tucker multipliers on the constraints on labor supply.

If we take the first-order condition from equation (1-5) with respect to consumption, leisure, λ, and μ_t we get the following expressions:

$$(1\text{-}6)\qquad \frac{\partial L}{\partial C_t}=\frac{1}{\delta}\frac{1}{\left(1+\rho\right)^{t-1}}\frac{\delta}{\sigma}\left(\hat{C}_t^{\sigma}+\alpha_t l_t^{\sigma}\right)^{\frac{\delta}{\sigma}-1}\sigma\hat{C}_t^{\sigma-1}-\lambda P_t d_t=0\ ,$$

$$(1\text{-}7)\qquad \frac{\partial L}{\partial \hat{H}_t}\left(=-\frac{\partial L}{\partial l_t}\right)=\frac{1}{\delta}\frac{1}{\left(1+\rho\right)^{t-1}}\frac{\delta}{\sigma}\left(\hat{C}_t^{\sigma}+\alpha_t l_t^{\sigma}\right)^{\frac{\delta}{\sigma}-1}\sigma\alpha_t l_t^{\sigma-1}-\lambda W_t'd_t-\lambda\mu_t d_t=0$$

$$\frac{\partial L}{\partial \lambda}=\ P_{K_1}K_1+\sum_{t=1}^{T}\left\{W_t'\left(H^{*}-l_t\right)+TR_t+IN_t-P_tC_t\right\}d_t-P_{B_T}B_Td_T$$

$$(1\text{-}8)\qquad +\sum_{t=1}^{T}\mu_t\left(H^{*}-l_t\right)d_t=0\qquad ,$$

and

$$(1\text{-}9)\qquad \frac{\partial L}{\partial \mu_t}=\left(H^{*}-l_t\right)\geq 0\ .$$

$$\begin{pmatrix} i.e., \text{ if } \left(H^{*}-l_{t}\right)>0, \text{ then } \mu_{t}=0 \\ \text{if } \left(H^{*}-l_{t}\right)=0, \text{ then } \mu_{t}>0 \end{pmatrix}$$

In other words, if we have positive labor supply, then μ_t=0, and W_t' is the effective wage. If we have zero labor supply, then μ_t>0, and $W_t' + \mu_t$ is the reservation wage at which the consumer chooses to supply exactly zero labor.

Rearranging terms of (1-6) and (1-7) gives us the following equations, indicating that the marginal utility of the consumption at time t must equal the marginal cost of consumption, and marginal utility of the leisure must equal its marginal opportunity cost:

(1-10) $$\frac{1}{(1+\rho)^{t-1}}\left(\hat{C}_t^{\sigma}+\alpha_t l_t^{\sigma}\right)^{\frac{\delta}{\sigma}-1}\hat{C}_t^{\sigma-1}=\lambda P_t d_t$$

and

(1-11) $$\frac{1}{(1+\rho)^{t-1}}\left(\hat{C}_t^{\sigma}+\alpha_t l_t^{\sigma}\right)^{\frac{\delta}{\sigma}-1}\alpha_t l_t^{\sigma-1}=\lambda\left(W_t'+\mu_t\right)d_t.$$

Dividing (1-10) by (1-11) yields

$$\frac{\hat{C}_t^{\sigma-1}}{\alpha_t l_t^{\sigma-1}}=\frac{P_t}{W_t'+\mu_t}\ .$$

We rearrange terms to get the path of leisure as a function of discretionary consumption and parameters.

$$\alpha_t l_t^{\sigma-1}=\left(\frac{W_t'+\mu_t}{P_t}\right)\hat{C}_t^{\sigma-1}$$

$$l_t^{\sigma-1} = \left(\frac{W_t' + \mu_t}{\alpha_t P_t}\right)\hat{C}_t^{\sigma-1}$$

$$l_t = \left(\frac{W_t' + \mu_t}{\alpha_t P_t}\right)^{\frac{1}{\sigma-1}} \hat{C}_t \ .$$

Thus

(1-12) $$l_t = \hat{C}_t \xi_t \ ,$$

where $\xi_t = \left(\frac{W_t' + \mu_t}{\alpha_t P_t}\right)^{\frac{1}{\sigma-1}}$.

Substituting (1-12) into (1-10) gives an expression in terms of $\hat{C}_t$, λ, P_t, ξ_t, and parameters such as ρ, σ, and δ.

$$\frac{1}{(1+\rho)^{t-1}}\left(\hat{C}_t^{\sigma} + \alpha_t\left(\hat{C}_t \xi_t\right)^{\sigma}\right)^{\frac{\delta}{\sigma}-1} \hat{C}_t^{\sigma-1} - \lambda P_t d_t = 0$$

We rearrange terms to get an expression of $\hat{C}_t$ in terms of other terms and parameters.

$$\frac{1}{(1+\rho)^{t-1}}\left(\hat{C}_t^{\sigma}\left(1 + \alpha_t \xi_t^{\sigma}\right)\right)^{\frac{\delta}{\sigma}-1} \hat{C}_t^{\sigma-1} = \lambda P_t d_t$$

$$\frac{1}{(1+\rho)^{t-1}}\left(1 + \alpha_t \xi_t^{\sigma}\right)^{\frac{\delta}{\sigma}-1} \hat{C}_t^{\delta-\sigma} \hat{C}_t^{\sigma-1} = \lambda P_t d_t$$

$$\hat{C}_t^{\delta-1} = \lambda P_t d_t (1+\rho)^{t-1}\left(1 + \alpha_t \xi_t^{\sigma}\right)^{\left(1-\frac{\delta}{\sigma}\right)}$$

$$\hat{C}_t^{\delta-1} = \lambda P_t \frac{(1+\rho)^{t-1}}{\prod_{s=1}^{t-1}(1+r_s)}\left(1+\alpha_t\xi_t^{\sigma}\right)^{\left(1-\frac{\delta}{\sigma}\right)}$$

(1-13) $$\hat{C}_t = \lambda^{\frac{1}{\delta-1}} P_t^{\frac{1}{\delta-1}} \left(\frac{(1+\rho)^{t-1}}{\prod_{s=1}^{t-1}(1+r_s)}\right)^{\frac{1}{\delta-1}} \left(1+\alpha_t\xi_t^{\sigma}\right)^{\left(1-\frac{\delta}{\sigma}\right)\left(\frac{1}{\delta-1}\right)} .$$

From the equation (1-13), we get

(1-14) $$\hat{C}_{t-1} = \lambda^{\frac{1}{\delta-1}} P_{t-1}^{\frac{1}{\delta-1}} \left(\frac{(1+\rho)^{t-2}}{\prod_{s=1}^{t-2}(1+r_s)}\right)^{\frac{1}{\delta-1}} \left(1+\alpha_{t-1}\xi_{t-1}^{\sigma}\right)^{\left(1-\frac{\delta}{\sigma}\right)\left(\frac{1}{\delta-1}\right)} .$$

Dividing (1-13) by (1-14), and rearranging gives us the ratio of $\hat{C}_t$ over $\hat{C}_{t-1}$:

$$\frac{\hat{C}_t}{\hat{C}_{t-1}} = \left(\frac{P_t}{P_{t-1}}\right)^{\frac{1}{\delta-1}} \left(\frac{1+\rho}{1+r_{t-1}}\right)^{\frac{1}{\delta-1}} \left(\frac{1+\alpha_t\xi_t^{\sigma}}{1+\alpha_{t-1}\xi_{t-1}^{\sigma}}\right)^{\left(1-\frac{\delta}{\sigma}\right)\left(\frac{1}{\delta-1}\right)}$$

$$\frac{\hat{C}_t}{\hat{C}_{t-1}} = \left(1+\left(\frac{1+\rho}{1+r_{t-1}}\right)^{\frac{1}{\delta-1}} - 1\right)\left(\frac{P_t}{P_{t-1}}\right)^{\frac{1}{\delta-1}} \left(\frac{1+\alpha_t\xi_t^{\sigma}}{1+\alpha_{t-1}\xi_{t-1}^{\sigma}}\right)^{\left(1-\frac{\delta}{\sigma}\right)\left(\frac{1}{\delta-1}\right)}$$

(1-15) $$\frac{\hat{C}_t}{\hat{C}_{t-1}} = (1+\eta_t)\left(\frac{P_t}{P_{t-1}}\right)^{\frac{1}{\delta-1}} \left(\frac{1+\alpha_t\xi_t^{\sigma}}{1+\alpha_{t-1}\xi_{t-1}^{\sigma}}\right)^{\psi} ,$$

$$\text{where } \begin{cases} \eta_t = \left(\dfrac{1+\rho}{1+r_{t-1}}\right)^{\frac{1}{\delta-1}} - 1, \; i.e., \text{ the reference growth rate of consumption,} \\ \text{and} \\ \psi = \left(1-\dfrac{\delta}{\sigma}\right)\left(\dfrac{1}{\delta-1}\right) = \left(\dfrac{\sigma-\delta}{\sigma}\right)\left(\dfrac{1}{\delta-1}\right) = \dfrac{\sigma-\delta}{\sigma(\delta-1)} \,. \end{cases}$$

Recursive application of (1-15) over successive periods yields

$$\frac{\hat{C}_{t-1}}{\hat{C}_{t-2}} = (1+\eta_{t-1})\left(\frac{P_{t-1}}{P_{t-2}}\right)^{\frac{1}{\delta-1}}\left(\frac{1+\alpha_{t-1}\xi_{t-1}}{1+\alpha_{t-2}\xi_{t-2}}\right)^{\psi},$$

$$\vdots$$

$$\vdots$$

$$\vdots$$

$$\frac{\hat{C}_2}{\hat{C}_1} = (1+\eta_2)\left(\frac{P_2}{P_1}\right)^{\frac{1}{\delta-1}}\left(\frac{1+\alpha_2\xi_2^{\sigma}}{1+\alpha_1\xi_1^{\sigma}}\right)^{\psi}.$$

If we multiply successively the above equations, we get

$$\frac{\hat{C}_t}{\hat{C}_1} = \left(\left(\frac{1+\rho}{1+r_1}\right)\left(\frac{1+\rho}{1+r_2}\right)\cdots\left(\frac{1+\rho}{1+r_{t-1}}\right)\right)^{\frac{1}{\delta-1}}\left(\frac{P_t}{P_1}\right)^{\frac{1}{\delta-1}}\left(\frac{1+\alpha_t\xi_t^{\sigma}}{1+\alpha_1\xi_1^{\sigma}}\right)^{\psi}.$$

We rearrange terms to get the expression of $\hat{C}_t$ in terms of $\hat{C}_1$ and the parameters of the problem:

$$\frac{\hat{C}_t}{\hat{C}_1} = \left(\frac{(1+\rho)^{t-1}}{\prod_{s=1}^{t-1}(1+r_s)}\right)^{\frac{1}{\delta-1}}\left(\frac{P_t}{P_1}\right)^{\frac{1}{\delta-1}}\left(\frac{1+\alpha_t\xi_t^{\sigma}}{1+\alpha_1\xi_1^{\sigma}}\right)^{\psi}$$

$$\frac{\hat{C}_t}{\hat{C}_1} = \left(\frac{P_t}{P_1}\right)^{\frac{1}{\delta-1}} \left((1+\rho)^{t-1} d_t\right)^{\frac{1}{\delta-1}} \left(\frac{1+\alpha_t \xi_t^{\sigma}}{1+\alpha_1 \xi_1^{\sigma}}\right)^{\psi}$$

$$\hat{C}_t = \hat{C}_1 \left\{ \left(\frac{P_t}{P_1}\right) (1+\rho)^{t-1} d_t \right\}^{\frac{1}{\delta-1}} \left(\frac{1+\alpha_t \xi_t^{\sigma}}{1+\alpha_1 \xi_1^{\sigma}}\right)^{\psi}$$

(1-16) $$\hat{C}_t = \hat{C}_1 \Omega_t \ ,$$

where $\Omega_t = \left\{ \left(\frac{P_t}{P_1}\right) (1+\rho)^{t-1} d_t \right\}^{\frac{1}{\delta-1}} \left(\frac{1+\alpha_t \xi_t^{\sigma}}{1+\alpha_1 \xi_1^{\sigma}}\right)^{\psi}$.

Equation (1-16) represents an optimal consumption path. Once optimal $\hat{C}_1$ is known, we can obtain an optimal consumption path, conditional on expected prices and interest rates.

Differentiating the Lagrangean function with respect to the consumer's bequests (B_T) yields an expression indicating that the marginal utility of the bequest must equal its marginal opportunity cost:

$$\frac{\partial L}{\partial B_T} = \frac{1}{(1+\rho)^T} b^{1-\delta} B_T^{\delta-1} = \lambda P_{B_T} d_T .$$

Rearranging terms yields:

(1-17) $$\frac{1}{(1+\rho)^T} b^{1-\delta} B_T^{\delta-1} = \lambda P_{B_T} d_T .$$

From equation (1-10),

$$\lambda = \frac{1}{P_T d_T} \frac{1}{(1+\rho)^{T-1}} \left(\hat{C}_T^{\sigma} + \alpha_T l_T^{\sigma}\right)^{\frac{\delta}{\sigma}-1} \hat{C}_T^{\sigma-1}.$$

From (1-12), $l_T^{\sigma} = \left(\hat{C}_T \xi_T\right)^{\sigma} = \hat{C}_T^{\sigma} \xi_T^{\sigma}$; thus, substituting this into the above equation gives us:

$$\lambda = \frac{1}{P_T d_T} \frac{1}{(1+\rho)^{T-1}} \left(\hat{C}_T^{\sigma} + \alpha_T \hat{C}_T^{\sigma} \xi_T^{\sigma}\right)^{\frac{\delta}{\sigma}-1} \hat{C}_T^{\sigma-1}.$$

Rearranging terms:

$$\lambda = \left((1+\rho)^{T-1} P_T d_T\right)^{-1} \left(\hat{C}_T^{\sigma}\left(1 + \alpha_T \xi_T^{\sigma}\right)\right)^{\frac{\delta}{\sigma}-1} \hat{C}_T^{\sigma-1}$$

$$\lambda = \left((1+\rho)^{T-1} P_T d_T\right)^{-1} \left(1 + \alpha_T \xi_T^{\sigma}\right)^{\frac{\delta}{\sigma}-1} \hat{C}_T^{\delta-1}.$$

From (1-16), $\hat{C}_T = \hat{C}_1 \Omega_T$. Substituting this expression into the above equation yields:

$$\text{(1-18)} \qquad \lambda = \left((1+\rho)^{T-1} P_T d_T\right)^{-1} \left(1 + \alpha_T \xi_T^{\sigma}\right)^{\frac{\delta}{\sigma}-1} \left(\hat{C}_1 \Omega_T\right)^{\delta-1}.$$

Substitute (1-18) into (1-17)

$$\frac{1}{(1+\rho)^T} b^{1-\delta} B_T^{\delta-1} = \left((1+\rho)^{T-1} P_T d_T\right)^{-1} \left(1 + \alpha_T \xi_T^{\sigma}\right)^{\frac{\delta}{\sigma}-1} \left(\hat{C}_1 \Omega_T\right)^{\delta-1} P_{B_T} d_T$$

Rearranging this gives us an expression for the optimal bequest in terms of discretionary consumption in the base period.

$$B_T^{\delta-1} = \frac{(1+\rho)^T d_T}{(1+\rho)^{T-1} P_T d_T} b^{\delta-1}\left(1+\alpha_T \xi_T^{\sigma}\right)^{\frac{\delta}{\sigma}-1}\left(\hat{C}_1 \Omega_T\right)^{\delta-1} P_{B_T}$$

$$B_T^{\delta-1} = \left(\frac{1+\rho}{P_T}\right) P_{B_T} b^{\delta-1}\left(1+\alpha_T \xi_T^{\sigma}\right)^{\frac{\delta}{\sigma}-1}\left(\hat{C}_1 \Omega_T\right)^{\delta-1}$$

$$B_T = \left(\frac{(1+\rho)P_{B_T}}{P_T}\right)^{\frac{1}{\delta-1}} b\left(1+\alpha_T \xi_T^{\sigma}\right)^{\left(\frac{\delta-\sigma}{\sigma}\right)\left(\frac{1}{\delta-1}\right)} \hat{C}_1 \Omega_T$$

$$B_T = b\left(\frac{(1+\rho)P_{B_T}}{P_T}\right)^{\frac{1}{\delta-1}} \left(1+\alpha_T \xi_T^{\sigma}\right)^{\left(\frac{\delta-\sigma}{\sigma}\right)\left(\frac{1}{\delta-1}\right)} \hat{C}_1 \Omega_T \ .$$

Thus,

(1-19) $$B_T = b\phi \hat{C}_1 \Omega_T,$$

where $\phi = \left(\frac{(1+\rho)P_{B_T}}{P_T}\right)^{\frac{1}{\delta-1}} \left(1+\alpha_T \xi_T^{\sigma}\right)^{\frac{\delta-\sigma}{\sigma(\delta-1)}}$.

Equation (1-19) implies that bequests are equal to zero when the bequest intensity parameter (b) is zero. Bequests increase with b. Although (1-19) suggests a linear relationship between bequests and b, this is not the case, since a higher value of b entails lower discretionary consumption (we have to reduce consumption in order to leave more bequest).

Now substitute (1-16) into (1-12):

$$l_t = \hat{C}_1 \Omega_t \xi_t . \tag{1-20}$$

From (1-16),

$$C_t - C^* = (C_1 - C^*)\Omega_t .$$

Rearranging terms gives us:

$$C_t = C^* + (C_1 - C^*)\Omega_t .$$

$$C_t = C^* + \hat{C}_1 \Omega_t . \tag{1-21}$$

Substitute (1-16), (1-19), (1-20), and(1-21) into (1-8):

$$P_{K_1} K_1 + \sum_{t=1}^{T} \left[W_t' \left(H^* - \hat{C}_1 \Omega_t \xi_t \right) + TR_t + IN_t - P_t \left(C^* + \hat{C}_1 \Omega_t \right) \right] d_t - P_{B_T} b\phi \hat{C}_1 \Omega_T d_T$$
$$+ \sum_{t=1}^{T} \mu_t \left(H^* - \hat{C}_1 \Omega_t \xi_t \right) d_t = 0 \ .$$

Rearranging terms gives us an equation for initial consumption:

$$P_{K_1} K_1 + \sum_{t=1}^{T} \left\{ (W_t' + \mu_t) H^* + TR_t + IN_t - P_t C^* \right\} d_t = \sum_{t=1}^{T} \left(W_t' \Omega_t \xi_t d_t + \mu_t \Omega_t \xi_t d_t + P_t \Omega_t d_t \right) \hat{C}_1$$
$$+ P_{B_T} b\phi \Omega_T d_T \hat{C}_1$$

$$P_{K_1} K_1 + \sum_{t=1}^{T} \left\{ (W_t' + \mu_t) H^* + TR_t + IN_t - P_t C^* \right\} d_t = \sum_{t=1}^{T} \left\{ (W_t' + \mu_t) \Omega_t \xi_t d_t + P_t \Omega_t d_t \right\} \hat{C}_1$$
$$+ P_{B_T} b\phi \Omega_T d_T \hat{C}_1$$

$$P_{K_1}K_1 + \sum_{t=1}^{T}\left\{(W_t' + \mu_t)H^* + TR_t + IN_t - P_t C^*\right\}d_t = \left[\sum_{t=1}^{T}\Omega_t\left\{(W_t' + \mu_t)\xi_t + P_t\right\}d_t + P_{B_T} b\phi\Omega_T d_T\right]\hat{C}_1$$

$$\hat{C}_1 = \frac{P_{K_1}K_1 + \sum_{t=1}^{T}\left\{(W_t' + \mu_t)H^* + TR_t + IN_t - P_t C^*\right\}d_t}{\sum_{t=1}^{T}\Omega_t\left\{(W_t' + \mu_t)\xi_t + P_t\right\}d_t + P_{B_T} b\phi\Omega_T d_T}$$

Thus

$$\text{(1-22)} \qquad C_1 = \mathrm{C}^* + \frac{P_{K_1}K_1 + \sum_{t=1}^{T}\left\{(W_t' + \mu_t)H^* + TR_t + IN_t - P_t C^*\right\}d_t}{\sum_{t=1}^{T}\Omega_t\left\{(W_t' + \mu_t)\xi_t + P_t\right\}d_t + P_{B_T} b\phi\Omega_T d_T}$$

In the above equation, base-period consumption is linearly homogeneous in lifetime resources (initial wealth plus the present value of lifetime labor time, transfers, and inheritances). Equations (1-22) and (1-15) imply that, for given lifetime resources and prices, a lower *b* indicates higher consumption at each point in time.

Once we get the initial equilibrium consumption level ($\hat{C}_1$), we can calculate an equilibrium consumption path according to (1-16). By substituting this equilibrium consumption path into (1-12) and the leisure constraint, we can get the equilibrium leisure path and thus the equilibrium labor path:

$$\left[\begin{array}{l} C_t = C^* + (C_1 - C^*)\Omega_t \\ l_t = (C_t - C^*)\xi_t \\ H_t = H^* - l_t \end{array}\right.$$

2. PROCEDURES FOR DETERMINING THE INTERGENERATIONAL ALLOCATION OF ENDOWMENTS CONSISTENT WITH OBSERVED AGGREGATE DATA (CALIBRATION PROCESS)

We assume that each generation or cohort has an economic life of 55 years. In addition, we calculate equilibria for five-year periods. Since a new cohort is born each period, there are 11 living cohorts, with different endowments of labor and capital. We describe the procedure for calculating the labor and capital endowments for each cohort, based on aggregate data. This parameterization procedure must satisfy two kinds of requirements: a ***replication requirement*** and a ***balanced-growth requirement***. The labor and capital endowments of each cohort must be such as to generate individual cohort behavior which, when aggregated, replicates observed aggregate values and leads to steady-state growth of the economy.

2.1. Exogenous Parameters

The critical exogenous parameters here are δ, the intertemporal substitution parameter, σ, the intratemporal substitution parameter, and b, the bequest intensity parameter. The growth rate of population, g, is also exogenous here, although this growth rate is actually determined in a separate data consistency program based on the observed rate of net capital accumulation. Finally, the reference steady-state growth rate of consumption, $\overline{\eta}$, is exogenous. From the definition of $\overline{\eta}$ $\left(= \left(\frac{1+\rho}{1+\bar{r}}\right)^{\frac{1}{\delta-1}} - 1 \right)$, we determine the rate of time preference (ρ).

2.2. Individual Consumption Paths

Let $C_{n,t}$ denote consumption of cohort *n* at time *t*. At *t*=1 (which represents the benchmark year), the living cohorts are indexed from 1 to *N*, where *N*=11. Cohort *N* is the "newcomer" cohort, *i.e.*, the youngest cohort alive in the benchmark year.

The endowment allocation for each cohort begins with the consumption aggregation condition, *i.e.*, the total of the consumption of the cohorts living during the benchmark year must be equal to the observed aggregate consumption (C_A). Thus,

(2-1) $$\sum_{n=1}^{N} C_{n,1} = C_A$$

where C_A is observed aggregate consumption.

From equation (1-16),

$$\hat{C}_{n,t} = \hat{C}_{n,1}\Omega_t,$$

for the newcomer cohort "*N*", it implies that:

$$\hat{C}_{N,t} = \hat{C}_{N,1}\Omega_t$$

Thus

$$C_{N,t} - C^{\bullet}_{N,t} = \left(C_{N,1} - C^{\bullet}_{N,1}\right)\Omega_t \ ,$$

or

(2-2) $$C_{N,t} = C^{\bullet}_{N,t} + \left(C_{N,1} - C^{\bullet}_{N,1}\right)\Omega_t \ ,$$

where Ω_t is a function of prices, interest rates, and parameters such as δ, σ, ρ, and α_t. The steady-state values for the prices and interest rates are known ($P_t = \overline{P}$ and $r_t = \bar{r}$). Therefore, in the steady-state,

$$\Omega_t = \left\{\left(\frac{1+\rho}{1+\bar{r}}\right)^{t-1}\right\}^{\frac{1}{\delta-1}}\left(\frac{1+\alpha_t\xi_t^{\sigma}}{1+\alpha_1\xi_1^{\sigma}}\right)^{\mu}$$

since P_t and P_1 cancel each other out. The parameter values δ, σ, and ρ are chosen exogenously. The only relevant parameter that is unknown is α_t. For the purpose of this exposition, it will be convenient to proceed as if α_t were known here; in fact, α is calculated by an iterative procedure which will be described below.

In the steady state, per-capita consumption is a function of age (*k*) only. However, cohort size increases at the rate of "*g*" over time, implying that when cohort *n*+*j* reaches age *k*, its consumption will be $(1+g)^j$ times larger than cohort *n*'s consumption at age *k*. This in turn implies that

(2-3) $$C_{N-j,1} = C_{N,j+1}(1+g)^{-j} \ .$$

From (2-2), we have

(2-4) $$C_{N,j+1} = C^{\bullet}_{N,j+1} + (C_{N,1} - C^{\bullet}_{N,1})\Omega_{j+1}.$$

Substituting (2-4) into (2-3) yields

(2-5) $$C_{N-j,1} = \left[C^{\bullet}_{N,j+1} + \left(C_{N,1} - C^{\bullet}_{N,1}\right)\Omega_{j+1}\right]\!(1+g)^{-j}.$$

Since $\sum_{n=1}^{N} C_{n,1} = \sum_{j=0}^{N-1} C_{N-j,1}$, by substituting (2-5) into (2-1), we can rewrite the consumption aggregate condition (2-1) in terms of the consumption of the newcomer cohort, and the minimum consumption level of the newcomer cohort over his lifetime:

$$\sum_{j=0}^{N-1}\left[C^{\bullet}_{N,j+1} + \left(C_{N,1} - C^{\bullet}_{N,1}\right)\Omega_{j+1}\right]\!(1+g)^{-j} = C_A .$$

Rearranging terms in the above equation gives the value of the newcomer cohort's initial consumption, $C_{N,1}$:

$$\sum_{j=0}^{N-1} C^{\bullet}_{N,j+1}(1+g)^{-j} + \sum_{j=0}^{N-1}\left(C_{N,1} - C^{\bullet}_{N,1}\right)\Omega_{j+1}(1+g)^{-j} = C_A$$

$$\sum_{j=0}^{N-1}\left(C_{N,1} - C^{\bullet}_{N,1}\right)\Omega_{j+1}(1+g)^{-j} = C_A - \sum_{j=0}^{N-1} C^{\bullet}_{N,j+1}(1+g)^{-j}$$

$$\left(C_{N,1} - C^{\bullet}_{N,1}\right)\sum_{j=0}^{N-1}\Omega_{j+1}(1+g)^{-j} = C_A - \sum_{j=0}^{N-1} C^{\bullet}_{N,j+1}(1+g)^{-j} .$$

Thus

(2-6) $$\left(C_{N,1}-C^{*}_{N,1}\right)=\frac{C_A-\sum_{j=0}^{N-1}C^{*}_{N,j+1}(1+g)^{-j}}{\sum_{j=0}^{N-1}\Omega_{j+1}(1+g)^{-j}},$$

or

(2-7) $$C_{N,1}=C^{*}_{N,1}+\frac{C_A-\sum_{j=0}^{N-1}C^{*}_{N,j+1}(1+g)^{-j}}{\sum_{j=0}^{N-1}\Omega_{j+1}(1+g)^{-j}}.$$

The newcomer cohort's initial consumption, $C_{N,1}$, is expressed as a function of C_A, g, Ω, $C^{*}_{N,1}$, and $C^{*}_{N,j+1}$. Once $C_{N,1}$ is determined by (2-7), the benchmark consumption of other cohorts can be calculated by substituting (2-6) into (2-5).

$$C_{N-j,1}=\left[C^{*}_{N,j+1}+\left(\frac{C_A-\sum_{j=0}^{N-1}C^{*}_{N,j+1}(1+g)^{-j}}{\sum_{j=0}^{N-1}\Omega_{j+1}(1+g)^{-j}}\right)\Omega_{j+1}\right](1+g)^{-j}.$$

2.3. Cohort Labor Time Endowments

The benchmark leisure for each cohort can be calculated based on

(2-8) $$l_{n,1}=\hat{C}_{n,1}\xi_{n,1},$$

$$\text{where} \left[\begin{array}{l} \xi_{n,1} = \left(\dfrac{W_1 e_{n,1} + \mu_{n,1}}{\alpha_{n,1} P_1} \right)^{\frac{1}{\sigma - 1}} \\ \\ e_{n,1} \text{ is labor efficiency parameter for cohort } n \text{ at time 1} \\ \\ \alpha_{n,1} \text{ is leisure intensity parameter for cohort } n \text{ at time 1} \\ \\ \end{array} \right.$$

The parameters $e_{n,1}$ and $\alpha_{n,1}$ are based on age only, and the age profiles of e and α are identical for all cohorts. Thus, the leisure path for each cohort is calculated as follows:

(2-9) $$l_{n,t} = \hat{C}_{n,t} \xi_{n,t} \ .$$

Aggregate labor time ($H_A^{\bullet}$) is determined by

(2-10) $$H_A^{\bullet} = H_A + \sum_{n=1}^{N} l_{n,1} \ .$$

To determine $H_A^{\bullet}$, we have to know H_A and $l_{n,1}$. While $l_{n,1}$ is determined above by (2-8), H_A will be determined by the iterative procedure which will be explained below.

Individual cohort time endowments ($H_{n,1}^{\bullet}$) must satisfy the aggregate condition:

(2-11) $$\sum_{n=1}^{N} H_{n,1}^{\bullet} = H_A^{\bullet} \ .$$

Cohort labor time endowments increase from cohort to cohort at the steady-state growth rate (g), but per-capita endowments of labor time are constant within each cohort's lifetime. Since

(2-12) $$H^{*}_{n,1} = \frac{H^{*}_{N,1}}{(1+g)^{N-n}} .$$

Substituting (2-12) into (2-11) yields

(2-13) $$\sum_{n=1}^{N} \frac{H^{*}_{N,1}}{(1+g)^{N-n}} = H^{*}_{A} ,$$

or

(2-14) $$H^{*}_{N,1} = \frac{H^{*}_{A}}{\sum_{n=1}^{N}(1+g)^{n-N}} .$$

Equation (2-14) shows the labor time endowment for the newcomer cohort. By substituting (2-14) into (2-12), we can get the time endowments of all other cohorts ($H^{*}_{n,1}$):

(2-15) $$H^{*}_{n,1} = \left(\frac{H^{*}_{A}}{\sum_{n=1}^{N}(1+g)^{n-N}} \right)(1+g)^{n-N} .$$

2.4. Capital Endowment in the Benchmark

The capital owned by each cohort in the benchmark year is a reflection of the time path of capital ownership over a given cohort's lifetime. We consider two cases: 1) b=0 (the no-bequest scenario) and 2) b>0, in which case there will be positive bequests.

In the case of b=0, we calculate the newcomer cohort's capital path from birth, using income and the saving path, and the assumption of zero initial wealth. This time path of capital for the newcomer cohort translates into the benchmark capital of other cohorts according to

$$(2\text{-}16) \qquad K_{N-j,1} = \frac{K_{N,j+1}}{(1+g)^j}.$$

In the positive-bequest case, the procedure is a bit more complex. An initial guess is made of the benchmark bequest. We assume that each cohort's bequest is divided to the 11 living cohorts according to the actual data.[42] Thus, we can get the initial inheritance, *i.e.*, initial wealth of the newcomer cohort. Using the income path and the saving path for the newcomer cohort, we calculate the time path of non-human wealth, as well as the eventual bequest, which is equal to the value of wealth of the newcomer cohort at death. Since bequests increase at the rate of population growth (g) over time, if we divide the eventual bequest by the newcomer cohort at the end of his lifetime by $(1+g)^{11}$, we can calculate the bequest left to all 11 living cohorts at the benchmark period. The guess of the initial bequest (which is divided among the 11 living cohorts) at the benchmark is adjusted by an iterative procedure until this initial bequest value is equal to the eventual bequest left by the newcomer cohort at the end of his lifetime divided by $(1+g)^{11}$.

42The division of total bequests among 11 living cohorts in the benchmark is based on Consumer Expenditure Survey data, which Projector and Weiss (1966) used in their unpublished work sheet. However, since these data do not conform to the age brackets of my model, I smoothed the data.

2.5. Qualification

The procedure described above neglected two significant details. First, from equation (2-2), the calculation of individual consumption path ($C_{N,t}$) depends on the α profile, since Ω_t is a function of α. The shape of α profile is given exogenously: $\alpha_t = \alpha_h \alpha_0$ (h=1, ..., 11). We assume that leisure intensity is constant across cohorts ($\alpha_h = 1$). Thus, we have $\alpha_t = \alpha_0$ and α_t is defined for the range of h. However, α_0 must be determined in the calibration procedure. From (2-7), we know that, for any α_0, there is a unique value of $C_{N,1}$ which is consistent with the aggregation requirements. However, the newcomer's initial consumption ($C_{N,1}$) must also be consistent with its lifetime resources, as expressed by equation (1-22). Equation (1-22) implicitly poses a second relationship between α and $C_{N,1}$, and an iterative procedure is employed to find the combination of α and $C_{N,1}$ satisfying both equations of (1-22) and (2-7):

From (1-22), we have

$$\text{(2-17)} \qquad C_1 - C^* = \frac{P_{K_1}K_1 + \sum_{t=1}^{T} IN_t d_t + \sum_{t=1}^{T}\left\{(W_t' + \mu_t)H^* + TR_t\right\}d_t - \sum_{t=1}^{T} P_t C^* d_t}{\sum_{t=1}^{T}\Omega_t (W_t' + \mu_t)\xi d_t + \sum_{t=1}^{T}\Omega_t P_t d_t + P_{B_T} b\phi \Omega_T d_T}$$

Now, let

$$T_1 = P_{K_1}K_1 + \sum_{t=1}^{T} IN_t d_t$$

$$T_2 = \sum_{t=1}^{T}\left\{(W_t' + \mu_t)H^* + TR_t\right\}d_t$$

$$T_3 = \sum_{t=1}^{T} P_t C^* d_t$$

$$T_4 = P_{B_T} b \phi \Omega_T d_T$$

$$T_5 = \sum_{t=1}^{T} \Omega_t P_t d_t$$

Then, we can rewrite the equation (2-17) by using these values:

$$\text{(2-18)} \qquad C_1 - C^* = \frac{T_1 + T_2 - T_3}{\sum_{t=1}^{T} \Omega_t (W_t' + \mu_t)\ \xi d_t + T_5 + T_4} \ ,$$

where $\sum_{t=1}^{T} \Omega_t (W_t' + \mu_t) \xi d_t = \sum_{t=1}^{T} \Omega_t (W_t' + \mu_t) \left(\frac{W_t' + \mu_t}{\alpha_t P_t} \right)^{\frac{1}{\sigma - 1}} d_t$.

Rearranging terms gives us:

$$\sum_{t=1}^{T} \Omega_t (W_t' + \mu_t) \xi d_t = \sum_{t=1}^{T} \Omega_t (W_t' + \mu_t) \left(\frac{W_t' + \mu_t}{P_t} \right)^{\frac{1}{\sigma - 1}} (\alpha_t)^{-\left(\frac{1}{\sigma - 1}\right)} d_t$$

Since $\alpha_t = \alpha_h \alpha_0$ and we assumed that $\alpha_h = 1$, $\alpha_t = \alpha_0$. Thus, the above expression can be rewritten:

$$\sum_{t=1}^{T} \Omega_t (W_t' + \mu_t) \xi d_t = \sum_{t=1}^{T} \Omega_t (W_t' + \mu_t) \left(\frac{W_t' + \mu_t}{P_t} \right)^{\frac{1}{\sigma - 1}} (\alpha_0)^{-\left(\frac{1}{\sigma - 1}\right)} d_t$$

Rearranging terms:

$$\sum_{t=1}^{T}\Omega_t(W_t'+\mu_t)\xi_t d_t = \left(\sum_{t=1}^{T}\Omega_t(W_t'+\mu_t)\left(\frac{W_t'+\mu_t}{P_t}\right)^{\frac{1}{\sigma-1}} d_t\right)\alpha_0^{-\left(\frac{1}{\sigma-1}\right)}$$

(2-19) $$\sum_{t=1}^{T}\Omega_t(W_t'+\mu_t)\xi_t d_t = T_7\alpha_0^{-\left(\frac{1}{\sigma-1}\right)},$$

where $T_7 = \sum_{t=1}^{T}\Omega_t(W_t'+\mu_t)\left(\frac{W_t'+\mu_t}{P_t}\right)^{\frac{1}{\sigma-1}} d_t$.

Substituting (2-19) into (2-18), we have

$$C_1 - C^* = \frac{T_1 + T_2 - T_3}{T_7 * \alpha_0^{-\left(\frac{1}{\sigma-1}\right)} + T_5 + T_4}$$

We rearrange terms to isolate α_0:

$$T_7 * \alpha_0^{-\left(\frac{1}{\sigma-1}\right)} + T_5 + T_4 = \frac{T_1 + T_2 - T_3}{C_1 - C^*}$$

$$T_7 * \alpha_0^{-\left(\frac{1}{\sigma-1}\right)} = \frac{T_1 + T_2 - T_3}{C_1 - C^*} - T_5 - T_4$$

$$\alpha_0^{-\left(\frac{1}{\sigma-1}\right)} = \frac{\frac{T_1 + T_2 - T_3}{C_1 - C^*} - T_5 - T_4}{T_7} .$$

Thus,

$$\alpha_0 = \left(\frac{\frac{T_1 + T_2 - T_3}{C_1 - C^*} - T_5 - T_4}{T_7}\right)^{-(\sigma-1)} .$$

We do the iterative procedure until α_0 value satisfies both equations (1-22) and (2-7).

The second qualification is that, although H_A (aggregate labor supplied) is used in equation (2-10) to determine H_A^* (aggregate labor time), it is not a component of the benchmark data. However, the "value" of labor supply (VH_A) is part of the benchmark data, and VH_A and H_A are related to each other according to

$$(2\text{-}20) \qquad H_A = \frac{VH_A}{W^*},$$

where

$$(2\text{-}21) \qquad W^* = \frac{\sum_{n=1}^{N} P_L e_{n,1} H_{n,1}}{H_A} .$$

Since $P_L = 1$ in steady-state, we can rewrite the above equation as:

$$(2\text{-}22) \qquad W^* = \frac{\sum_{n=1}^{N} e_{n,1} H_{n,1}}{H_A}$$

The wage index W^* is necessary to calculate H_A from observed VH_A, but W^* itself depends on H_A and $H_{n,1}$ (benchmark labor supplies of individual cohorts). Since H_A and W^* are dependent each other, it is necessary to employ an iterative procedure which adjusts guesses of W^* until the conditions in (2-20) and (2-22) are simultaneously satisfied.

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