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On financing retirement with an aging population

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A problem that faces many countries including the United States is how to finance retirement consumption as the population ages. Proposals for switching to a saving-for-retirement system that does not rely on high payroll taxes have been challenged on the grounds that welfare would fall for some groups such as retirees or the working poor. We show how to devise a transition path from the current U.S. system to a saving-for-retirement system that increases the welfare of all current and future generations, with estimates of future gains higher than those found in typically used macroeconomic models. The gains are large because there is more productive capital than commonly assumed. Our quantitative results depend importantly on accounting for differences between actual government tax revenues and what revenues would be if all income were taxed at the income-weighted average marginal tax rates used in our analysis.

Keywords. Retirement, taxation, Social Security, Medicare.

JEL classification. E13, H55, I13.

1. Introduction

Many countries including the United States are facing the challenging policy issue of how to finance retirement consumption as the population ages and the number of workers per retiree falls. One proposal is to move from the current U.S. retirement system—which relies heavily on payroll taxes so as to make lump-sum transfers to retirees—to a saving-for-retirement system that eliminates these payroll taxes and old-age transfers. To do so in a welfare-improving way for individuals of all ages and incomes poses a challenge. Using a general equilibrium overlapping-generations (OLG) model, we show that

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a move from the current U.S. system to a saving-for-retirement system is feasible and welfare improving for all alive at the time of the policy change and especially for future cohorts, with predicted welfare gains from eliminating payroll taxes and old-age transfers over 16 percent of lifetime consumption for most households.

With our OLG model, we compute equilibrium transition paths, with the initial state calibrated to averages for the U.S. economy over the period 2000–2010, referred to below as the current U.S. economy. We allow for within-cohort heterogeneity, with differences arising from differences in productivity, so that we can explore the impact of policy on different birth cohorts and income groups. The simulated data from the model we use are consistent with both the U.S. national income and product accounts and the U.S. productive capital stocks as reported by the Bureau of Economic Analysis (BEA) and U.S. income distributions as reported in the Current Population Survey (CPS) March Supplement (U.S. Department of Labor (1962–2016)). The transitions involve both changes in demographics and changes in taxes and government transfers. We model the current U.S. economy as having four workers per retiree, and we study the transition as that number falls to about 2.4. Coincident with the demographic transition is the phasing in of new policy. For the sake of comparison, we first consider transitions to a tax-transfer system that is essentially the one currently in use—that is, with its high labor and capital income tax rates and large transfers to retirees. As the population ages, taxes must rise to finance the additional old-age transfers.

We then compare the results of continuing the current U.S. policy with variations of a saving-for-retirement system, modifying the policy in steps so that we can highlight the role that each factor plays. First, we show what happens if we phase out payroll taxes on Medicare and Social Security along with accompanying transfers made to retirees that are neither welfare nor local public goods.[1] A second variation that turns out to be critical for a Pareto-improving transition involves changing the net tax schedule for workers—the schedule that determines total taxes less transfers as a function of labor income—by broadening the tax base and lowering marginal tax rates on labor income during the transition to a new system. In all experiments that we consider, we retain current expenditure shares for government purchases of goods and services, as well as transfers normally included in the national income and product accounts (NIPA) other than transfers for Medicare and Social Security, and we set consumption taxes residually to ensure that the government's budget balances each period. In each case, the measure of welfare that we compute is remaining-lifetime consumption equivalents for each birth-year cohort and productivity type currently alive and each cohort-type joining the workforce in the future.

To generate transition paths that will leave all individuals better off, we devise a tax and transfer scheme that delays the fall in transfers to retirees relative to the fall in payroll taxes. Current retirees cannot take advantage of lower payroll taxes, and changes in interest rates on retirees' assets are of second-order importance. Workers, on the other hand, can take advantage of lower taxes on wages, and therefore we phase out payroll taxes more quickly than old-age transfers. To balance the government's budget as payroll

[1] The payroll taxes are those imposed by the Federal Insurance Contribution Act (FICA).

tax revenues decline, we exploit the fact that total government revenue is much larger than collected tax revenue because important components of income are not taxed and because the income tax schedule is convex. The untaxed incomes that we consider are employer fringe benefits. During the transition, we suspend the deductibility of these benefits, which provides an additional revenue source. We also temporarily flatten the workers' net tax schedule by lowering their marginal tax rates, and we simultaneously modify household budget sets by reducing the difference between actual tax revenues and what tax revenues would be if income were taxed at the marginal tax rates that we use in our analysis.[2] The lower marginal rates have a sufficiently positive impact on output and revenues to avoid the negative impact of increasing consumption taxes on retirees and the working poor.

The predicted welfare gains for our model are larger than those estimated with typically used macroeconomic models and are more likely to be positive for all current and future households. This result follows from the fact that our estimate of the U.S. capital stock at reproduction cost is 5.8 times gross national product (GNP)—nearly twice as large as estimates commonly used in macroeconomic analyses. Auerbach and Kotlikoff (1987), for example, use a capital share that is consistent with a capital stock of 2.8 times GNP, which is the size of fixed assets reported by the BEA.[3] Our capital stock is larger because we include consumer durables, inventories, land, and business intangible capital, which implies additional productive capital of three times GNP. Our stock is larger and rises by more when we change the tax system, implying much larger welfare gains from reform.

To determine which, if any, parameter choices are crucial for our main findings, we rerun our policy experiments using various versions of the OLG framework. We explore alternative assumptions for preferences, production technologies, savings opportunities, properties of the life cycle, and future tax policies. We find that our results are robust to variations in parameters that are consistent with the BEA and CPS data we use.

In Section 2, we discuss the related literature. Section 3 presents the model used to evaluate the alternative retirement financing systems. Section 4 discusses the model parameters that are chosen to be consistent with macro data from the U.S. national accounts and fixed assets and the micro data from the CPS March Supplement. Results of our policy experiments are reported in Section 5. In Section 6, we conclude.

2. Related literature

The literature concerned with financing retirement consumption is large and growing. Papers most closely related to ours focus on shifting from the current pay-as-you-go

[2]To better estimate the impact of tax reforms on aggregated groups in the U.S. economy, we apply the methodology of Barro and Redlick (2011) to construct income-weighted average marginal income tax rates. The adjustment we make to the budget sets is necessary to avoid overstating actual tax revenues in the case in which marginal rates are higher than average rates.

[3]We do not include the large stock of nonrival human capital in the model's capital stock because in retirement, human capital cannot be sold and the proceeds used to finance retirement consumption.

Social Security system to mandatory savings programs with individual accounts.[4] The main conclusion from this literature is that the long-term gains from switching to a saving-for-retirement system are positive—especially if distorting taxes on incomes can be reduced—but the welfare gains for future cohorts come at the cost of welfare losses for generations living during the transition. For example, Huang, Imrohoroglu, and Sargent (1997) study transitions that follow a surprise elimination of social security in which the government fully compensates all cohorts alive at the time of the policy change by issuing a large amount of government debt. Although labor income taxes in the future can be lowered, they are temporarily high while the government pays off the entitlement debt, and they result in welfare losses for generations born just after the policy change.[5] Conesa and Krueger (1999), Nishiyama and Smetters (2007), and Imrohoroglu and Kitao (2012) argue that adding idiosyncratic uncertainty makes the switch more challenging because Social Security provides partial insurance in circumstances in which private insurance is unavailable. The policy reforms we consider do not eliminate government social insurance and assistance programs for the poor. The reforms we consider eliminate only Social Security and Medicare transfers for the elderly.[6]

So as to consider alternative fiscal policy plans more systematically, Conesa and Garriga (2008) consider a set of social welfare functions and derive optimal policies. They are interested in designing plans that are welfare improving for transitional generations. They show that such a plan is possible but find paths for tax rates, especially tax rates on capital income, that "call into question its relevance" as an actual policy option (p. 294). For example, in their baseline economy in which the government chooses both labor and capital income tax rates, the optimal capital income tax rate oscillates between 60 percent and −60 percent. Here, we focus attention on smoothly declining paths for income tax rates and find that it is easy to construct policies that are welfare improving for all current and future birth-year cohorts and all income groups.

Another avenue for the government is to issue a large amount of debt, which people can buy when young and sell during their retirement. The debt is used to smooth consumption over one's lifetime. In a model with a much smaller capital stock than used here, Birkeland and Prescott (2007) find that the needed quantity of debt is about five times GNP—much larger than that observed in any advanced nation.[7] In this paper, we show that a large stock of debt is not a necessary feature of a Pareto-improving tax

[4]The Feldstein (1998) volume is a nice collection of papers that consider saving-for-retirement systems in the United States, Chile, Australia, the United Kingdom, Mexico, and Argentina. Of particular relevance for our paper are the transitional studies of Feldstein and Samwick (1998) and Kotlikoff (1998), who study the United States. See also De Nardi, Imrohoroglu, and Sargent (1999) for a detailed analysis of the U.S. system.

[5]Kotlikoff, Smetters, and Walliser (1999) study transitional dynamics following a wide array of policy options and find that although "privatization offers significant long-run gains, it does so at some nontrivial short-run costs" (p. 533). See also Kotlikoff, Smetters, and Walliser (2007).

[6]Furthermore, as Krueger and Kubler (2006) have shown, gains from reducing consumption risk in old age through Social Security are outweighed by the crowding out of capital even in the absence of these additional programs. The crowding-out effect would be even stronger in our economy that has more capital than is typically assumed.

[7]Conesa and Garriga (2008) and Prescott (2004) also consider a reform of the U.S. Social Security system that requires a large amount of debt to finance the transition.

reform even if the number of workers per retiree falls significantly.[8] In fact, when we investigate the impact of increasing the debt-to-GNP ratio in our simulations, we do not find significant differences in the main results.

3. The model economy

The model economy has an OLG structure with measure $n_t^{1,k}$ arriving as working-age households with productivity level $k \in \{1, 2, \dots, K\}$ at the beginning of date t. The year since entry into the workforce is called *age* and is denoted by j. The measure of age j households with productivity level k at date t is $n_t^{j,k}$. The maximum possible age is J. The probability of an age $j < J$ household of any type at date t surviving to age $j+1$ is $\sigma_t^j > 0$. The $n_t^{1,k}$ are parameters that define the population dynamics. We restrict attention to

$$n_{t+1}^{1,k} = (1 + \eta_t) n_t^{1,k}$$

with $\sum_k n_0^{1,k} = 1$, where η_t is the growth rate of households entering the workforce.

3.1 *State vector*

To simplify notation, we use recursive competitive equilibrium language. Given that the economy is nonstationary, t is included as an element of the aggregate state vector. All stocks are beginning of period stocks. The variables that define the aggregate state vector s are as follows:

(i) The term $t = 0, 1, 2, \dots,$ is the time period.

(ii) The terms $\{a^{j,k}, n^{j,k}\}$ are the assets $a^{j,k}$ (net worth) of an age j, type k household, and $n^{j,k}$ is the measure of these households.

(iii) The term B is the government debt owned by the private sector.

(iv) The terms K_{T1} and K_{T2} are aggregate tangible capital stocks for two business sectors (described below).

(v) The terms K_{I1} and K_{I2} are aggregate intangible capital stocks for two business sectors.

Two business sectors are needed because different legal categories of businesses are subject to very different tax systems and, as a consequence, the market values of their equity and net debt relative to their capital stock are different. The empirical counterpart of sector 1 is Schedule C corporations, which are subject to the corporate income tax. Schedule S and other corporations that distribute all profits to owners, unincorporated businesses, and household businesses are in sector 2, as are government enterprises.

[8]The problem is not that the aging population will lead to overaccumulation of capital with a saving-for-retirement system. As Thompson (1967, p. 1206) established, absent forced savings, there cannot be an equilibrium with overaccumulation of capital if debt contracts are permitted. Abel et al.'s (1989) findings that overaccumulation of capital was not the case in the United States in the period they examined hold for the economies and policies we consider.

3.2 *Prices and policy*

The relevant equilibrium *price* sequences for the households are interest rates $\{i_t\}$ and wage rates $\{w_t\}$.

Policy specifies the following sequences:

(i) Tax rates $\tau = \{\tau_t^c, \tau_{1t}^d, \tau_{2t}^d, \tau_{1t}^\pi\}$, where c denotes consumption, d denotes distributions from businesses to their owners, and π denotes profits. Note that sector 2 businesses are not subject to the corporate profit tax and must distribute all their profits to their owners.

(ii) Net tax schedules $\{T_t^w(\cdot), T_t^r(\cdot)\}$ for those with positive labor income (e.g., workers) and no labor income (e.g., retirees).

(iii) Government debt $\{B_t\}$.

(iv) Pure public good consumption $\{G_t\}$.

Constraints on the stock of government debt relative to GNP are $B_t \leq \phi_{Bt} GNP_t$, where ϕ_{Bt} are policy-constraint parameters. The motivation for this constraint is that, empirically, governments have limited ability to commit to honoring their sovereign debt promises. The final set of policy variables is the public goods consumption, $\{G_t\}$, which is a given fraction of GNP: $G_t = \phi_{Gt} GNP_t$.

3.3 *The households' problem*

The value function of a household of age $j \in \{1, 2, \dots, J\}$ with productivity level $k \in \{1, 2, \dots, K\}$ satisfies

$$v_j(a, s, k) = \max_{a', c, \ell \geq 0} \left\{ u(c, \ell) + \beta \sigma_t^j v_{j+1}\left(a', s', k\right) \right\}$$

subject to

$$(1 + \tau_{ct})c + a' \sigma_t^j = (1 + i_t)a + y_t - T_t^j(y_t),$$

$$y_t = w_t \ell \epsilon^k,$$

$$s' = F(s).$$

Symbol ℓ denotes the labor services of a household. Households with $j > J_R$ are retired and their ℓ's are zero. The net tax schedule for retirees $(j > J_R)$ is $T^j(y) = T^r(0)$ and is equal to the (negative) transfers to retirees since they have no labor income. The net tax schedule for workers $(j \leq J_R)$ is $T^j(y) = T^w(y)$ and is equal to their total taxes on labor income less any transfers. The prime denotes the next period value of a variable and $v_{J+1} = 0$.[9] Savings are in the form of an annuity that makes payments to members of a cohort in their retirement years conditional on them being alive. Effectively, the return

[9] Later, we explore variations of this baseline model with survival probabilities also indexed by k, productivity levels also indexed by j, and with no annuity markets. We show that these choices do not have an impact on our main quantitative results.

on savings depends on the survival probability as well as the interest rate. Aggregate labor supply L is

$$L = \sum_{j,k} n^{j,k} \ell^{j,k} \epsilon^{k}.$$

The equilibrium law of motion of the aggregate state variable, F, is taken as given by the private agents.

3.4 *Technology*

One sector is subject to the corporate income tax and produces intermediate good Y_{1t}, and one sector produces intermediate good Y_{2t}. The aggregate production function of the composite final good is

$$Y_t = Y_{1t}^{\theta_1} Y_{2t}^{\theta_2},$$

where the exponents are positive and sum to 1.

The aggregate sectoral production function is Cobb–Douglas with inputs of tangible capital K_{iTt}, intangible capital K_{iIt}, and labor L_{it}:

$$Y_{it} = K_{iTt}^{\theta_{iT}} K_{iIt}^{\theta_{iI}} (\Omega_t L_{it})^{1-\theta_{iT}-\theta_{iI}}$$

for $i = 1, 2$. The labor-augmenting technical level at date t in both sectors is Ω_t, which grows at rate γ, so

$$\Omega_{t+1} = (1+\gamma)\Omega_t.$$

Capital stocks depreciate at a constant rate, so

$$K_{iT,t+1} = (1-\delta_{iT})K_{iTt} + X_{iTt},$$
$$K_{iI,t+1} = (1-\delta_{iI})K_{iIt} + X_{iIt}$$

for $i = 1, 2$, where T and I denote tangible and intangible, respectively, and X is investment. Depreciation rates are denoted as δ and are indexed by sector and capital type. The resource balance constraint is

$$Y_t = C_t + X_{Tt} + X_{It} + G_t,$$

where $X_{Tt} = \sum_i X_{iTt}$ and $X_{It} = \sum_i X_{iIt}$.

3.5 *Government budget constraints*

Some notation must be set up before the law of motion for government debts can be specified. The prices of the intermediate good relative to the final good are p_{1t} and p_{2t}. The accounting profits of Schedule C corporations are given by

$$\Pi_{1t} = p_{1t}Y_{1t} - w_t L_{1t} - X_{1It} - \delta_{1T}K_{1Tt},$$

and distributions to the corporations' owners are

$$D_{1t} = \big(1 - \tau_{1t}^{\pi}\big)\Pi_{1t} - K_{1T,t+1} + K_{1Tt}.$$

Other business distributions to their owners are

$$D_{2t} = \Pi_{2t} = p_{2t}Y_{2t} - w_t L_{2t} - X_{2It} - \delta_{2T}K_{2Tt}.$$

We can now specify the law of motion of government debt:

$$B_{t+1} = B_t + i_t B_t + G_t - \sum_{j,k} n_t^{j,k} T_t^j \big(w_t \ell_t^{j,k} \epsilon^k\big) - \tau_t^c C_t - \tau_{1t}^{\pi}\Pi_{1t} - \tau_{1t}^d D_{1t} - \tau_{2t}^d D_{2t}.$$

Thus, next period's debt is this period's debt plus interest on this period's debt, plus public consumption, minus tax revenues (net of transfers). Taxes are levied on labor income and consumption, on profits of Schedule C corporations, on distributions of Schedule C corporations to their owners, and on distributions of other business firms to their owners.

3.6 *Equilibrium conditions*

The equilibrium conditions are as follows:

(i) Labor, capital, and goods markets clear at each point in time.

(ii) The household policy functions $\{a' = f_j(s, k)\}_j$ imply the aggregate law of motion $s' = F(s)$.

4. Model parameters

We choose parameters of the model so that the balanced growth path of our baseline model is consistent with *both* the national accounts and fixed assets reported by the BEA over the period 2000–2010 *and* the distribution of individual and household incomes reported in the CPS March Supplement at the midpoint year of 2005.[10] This is done in two steps. First, we set parameters governing demographics, household preferences, firm technologies, spending and debt shares, and capital income tax rates so that the national accounts and fixed asset tables implied by the model are consistent with the BEA aggregate data. Second, we set population weights, productivity levels, transfers, and taxes on labor income to match micro data on population shares, labor income, transfer income, and marginal and average tax rates.

[10] The year 2005 was specifically chosen because data are available that allow us to match up personal income reported by the BEA and adjusted gross income reported by the Internal Revenue Service (U.S. Department of the Treasury, IRS (1918–2016)). See the November issue of the *Survey of Current Business*, 2007.

4.1 *Macro data*

We first describe the data from U.S. national accounts and fixed asset tables and adjustments that need to be made to the accounts so that they better conform to the theory used to construct the model economy. We then discuss the parameters that are consistent with averages for these data over the period 2000–2010.

4.1.1 *NIPA accounts* Table 1 displays the annual averages from the U.S. national income and product accounts with several adjustments made to NIPA GNP.[11] Adjusted GNP is equal to NIPA GNP after subtracting sales tax and adding imputed capital services for consumer durables and government capital. Thus, unlike NIPA, we are consistent in using business sector prices and in treating consumer durables and government capital like other investments when constructing the national income and product accounts.

We categorize income as "labor" or "capital." *Labor income* includes compensation of employees plus part of proprietors' income and comprises 59 percent of total adjusted income. *Capital income* includes all other NIPA categories of income, except the sales tax part of taxes on production and imports. The rental income of consumer durables is imputed and added to capital income. Specifically, we add consumer durables depreciation to NIPA depreciation and impute consumer durables rents less depreciation to the rental income of households. The imputed income is the product of the average after-tax real return on capital and the current-cost net stock of consumer durables. Services of government capital are also imputed and added to capital income; they are estimated to be the product of the average after-tax real return on nonpublic capital and the current-cost net stock of government capital. We do not add depreciation of government capital because it is already included in NIPA depreciation. We use an after-tax real return of 4 percent when imputing income for both durables and government capital.

On the product side, we consolidate expenditures into three categories: consumption, tangible investment, and defense spending. Intangible investment does not appear here because it is expensed from accounting profits and thus appears in neither product nor income. *Consumption* includes private consumption of nondurables and services and the nondefense spending portion of NIPA government consumption, with adjustments made for sales tax and imputed capital services.[12] Consumption measured this way comprises 74 percent of total adjusted product. *Tangible investment* includes gross private domestic investment, consumer durables, the nondefense portion of government investment, net exports, and net foreign income, with an adjustment made for sales taxes on consumer durables. This category is 21 percent of adjusted total product. To estimate the division of gross private domestic investment into investment of Schedule C corporations (which we earlier categorized as sector 1 business) and all other private business, we use balance sheet data of corporations from the Internal Revenue

[11] Throughout, we are using data definitions prior to the BEA's 2013 comprehensive revision, which incorporated some, but not all, intangible investment. Below, we discuss our sources for measures of intangible capital stocks and investments.

[12] We assume that all sales taxes in NIPA are assessed on consumption, with pro rata shares attributed to nondurables, services, and durables.

Table 1. Revised national income and product accounts: Averages relative to adjusted GNP, 2000–2010.

Total Adjusted Income	*1.000*
Labor Income	*0.585*
Compensation of employees	0.531
Wages and salary accruals	0.433
Supplements to wages and salaries	0.099
70% of proprietors' income with IVA, CCadj	0.053
Capital Income	*0.415*
Corporate profits with IVA and CCadj	0.073
30% of proprietors' income with IVA, CCadj	0.023
Rental income of persons with CCadj	0.017
Surplus on government enterprises	0.000
Net interest and miscellaneous payments	0.056
Net income, rest of world	0.007
Taxes on production and imports[a]	0.072
Less: Sales tax	0.042
Consumption of fixed capital	0.117
Consumer durable depreciation	0.060
Imputed capital services[b]	0.037
Statistical discrepancy	−0.004
Total Adjusted Product	*1.000*
Consumption	*0.745*
Personal consumption expenditures	0.655
Less: Consumer durable goods	0.081
Less: Imputed sales tax, nondurables and services	0.037
Plus: Imputed capital services, durables[b]	0.013
Government consumption expenditures, nondefense	0.111
Plus: Imputed capital services, government capital[b]	0.025
Consumer durable depreciation	0.060
Tangible investment	*0.211*
Gross private domestic investment[c]	0.145
Schedule C corporations	*0.069*
Other private business	0.076
Consumer durable goods	0.081
Less: Imputed sales tax, durables	0.005
Government gross investment, nondefense	0.025
Net exports of goods and services	−0.042
Net income rest of world	0.007
Defense spending	*0.044*
Government expenditures, national defense	0.044

(*Continues*)

Service (IRS) and Board of Governors Flow of Funds (Board of Governors (1945–2016)). Specifically, we assume that the ratio of investments is equal to the ratio of depreciable assets and, therefore, we assume that 83.5 percent of corporate investment is made by Schedule C corporations. The remainder is included with noncorporate investment. *De-*

Table 1. *Continued.*

Addendum:	
NIPA GDI	0.942
NIPA GDP	0.938
NIPA GNP	0.945
Adjustments to NIPA GNP	0.055

Note: The data sources are the NIPA and fixed asset tables published by the BEA prior to the 2013 comprehensive revision. IVA, inventory valuation adjustment; CCadj, capital consumption adjustment; NIPA, national income and product accounts.
[a]This category includes business transfers and excludes subsidies.
[b]Imputed capital services are equal to 4 percent times the current-cost net stock of government fixed assets and consumer durable goods.
[c]The corporate share of gross private domestic investment is 56.5 percent. To determine the share of Schedule C corporations, we assume that the ratio of investments for these corporations and all other corporations is the same as the ratio of their depreciable assets. Based on balance sheet data from the IRS corporate tax returns, this would imply that 83.5 percent of corporate investment is made by Schedule C corporations.

fense spending—which we label G throughout—is NIPA's national defense concept and is a little over 4 percent of total adjusted product.

Here, we have included nondefense government consumption in our measure of consumption and nondefense government investment in our measure of tangible investment. In this case, the government purchases are effectively lump-sum transfers to households because we assume they are perfectly substitutable with private consumption and investment. Nondefense expenditures include expenditures on general public service, public order and safety, transportation and other economic affairs, housing and community services, health, recreation and culture, education, and welfare.[13] Later, when we consider reforms to phase out transfers for Medicare and Social Security, we always assume that the other transfers along with nondefense government spending are not cut; added together, these categories are about 19 percent of adjusted GNP. We also investigate whether our categorization of defense and nondefense spending as G and C has an impact on our quantitative results.

4.1.2 *Fixed asset tables* The revised fixed asset tables are reported in Table 2 for the period 2000–2010. The stocks of tangible capital categorized as private and public fixed assets and consumer durables are values of reproducible costs reported by the BEA in its fixed asset tables. As with tangible investments, we estimate that 83.5 percent of corporate capital is owned by Schedule C corporations, implying a stock of 0.67 times adjusted GNP in the category of private fixed assets. The remaining 1.52 GNPs of private fixed assets is categorized with other business; roughly 1.14 GNPs is residential capital. Together, private and public fixed assets are equal to 2.8 times adjusted GNP. If we include consumer durables, the total stock reported by the BEA is 3.1 times adjusted GNP.

To derive an estimate of the total tangible capital stock, we add the value of inventories from the NIPA accounts and the value of land from the Flow of Funds balance sheets.

[13]This approach is consistent with the accounting of the World Bank International Comparison Program (2014) that assumes "actual individual consumption comprises all the goods and services that households consume to meet their individual needs... whether they are purchased by households or are provided by general government and nonprofit institutions service households" (p. 9).

Table 2. Revised fixed asset tables with stocks end of period: Averages relative to adjusted GNP, 2000–2010.

Tangible Capital	*4.117*
Fixed assets, private[a]	2.193
Schedule C corporations	*0.674*
Other private business	1.519
Fixed assets, government	0.602
Consumer durables	0.304
Inventories[a]	0.134
Schedule C corporations	*0.103*
Other private business	0.031
Land[a]	0.885
Schedule C corporations	*0.109*
Other private business	0.776
Nonfinancial corporate	0.022
Nonfinancial noncorporate	0.298
Households and nonprofits	0.455
Intangible Capital	*1.7*
Total	*5.8*

Note: The sources of data on tangible capital stocks are the fixed asset tables published by the BEA prior to the 2013 comprehensive revision, corporate tax returns published by the IRS, and the Flow of Funds accounts published by the Board of Governors of the Federal Reserve. See the text for a discussion of estimates for intangible capital.

[a]The corporate shares of private fixed assets, inventories, and land are 36.8 percent, 92.1 percent, and 15.0 percent, respectively. In the case of inventories, we assume that 13 percent of farm inventories are corporate, based on the ratio of corporate farmland and buildings relative to total corporate stocks reported in Table 828 of the *U.S. Statistical Abstract*, 2012. To determine the share of Schedule C corporations, we assume that the ratio of stocks for these corporations and all other corporations is the same as the ratio of their depreciable assets. Based on balance sheet data from the IRS corporate tax returns, this would imply that 83.5 percent of corporate capital is owned by Schedule C corporations.

We include land in the tangible capital stock because it is in large part a produced asset associated with real estate development. Developers can and do vary the stock of real estate by shifting land use, say from farms to suburbs or single-family homes to high-rise apartments.[14] With inventories and land included, the total tangible capital stock is 4.1 times our measure of adjusted GNP.

To derive an estimate of the total capital available for financing retirement consumption, we add the value of intangible capital owned by private businesses. The estimated stock of business intangible capital is as large as the stock of business tangible capital, averaging about 1.7 GNPs over the 10-year period 2000–2010. This estimate is based on findings in an evolving literature that studies both indirect and direct measures of intangible capital and investment.[15] Indirect measures infer intangible *capital stocks* with the aid of growth theory predictions and data from U.S. national accounts and tax col-

[14]See Rossi-Hansberg and Wright (2007) for introducing developers into a competitive equilibrium model with endogenous cities. The BEA does not include land as a component of fixed assets at reproduction costs because it does not have good measures of these costs. We use market values in our capital stock number because of the lack of measures of the value of land at reproduction costs.

[15]For an indirect estimate, see, for example, McGrattan and Prescott (2010a). For direct estimates, see, for example, Corrado et al. (2012), Corrado, Hulten, and Sichel (2005), and Nakamura (2010).

lections; the main identifying assumption is that after-tax returns on all capitals must be equated in equilibrium. Direct measures use expenditure data on computerized information (software and databases), innovative property (mineral exploration, scientific R&D, entertainment and artistic originals, new products or systems in financial services, design and other new products or systems), brand equity (advertising and market research), and firm-specific resources (employer-provided training and organizational structure), and we find that business intangible *investments* are roughly the same share of GNP as business tangible investments.[16]

We do not include human capital owned by individuals in our measure of the capital stock because retired people do not rent their human capital to the business sector and cannot sell it to finance retirement consumption.[17]

Notice that the total stock in Table 2 is 5.8 times adjusted GNP, almost twice as large as the stock of reproducible assets reported in the BEA's fixed asset tables. Including only fixed assets reported by the BEA is standard in the literature. Later, we discuss how our results would change if we did the same.

4.1.3 *Parameters based on macro data* Table 3 reports the parameters used in the baseline economy—the economy with current U.S. demographics and current U.S. policies. These parameters imply that the model's balanced growth path is consistent with U.S. aggregate statistics.[18]

The first set of parameters governs demographics. For the baseline economy, we set the growth rate of the population equal to 1 percent, the work life to 45 years, and the survival probabilities to match the 2010 life tables in Bell and Miller (2005). We chose these parameters because they imply that the ratio of workers to retirees is 3.93, which is equal to the ratio of people over age 15 in the 2005 CPS March Supplement not receiving Social Security and Medicare benefits to those who are receiving these benefits.[19]

The preference parameters are chosen so that the model's labor input and labor share are consistent with that of the United States. Using aggregate data from the CPS, we find that total hours of work relative to the working-age population averaged 1442 hours per year. If discretionary time per week is 100 hours, then the fraction of time at work is 0.277. Assuming logarithmic preferences, namely,

$$u(c, \ell) = \log c + \alpha \log(1 - \ell),$$

we set α equal to 1.185 to get the same predicted hours of work for the model.[20] In addition, we set $\beta = 0.987$, so that the model's predicted division of income into labor and capital matches that of the U.S. accounts shown in Table 1.

[16]Software and mineral exploration are included with investment reported by the BEA prior to the 2013 comprehensive revision, which is what we use in our analysis.

[17]The stock of human capital is large, with just the part acquired on the job at around two times GNP, according to independent estimates of Heckman, Lochner, and Taber (1998) and Parente and Prescott (2000). Abstracting from this stock would not be appropriate when addressing some other questions.

[18]See McGrattan and Prescott (2016) for full details on data sources.

[19]We have also done computations using the ratio of full-time equivalent workers to the number of people age 65 and over. The main results do not change.

[20]Later, we report results for an alternative specification of preferences that allows us to vary the labor supply elasticity.

Table 3. Parameters of the economy calibrated to U.S. aggregate data

Demographic parameters	
Growth rate of population (η)	1%
Work life in years	45
Number of workers per retiree	3.93
Preference parameters	
Disutility of leisure (α)	1.185
Discount factor (β)	0.987
Technology parameters	
Growth rate of technology (γ)	2%
Income share, Schedule C corporations (θ_1)	0.500
Capital shares	
Tangible capital, Schedule C (θ_{1T})	0.182
Intangible capital, Schedule C (θ_{1I})	0.190
Tangible capital, other business (θ_{2T})	0.502
Intangible capital, other business (θ_{2I})	0.095
Depreciation rates	
Tangible capital, Schedule C (δ_{1T})	0.050
Intangible capital, Schedule C (δ_{1I})	0.050
Tangible capital, other business (δ_{2T})	0.015
Intangible capital, other business (δ_{2I})	0.050
Spending and debt shares	
Defense spending (ϕ_G)	0.044
Government debt (ϕ_B)	0.533
Capital tax rates	
Profits, Schedule C corporations (τ_1^π)	0.330
Distributions, Schedule C corporations (τ_1^d)	0.144
Distributions, other business (τ_2^d)	0.382

The technology parameters in Table 3 govern technological growth, investment rates, and capital income shares across business sectors. The growth rate of labor-augmenting technology is set equal to 2 percent, which is consistent with trend growth in the United States. The share parameter in the aggregate production function θ_1—which determines the relative share of income to Schedule C corporations—is set equal to one-half. This parameter is somewhat arbitrary because we do not have detailed NIPA data covering only Schedule C corporations. Instead, we have information on receipts and deductions from corporate tax returns and base our estimate on these data.[21]

The choice of tangible capital shares $(\theta_{1T}, \theta_{2T})$ and tangible depreciation rates $(\delta_{1T}, \delta_{2T})$ ensures that the model's investments and fixed assets line up with tangible investments and stocks reported by the BEA and Flow of Funds. As we noted earlier, we use data from the IRS on depreciable assets of Schedule C corporations to determine the relative quantities of investments and fixed assets for the model's two sectors. Doing so, we estimate tangible capital shares of $\theta_{1T} = 0.182$ and $\theta_{2T} = 0.502$ in the two sectors. The annual depreciation rates that generate investment rates consistent with U.S. data

[21]We experimented with lowering this share parameter and found our main results unaffected.

are $\delta_{1T} = 0.051$ and $\delta_{2T} = 0.015$. The high capital share and low depreciation in sector 2 follow from the fact that we have included housing and land.

The intangible capital shares and depreciation rates, θ_{1I}, θ_{2I}, δ_{1I}, and δ_{2I}, are not uniquely identifiable with the data we have. For the baseline model, we assume that two-thirds of the intangible capital is in Schedule C corporations and one-third in other businesses, and we set the depreciation rates on intangible capital equal to that of tangible capital in Schedule C corporations.[22]

The last set of parameters in Table 3 includes some of the policy parameters. We set the level of government consumption equal to 0.044 times GNP for all periods, that is, $\phi_{Gt} = 0.044$ for all t. This is the average share of military expenditures in the baseline economy for the 10-year period 2000–2010. We set the maximum debt constraint parameter ϕ_{Bt} equal to the average ratio of U.S. government debt to GNP for 2000–2010. Thus, $\phi_{Bt} = 0.533$ for all t. When we consider changing tax and transfer policies, we hold the spending and debt shares fixed.

Capital tax rates are listed next in Table 3 and are assumed to be the same for all asset holders, an assumption motivated later by the fact that most household assets are not held directly and are in untaxed accounts. Two categories of businesses are subject to different taxation: Schedule C corporations and all other businesses. Schedule C corporations are subject to the corporate income tax. The statutory corporate income tax rate τ_1^π is about 40 percent for the United States when federal and state taxes are combined. However, if the total revenue recorded by the IRS—about 2.6 percent of GNP over the period 2000–2010—is used to construct an estimate of the effective tax rate, then it is lower, on the order of 33 percent, which is the rate we use here.[23]

An additional tax on distributions τ_1^d is paid by investors in these corporations, where distributions are in the form of dividends and share buybacks. We use an estimate of 14.4 percent, which is equal to the average marginal rate as computed by the TAXSIM model times the fraction of equity that is in taxed accounts (see Feenberg and Coutts (1993)) for details on the TAXSIM model). The average marginal rate that we use is that for 2013 (rather than an average over 2000–2010) because we want to take into account the expiration of policies under the Jobs and Growth Tax Relief Reconciliation Act of 2003. To calculate the fraction of equity that is in taxed accounts, we use two different methods that yield close to the same estimate. First, we compute the fraction of equity in pension funds, life insurance reserves, individual retirement accounts, and nontaxable accounts of nonprofits. The estimates are based on balance sheet data with equity detail from the U.S. Flow of Funds (Table B.100.e) and data on equity holdings in retirement accounts from the Investment Company Institute (2012). These data indicate that 44 percent of equity holdings are in nontaxable accounts. Second, we use NIPA and IRS

[22]We did extensive sensitivity analysis and found that the results are not sensitive to the allocation of intangible stocks across sectors, but rather to the aggregate stock of capital available for retirees to finance consumption.

[23]The revenue estimate includes the small portion of property tax revenues paid by corporations, which we estimate to be about 0.3 percent of GNP based on assessed land values.

data to compute the fraction of corporate dividends distributed to nontaxed entities.[24] These data indicate that 45 percent of the dividends are in nontaxable accounts.

Our second category of businesses includes businesses that distribute their accounting earnings to their owners and whose earnings are treated as ordinary income for tax purposes. This business category includes unincorporated businesses and pass-through corporate entities, namely, Schedule S corporations, regulated investment companies (RICs), and real estate investment trusts (REITs). We add household and government businesses to this set.[25] For the tax rates on these other business distributions (τ_2^d), we use an estimate of the income-weighted average marginal tax rate on wage-like income based on the calculations of Barro and Redlick (2011) extended with the TAXSIM model. Over the period 2000–2010, this rate is estimated to be 38.2 percent when federal, state, and FICA taxes are included.[26]

When we simulate the model using the parameters in Table 3, our national account and fixed asset statistics are exactly the same as those shown in Tables 1 and 2 for the United States.

4.2 *Micro data*

In this section, we disaggregate national incomes using micro data. The primary source of our micro data is the CPS March Supplement from 2005 with estimates for 2004.[27] The micro data are used to impute income distributions for all categories of personal income in the NIPA. Individuals in the CPS sample are then assigned to different income brackets and, for each bracket, we construct population shares, income shares, and marginal and average tax rates. We then use estimates for these variables to set population weights, productivity levels, and the net tax schedules for workers and retirees.

4.2.1 *CPS March Supplement* In constructing the distribution of incomes and transfers, we first assign individuals in the CPS sample to *families*, and then we compute per capita family adjusted gross income (AGI). Families are defined to be a group of people living in the same household who are either related or unmarried partners and their relatives. A family's AGI is the sum of the AGIs of all members, and per capita family AGI is found by dividing this sum by the number of members who are of working age, assumed here to be at least 15 years old. We use families rather than individuals because many

[24] In various issues of the BEA's *Survey of Current Business* (U.S. Department of Commerce (1929–2016)), BEA estimates of personal income are compared with IRS estimates of adjusted gross income, with details of nontaxed distributions to pension funds, life insurance reserves, fiduciaries, and nonprofits.

[25] Since the value added of government business is small, we think that just aggregating it with the noncorporate taxpaying sector is reasonable because it has a negligible effect on the quantitative findings reported in this paper. Our strategy is to develop and use as simple an abstraction as possible to answer the questions we are addressing. Even with this strategy, the abstraction is far from simple, and modeling all of the unimportant details of the tax system would greatly complicate the analysis.

[26] The composition of the 38.2 percent is 23.1 percent for federal taxes, 4.5 percent for state and local taxes, and 10.6 percent for FICA taxes.

[27] We use the CPS survey because it is a large, representative survey that includes information about household tax filings. See McGrattan and Prescott (2016) for more details and more analysis with the micro data used here.

individuals in our sample have little or no income—from either earnings or government transfers—but live with relatives who have incomes and file tax returns. We assume that intrafamilial transfers are being made, but we cannot measure them directly. Instead, we group the family members and treat them as if they had the same per capita consumptions, hours, and incomes.

In Table 4, we report populations by size of family per capita AGI. In the CPS, individuals are asked if they filed a tax return or are the spouse or dependent of a tax filer.[28] Three groups are listed: tax filers, nonfilers or dependents who are less than age 15, and nonfilers or dependents who are age 15 or older. Tax filers include married spouses filing jointly. The total U.S. population in 2004 is 291 million people, of which 176 million are tax filers. To construct per capita estimates, we include the 54 million nonfilers and dependents who are age 15 and older and, thus, we have a working-age population of 230 million.

For each family AGI category listed in Table 4, we assign the group's share of national incomes and transfers reported by the BEA.[29] Total incomes by source of income are listed in the last row of the table, with the grand total equal to $12,233 billion (in 2004). This total is found by adding BEA personal income ($9731), the employee contribution to social insurance ($419), the employer contribution to social insurance ($407), and nondefense spending ($1675), where all are reported in billions of dollars.[30] Wages and salaries (W&S), which is the largest income category at $5392 billion, includes wages and salaries that are part of personal income and the employee contribution to social insurance. The next category of income listed in Table 4 is proprietors' income ($911 billion), which we treat as part labor income (70 percent) and part capital income (30 percent). Incomes included in the capital income category are rental income of persons, personal dividend income, and personal interest income; these categories sum to $1555 billion. We split transfers into three categories: Social Security (SS), Medicare, and all other NIPA transfers, which together are $1426 billion. Finally, wage supplements equal to $866 billion that are included in personal income are employer contributions for private insurance and pension. Another employer contribution, which is not included in personal income, is the FICA contribution for social insurance.

The distributions of incomes reported in Table 4 are found in several steps. First, we construct distributions based on data reported in the CPS March Supplement. For each income category and family, we estimate the amount received and attribute that amount to the relevant bracket of per capita family AGI in the first column. Since the money incomes in the CPS and the national incomes reported by the BEA are not a perfect match, we use the closest proxy. In the case of wages and salaries, there is a close match, and the total reported by the CPS for 2004 is $5351 billion, which is close to the BEA total. Our CPS proxy for proprietors' income is the sum of own-business self-employment and farm income. The CPS estimate is $350 billion, well below the BEA total. Incomes in the

[28]Tax return information is supplied by the Census Bureau's tax model, not by those being surveyed.

[29]In McGrattan and Prescott (2016), we also report the group's share of CPS money incomes.

[30]The baseline parameterization assumes that nondefense spending is included with private consumption. In our sensitivity analysis, we show that more or fewer spending categories could be added to G with little impact on the main results.

TABLE 4. Distribution of incomes based on 2005 CPS March Supplement, scaled to BEA totals with families sorted into AGI groups.

Per Capita	Tax	Dependents			Incomes			Transfers			Wage Supplements			Nondefense
Family AGI[a]	Filers	<15	≥15	Total[d]	W&S	Proprietors	Capital	SS	Medicare	Other	Insurance	Pension	FICA	Spending
Nonfilers	0	4	30	773	8	0	19	198	136	194	1	0	1	217
Filers, by AGI	176	56	24	10,197	5281	827	460	287	170	441	539	326	406	1458
No AGI	5	1	1	129	9	−3	8	34	21	21	1	0	1	38
1–5000	6	3	3	181	22	8	2	17	11	51	3	0	2	64
5–10,000	14	6	5	450	117	28	9	32	20	82	14	3	11	134
10–15,000	21	7	5	717	254	47	16	46	29	77	33	9	22	183
15–20,000	20	7	3	781	345	53	18	32	19	52	46	15	30	171
20–25,000	20	6	2	873	428	65	22	23	14	41	57	22	37	163
25–30,000	17	5	1	818	428	59	24	18	11	30	55	24	36	133
30–40,000	26	8	2	1440	790	104	51	29	17	39	97	50	65	199
40–50,000	17	5	1	1174	681	84	52	15	9	21	76	47	55	133
50–75,000	16	5	1	1387	812	118	88	19	10	18	77	56	64	125
75–100,000	8	3	0	837	501	79	61	11	5	6	41	36	37	59
100–200,000	6	2	0	905	553	110	83	9	4	2	30	39	32	42
200,000+	2	1	0	507	342	74	26	1	1	1	9	24	15	13
Unassigned[b]	0	0	0	1263	103	84	1076	0	0	0	0	0	0	0
Total[c]	176	61	54	12,233	5392	911	1555	485	306	635	540	326	407	1675

Note: [a]Families consist of related persons and unmarried partners in a household. Family AGI is the sum of member AGIs divided by all members age 15 and over.
[b]Unassigned income is BEA personal income less BEA-derived AGI and CPS income of nonfilers. See main text and SCB (2007) for details.
[c]Populations of tax filers and dependents under and over age 15 are in millions; BEA totals are in billions.
[d]BEA data are from the 2006Q4 archive to be consistent with estimates in SCB (2007).

CPS used to proxy capital income are dividends, interest, and rents that sum to $313 billion, also significantly below BEA totals.[31]

There are two important sources of underreporting for proprietors and capital investors, which are most evident if we compare the BEA aggregate incomes with two measures of AGI: a BEA-derived measure of AGI and AGI reported by the IRS (see *Survey of Current Business* [SCB] (2007)). The difference between BEA personal proprietors' income and the BEA-derived AGI for this category is only $84 billion (out of a total of $911 billion). But the difference between BEA-derived AGI and reported IRS AGI is large, roughly $573 billion. The large discrepancy between the two measures of AGI is due primarily to a significant misreporting of income by proprietors; the BEA imputes a significant fraction of proprietors' personal income using data from tax compliance studies. In the case of capital income from dividends, interest, and rents, the situation is reversed: the difference between the BEA personal income and the BEA-derived AGI is large, roughly $1095 billion (out of $1555 billion), whereas the difference between the BEA AGI and the IRS AGI is small, only $86 billion. The reason for the large discrepancy between BEA personal income and BEA-derived AGI is that most of the capital income is earned on assets in untaxed or tax-deferred accounts and thus not part of AGI.[32]

To deal with the discrepancies between aggregated CPS incomes and the BEA aggregates, we add another category under per capita family AGI, called *unassigned*. In that category, we include the difference between the BEA total personal income and the BEA-derived AGI. If the CPS sample includes income earned by nonfilers, we subtract that as well before recording the unassigned income. If all earned income were to appear on tax forms, the unassigned income would equal zero. We make a second adjustment so that the disaggregated data sum to the aggregates; namely, for each AGI category, we multiply the CPS incomes by the ratio of the BEA personal income to the sum of CPS incomes. If no misreporting of income to the CPS or IRS occurred, the ratio of these incomes would be 1, and no adjustment would be needed. The resulting income distributions, after these two adjustments are made, are shown in the sixth to eighth columns of Table 4.

The ninth through eleventh columns of Table 4 list three types of transfers: Social Security, Medicare, and other, where the latter is all other transfers recorded in the NIPA accounts. Again, the units are billions of 2004 dollars. Social Security incomes reported in the CPS sum to $426 billion, whereas the BEA total is $485. For Medicare, the CPS reports the person market value, which is the average cost of the program per respondent for the government. The CPS total is $290 billion, which is close to the BEA total of $306 billion. The category "other" includes all other NIPA transfers. To get an estimate of the distribution of these other transfers, we sum the CPS data on income from worker's compensation, supplemental security, public assistance, unemployment compensation, and veteran payments, as well as the person market value of Medicaid, the earned income tax credit, the child tax credit, and the additional child tax credit. For all

[31] We also use IRS *Statistics of Income* to construct distributions for proprietors' income and all capital incomes, but find little difference in the implied parameter estimates.

[32] This fact motivates our assumption that households face the same after-tax interest rate, regardless of their AGI.

transfer categories, we inflate the CPS estimates by multiplying each by the ratio of the BEA estimate of total income divided by the CPS estimate of total income.

Distributions of wage supplements are listed in the twelfth to fourteenth columns. These are employer contributions for private insurance, pensions, and social insurance. For an estimate of the distribution of insurance, we use the CPS data on employer contributions for health insurance, which is the primary type of insurance included in the BEA total. The CPS total for employer contributions to health insurance is $362 billion, whereas the BEA estimates that all payments for insurance total $540 billion. For pensions, the CPS survey asks if the respondent is included in a pension plan at work, but does not provide an estimate of the employer contribution. If the respondent says yes, we impute a value for the contribution that is proportional to income, with the rate chosen so that the imputed values sum up to the BEA total of $326 billion. The last item under wage supplements is employer contributions for social insurance, listed as FICA. Here, we use CPS data on worker payroll deductions for social insurance to infer the employer payments.

The last column of Table 4 is nondefense spending, which we include with other transfers and allocate pro rata shares.

We report estimates of marginal and average tax rates in Table 5. Marginal tax rates are averages of income-weighted marginal tax rates for tax filers (and spouses for joint filers).[33] The "total marginal" rate is the sum of the rates from federal and state tax filings plus the FICA tax—which includes both the employee and employer parts.[34] We make two adjustments to the rates based on information in the CPS about the receipts from the earned income tax credit (EITC) and the child tax credit (CTC). To adjust our marginal rates for tax credit recipients, we use the IRS 2004 tax-year worksheets to determine the change in tax payments with an additional dollar of income. The adjustments for these credits are reported in the seventh and eighth columns of Table 5. In the last three columns of Table 5, we report the average federal, state, and FICA tax rates, aggregated over families in each AGI bracket. To compute the aggregate average rate, we compute an income-weighted average to ensure that the aggregates are total tax paid divided by total income. This is done for all categories, namely, federal, state, and FICA.

4.2.2 *Parameters based on micro data* The next step is to set the parameters relevant for the model's predicted distributions of income and net taxes. Specifically, we show how we use the data from Tables 4 and 5 to estimate the productivity levels, ϵ^k, and the initial net tax schedules $T_0^j(\cdot)$.

For our baseline parameterization, we assume that there are four types of families that differ in terms of their levels of productivity; we refer to the types as *low*, *medium*, *high*, and *top* 1 *percent*. (Later, as a robustness check, we analyze an economy with more levels.) The value of ϵ^k for the low types is chosen so that the share of their labor income in the model matches the share of labor income for U.S. families in AGI brackets

[33] When constructing marginal rates, we used the methodology of Barro and Redlick (2011). We do not assume that households take into account whether an additional hour puts them over a benefit threshold when retired, as in Huggett and Parra (2010).

[34] If we aggregate to one type, our results are consistent with those in Barro and Redlick (2011).

Table 5. Distribution of tax rates based on 2005 CPS March Supplement with families sorted into AGI groups.

Per Capita Family AGI[a]	Tax Filers	Dependents		Marginal Tax Rates						Average Tax Rates			
		<15	≥15	Total	Federal	EITC[c]	CTC[c]	State	FICA	Total	Federal	State	FICA
Nonfilers[b]	0	4	30	14.2	0	0	0	0	14.2	14.2	0	0	14.2
Filers, by AGI													
No AGI	5	1	1	14.6	0.0	0.1	0.0	0.0	14.4	14.4	0.0	0.0	14.4
1–5000	6	3	3	4.7	0.9	−10.3	−0.9	0.2	14.8	13.2	0.1	0.1	14.3
5–10,000	14	6	5	20.7	5.1	1.8	−2.2	1.2	14.7	13.8	−0.8	0.5	14.1
10–15,000	21	7	5	28.2	9.6	2.6	−1.1	2.4	14.7	15.3	0.5	1.1	13.7
15–20,000	20	7	3	32.6	13.1	1.9	−0.4	3.2	14.7	18.7	2.8	1.7	14.2
20–25,000	20	6	2	34.2	14.9	1.0	−0.1	3.8	14.7	21.4	4.8	2.1	14.4
25–30,000	17	5	1	35.3	15.8	1.0	0.0	4.0	14.5	23.5	6.5	2.4	14.6
30–40,000	26	8	2	35.9	17.1	0.3	0.0	4.3	14.2	25.6	8.3	2.7	14.6
40–50,000	17	5	1	41.2	23.2	0.0	0.0	4.7	13.3	28.2	10.6	3.1	14.5
50–75,000	16	5	1	41.9	24.8	0.0	0.0	5.0	12.1	30.3	13.0	3.3	14.0
75–100,000	8	3	0	41.8	27.3	0.0	0.0	5.1	9.4	32.3	15.5	3.5	13.3
100–200,000	6	2	0	41.2	30.0	0.0	0.0	5.4	5.9	32.7	18.1	3.8	10.9
200,000+	2	1	0	43.4	34.4	0.0	0.0	5.2	3.8	35.6	24.8	3.9	6.9

Note: [a]Families consist of related persons and unmarried partners in a household. Family AGI is the sum of member AGIs divided by all members age 15 and over.
[b]Populations of tax filers and dependents under and over age 15 are in millions; tax rates are in percent.
[c]Adjustments are made to federal tax rates to account for the impact of refundable tax credits and public assistance. See U.S. Congress, CBO (2012).

covering \$0 to \$15,000 (in 2004 dollars). These families comprise 38 percent of the population over 15 years old. (See Table 4.) Similarly, the values of ϵ^k for the medium, high, and top 1 percent types are chosen so there is a match between the group's labor income share in the model and that of U.S. families in AGI brackets \$15,000 to \$40,000, \$40,000 to \$200,000, and over \$200,000, respectively. The population shares for the medium, high, and top 1 percent are 40, 21, and 1 percent, respectively.

To construct the share of labor income for each AGI group in our data set, we first add 70 percent of proprietors' income to wages and salaries in Table 4. We then attribute the unassigned income proportionally across AGI brackets and compute income shares for the relevant subgroups in our baseline economy. Doing this, we find shares for the wage income for the lowest to highest types equal to 8, 38, 47, and 7 percent. We generate the same shares in our baseline model if we set ϵ^k equal to 0.33, 0.98, 2.05, and 6.25 for the four productivity types. As we noted earlier, we do not use the distribution of capital income from the micro data when choosing the productivity parameters because most of it is unassigned.

To parameterize the initial net tax schedules, $T_0^j(\cdot)$, we use data shown in Table 4 on transfers, wage supplements, and nondefense spending and data shown in Table 5 on tax rates. We assume that all workers *face the same schedule*, $T_0^j(y) = T^w(y)$, $j \leq J_R$. Similarly, all retirees *face the same schedule*, $T_0^j(y) = T^r(0)$, $j > J_R$, which does not vary with labor income because retirees are assumed to have no labor income.

Regarding the construction of $T^w(y)$, two features matter for generating an accurate assessment of the proposed tax reforms. First, it is critical that we have a good estimate of marginal tax rates—or slopes of $T^w(y)$ at different income levels—because marginal rates appear in the household first-order condition governing the labor–leisure tradeoff. Second, it is critical that the aggregated budget sets of households—which depend on the magnitudes of $T^w(y)$ at different income levels—match the U.S. aggregate data. To achieve full flexibility, we construct a piecewise linear function for $T^w(y)$ and allow for discontinuities in the function. Discontinuities can arise with transfer programs like Medicaid that have a cliff-like income threshold, with families below a certain income threshold qualifying for full benefits and those above not qualifying. They can also arise because of differences in characteristics of jobs or occupations. For example, some employers offer fringe benefits, which are untaxed incomes, and some do not. High-income individuals (in our CPS data set) are more likely than low-income individuals to have jobs with benefits. In many cases, the amount of benefits received is not affected by working an extra hour, but rather by switching jobs or occupations.

To construct the piecewise net tax schedule for workers, we linearize $T^w(y)$ on each AGI income interval $[\underline{y}_i, \bar{y}_i]$, $i = 1, \dots, I$, as follows:

$$\begin{aligned} T^w(y) &= T_i(y) - \Psi_i^w \\ &\simeq T_i'(\bar{y})y - \{[T_i'(\bar{y}) - T_i(\bar{y})/\bar{y}]\bar{y} + \Psi_i^w\} \\ &\equiv \beta_i y + \alpha_i, \end{aligned} \tag{4.1}$$

where $\bar{y}$ is the midpoint in $[\underline{y}_i, \bar{y}_i]$ and Ψ_i^w is a constant transfer to workers with labor income in this bracket. The local slope of the function is β_i, and the intercept of the line over this interval is α_i. Notice that the intercept has two terms. The first is a measure of the tax schedule's progressivity for this particular income group, namely, the difference between the local marginal rate $T_i'(\bar{y})$ and the local average tax rate $T_i(\bar{y})/\bar{y}$ at $\bar{y}$. The second term Ψ_i^w includes transfers that are the same for all income earners in this interval. At the midpoint of the interval, the net tax is $T^w(\bar{y}) = T_i(\bar{y}) - \Psi_i^w$, which is *equal to the actual tax revenues* (or, equivalently, the average tax rate times the income) less the transfers included in Ψ_i^w. Thus, we ensure that aggregation of the household budgets generates the observed tax revenues. We refer to term $\beta_i y$ in (4.1) as the *marginal component* of the net tax schedule, since it depends on income y, and the intercept α_i as the *nonmarginal component* of the net tax schedule, since it is the same for all income earners in the ith bracket.

The marginal tax rates, $T_i'(\bar{y})$, for the U.S. data are displayed in Figure 1A. We start with the income-weighted marginal tax rates shown in Table 5 and make an adjustment for employer-sponsored pensions. More specifically, we assume that the pension benefits increase with an additional hour of work and, therefore, lower the effective marginal tax rates. We compute the change in the benefits relative to the change in compensation using the data in Table 4 and subtract the result from the rates in Table 5. We then plot these rates relative to per capita compensation and fit a smooth curve through the new rates. The result is "average marginal rates" shown in Figure 1A.[35]

As a point of comparison, we also plot the marginal tax rate estimates of Heathcote, Storesletten, and Violante ((2014); hereafter, HSV), who study the progressivity of the U.S. tax and transfer system. They use the functional form for the net tax schedule,

$$T^w(y) = y - \lambda y^{1-\tau}, \tag{4.2}$$

and estimate τ and λ with data from the Panel Study of Income Dynamics (PSID). Their estimated marginal rates, labeled HSV in Figure 1A, are given by $1 - \lambda(1 - \tau)y^{-\tau}$, with $\lambda = 4.74$ and $\tau = 0.151$. These rates are lower than ours because HSV restrict attention to the labor income of households aged 25–60 with a head or spouse working at least 260 hours per year and exclude taxes for social insurance and transfers for Social Security and Medicare.[36]

In Figure 1B, we show the data underlying the nonmarginal components (that is, the α_i's) of the net tax schedule in (4.1) for each family AGI bin in our sample. All estimates are in per capita terms. The first two categories are government spending on nondefense spending and transfers other than Social Security and Medicare. When allocating this spending between workers and retirees, we assume that 80 percent—which is the fraction of the population over 15 years of age not receiving Social Security or Medicare—is included with transfers to workers.[37] The third category uses data on employer contribu-

[35] Eleven distinct rates are visible in the figure because rates for the top two income brackets are the same.

[36] Marginal rates for incomes below $5000 are found by extrapolating their estimated function.

[37] Included here are some means-tested transfers that phase out gradually with income and, therefore, should be included with the marginal components of the net tax schedule. We do not have specific information in our data set to reallocate them, but we do know that they are small relative to programs such as Medicaid and the Children's Health Insurance Program, which have cliff-like income thresholds. For more details, see U.S. Congress, Congressional Budget Office (2012).

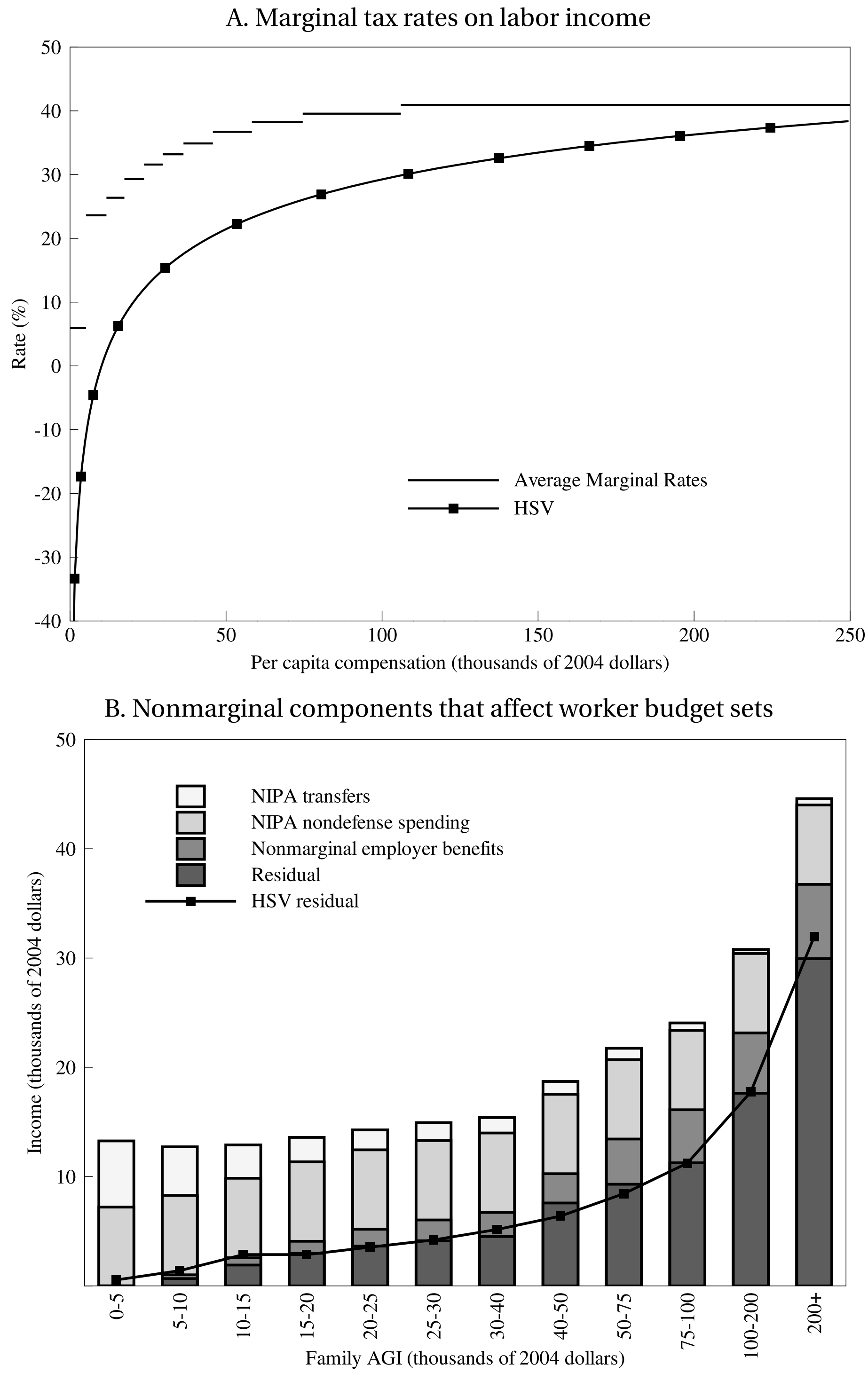

Figure 1. Marginal and nonmarginal components of the net tax function: The benchmark model compared to Heathcote et al. (HSV (2014)).

tions that we categorize as nonmarginal. More specifically, if the family receives a fringe benefit f, regardless of how much they earn, and it is deducted from total wages, then the budget set includes a term equal to f times their marginal tax rate. Here, we include employer contributions for insurance, since they do not have an impact on the static labor–leisure decision. The values shown in Figure 1B are these benefits multiplied by the relevant marginal tax rates.

The fourth category is the residual category, namely, $[T_i'(\bar{y}) - T_i(\bar{y})/\bar{y}]\bar{y}$ in (4.1). To compute this, we take the sum of the differences between the marginal and average tax rates from federal and state income filings and the employee's part of FICA and multiply it by the amount of taxed labor income. The taxed labor income is wages and salaries (sixth column of Table 4) plus 70 percent of proprietors' income (seventh column of Table 4). As a reference, we also plot this residual for HSV's estimated net tax schedule. Although the two sets of estimates are close, there are some differences. For example, HSV use household incomes and exclude FICA taxes, and we use family incomes and include FICA taxes.

Taken together, the estimates in Figure 1A—multiplied by labor income—less the estimates in Figure 1B form the piecewise linear net tax schedule that we use in the model. To smooth out the function, we regress the expenditures in Figure 1B on the midpoints of the intervals $[\underline{y}_i, \bar{y}_i]$ and use the linear approximation for the nonmarginal components of the net tax schedule (that is, the α_i intercept terms). The outcome is shown in Table 6 under the heading "Current Policy." The first column under that heading shows the intercepts, and the second column shows the slopes, both by income bracket. We should emphasize that *all families in the model face this same net tax schedule*, regardless of their productivity type.

Table 6. Current and future labor income net tax schedules, $T_\infty^w(y) = \alpha_i + \beta_i y$.

					Additionally			
	Current Policy		No FICA		Suspend Deductibility		Lower Marginal Rates	
Earnings Over	α_i	β_i	α_i	β_i	α_i	β_i	α_i	β_i
0	−11,762	0.059	−11,401	−0.066	−11,376	−0.066	−13,344	0.000
5,132	−12,819	0.246	−12,619	0.056	−12,268	0.056	−13,344	0.044
11,664	−13,518	0.264	−13,427	0.123	−12,752	0.123	−13,344	0.088
17,418	−14,365	0.293	−14,403	0.160	−13,302	0.160	−13,344	0.132
23,718	−15,211	0.316	−15,379	0.175	−13,836	0.175	−13,344	0.176
29,692	−15,971	0.332	−16,255	0.187	−14,353	0.187	−13,344	0.220
36,351	−17,000	0.349	−17,447	0.192	−15,245	0.192	−13,344	0.230
45,274	−18,503	0.367	−19,182	0.242	−16,505	0.242	−13,344	0.240
58,274	−20,359	0.382	−21,325	0.275	−17,189	0.275	−13,344	0.250
74,560	−22,880	0.396	−24,236	0.301	−19,382	0.301	−13,344	0.260
106,007	−28,810	0.409	−31,083	0.332	−25,571	0.332	−13,344	0.270
191,264	−45,792	0.409	−50,690	0.372	−43,894	0.372	−13,344	0.290

Note: Earnings and net tax function intercepts are reported in 2004 dollars.

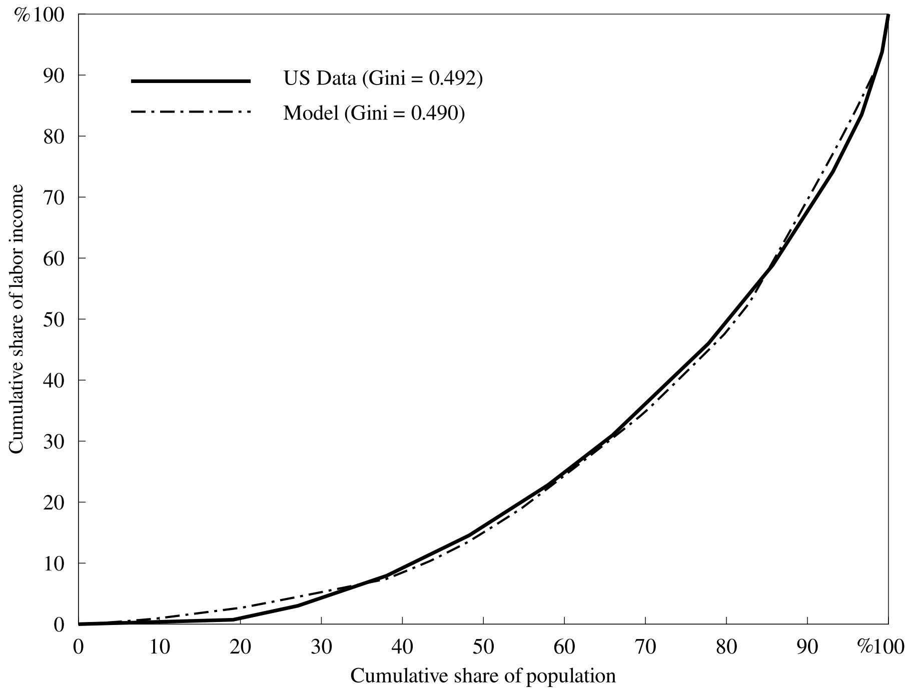

Figure 2. Concentration of labor income, before taxes and transfers.

The final step in parameterizing the net tax schedule is the estimation of transfers to retirees, $T^r(\cdot)$. In our total measure of retiree transfers, we include the remaining 20 percent of government spending not allocated to workers and all spending on Social Security and Medicare. We find that the total varies little across AGI groups and therefore assume it is the same for all income groups in our model.[38] In the aggregate, our estimate of expenditures on Social Security, Medicare, and the retiree share of other government spending is a little over 10 percent of GNP over the period 2000–2010, which translates to a per capita figure of $32,526 in 2004 dollars.

The last parameter to be set is the consumption tax, which is residually determined so that the government's budget balances. For our baseline parameterization, this requires setting the tax rate to 6.5 percent.

As a check on the model parameterization, we compute the concentration of labor income for the model using our baseline parameterization for the 2000–2010 period and for the United States using the 2005 CPS sample. The results are shown in Figure 2. Even though we have only four productivity types, there is sufficient variation in earnings over

[38]In the data, Social Security benefits increase with income, but higher incomes pay taxes on these benefits. The CPS data do not record these taxes separately, but the BEA aggregates for 2004 show that roughly 25 percent of Social Security income was taxable (see the *Survey of Current Business* (SCB) (2007)). The CPS data for Medicare are average costs, which vary by state but not by income. Steurle and Quakenbush (2013) estimate that a hypothetical one-earner couple who turn 65 in 2005 and earn a wage 60 percent above the average wage will have *total lifetime* Social Security and Medicare benefits under current law that are only 18 percent higher than a one-earner couple in the same cohort that earn the average wage.

the life cycle to generate an accurate prediction for the dispersion in labor income. In fact, the Gini index is 0.490 in the model and 0.492 in the data.

5. Evaluation of alternative policies

Next, we turn to our policy experiments.[39] We start by analyzing a policy regime that is effectively a continuation of current U.S. policy—that is, a system that taxes labor and capital incomes and uses part of the proceeds to finance the consumption of retirees. Because the number of workers per retiree is falling, a continuation of this policy necessitates increasing one or more tax rates over time.[40] In the experiments reported here, we assume that the consumption tax is increased so as to finance additional old-age transfers.[41] We compare a continuation of the current U.S. policy with variations on a saving-for-retirement regime. To start, we phase out FICA taxes and transfers to retirees that are neither welfare nor local public goods. So as to produce a Pareto-improving transition, we introduce two additional tax reforms—suspend deductibility of certain employer benefits and partially flatten the net tax schedule of workers—and find an improvement for all, even if the changes to the net tax schedule are temporary. We also consider phasing out all taxes on profits and distributions and phasing in government transfers for low- and middle-income families.

To compute the transition paths and welfare consequences for these alternative policy reforms, we start with the initial state in the baseline economy and hold fixed over time the ratios of debt to GNP, defense spending to GNP, and the fraction of the population with a particular productivity level. The initial state is summarized by the level of government debt and the distribution of household asset holdings. The initial distribution of ages is determined by the parameters of the baseline economy, and in all transitions, we assume a linear decline in the population growth rate over the first 45 years.[42] At time $t = 0$, a demographic transition occurs, and we determine the welfare consequences for people of all ages and productivity levels who are alive at the time of the demographic and policy regime change and for all new cohorts entering the workforce in years subsequent to the change.

5.1 *Continue U.S. policy*

The first transition path that we compute assumes a continuation of U.S. policy as the population ages. The main policy changes are increases in transfers for the retirees and increases in consumption taxes to finance them, where the latter are residually determined to satisfy the government budget constraint. The consumption tax rate required

[39] In McGrattan and Prescott (2016), we provide details of the algorithm used to compute equilibria.

[40] The continuation policy we consider assumes that transfers for Social Security and Medicare rise at the same rate as the retiree population. According to annual reports summarized in U.S. Social Security Administration (2013), this is a conservative estimate for the growth rate of these transfers.

[41] We also tried increasing the labor tax rate but could not raise sufficient funds to finance all of the additional old-age transfers because of the significant decline in the labor input and GNP.

[42] We also considered more immediate changes in the growth rate and found that the results are not sensitive to this choice.

Table 7. Impact of demographic and policy change.

	Continue	Reform	Vary Reform		Vary Model Parameters			
Statistic/Economy	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Interest rate, level (%)	4.3	4.0	4.2	4.2	4.0	4.0	4.5	4.2
Changes relative to current U.S. (%)								
Tangible capital	−2.4	27.0	17.5	21.6	25.4	28.2	21.3	11.4
Intangible capital	−4.4	21.6	13.9	17.0	20.0	22.5	17.2	7.2
Labor input	−10.0	5.0	2.4	4.8	4.2	5.6	5.6	−5.8
Wage rate	4.5	9.4	6.8	8.7	9.5	9.7	8.0	8.5
Consumption	−0.2	19.5	15.2	18.8	16.2	20.5	19.6	6.7
GNP	−4.5	16.1	10.7	15.2	14.9	16.9	15.2	3.0
Net worth	−3.0	24.9	16.2	19.6	23.4	26.0	19.8	6.0
Range of gains in transition (%)								
Low productivity	—	0.25	0.38	0.59	0.26	0.22	0.13	−0.96
	—	9.9	9.9	10.4	10.3	9.6	13.3	11.6
Medium productivity	—	0.42	0.47	0.89	0.50	0.36	0.24	−0.66
	—	12.1	8.7	12.2	12.8	11.8	14.9	12.3
High productivity	—	0.45	0.49	0.93	0.55	0.38	0.48	−0.37
	—	15.3	10.2	15.3	15.8	15.6	18.9	14.7
Top 1%	—	0.47	0.51	0.97	0.58	0.39	0.51	−0.23
	—	22.2	15.6	21.7	22.8	21.6	25.7	19.7

Note: Values for the first eight rows are computed after the transition has occurred. Values in the ninth through sixteenth rows are the lowest and highest gains across all birth-year cohorts recorded during the transition. Current U.S. policy is continued in economy (1). The baseline reform with $T^w(y)$ changed permanently is adopted in economy (2). Only Social Security is phased out in (3). The debt to GNP level is equal to 1 in (4). In (1)–(4), life expectancies do not vary with productivity, productivities are independent of age, annuity markets are available, and the Frisch labor elasticity is 2.6. Survival probabilities depend on productivity in (5), productivities are age-dependent in (6), annuity markets are shut down in (7), and the Frisch elasticity is 0.5 in (8). Changes in the second through eighth rows are computed after variables are detrended by the current U.S. economy growth trend.

to finance these transfers rises from a baseline rate of 6.5 percent to roughly 12 percent. The net tax schedules for workers and retirees are not changed, but revenues and transfers change in response to the demographic transition.

In column 1 of Table 7, we report summary statistics for this economy. The first eight rows are model predictions once the transition has occurred. (McGrattan and Prescott (2016) report the full set of statistics for the transition path, including time series for the interest rate, wage rate, factor inputs, GNP and the national accounts, household net worth, components of the government budget constraints, and net taxes and transfers for workers and retirees by productivity type.) The first statistic in Table 7 is the level of the interest rate, which would be 4.6 percent if there were no demographic or policy changes, and is 4.3 percent given that a demographic transition occurs and current U.S. policy is continued. Next, we report the changes in key aggregates, which are computed relative to the current U.S. growth trend. Consider first the changes in factor inputs. Tangible and intangible capital stocks fall by 2.4 percent and 4.3 percent, respectively, and the labor input falls even more, roughly by 10 percent, as the fraction of workers declines. Wages do rise but not enough for consumption, national income, or wealth to rise. By the end of the transition, GNP is below trend by 4.5 percent and household net worth is below trend by 3 percent.

The continuation of U.S. policy is our reference point when conducting welfare analysis of saving-for-retirement policies. It will be useful to compare these results with those associated with the saving-for-retirement reforms discussed next.

5.2 *Phase out FICA taxes, Medicare, and Social Security*

The first saving-for-retirement policy that we analyze involves the phasing out of FICA taxes and transfers for Medicare and Social Security. In this case, we use a step-by-step approach when constructing a welfare-improving transition for all birth-year cohorts and productivity types.

The step-by-step construction is illustrated in Figures 3 and 4. In panel A of Figure 3, we show the welfare gains—and, for some, losses—of gradually eliminating FICA taxes and old-age transfers. Elimination of FICA taxes implies setting the tax rates in the tenth and the last columns in Table 5 to zeros for future generations, and elimination of old-age transfers implies setting the transfers in the ninth and tenth columns of Table 4 to zeros. The policy reform necessitates two modifications to the future net tax schedule of workers. First, we must change the slopes $\{T'_{it}(\bar{y})\}$ in future years at all income intervals, $[\underline{y}_i, \bar{y}_i]$. Second, we must lower the residual in (4.1) to account for the fact that marginal tax rates are being lowered. In other words, we have a new piecewise linear net tax schedule for the economy on the final balanced growth path, with new values for $\{\alpha_i, \beta_i\}$ on AGI intervals $i = 1, \dots, I$. We report this new schedule in the columns under the heading "No FICA" in Table 6. The final retiree transfers in this case are equal to $T^r_\infty = -13{,}344$, which is an estimate of per capita expenditures that, when aggregated, provides the roughly 19 percent of adjusted GNP of resources needed to maintain current spending levels for public goods and transfers (other than Medicare and Social Security).[43]

Along the transition, we assume that net taxes and transfers are computed with a linear combination of the initial tax schedules, $T^j_0(\cdot)$, and the final tax schedules, $T^j_\infty(\cdot)$. The rate of change of retiree transfers is equal to the rate of change of the fraction retired. More specifically, let r_t be the fraction of the population that is retired in year t, and let μ_t be the ratio of new retirees in period t relative to new retirees on the final balanced growth path, that is, $\mu_t = (r_t - r_1)/(r_\infty - r_1)$, which starts at 0 and rises to 1 over time. We assume that transfers for Medicare and Social Security paid to retirees fall at the same rate as $-\mu_t$.

The rate of change of worker net taxes is assumed to be faster.[44] If tax rates are lowered at the same rate that old-age transfers fall, current retirees are indifferent between a continuation of current policy and a shift to the new system because their benefits are not affected. But workers are worse off; they face higher tax rates on their labor income when young, but receive lower transfers by the time they reach the retirement age.

[43] This estimate is used in all experiments in which FICA taxes and transfers are phased out.

[44] See McGrattan and Prescott (2016) for results of the experiment with transfers phased out at the same rate.

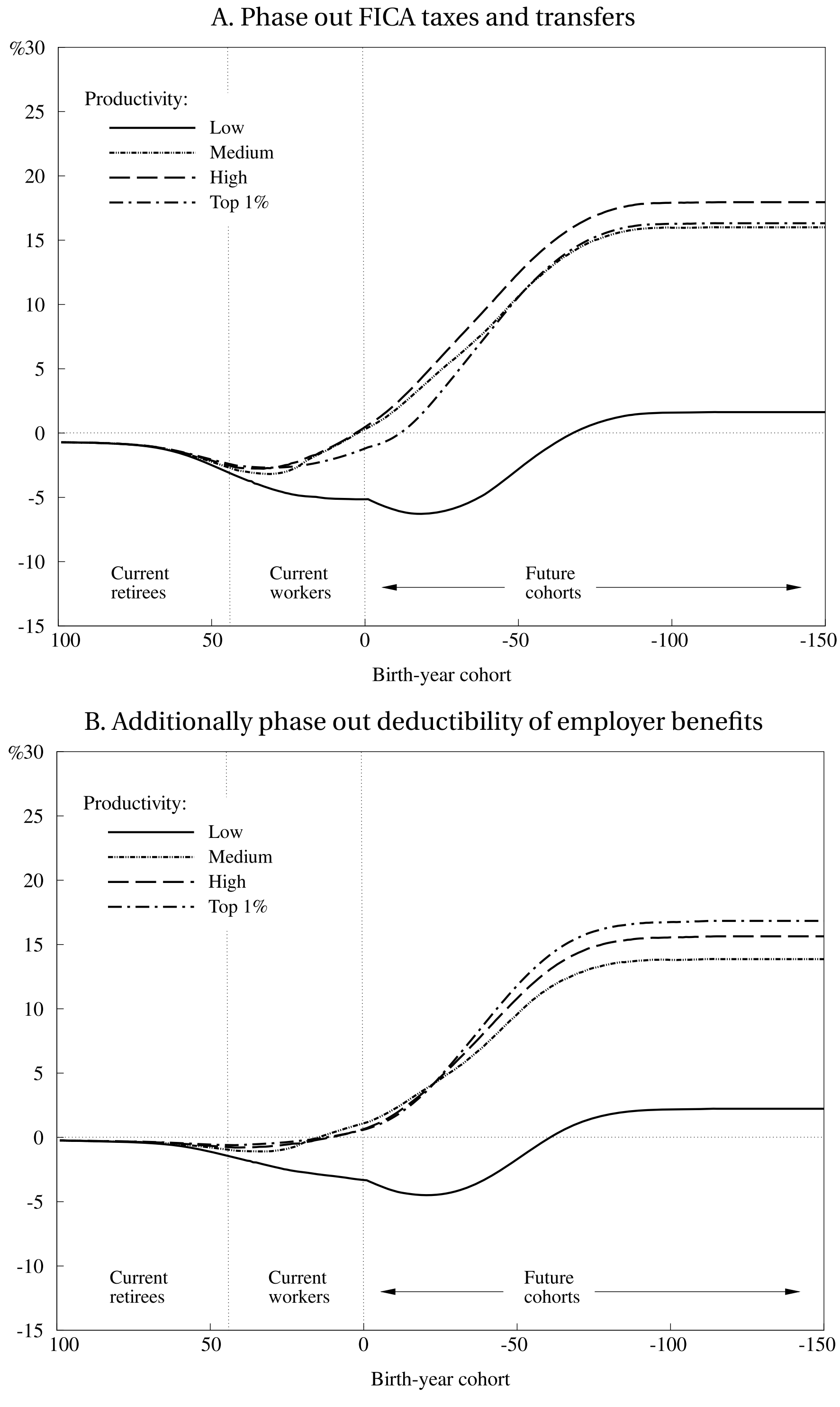

FIGURE 3. Percentage welfare gains by age cohort and productivity type: Step 1. Phase out FICA taxes and transfers.

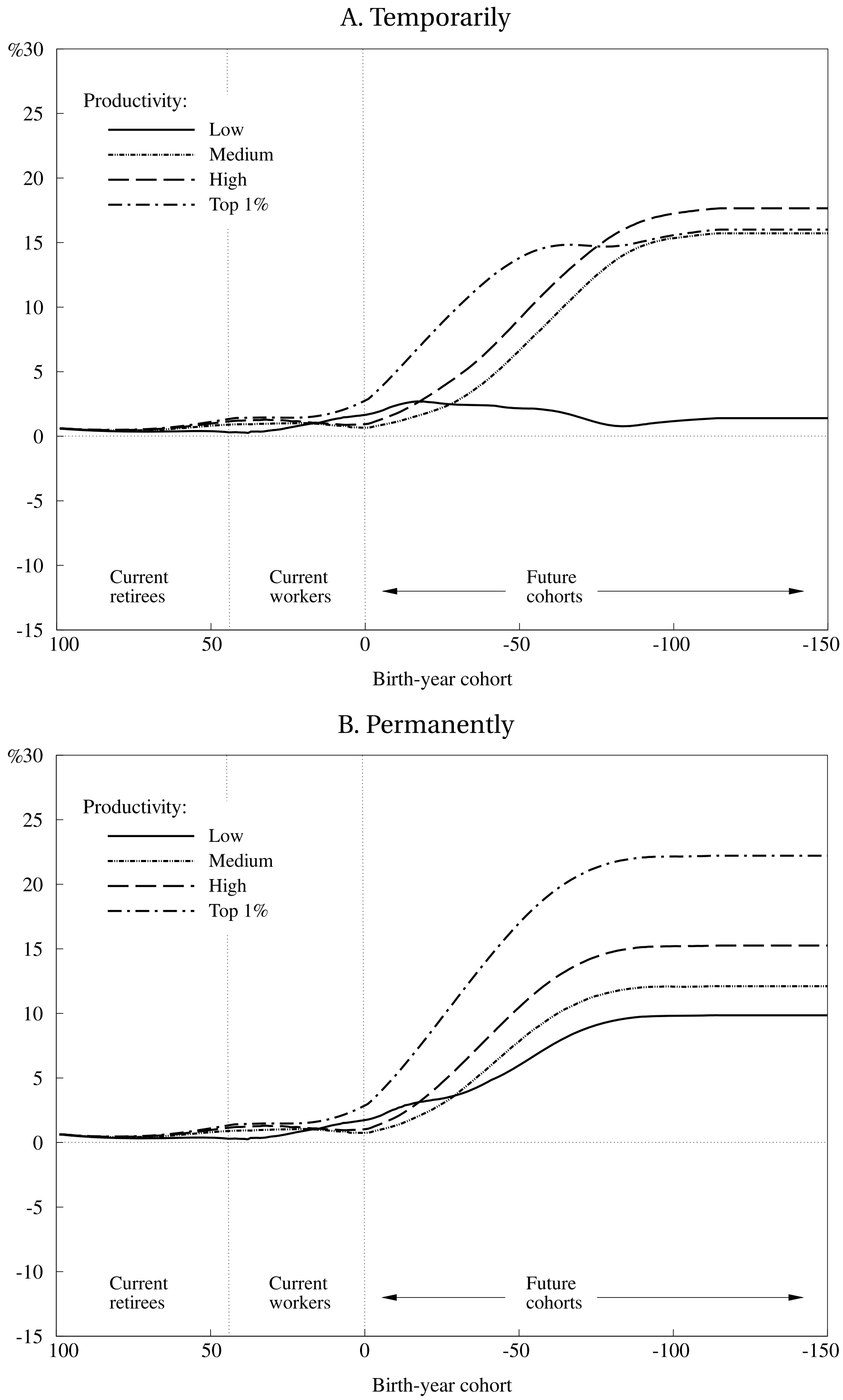

Figure 4. Percentage welfare gains by age cohort and productivity type: Step 2. Additionally reduce marginal tax rates.

If payroll taxes are lowered more quickly than Social Security and Medicare transfers, then current workers can immediately take advantage of lower taxes on their labor income. Specifically, we let $\xi_t = \tanh(1.5 - 0.1t)$, which is a smoothly declining function with range $[-1, 1]$, and we assume that the workers' net tax schedule at time t is given by $T_t^w(y) = 1/2(T_0^w(y) + T_\infty^w(y)) + 1/2(T_0^w(y) - T_\infty^w(y))\xi_t$, which falls at a rate that is a little more than twice as fast as the phaseout of the transfers.

The welfare results for this case are shown in panel A of Figure 3. The welfare measure that we use is remaining lifetime consumption equivalents of cohorts by age at the time of the policy change and lifetime consumption equivalents of future cohorts. Notice that under this reform, there are gains for most future cohorts because they take full advantage of the lower tax rates on labor income, but those currently alive and those unborn in the least productive group are worse off because consumption tax rates have to rise to make up the shortfall in revenue from lowering FICA taxes. In other words, the positive impact of lower payroll taxes is not sufficient to offset the negative impact of higher consumption taxes.

5.3 *Additionally phase out deductibility of employer benefits*

The next step in the construction of a welfare-improving transition path involves two additional changes that further improve the situation for all current retirees and current workers. In the first, we phase out the deductibility of employer contributions to insurance at the same rate that we lower the payroll taxes in the first experiment (of Figure 3A). In effect, we lower a component of α_i in (4.1), namely, the nonmarginal employer benefits shown in Figure 1B. The eventual net tax schedule for workers is reported in Table 6 under the column heading "Suspend Deductibility."

The welfare results in this case are shown in panel B of Figure 3. If we compare these results with those in Figure 3A, we see a significant improvement in welfare for current workers and retirees, in the range of 1–3 percentage points. The broadening of the labor income tax base provides a source of revenue for financing the transition in addition to consumption taxes. Future gains are lower for the medium and high productivity types, primarily because they are the main recipients of fringe benefits. However, the least productive workers, both current and in the near future, are still worse off under the new saving-for-retirement system than under a continuation of the current tax and transfer system.

5.4 *Additionally reduce marginal tax rates*

If we additionally change the net tax schedule for workers by lowering marginal rates on labor income, then we can accomplish our goal of constructing a Pareto-improving policy reform.

In this case, we modify the net tax schedule by lowering the marginal rates shown in Figure 1A. We compute welfare gains assuming that the changes in the net tax schedule for workers are temporary, and then again assuming that they are permanent. In the case in which the changes are permanent, we vary the net tax schedule over time as before, using ξ_t to govern the rate of change. In the case in which the changes are temporary, we assume a reversal in policy and set the final net tax schedule to be the same as the "No FICA" case in Table 6. For this case, the deductibility of employer benefits is reintroduced and the (non-FICA) marginal tax rates are restored to their earlier levels (found by subtracting the FICA taxes in the tenth column of Table 5 from the total tax rates in the fifth column of Table 5). The reversion occurs at the midpoint of the transition.

In the case in which the change is permanent, the eventual net tax schedule is that shown in the last two columns of Table 6 under the heading "Lower Marginal Rates." Our choice of marginal rates (last column of Table 6) does not uniquely generate a Pareto-improving transition, but it is consistent with a flat profile (that is, one with a constant α_i across earnings brackets) for the nonmarginal components of the workers' net tax schedule (4.1)—one that is easy to describe and interpret.[45] The new profile is flat relative to the current policy because the residual category $T_i'(\bar{y})\bar{y} - T_i(\bar{y})$ must be reduced when we lower the marginal rates $T_i'(\bar{y})$ (and hold fixed the average rates $T_i(\bar{y})/\bar{y}$). For our new marginal rates, we find the nonmarginal components are roughly constant across AGI brackets, at $13,344 per person in 2004 dollars—an amount that when aggregated is equal to the current transfers (other than Social Security and Medicare) and nondefense spending covered in the NIPA accounts. In other words, we retain funding for general public service, public order and safety, transportation and other economic affairs, housing and community services, health, recreation and culture, education, income security, unemployment insurance, veterans' benefits, workers' compensation, public assistance, employment and training, and all other transfers to persons unrelated to Social Security or Medicare.

Figure 4 shows the main results if the changes in the net tax schedule are temporary (panel A) or permanent (panel B). Notice that the welfare gains of future cohorts in Figure 4A are the same as the welfare gains of the first experiment in Figure 3A—in both, *the predicted welfare gains from eliminating payroll taxes and old-age transfers are over* 16 *percent of lifetime consumption for most families* (that is, all families except the least productive). Notice also that regardless of whether there is a temporary or permanent change in the workers' net tax schedule, we find that *all productivity types and birth cohorts are made better off if we switch from the current system to a saving-for-retirement system that does not rely on high payroll taxes*. The most significant difference between these results and the previous results shown in Figure 3 is the impact on welfare of the least productive workers, both current and future.

To see why the policy changes underlying these experiments are desirable for all groups, it helps to compare the sources of tax revenues along the transition paths. If we suspend deductibility but do not lower marginal tax rates further—and, therefore, use the tax schedule in the sixth and seventh columns of Table 6—we find that the labor input falls in the early part of the transition and additional revenues from consumption taxes are needed to make up for the decline in labor tax revenues. If we lower marginal tax rates further—and use the tax schedule in last two columns of Table 6—we find that

[45] The choice of a piecewise linear specification for $T^w(y)$ not only does well in fitting U.S. data at all income levels (unlike the HSV two-parameter specification), but also facilitates a larger set of possible tax reforms.

the total labor input rises rather than falls and the implied net tax revenues $T^w(y)$ are higher than they would be if the U.S. policy was continued. Here, as in Werning (2007), Pareto improvements require "a Laffer-like effect," with lower tax rates that do not lower tax revenue. With higher net tax revenues from labor, we find that consumption tax revenues *fall*. The fall in consumption taxes helps the least productive workers and the retirees who gain little or nothing from the lower payroll tax rates.[46]

We experimented with variations on the workers' net tax schedule that are not too far from those listed in the last columns of Table 6 and found that Pareto improvements are possible for other parameterizations. However, if we flatten the tax schedule too much (by lowering the β_i terms), while maintaining current levels of nondefense spending and other NIPA transfers (that is, by holding α_i fixed), we find that we cannot guarantee a Pareto-improving transition. For example, we reran the experiment with the β_i terms equal to U.S. average rates and the α_i terms at −13,344 and found that many cohorts and productivity types preferred the current policy to the saving-for-retirement alternative. In this case, there was insufficient revenue from the taxation of labor income, and consumption tax rates had to rise to make up the difference.

Although there is a Pareto improvement regardless of whether the marginal tax rates on labor income are lowered temporarily or permanently, the welfare gains for different groups do depend on the duration of the policy. Interestingly, it is the least productive families—those with the lowest earnings—who gain most from a permanent decline in the rates. As we noted above, what matters most for this group is the tax rate on consumption. The tax rate on consumption on the new balanced growth path is higher if marginal rates are lowered temporarily than if they are lowered permanently.[47]

In column 2 of Table 7, we report additional statistics for the policy reform with a permanent change in marginal tax rates. As described earlier, the first eight rows show the impact on key aggregate variables after the transition has occurred. The bottom eight rows show the range of welfare gains across all birth-year cohorts and productivity types. In this case, the welfare estimates can be read directly from Figure 4 and will be a useful baseline when comparing to alternative economies. If we compare the aggregate predictions for the reform with predictions for continuing U.S. policy (column 1), we see dramatic differences, with the exception of the level of the interest rate. First, factor inputs, consumption, GNP, and household net worth all rise, whereas they fell in the case of a continuation of current U.S. policy. The increases in the tangible and intangible capital stocks are notably large, 27 and 22 percent relative to trend, respectively. The labor input rises by a more modest 5 percent, but labor income rises by much more, since the wage rate is 9.4 percent above trend by the end. This large rise in the wage rate depends importantly on the larger capital stocks implied by our baseline parameterization. By the end of the transition, consumption is 19.5 percent above trend, GNP is 16.1 percent above trend, and household net worth is 24.9 percent above trend.

[46] For more details on the transition paths of government revenues, see McGrattan and Prescott (2016).

[47] The tax rate in the case of a permanent change falls below zero by the end of the simulation. Putting a lower bound on the rate would imply results intermediate to those shown. See McGrattan and Prescott (2016) for details.

In sum, we show how to construct a welfare-improving path when switching from the current U.S. tax and transfer system to a saving-for-retirement system. In all cases, the welfare gains to most future generations of doing so are large. Next, we analyze variations on the baseline model to determine the robustness of our results.

5.5 *Sensitivity of the results*

How sensitive are these results to our choices of future policy and our model parameters? To answer this question, we rerun the policy reforms for the case shown in Figure 4B and Table 7, column 2, using alternative parameterizations of the baseline model and alternative policy scenarios. Here, we briefly describe the results of these robustness tests. More details and additional robustness checks are provided in McGrattan and Prescott (2016).

Two variants on the policy reform are considered. In the first, we phase out Social Security but not Medicare. Social Security is about 60 percent of the total payout in 2004 if we combine the two (see Table 4). The results of this experiment are shown in Table 7, column 3. Not surprisingly, the policy impact on factor inputs, GNP, household net worth, and welfare gains of future cohorts are all lower than what we found in the baseline reform (Table 7, column 2). For example, GNP rises 11 percent relative to trend, and the highest gains are in the range of 10–16 percent. The second variation on policy that we examine assumes a larger debt-to-GNP ratio, which we set equal to 1—roughly twice that of the baseline—at the start of and throughout the transition. Statistics for this case are reported in Table 7, column 4. A higher debt level implies lower eventual increases in the capital stocks and household net worth, but does help raise welfare for all productivity types during the transition. The lowest recorded gain in this case is 0.59 percent, more than double that of the baseline simulation.

The last four columns of Table 7 provide summary statistics as we vary the baseline model's parameters. We first investigated variations on our parameter choices governing the life cycle, namely, the assumptions that life expectancy is the same for all productivity types and that productivity profiles are flat. If we assume that the more productive live longer than the less productive, our predictions for increases in productive activity are slightly lower than the baseline, and our predictions for welfare gains are slightly higher for all but a few cohorts.[48] If we use age-dependent productivities based on CPS wage profiles, we find that the results are surprisingly close.[49]

We investigated our choice of including perfect annuity markets by shutting them down. The results for this economy are shown in Table 7, column 7. In this case, the interest rate is 4.5 percent, which is closer to the rate computed for the current United States. The changes in capital stocks are still large but not as large as the baseline case

[48] Using data from Brown (2002), we set the probability of surviving from 67 to 77 for our two most productive groups of families to match data for the college educated, the lowest to match data for those with less than a high school education, and the middle to match high school and some college.

[49] Since we work with families, we computed weighted averages of wages and ages for each family and then assigned families to different groups on the basis of their total AGI. As a second check, we redid the calculations using individual wage profiles which are steeper over early ages, and found no appreciable difference.

in column 2. For this reason, the wage rate, GNP, and net worth are not as high as in the baseline. But the predicted gains in welfare for future generations are higher because the policy change has a larger impact on consumption when annuity markets are unavailable. The range of gains for future cohorts is 13.3–25.7 percent, whereas in the baseline the range was 9.9–22 percent.

We allowed for a more flexible utility function, namely,

$$u(c, \ell) = \log c + \alpha(1 - \ell)^{1-\zeta}/(1 - \zeta),$$

which nests the baseline model with log preferences if $\zeta = 1$. We chose log preferences as our baseline parameterization so that the model will be consistent with aggregate observations—both the levels and the cyclical behavior if there were shocks to the model economy. (See McGrattan and Prescott (2010b) for a version of our model suited to the study of business cycles.) In business cycle research, predictions of aggregate fluctuations of the labor input are highly sensitive to the choice of ζ; higher values imply lower Frisch elasticities of labor and cyclical fluctuations that are too smooth relative to U.S. data. In our baseline case, the Frisch elasticity is 2.6. We also computed results using a much smaller Frisch elasticity of 0.5 ($\zeta = 5$), with α set equal to 0.2 so as to generate the same aggregate labor input as in the baseline.[50] This is a typical choice made in the labor literature that does not attempt to reconcile theoretical predictions of cyclical behavior with U.S. aggregate fluctuations.

The results of the case with the low Frisch elasticity are reported in Table 7, column 8. As in the business cycle literature, we see that the capital stocks, GNP, and net worth change by much less than in the baseline case and the labor input is below trend by 5.8 percent after the transition. However, given the large stock of capital in our model economy, the rise in the wage rate is still large, about 8.5 percent relative to trend, and the range of welfare gains is not significantly affected. Although there are losses during the transition for some cohorts alive when the policy is implemented, the losses are all less than 1 percent. Furthermore, the predicted gains for the future cohorts are not much different from the baseline—the gains are slightly higher for the least productive and slightly lower for the most productive. We varied ζ between the baseline value of 1 and the extreme value of 5 to determine the point at which there would be losses in welfare for some individuals. We found the threshold case—for the least productive—to be $\zeta = 2$ (and $\alpha = 0.765$), which implies a Frisch elasticity of 1.3, half of the baseline value. Even for this value, the business cycle predictions are grossly at odds with U.S. data.

We investigate two alternative but related models in the supplementary appendix (available in a supplementary file on the journal website, http://qeconomics.org/supp/648/supplement.pdf). (See McGrattan and Prescott (2016).) In the first alternative, we assume that there are more productivity types. We do so to introduce a group of families who have the same share of labor income as that of U.S. families in the lowest AGI bracket of our sample (that is, with either no AGI or AGI less than $5000 in 2004 dollars). The average per capita compensation for this group is only $1200, much lower than what

[50] With a Frisch elasticity of 0.5, McGrattan and Prescott (2010b) would find that the predicted standard deviation of total hours is roughly one-fifth of the actual standard deviation of U.S. data.

they receive in government transfers. If we use the same net tax schedule and retiree transfers as we did in the baseline case, we again find a Pareto-improving transition for all existing and future cohorts. All families prefer to switch policies, even those with very low per capita earnings.

Finally, we investigate a more typical model with one type of capital and one business sector. The model is a nested case of the model used here, but we do not choose parameters to match BEA aggregates in Tables 1 and 2. Instead, we set the tangible capital share equal to 1/3, the depreciation rate equal to 6 percent, and the discount factor so that the tangible capital stock is three times GNP. As in most of the macroeconomic literature, we abstract from intangible capital and taxes on distributions. When we rerun the baseline policy experiment, we find a much lower interest rate of 3.2 percent after the transition and much smaller increases in all aggregate variables. For example, the tangible capital stock rises by only 13 percent and GNP rises by only 7 percent, much less than in our baseline model. In terms of welfare during the transition, we find that some cohorts lose if they switch to the new policy, but the losses are somewhat surprisingly small and only occur for some birth-year cohorts born after the policy is implemented. The main differences in the welfare calculations are the estimates of welfare gains for future cohorts: all but the top 1 percent in terms of productivity have gains in the range of 6–9 percent, well below the baseline estimates in Table 7, column 2.

In summary, we find that our main results are robust to a wide variety of variations of the baseline model. In the decision of whether to abandon tax and transfer schemes currently used in the United States in favor of a private saving-for-retirement scheme, several factors turn out to be quantitatively important. First, accounting for differences between actual government tax revenues and what revenues would be if all income were taxed at the marginal rates we use turns out to be important for devising a welfare-improving transition. Second, including all capital available to retirees for financing their retirement consumption turns out to be important for policy to have a quantitatively large impact on factor inputs, wages, consumption, GNP, household net worth, and welfare gains.

6. Conclusions

A challenging economic policy issue facing the United States and many other nations is the financing of retirement as the population ages and the number of workers per retiree falls. We find that the fall in the number of workers per retiree can be handled without a major change in the current retirement financing scheme. Some tax policy changes, however, dramatically increase welfare. These changes entail lowering or eliminating income taxes and relying more on saving for retirement and less on lump-sum transfers to retirees. The broadening of the (nonhuman) capital stock is important for our analysis, as is requiring the model to be consistent with both the aggregate data from the national accounts and the micro data from household surveys.

Through discussions and insights, we hope and expect that better abstractions for predicting the consequences of alternative tax and transfer policies will develop. We do not model human capital investments made over working lives, and this may also have a consequence for the stock of savings.[51] We restrict attention to the United States, but other countries are facing the same challenges, and the solutions they propose could possibly influence U.S. savings decisions. We analyze the impact of tax reform, varying assumptions about the extent of intergenerational transfers and bequests between family members, but better measurement of these transfers is needed and further study of their economic impact is warranted.

In this paper, we have focused attention on financing retirement, but the framework we develop can be used to address a wide variety of public finance questions. Especially relevant are policy questions requiring accurate predictions of micro data from household surveys and macro data from the national accounts.

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