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Implications of Increasing College Attainment for Aging in General Equilibrium*

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Abstract

We develop and calibrate an overlapping generations general equilibrium model with heterogeneous consumers who face idiosyncratic earnings and health risk to study the implications of exogenous trends of increasing college attainment, decreasing fertility, and increasing longevity. Keeping the major U.S. social insurance programs in place, we perform comparative statics with balanced growth paths. While all three exogenous trends contribute to a higher old age dependency ratio, increasing college attainment has different macroeconomic implications because it also leads to more productive workers. Increasing college attainment lowers the required increase in the labor tax rate due to decreasing fertility and increasing longevity by 8.3 percentage points. The required increase in the labor tax rate is 2.9 percentage points higher under general equilibrium than in a small open economy with constant prices because lower interest rates reduce capital income tax revenues.

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Keywords: college attainment, aging, health care, taxation, overlapping generations.

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1 Introduction

The ratio of the population 65 and older to the population that is 20–64 (that is, the *old age dependency ratio*) in the United States is projected to increase from about 25 percent in 2010 to more than 50 percent by 2100 according to estimates by the United Nations. The literature has used overlapping generations models with heterogeneous consumers to analyze the implications of the projected increase in the old age dependency ratio due to decreasing fertility rates and increasing longevity. Attanasio et al. (2010), for example, have argued that the U.S. government will have to increase the labor tax rate by about 13 percentage points by 2080 to finance the increase in Medicare, Medicaid, and Social Security spending. Our paper extends this literature by introducing increasing college attainment into the model. We argue that increasing college attainment — which accounts for some of the increase in the old age dependency ratio because college-educated individuals have higher life expectancy — has different macroeconomic implications than decreasing fertility and increasing longevity because higher college attainment also leads to a more productive labor force.

Following Conesa et al. (2018), we develop an overlapping generations general equilibrium model with heterogeneous consumers who face idiosyncratic earnings and health risk. Consumers are *ex ante* heterogeneous in education; some are college-educated, some are not. Consistent with the data, college-educated consumers in the model have both higher life expectancy and higher labor productivity. Consumers in our model can save in non-state-contingent bonds and partially insure against health risk through employer-provided insurance or by purchasing private insurance. Furthermore, the model economy incorporates the key social insurance programs in the United States through Medicare, Medicaid, Social Security, and a welfare program that combines institutional features of food stamps, disability insurance, and medical relief for the poor (for brevity, referred to as *Emergency Relief*). The government finances its spending on consumption, interest payments on debt, Medicare, Medicaid, Emergency Relief, and Social Security by levying consumption taxes, capital income taxes, and labor taxes. We assume that the consumption and capital income tax rates stay fixed, and that the government balances its budget period-by-period by means of the labor tax.

After calibrating the model to match key features of the U.S. economy in 2005, we use the model to study the macroeconomic implications of three channels that contribute to an increase in the old age dependency ratio: increasing college attainment, decreasing fertility, and increasing longevity (for brevity, we refer to the three channels that lead to an increase in the old age dependency ratio as the three channels of *aging*). In particular, we change the percentage of 20-year-olds with a college degree, the growth rate of 20-year-olds, and the age-specific survival probabilities to match projections for 2100. Increasing college attainment increases the old age dependency ratio because college graduates have higher life expectancy than non-college graduates. Decreasing fertility increases the old age dependency ratio because it leads to relatively fewer young consumers. Lastly, increasing longevity increases the old age dependency ratio because it leads to relatively more old consumers. We then use the model with balanced growth paths to perform comparative statics.

We start by studying the individual fiscal implications of the three channels of aging. Our results show that decreasing fertility and increasing longevity require the government to increase the labor tax rate, whereas increasing college attainment allows the government to reduce the labor tax rate. There are a number of reasons for this result. First, and most importantly, an increase in college attainment leads to an economy with more productive workers and therefore higher labor earnings, which in turn leads to higher labor tax revenues. Second, college graduates are less likely to enroll in Medicaid and Emergency Relief. Higher college attainment thus reduces government spending on these programs. Third, higher college attainment leads to higher consumption tax revenues and higher capital income tax revenues. This follows because college graduates both consume and save more than non-college graduates. College graduates save more since they have higher labor earnings, higher life expectancy, and a stronger precautionary savings motive because they are less likely to enroll in Medicaid and Emergency Relief. Lastly, there are general equilibrium effects. Higher college attainment leads to higher capital accumulation, which in turn leads to lower interest rates and higher wages. Lower interest rates reduce interest payments on government debt, thereby lowering government spending. Higher wages lead to a further increase in labor tax revenues, not only because of the direct effect of higher wages on earnings, but also because higher wages induce consumers to work more.

The forces that we have mentioned so far contribute to lower labor taxes, but there are forces that move in the opposite direction. In particular, an increase in college attainment leads to higher spending on Medicare and Social Security. This is because college-educated consumers have higher life expectancy than non-college-educated consumers and because college-educated consumers claim higher Social Security benefits due to higher lifetime labor earnings. In addition, the reduction in the interest rate brought about by higher college attainment dampens the increase in capital income tax revenues.

We then study the joint fiscal implications of the three channels of aging. In particular, we study the fiscal implications of introducing increasing college attainment into the model with decreasing fertility and increasing longevity. We find that adding higher college attainment to the model with decreasing fertility and increasing longevity lowers the required increase in the labor tax rate from 10.7 to 2.5 percentage points. Consequently, higher college attainment mitigates 77 percent of the required increase in the labor tax rate caused by decreasing fertility and increasing longevity.

Next, to identify the general equilibrium effects in our results, we compare the results from the benchmark closed economy with the results from those of a small open economy in which the real interest rate is constant and exogenous. By construction, the wage rate in the detrended balanced growth economy is also constant in the small open economy. We find that the capital stock increases in both the general equilibrium model and the small open economy model. In the general equilibrium model, however, the increase in the capital stock also leads to higher wages and lower interest rates. On the one hand, higher wages under general equilibrium lead to higher earnings, not only because of the direct effect of higher wages, but also because higher wages induce consumers to work more. Higher earnings, in turn, lead to increased revenues from labor, consumption, and capital income taxation, the last two of which follow from the fact that higher earnings induce consumers to both consume and save more. On the other hand, lower interest rates under general equilibrium reduce government revenues from capital income taxation. Consequently, introducing higher college attainment in the model with decreasing fertility and increasing longevity leads to a larger increase in capital income tax revenues per capita in the small open economy model than under general equilibrium. Our results show that this additional increase in government revenues from capital income taxation results in a larger reduction in the labor tax rate in the small open economy model than in the general equilibrium model. In particular, adding higher college attainment in the model with decreasing fertility and increasing longevity lowers the required increase in the labor tax rate by 8.3 percentage points in the general equilibrium model, but by 11.1 percentage points in the small open economy model.

Finally, we study the implications for welfare. We measure the welfare effects of aging by means of *consumption equivalent variation*. In particular, we measure welfare as the percentage change in consumption in all periods and all states of the world in the economy without the three channels of aging that would make a consumer indifferent between entering that economy and entering the economy with aging. We focus on a 20-year-old who has zero assets, and for whom the education type (college or non-college) has been revealed, but not the stochastic components of productivity and health. Note that all consumers entering a balanced growth economy in the future are better off because of economic growth. We therefore focus on the welfare implications in the *detrended* models. Our results show that both 20-year-old consumers with a college degree and 20-year-old consumers without a college degree entering an economy with higher college attainment experience higher welfare. In contrast, both 20-year-old consumers with a college degree and 20-year-old consumers without a college degree entering an economy with decreased fertility or increased longevity experience lower welfare. These results follow from the fact that higher college attainment allows the government to reduce the labor tax rate, whereas the other two channels require the government to increase the labor tax rate.

Our paper is related to the literature that develops general equilibrium overlapping generations models to study the implications of decreasing fertility and increasing longevity. These demographic trends will lead to a large increase in government spending on Medicare, Medicaid, and Social Security over the next century. De Nardi et al. (1999), Kotlikoff et al. (2007), and Attanasio et al. (2010) study the macroeconomic and welfare implications of various fiscal policy reforms that have been proposed to finance government spending on social insurance programs in the future, such as increasing payroll taxes, increasing the eligibility age for benefits, or reducing the generosity of benefits. In a recent paper, Jung et al. (2017) develop a general equilibrium overlapping generations model with endogenous health to study the implications of aging for health care spending and health insurance coverage. They use the model to study how the implications of aging are affected by the introduction of the Patient Protection and Affordable Care Act (ACA). Unlike our paper, these papers do not focus on increasing college attainment. While increasing college attainment, decreasing fertility, and increasing longevity all contribute to an increase in the old age dependency ratio, we show that increasing college attainment has different macroeconomic implications than decreasing fertility and increasing longevity.

Our paper also contributes to the literature that develops overlapping generations models to study the implications of earnings, health, medical expenditure, and mortality risk. Auerbach and Kotlikoff (1987), Conesa and Krueger (1999), Kotlikoff et al. (1999), Altig et al. (2001), Nishiyama and Smetters (2007), and İmrohoroğlu and Kitao (2012) develop overlapping generations models to study the implications of Social Security and tax reforms. Hubbard et al. (1994), Palumbo (1999), De Nardi et al. (2010), Kopecky and Koreshkova (2014), and Nakajima and Telyukova (2018) develop models to examine how medical expenditure risk affects savings of the elderly. Pashchenko and Porapakkarm (2013) develop a model to examine the implications of the ACA, and Conesa et al. (2019) develop a model to study the macroeconomic and welfare effects of Medicare. Finally, Ozkan (2014), Jung and Tran (2016), Scholz and Seshadri (2016), and Cole et al. (2019) develop models in which health evolves endogenously over the life-cycle to study the macroeconomic effects of health insurance reforms. Our paper extends this literature by developing a general equilibrium overlapping generations model to study the long-run implications of increasing college attainment, decreasing fertility, and increasing longevity.

2 Model

The following subsections present the benchmark model used in the analysis. The model is a discrete time, general equilibrium, overlapping generations model with heterogeneous consumers that follows closely that in Conesa et al. (2018).

2.1 Firms

Firms hire labor at wage w_t and rent capital at rate r_t from consumers to produce goods. We assume that the technology can be represented by a constant returns to scale Cobb-Douglas production function:

$$\hat{Y}_t = \hat{K}_t^{\alpha} \left(Z_t N_t\right)^{1-\alpha}, \tag{1}$$

where $\hat{K}_t$ is the aggregate capital stock, Z_t denotes labor-augmenting technological progress, N_t denotes effective labor supply, and α is capital's share of income. Technological progress is given by $Z_t = \theta \left(1 + g_z\right)^t$, where g_z denotes the growth rate of technology. Similarly, g_n denotes the growth rate of 20-year-old consumers, which is the age at which consumers enter the economy.

Output is used for total private consumption, $\hat{C}_t$, government consumption, $\hat{G}_{c,t}$, investment, $\hat{K}_{t+1} - (1-\delta)\hat{K}_t$, and purchase of health care services, $\hat{M}_t$, where δ denotes the rate of capital depreciation. Let $x_t \equiv \frac{\hat{x}_t}{(1+g_z)^t}$ denote productivity-detrended variables. The detrended resource constraint can then be written as follows:

$$C_t + G_{c,t} + M_t + \left(1+g_z\right)\left(1+g_n\right) K_{t+1} = K_t^{\alpha} \left(\theta N_t\right)^{1-\alpha} + (1-\delta) K_t. \tag{2}$$

For the remainder of the paper, we drop time subscripts and use $'$ to denote next-period variables.

2.2 Consumers

The economy is populated by a continuum of *ex ante* and *ex post* heterogeneous consumers. Consumers are indexed by type $s = (j, e, h, \eta, a, i)$, where j is age, e is educational level, h is health status, η is the stochastic component of labor productivity, a is assets, and i is the consumer's health insurance status. We let $\Phi(s)$ denote the measure of consumers of type s.

The consumer's educational level is permanent over her lifetime and can take two values: college or non-college. Health status is stochastic and is a function of the consumer's current age, education, and health. It follows a finite-state Markov process with stationary transitions over time:

$$Q_{j,e}\left(h, H\right) = Prob\left(h' \in H \,:\, (h,\, j,\, e)\right), \tag{3}$$

where $Q_{j,e}\left(h, H\right)$ denotes the probability of next period's health conditional on current health, age, and education. The stochastic component of labor productivity is given by a stationary finite-state Markov process:

$$Q\left(\eta, E\right) = Prob\left(\eta' \in E \,:\, \eta\right), \tag{4}$$

where $Q(\eta, E)$ denotes the probability of next period's stochastic labor productivity conditional on current stochastic labor productivity. Lastly, the consumer's health insurance status, i, specifies whether she is uninsured, i_S, has private health insurance, i_P, or has employer-provided health insurance, i_E.

Consumers are endowed with one unit of time in every period that can be allocated between work and leisure. The period-by-period utility function is given by

$$U(c, \ell) = \frac{\left[c^{\gamma}(1-\ell)^{1-\gamma}\right]^{1-\sigma}}{1-\sigma}, \tag{5}$$

where c denotes consumption and ℓ denotes labor supply. We assume that labor supply is indivisible. In particular, ℓ can take on four values: $\ell \in \{0, \ell_p, \ell_f, \ell_e\}$, where ℓ_p, ℓ_f, and ℓ_e refer to part-time, full-time, and extra time, respectively. The consumer's labor earnings depend on her labor supply, ℓ, stochastic labor productivity, η, health status, ξ_h, and deterministic life cycle labor productivity, ϵ_{je}, the last of which varies with the consumer's age and educational level. Starting at age j_r, all consumers receive health insurance from the government in the form of Medicare. They also receive Social Security benefits, SS_{je}, that depend on their cohort and education. Lastly, consumers face a conditional survival probability, ψ_{jeh}, that depends on their age, education, and health. The maximum life span of consumers is J. In the event of death, the consumers's assets are uniformly distributed across the population by means of lump-sum transfers, B.

2.3 Health insurance and welfare programs

This section presents the different types of health insurance in the economy. As noted earlier, health insurance is available in the form of private health insurance and employer-provided health insurance. In addition, the government provides health insurance through Medicare and Medicaid. Health insurance is used to cover non-discretionary health care expenses, m_{jh}, which vary with the consumer's age and health status. Throughout, we let χ_P, χ_E, χ_{CARE}, and χ_{CAID} denote the coinsurance rate for private health insurance, employer-provided health insurance, Medicare, and Medicaid, respectively. To illustrate, a value of 0.229 for χ_P means that the consumer covers 22.9 percent of the health care expenses, and that private health insurance covers the remaining 77.1 percent of the health care expenses.

Medicaid Medicaid is a means-tested program that provides health insurance to income/asset poor consumers. Consistent with the U.S. eligibility criteria, we model two ways to qualify for Medicaid. First, consumers qualify under the *categorical* criterion if the sum of their gross income and interest earnings is below a threshold, y^{CAT}. Second, consumers qualify under the *medically needy* criterion if the sum of their gross income and interest earnings net of out-of-pocket medical expenses is below a threshold, y^{MN}, and their assets are less than a threshold, a^{MN}. Consumers that qualify for Medicaid in the model choose whether or not to enroll in the program, i_{CAID}. Eligible consumers that choose to enroll suffer a disutility cost, λ. This disutility cost enables us to account for the observation that a large percentage of individuals that qualify for Medicaid in the United States do not enroll in the program.

Medicare The government also provides health insurance in the form of Medicare. Unlike Medicaid, Medicare is not a means-tested program, but covers a share $1 - \chi_{CARE}$ of health care expenses of all consumers aged j_r and older. Since Medicare has a positive coinsurance rate, $\chi_{CARE} > 0$, old consumers can purchase private health insurance to further lower their out-of-pocket medical expenditure risk.

Emergency relief The government runs a welfare program that combines institutional features of food stamps, disability insurance, and medical relief for the poor (for brevity, referred to as *Emergency Relief*). To qualify for this program in the model, consumers have to forfeit all assets and work zero hours. In return, the government covers all health care costs and guarantees a minimum consumption level, $\underline{c}$. We assume that consumers that choose to go on Emergency Relief suffer the same disutility cost as those that enroll in Medicaid, λ.

Private health insurance Consumers can purchase private health insurance for the following period. We assume that the premium for private health insurance is actuarially fair for each insurance pool, where the insurance pool is given by consumers with the same age, education, and health (j, e, h). This gives the following expression for the detrended private health insurance premium:

$$\pi_{jeh} = \begin{cases} \frac{\psi_{jeh}(1-\chi_P)(1+g_z)\int m_{j'h'} Q_{j,e}\left(h, dh'\right)}{1+r} & \text{if } j < j_r - 1 \\ \\ \frac{\psi_{jeh}(1-\chi_P)\chi_{CARE}(1+g_z)\int m_{j'h'} Q_{j,e}\left(h, dh'\right)}{1+r} & \text{if } j \geq j_r - 1, \end{cases} \tag{6}$$

where π_{jeh} is the expected medical expense for the insurance company, discounted by the real interest rate.

Employer-provided health insurance We assume that a fraction of consumers that are younger than age j_r work for an employer that provides health insurance. In that case, $i = i_E$. The employer pools the health care expenses of all their employees that do not choose to go on Emergency Relief. These costs are then split evenly across the employees. That is, we model employer-provided health insurance as a pay-as-you-go system where current contributors pay for the health care expenses of current receivers. This gives the following expression for the detrended employer-provided health insurance premium:

$$\pi_E = \frac{(1-\chi_E)\int \mathbf{1}_{F=0} m_{jh} \Phi\left(\{1,\ldots,j_r-1\}\times de \times dh \times d\eta \times da \times \{i_E\}\right)}{\int \mathbf{1}_{\ell>0} \Phi\left(\{1,\ldots,j_r-1\}\times de \times dh \times d\eta \times da \times \{i_E\}\right)}, \tag{7}$$

where the indicator function $\mathbf{1}_{F=0}$ in the numerator equals one for all consumers that do not choose to go on Emergency Relief. We assume that consumers are not allowed to have both employer-provided and private health insurance. Moreover, to alleviate the adverse selection problem associated with group insurance plans, we assume that consumers that work for an employer that provides health insurance are not allowed to opt out of employer-provided insurance. Lastly, motivated by the low take-up rate of employer-provided health insurance among individuals that are older than 65 in the United States, we assume that consumers aged j_r and older do not receive employer-provided insurance in the model.

2.4 Government

The government engages in five activities in the model. First, as already noted, it provides public health insurance in the form of Medicare and Medicaid. Second, it runs a welfare program that covers all health care costs and guarantees a minimum consumption level. Third, it consumes goods. We assume that government consumption per capita, $\hat{g}_c$, grows at the rate of technological progress. Hence, total government consumption is given by $\hat{G}_c = \hat{g}_c \int \Phi(ds)$. We include government consumption in the model to equalize the size of the government sector in the model and the data, thereby ensuring that the tax burden in the model is consistent with the data. Fourth, it supplies one-period risk-free debt, $\hat{D}$, which by no arbitrage carries the same return as physical capital in equilibrium. We assume that government debt grows at the rate of technological progress. Lastly, it runs a Social Security program. In the United States, Social Security payments are tied to an individual's earnings history. To reduce computational costs, we abstract from this in the model and assume that benefits only depend on the consumer's education and cohort. In particular, we assume that a cohort's Social Security benefits depend on the wage rates that existed in the economy during the last 35 years before that cohort reached retirement age. Let b_e denote the education-specific Social Security replacement rate. Detrended Social Security benefits are given by

$$SS_{ej} = \frac{b_e}{35} \sum_{k=j_r-35}^{j_r-1} \frac{w_{k-j}}{(1+g_z)^{j-k}}. \tag{8}$$

This functional form implies that younger cohorts will receive higher Social Security benefits than older cohorts because of productivity-induced wage growth.

The government finances its expenditures on consumption, interest payments on public debt, Medicare, Medicaid, Emergency Relief, and Social Security by means of three taxes: a consumption tax, τ_c, a capital income tax on the net return on wealth, τ_k, and a proportional labor tax, τ_ℓ. Let G_M denote total productivity-detrended government spending on Medicare, Medicaid, and Emergency Relief. We assume that consumers on Emergency Relief do not pay taxes on their consumption. Moreover, we assume that the consumption and capital income tax rates stay fixed, and that the government balances its budget period-by-period by means of the labor tax. The labor tax rate then has to satisfy

$$\begin{aligned} \tau_\ell w N + \tau_c \int \mathbf{1}_{F=0} c\left(s\right) \Phi\left(ds\right) + \tau_k r \int \left(a\left(s\right) + B\right) \Phi\left(ds\right) + \left(1+g_z\right)\left(1+g_n\right) D' \\ = G_M + g_c \int \Phi\left(ds\right) + \left(1+r\right) D + SS_{ej} \int \Phi\left(ds | j \geq j_r\right), \end{aligned} \tag{9}$$

where the indicator function $\mathbf{1}_{F=0}$ equals one for all consumers that do not choose to go on Emergency Relief, and where by $\Phi\left(ds|j \geq j_r\right) = \Phi\left(\{j_r, \ldots, J\} \times de \times dh \times d\eta \times da \times di\right)$ it is understood that the integral is over all types s but restricted to agents of age $j \geq j_r$.

2.5 Consumer problem

The consumer's choice set depends on her current age and health insurance status. Throughout, we use the word *young* to denote consumers less than age j_r and *old* to denote consumers that are at least j_r years old. We start by presenting the problem of young consumers without employer-provided health insurance. This subsection also defines the value of going on Emergency Relief. Next, we set up the problem faced by young consumers with employer-provided health insurance. Lastly, we discuss the problem of old consumers.

2.5.1 Young consumers without employer-provided health insurance

Recall that a consumer's type is given by $s = (j, e, h, \eta, a, i)$, where j is age, e is educational level, h is health status, η is the stochastic component of labor productivity, a is assets, and i is the consumer's health insurance status. Let $V^I(s)$ denote the value of young consumers without employer-provided health insurance. Similarly, let $V^F(s)$ denote the value of going on Emergency Relief. Young consumers without employer insurance then solve the following problem:

$$V\left(s\right) = \max \left\{V^I\left(s\right), V^F\left(s\right)\right\}, \tag{10}$$

where $V^I(s)$ is given by

$$
\begin{aligned}
V^I(s) \quad = \quad & \max_{c,a',\ell,i',i_{CAID}} \; U(c,\ell) - i_{CAID}\lambda + \beta\psi_{jeh}\mathbb{E}_{\eta'|\eta}\mathbb{E}_{h'|jeh}V(s') \\
& \text{s.t.} \quad (1+\tau_c)\,c + (1+g_z)\,a' + m_{op} + \mathbf{1}_{i'=i_P}\pi_{jeh} = w\,(1-\tau_\ell)\,\eta\xi_h\epsilon_{je}\ell + (1+r\,(1-\tau_k))\,(a+B) \\
& m_{op} = \begin{cases} \mathbf{1}_{i=i_P}\chi_P m_{jh} + (1-\mathbf{1}_{i=i_P})\,m_{jh} & \text{if } \mathbf{1}_{CAID}(s,\ell)=0 \\ \mathbf{1}_{i=i_P}\chi_P\chi_{CAID}m_{jh} + (1-\mathbf{1}_{i=i_P})\,\chi_{CAID}m_{jh} & \text{if } \mathbf{1}_{CAID}(s,\ell)=1 \end{cases} \\
& \ell \in \{0,\ell_p,\ell_f,\ell_e\} \\
& c, a' \geq 0 \\
& i' \in \{i_P, i_S\} \\
& i_{CAID} \in \{0,1\}\,.
\end{aligned}
\tag{11}
$$

Consumers without employer insurance choose how much to consume, c, how much to save, a', how many hours to work, ℓ, and whether to purchase individual health insurance for the following period, i'. In addition, consumers that qualify for Medicaid, $\mathbf{1}_{CAID}(s,\ell)=1$, choose whether or not to enroll in the program, i_{CAID}. As noted earlier, qualified consumers that choose to enroll, $i_{CAID}=1$, suffer a disutility cost, λ. In the event that a qualified consumer chooses to enroll in Medicaid, Medicaid will cover a share $1-\chi_{CAID}$ of the consumer's out-of-pocket medical expenses, m_{op}, which are given by m_{jh} for self-insured consumers and $\chi_P m_{jh}$ for consumers that purchased private health insurance in the preceding period.

Consumers that choose to go on Emergency Relief have to forfeit all assets and work zero hours. In return, the government covers all out-of-pocket health care expenses and provides the consumer with a minimum consumption level, $\underline{c}$. Recall that consumers that choose to go on Emergency Relief suffer the same disutility cost as those that enroll in Medicaid. The value of going on Emergency Relief is then given by

$$
\begin{aligned}
V^F(s) \quad = \quad & U(\underline{c},0) - \lambda + \beta\psi_{jeh}\mathbb{E}_{\eta'|\eta}\mathbb{E}_{h'|jeh}V(s') \\
\text{s.t.} \quad & a' = 0 \\
& i' = i_S.
\end{aligned}
\tag{12}
$$

2.5.2 Young consumers with employer-provided health insurance

Let $V^E(s)$ denote the value of being on employer-provided health insurance. Young consumers with employer insurance solve the same problem as young consumers without employer insurance, with the exception that the former group is not allowed to purchase private health insurance. Young consumers with employer insurance then solve the following problem:

$$V(s) = \max \left\{ V^E(s), V^F(s) \right\}, \tag{13}$$

where $V^E(s)$ is given by

$$\begin{aligned}
V^E(s) \quad &= \quad \max_{c,a',\ell,i_{CAID}} \; U(c,\ell) - i_{CAID}\lambda + \beta\psi_{jeh}\mathbb{E}_{\eta'|\eta}\mathbb{E}_{h'|jeh}V(s') \\
&\text{s.t.} \quad (1+\tau_c)\,c + (1+g_z)\,a' + m_{op} + \mathbf{1}_{\ell>0}\pi_E = w\,(1-\tau_\ell)\,\eta\xi_h\epsilon_{je}\ell + (1 + r\,(1-\tau_k))\,(a+B) \\
&\quad m_{op} = \begin{cases} \chi_E m_{jh} & \text{if } \mathbf{1}_{CAID}(s,\ell) = 0 \\ \chi_E\chi_{CAID} m_{jh} & \text{if } \mathbf{1}_{CAID}(s,\ell) = 1 \end{cases} \\
&\quad \ell \in \begin{cases} 0, \ell_p, \ell_f, \ell_e & \text{if sick} \\ \ell_p, \ell_f, \ell_e & \text{if healthy} \end{cases} \\
&\quad c, a' \geq 0 \\
&\quad i' = i_E \\
&\quad i_{CAID} \in \{0,1\}.
\end{aligned} \tag{14}$$

Out-of-pocket health care expenses are given by $\chi_E m_{jh}$ for consumers on employer insurance. All consumers on employer insurance that work must pay a premium π_E. We assume that healthy consumers on employer insurance have to supply a minimum of $\ell_p > 0$ hours. Sick consumers, on the other hand, are free to choose zero hours. In the model, consumers are considered sick if they have a catastrophic health state (see Subsection 3.1.7 for details). Finally, the value of going on Emergency Relief is the same as above, with the exception that consumers continue to be eligible for employer-provided insurance in the following period, $i' = i_E$.

2.5.3 Old consumers

Let $V^R(s)$ denote the value of an old consumer of type s. Old consumers solve the same problem as young consumers without employer-provided health insurance:

$$V(s) = \max \left\{ V^R(s), V^F(s) \right\}, \tag{15}$$

where $V^R(s)$ is given by

$$\begin{aligned}
V^R(s) \quad &= \max_{c,a',\ell,i',i_{CAID}} \quad U(c,\ell) - i_{CAID}\lambda + \beta\psi_{jeh}\mathbb{E}_{\eta'|\eta}\mathbb{E}_{h'|jeh}V(s') \\
&\text{s.t.} \quad (1+\tau_c)c + a' + m_{op} + \mathbf{1}_{i'=i_P}\pi_{jeh} = SS_{ej} + w(1-\tau_\ell)\eta\xi_h\epsilon_{je}\ell + (1+r(1-\tau_k))(a+B) \\
&\quad m_{op} = \begin{cases} \mathbf{1}_{i=i_P}\chi_P\chi_{CARE}m_{jh} + (1-\mathbf{1}_{i=i_P})\chi_{CARE}m_{jh} & \text{if } \mathbf{1}_{CAID}(s,\ell) = 0 \\ \mathbf{1}_{i=i_P}\chi_P\chi_{CARE}\chi_{CAID}m_{jh} + (1-\mathbf{1}_{i=i_P})\chi_{CARE}\chi_{CAID}m_{jh} & \text{if } \mathbf{1}_{CAID}(s,\ell) = 1 \end{cases} \\
&\quad \ell \in \{0, \ell_p, \ell_f, \ell_e\} \\
&\quad c, a' \geq 0 \\
&\quad i' \in \{i_P, i_S\} \\
&\quad i_{CAID} \in \{0,1\}.
\end{aligned} \tag{16}$$

Note that old consumers are allowed to work in the model. This is motivated by the observation that nearly 20 percent of individuals aged 65 and older still participate in the workforce. Old consumers receive transfers from the government in the form of Medicare and Social Security, SS_{ej}, the last of which varies with their educational level and cohort. Neither program is tied to retirement, and hence consumers continue to receive both Medicare and Social Security even if they choose to work in old age. Out-of-pocket health care expenses are given by $\chi_{CARE}m_{jh}$ for self-insured consumers and $\chi_{CARE}\chi_P m_{jh}$ for consumers that purchased private health insurance in the preceding period.

2.6 Definition of equilibrium

Given consumption tax rates, τ_c, capital income tax rates, τ_k, government consumption, G_c, government debt, D, coinsurance rates χ_P, χ_E, χ_{CARE}, and χ_{CAID}, and initial conditions for capital K_1 and the measure of types Φ_1, an *equilibrium* in our model is a sequence of model variables such that:

1. Given prices, insurance premia, government policies, and accidental bequests, consumers maximize utility subject to their constraints.

2. Factor prices satisfy marginal product pricing conditions:

$$r = \theta\alpha\left(\frac{N}{K}\right)^{1-\alpha} - \delta$$

$$w = \theta\left(1-\alpha\right)\left(\frac{K}{N}\right)^{\alpha}.$$

3. Goods, capital, and labor market clearing conditions are met:

$$C + G_c + M + \left(1+g_z\right)\left(1+g_n\right)K' = \theta K^{\alpha}N^{1-\alpha} + (1-\delta)K$$

$$K' + D' = \frac{\int a'\left(s\right)\Phi\left(ds\right)}{\left(1+g_n\right)} + \frac{\int \mathbb{I}_{i'(s)=i_P}\pi_{jeh}\Phi\left(ds\right)}{\left(1+g_z\right)\left(1+g_n\right)}$$

$$N = \int \eta\epsilon_{je}\xi_h\ell\left(s\right)\Phi\left(ds\right).$$

4. Accidental bequests are given by

$$B' = \frac{\int\left(1-\psi_{jeh}\right)a'\left(s\right)\Phi\left(ds\right)}{\left(1+g_n\right)\int\Phi\left(ds\right)}.$$

5. Insurance market clearing conditions are met.

6. Government policies satisfy the government budget constraint.

7. The aggregate law of motion for Φ is induced by the policy functions and the exogenous stochastic processes for idiosyncratic risk.

3 Calibration

We calibrate the model in two steps. In the first step, we calibrate a set of parameters outside the model equilibrium. In the second step, we assume that the initial balanced growth economy is 2005 and jointly calibrate the remaining parameters to match moments in the U.S. economy in that year.

3.1 Parameters determined outside the model equilibrium

The following subsections discuss the parameters that are determined outside the model equilibrium. These parameters are presented in Table 1.

3.1.1 Life cycle

We assume that a model period is 5 years because the population estimates that we use from the United Nations are given for 5-year age bins (20–24, 25–29, ...). In our model, consumers enter the economy at age 20. We set the retirement age, j_r, to 10, which implies that consumers start receiving Medicare and Social Security benefits at age 65. The maximum life span, J, is set to 17 such that consumers live at most 100 years.

3.1.2 Preferences and indivisible labor

We set the consumption share in the utility function to 0.574 to match estimates in French (2005). We set the risk aversion parameter, σ, to 2.742, which implies an intertemporal elasticity of substitution of 0.5. The discrete grid for labor supply is $\ell \in \{0, 0.225, 0.300, 0.375\}$, which corresponds to working zero hours, part-time, full-time, and extra time, respectively.

3.1.3 Technology

We set the growth rate of labor-augmenting technological progress, g_z, to 0.104, which implies an annual growth rate of 2 percent. The capital share, α, is set to 0.36. Lastly, we set the depreciation rate, δ, to 0.262, which implies an annual rate of 0.059, as in Castañeda et al. (2003).

3.1.4 Idiosyncratic labor productivity

The idiosyncratic labor productivity in the model comprises the stochastic component, η, the health-specific stochastic component, ξ_h, and the age-education specific deterministic component, ϵ_{je}. The parameters of the idiosyncratic stochastic process are calibrated jointly in equilibrium, as will be discussed in Subsection 3.2. For the health-specific stochastic component, we set ξ_h to 1 for consumers with low and high health care expenses, and to 0 for consumers with catastrophic expenses (see Subsection 3.1.7 for details about the medical expenditure states). For the age-education-specific deterministic component, we convert the annual estimates from Conesa et al. (2018) to 5-year estimates by computing the averages for each age-education bin. Further details are given in the online appendix.

3.1.5 Taxes

We compute effective tax rates for consumption and capital income using OECD data on national accounts and tax revenues, following the methodology pioneered by Mendoza et al. (1994). We use the average value between 2005 and 2009, which results in a consumption tax rate, τ_c, of 4.7 percent, and a capital income tax rate, τ_k, of 32.1 percent. As noted in Section 2.4, the labor tax rate, τ_ℓ, is set to balance the government budget period-by-period and hence is determined endogenously in equilibrium.

3.1.6 Health insurance

We use the following approach to compute the coinsurance rates for private insurance, employer-provided insurance, and Medicaid. Using data from the Medical Expenditure Panel Survey (MEPS), we first derive each individual's primary insurance provider, defined as the insurer that pays for the largest share of the individual's health care expenses. To illustrate, if Medicaid and private health insurance both cover a share of the individual's health care expenses, but Medicaid covers the largest share, then we let Medicaid be defined as this individual's primary insurance provider. Next, we pool all the individuals in the MEPS with the same primary insurance provider and compute the average share of expenses paid by this insurance provider. Let these values be denoted by $\tilde{\chi}_P$, $\tilde{\chi}_E$, and $\tilde{\chi}_{CAID}$ for individuals with private health insurance, employer-provided health insurance, and Medicaid as their primary insurance provider, respectively. We then let the coinsurance rates be given by 1 minus these values. That is, $\chi_P = 1 - \tilde{\chi}_P$, $\chi_E = 1 - \tilde{\chi}_E$, and $\chi_{CAID} = 1 - \tilde{\chi}_{CAID}$. Finally, we set the coinsurance rate on Medicare, χ_{CARE}, to match the observation that about 50 percent of the elderly's total health care expenses are covered by Medicare in the United States.

We use the following approach to compute the Medicaid eligibility criteria. We first get data on state-specific Medicaid eligibility criteria from the Kaiser Family Foundation. We then set the categorical income limit, y^{CAT}, the medically needy income limit, y^{MN}, and the medically needy asset limit, a^{MN}, to match the corresponding weighted average limits in the data, with weights given by each state's share of total health care expenses. To ensure a balanced growth path, we assume that the Medicaid income and asset thresholds grow at the rate of technological progress, g_z.

3.1.7 Health care expenses and transition probabilities

We split health care expenses into three categories: low, high, and catastrophic. To identify these expenses in the MEPS, we first pool all health care expenses for each age and educational group (college or non-college), and compute the 60th and 99.9th percentile. We then identify age-education-specific low, high, and catastrophic health care expenses as the average value between the 0–60th percentile, the 60–99.9th percentile, and the 99.9–100th percentile, respectively. Since the MEPS top-codes age at age 85, we extrapolate health care expenses for consumers aged 85 to 100 using a log-linear trend. Finally, for each age group, we use the average value of health care expenses between college and non-college-educated individuals.

The health transition matrix must guarantee that, for each age and educational group, 60.0, 39.9, and 0.1 percent of consumers have low, high, and catastrophic health care expenses, respectively. The following discussion explains how we adjust the health transition probabilities. Using our MEPS sample, we first estimate age-health-education-specific health transition probabilities by running an ordered probit regression of next period's health on current age, age squared, education, health, and interaction terms. Next, we iterate on the transition matrix until the probabilities guarantee that, for each age and educational group, the correct percentage of consumers transition to each health state. That is, we iterate on the transition matrix, $Q_{j,e}(h, H)$, until $x^T Q_{j,e}(h, H) = x^T$, where $x^T = [0.600, 0.399, 0.001]$ denotes the probability distribution of consumers across health states. Note that this is an augmented version of the RAS method, which is a method used to generate matrices that satisfy pre-specified row and column sum constraints. Further details are given in the online appendix.

3.1.8 Survival probabilities

In the model, survival probabilities vary with age, education, and health, ψ_{jeh}. These probabilities cannot be derived directly from the MEPS since the MEPS does not sample institutionalized individuals. Survival probabilities estimated from the MEPS will therefore be upwardly biased. Moreover, the estimates are not guaranteed to match the education survival premium, defined as the difference in age-specific survival probabilities between college and non-college-educated individuals. Building on Attanasio et al. (2010), we therefore adjust the estimated survival probabilities to match both the age-specific survival probabilities in the data and the education survival premium. The following discussion explains how we adjust the survival probabilities.

We obtain age-specific survival probabilities from the Social Security Administration, $surv_j$. Next, we derive age-education-specific survival probabilities for college and non-college-educated individuals, where college-educated individuals are defined as individuals with at least a bachelor's degree or a minimum of 4 years of college. To do this, we first obtain mortality statistics from the 2010 National Vital Statistics System (NVSS). The NVSS provides data on the total number of deaths by age and educational attainment. We then use data from the 2010 census and the 2010 Current Population Survey (CPS) to obtain estimates of the total number of college and non-college educated individuals by age. Since the CPS top-codes age at age 85, we assume that 85- to 100-year-olds have the same college attainment as 80- to 84-year-olds. Lastly, we combine the NVSS, census, and CPS data, and compute the age-education-specific survival probabilities by dividing the total number of deaths by the total number of people in each age and educational group. These estimates are then used to compute the education survival premium by age, $educprem_j$, defined as the difference in age-specific survival probabilities between college and non-college-educated individuals.

Using the MEPS sample, we then estimate age-education-health-specific survival probabilities, $\tilde{\psi}_{jeh}$. Lastly, to ensure that the model matches both the age-specific survival probabilities and the education survival premium in the data, we solve the following system of equations:

$$\begin{aligned} surv_j &= \textstyle\sum_h \sum_e \Lambda_{jeh} a_{ej} \tilde{\psi}_{jeh} \\ educprem_j &= a_{2j} \tilde{\psi}_{j2h} - a_{1j} \tilde{\psi}_{j1h}, \end{aligned} \tag{17}$$

where $\Lambda_{je}(h)$ denotes the mass of individuals by age, education, and health in the MEPS. That is, we derive the scaling terms, a_{ej}, that solve Equation (17). The age-education-health-specific survival probabilities in the model are then given by $\psi_{jeh} = a_{ej} \tilde{\psi}_{jeh}$.

3.1.9 College attainment and 20-year-old population growth rate

For college attainment, we use data from the U.S. Census Bureau. For the initial balanced growth economy estimate, we use the average of the percentage of college graduates in the population aged 20+ from 1980 to 2005. To compute the 20-year-old population growth rate, we use population estimates from the World Population Prospects: The 2012 Revision, United Nations. This data set provides population estimates for 5-year age groups (20–24, 25–29, ...). We compute $g_{n,t}$ as the number of individuals aged 20–24 in period t divided by the number of individuals aged 20–24 in period $t-1$. For the initial balanced growth economy estimate, we use the average $g_{n,t}$ from 1980 to 2005.

3.2 Parameters determined jointly in equilibrium

Table 2 reports the parameters that are determined jointly in equilibrium. As mentioned above, we assume that the initial balanced growth economy is 2005. The parameters are calibrated jointly to match key moments of the U.S. economy during the period 2005–2009 (for simplicity, we refer to the period 2005–2009 as 2005 below).

We normalize θ such that GDP per capita is equal to 1 in 2005. The discount factor is set to match a capital-to-output ratio of 0.6, which corresponds to an annual value of 3. We calibrate the Social Security replacement rates, b_e, to match average Social Security benefits across individuals with and without a college degree. We calibrate the percentage of 20-year-olds that qualify for employer-provided insurance to match the percentage of individuals with either private or employer-provided insurance in the data. We calibrate government consumption, G_c, and government debt, D, to match government consumption to output and government debt to output, respectively. We scale the health care expenditures to match the 15.2 percent health care spending-to-GDP ratio. This is necessary since the MEPS does not sample institutionalized individuals, which account for a large share of total medical spending in the United States. Medical expenses derived from the MEPS must therefore be scaled up to match the aggregate statistics reported by the Centers for Medicare & Medicaid Services. The consumption floor, $\underline{c}$, is calibrated to match the average annual Supplemental Nutrition Assistance Program benefits reported by the United States Department of Agriculture. The utility cost of going on Medicaid and Emergency Relief, λ, is calibrated such that the model matches the percentage of health care expenses covered by Medicaid. To ensure a balanced growth path, we assume that the minimum consumption level and the disutility cost of going on Medicaid and Emergency Relief grow at the rate of technological progress.

Finally, we follow Castañeda et al. (2003) and calibrate the parameters of the stochastic labor productivity process to match the empirical earnings distribution in the United States. We choose a right-skewed productivity shock process to match the top decile of the earnings distribution, and calibrate the variance of the process to match the dispersion observed in the data.

4 Comparative statics: College attainment, fertility, and longevity

In this section, we perform comparative statics exercises with balanced growth paths for three channels that contribute to an increase in the old age dependency ratio: increasing college attainment, decreasing fertility, and increasing longevity. As we have explained, we assume that the initial balanced growth economy is 2005. For the comparative statics, we use projections for the year 2100, discussed in the next section.

4.1 Projections of college attainment, fertility, and longevity for 2100

Table 3 presents the 1980–2005 averages and the 2100 projections for measures of college attainment and fertility. As noted in Subsection 3.1.9, the parameters used for the 2005 balanced growth economy are the averages for 1980–2005. For the 2100 college attainment projection, we start by estimating a linear trend for the percentage of the population aged 20+ with a college degree from 1960 to 2010. We then extrapolate this trend to 2100 and assume that it stays fixed in the balanced growth path after that. If the increasing trend in college attainment continues, then the percentage of the population with a college degree will increase from an average of 23 percent during 1980–2005 to 67 percent in 2100. We view the 2100 projection for college attainment as an upper bound and perform comparative statics for different levels of college attainment.

In our model, changes in fertility rates are captured through changes in the population growth rate of 20-year-olds. To obtain estimates for the population growth rate of 20-year-olds in 2100, we use population forecasts for the years 2095 and 2100 from the World Population Prospects: The 2012 Revision, United Nations, the same data set used for the 2005 estimate. The U.N. forecasts are given for alternative simulations based on different assumptions about fertility, mortality, and migration. We use the median forecasts for fertility and mortality. Furthermore, because our model does not feature migration, we use the forecasts that are based on the assumption of zero migration. Table 3 shows that the population growth rate of 20-year-olds is projected to decrease from 1.50 percent per 5 years (an annual rate of 0.29 percent) to -0.26 percent per 5 years (an annual rate of -0.05 percent).

Increased longevity in our model is captured through increasing age-specific survival probabilities. For 2005, we use the age-education-health-specific estimates discussed in Subsection 3.1.8. For the 2100 projection, we first compute age-specific survival probabilities for the years 2005 and 2100 using the U.N. data. We then calculate the factor by which we need to increase the age-specific survival probabilities in 2005 to match the corresponding estimates in 2100. This scaling factor is depicted in Figure 1. Finally, we scale the age-education-health-specific 2005 survival probabilities by our scaling factor. Note that our approach relies on the assumption that, for each age group, the health and education survival premia discussed in Subsection 3.1.8 are the same in 2100 as in 2005.

4.2 Individual implications of college attainment, fertility, and longevity

We now show that although increasing college attainment, decreasing fertility, and increasing longevity all contribute to a higher old age dependency ratio, the macroeconomic implications of increasing college attainment are different from those of decreasing fertility and increasing longevity. In particular, we emphasize the implications for the labor tax rate and consumer welfare. We perform comparative statics exercises for different levels of the 2100 projections for college attainment, fertility, and longevity. In the figures, the three cases are referred to as college attainment, fertility, and longevity. The horizontal axes in the figures refer to the fraction of the 2100 projection. To illustrate, a value of 0.6 for fertility refers to the case of $g_n = 0.6g_{n,2100} + 0.4g_{n,2005}$.

Figure 2 plots the old age dependency ratio. All three channels lead to a higher old age dependency ratio. Increasing college attainment increases the old age dependency ratio because college graduates have higher life expectancy than non-college graduates. Decreasing fertility increases the old age dependency ratio because it leads to relatively fewer young consumers. Lastly, increasing longevity increases the old age dependency ratio because it leads to relatively more old consumers.

Although all three channels contribute to aging, they have different fiscal implications. In particular, we find that increasing college attainment allows the government to lower the labor tax rate, whereas decreasing fertility and increasing longevity require the government to increase the labor tax rate. This can be seen in Figure 3. Increasing college attainment allows the government to lower the labor tax rate for several reasons. First, and most importantly, since college-educated consumers have higher labor productivity than non-college-educated consumers, an increase in college attainment leads to an economy with more productive workers. Second, hours worked per capita is higher in the economy with higher college attainment. Both effects contribute to an increase in effective labor per capita, which in turn increases government revenues from labor taxation, thereby allowing the government to reduce the labor tax rate. Our results show that most of the increase in effective labor per capita following the increase in college attainment is driven by the direct effect of higher labor productivity. This can be seen from Figures 4b and 4c, which show that the increase in effective labor per capita is larger than the increase in hours worked per capita, and hence that higher labor productivity is the main driver of the increase in effective labor per capita following the increase in college attainment.

Third, college graduates are less likely to enroll in Medicaid and Emergency Relief. Increasing college attainment thus lowers government spending on these programs, thereby contributing to a lower labor tax rate. This mechanism is illustrated in Figures 5a, 5b, and 5c, which show how the health care expenditure distribution by insurance provider changes as we increase college attainment, decrease fertility, and increase longevity, respectively. In particular, Figure 5a shows that increasing college attainment lowers the share of health care expenses covered by both Medicaid and Emergency Relief. This is because college graduates, on average, have both higher earnings and wealth. Hence, in the model, enrolling in Medicaid and Emergency Relief is more costly for them. The reduction in government spending on Medicaid and Emergency Relief following the increase in college attainment contributes to a small reduction in public health care spending. This is illustrated in Figure 6a. In contrast, we find that decreasing fertility and increasing longevity lead to higher public health care spending per capita.

Fourth, as illustrated in Figures 7a and 7b, higher college attainment leads to both higher consumption tax revenues per capita and higher capital income tax revenues per capita. This follows because college graduates both consume and save more than non-college graduates. In contrast, decreasing fertility and increasing longevity lead to lower government revenues from consumption and capital income taxation.

A fifth reason why higher college attainment enables the government to reduce the labor tax rate is that higher college attainment leads to higher wages, thereby further increasing government revenues from labor taxation. This is illustrated in Figure 8. The wage rate goes up because the increase in college attainment leads to more capital per capita relative to effective labor per capita. This is largely driven by the fact that college-educated consumers save more than non-college-educated consumers. College graduates save more because they have higher labor earnings, higher life expectancy, and a stronger precautionary savings motive since enrolling in Medicaid and Emergency Relief is more costly for them.

Finally, the increase in capital accumulation due to higher college attainment leads to a lower real interest rate. This is illustrated in Figure 9, which shows that all three channels contribute to reduced interest rates. Lower interest rates reduce interest payments on government debt, which accounts for 7.9 percent of tax revenues in the initial steady state. We find that higher college attainment lowers interest payments on government debt per capita by 33.3 percent.

The forces that we have mentioned so far contribute to lower labor taxes, but there are forces that move in the opposite direction. In particular, an increase in college attainment leads to higher spending on Medicare and Social Security, the latter of which is illustrated in Figure 6b. This follows because college-educated consumers have higher life expectancy than non-college-educated consumers and because college graduates claim higher Social Security benefits due to higher lifetime labor earnings. Moreover, the reduction in the interest rate caused by higher college attainment dampens the increase in capital income tax revenues. These effects partially offset the reduction in the labor tax rate brought about by higher college attainment.

Thus far, we have studied how increasing college attainment affects labor taxes. Next, we study the implications for welfare. We use a *consumption equivalent variation* to measure the welfare effects of aging. In particular, we measure welfare as the percentage change in consumption in all periods and all states of the world in the economy without the three channels of aging that would make a consumer indifferent between entering that economy and entering the economy with aging (further details are given in the online appendix). We focus on a 20-year-old consumer who has zero assets, and for whom the education type (college or non-college) has been revealed, but not the stochastic components of productivity and health. Note that all consumers entering a balanced growth economy in the future are better off because of economic growth. In particular, by 2150, in a balanced growth path with none of the three channels active, real GDP per capita will be about 18 times higher than in 2005 because of the 2 percent annual productivity growth. In this paper, we only report the welfare results from the *detrended* models. Figures 10a and 10b show that both 20-year-old consumers with a college degree and 20-year-old consumers without a college degree that enter an economy with higher college attainment experience higher welfare. In contrast, 20-year-old consumers both with and without a college degree that enter an economy with decreased fertility or increased longevity experience lower welfare. These results are driven by the fact that higher college attainment allows the government to lower the labor tax rate, whereas the other two channels require the government to increase the labor tax rate. Note, however, that the welfare effects of increased longevity are downwardly biased. This follows because flow utility in the model is negative (that is, $U(c, \ell) < 0$ since $\sigma > 1$), whereas the value of being dead has been normalized to zero. Higher longevity thus mechanically leads to lower welfare in the model since it results in additional periods of negative flow utility. In contrast, if the value of being dead is sufficiently low compared to the value of being alive, then higher longevity will have positive implications for welfare in the model.

4.3 Joint implications of college attainment, fertility, and longevity

We now study the joint implications of increasing college attainment, decreasing fertility, and increasing longevity. We focus on the following scenarios: increasing college attainment only (college), decreasing fertility and increasing longevity (fertility + longevity), and introducing all three channels (all). We start by studying the joint implications of the three channels for the old age dependency ratio. Recall from Figure 2 that all three channels contribute to an increase in the old age dependency ratio. Figure 11a shows that the joint effect of college attainment, fertility, and longevity is larger than the individual effects of college attainment and fertility + longevity ($26.3 > 3.3 + 20.1 = 23.4$). Hence, higher college attainment not only increases the old age dependency ratio but also amplifies the increase in the old age dependency ratio brought about by decreasing fertility and increasing longevity.

Figures 11b and 11c compare the changes in the interest rate and the wage rate in the different models. We find that higher college attainment not only reduces the interest rate but also amplifies the reduction in the interest rate due to decreasing fertility and increasing longevity. Analogously, higher college attainment amplifies the increase in the wage rate brought about by the other channels. These interaction effects have implications for government spending. In particular, Figure 12a shows that the interaction effects between the three channels of aging amplify the increase in Social Security spending per capita by 12.1 percentage points. This is largely due to the amplified increase in the wage rate. Similarly, the amplified reduction in the interest rate leads to a further reduction in interest payments on government debt. As illustrated in Figure 12b, we find that the 1.8 percentage point reduction in the interest rate due to the three channels of aging leads to a 56.1 percent decline in interest payments on government debt.

Next, we study the implications for government revenues. Recall that the government derives revenues from consumption taxes, capital income taxes, and labor taxes. Figure 13a shows that consumption tax revenues per capita are higher in the model with all three channels of aging. This shows that the increase in consumption tax revenues due to higher college attainment more than offsets the reduction in consumption tax revenues caused by decreasing fertility and increasing longevity. Capital income tax revenues, on the other hand, decline when we introduce all three channels of aging in the model. That is, the increase in capital income tax revenues due to increased college attainment only partially mitigates the drop in capital income tax revenues caused by decreasing fertility and increasing longevity. This is partially because higher college attainment amplifies the reduction in the interest rate caused by decreasing fertility and increasing longevity, which in turn lowers government revenues from capital income taxation. The amplified increase in the wage rate, on the other hand, leads to higher labor tax revenues, not only because of the direct effect of higher wages on earnings but also because higher wages lead to an increase in effective labor per capita. This is illustrated in Figure 14a. The increase in effective labor per capita is partially driven by higher labor force participation rates among 20- to 64 year-old consumers. This is illustrated in Figures 14b and 14c, which report the changes in the labor force participation rates for 20–64 and 65+ year-old consumers in the model.

Our results show that the increase in government tax revenues and the reduction in interest payments on government debt due to higher college attainment more than offset the amplified increase in government spending on Social Security. Consequently, higher college attainment mitigates the negative fiscal implications of decreasing fertility and increasing longevity. In particular, we find that the labor tax rate has to increase by 10.7 percentage points in the model with decreasing fertility and increasing longevity, but by 2.5 percentage points in the model with all three channels of aging. Hence, higher college attainment mitigates 77 percent of the required increase in the labor tax rate.

Finally, we examine the welfare implications of the three channels. We continue to report the welfare effects in the detrended models. Our results show that the welfare of 20-year-old consumers both with and without a college degree is higher in the economy with all three channels of aging than in the economy with only decreased fertility and increased longevity. In particular, we find that consumption has to increase by 17.2 percentage points in all periods and contingencies in the economy with decreased fertility and increased longevity to make a 20-year-old consumer with a college degree indifferent between entering that economy and entering the economy with all three channels of aging. Similarly, we find that consumption has to increase by 16.5 percentage points to make a 20-year-old consumer without a college degree indifferent between entering these two economies.

4.4 General equilibrium effects of college attainment, fertility, and longevity

Lastly, we compare the results from the benchmark closed economy with the corresponding results from a small open economy with a constant and exogenous interest rate. By construction, the detrended wage rate is also constant in the small open economy. All other variables such as the labor tax rate, employer-provided insurance premium, and transfers are determined endogenously in equilibrium. We do this not because we think the United States is well modeled as a small open economy, but because it enables us to quantify the general equilibrium effects of higher wages and lower interest rates brought about by higher capital accumulation.

We start by studying the tax implications of introducing higher college attainment into two different versions of the model with decreasing fertility and increasing longevity: one, our benchmark general equilibrium model, and the other, the small open economy model. We compare the change in tax revenues and the resulting change in the labor tax rate needed to balance the government budget. These results are illustrated in Figures 15a, 15b, and 16b.

We find that the capital stock increases in both the general equilibrium model and the small open economy model. In the general equilibrium model, however, the increase in the capital stock also leads to higher wages and lower interest rates. Higher wages lead to higher earnings, not only because of the direct effect of higher wages but also because higher wages induce consumers to work more. This can be seen from Figure 16a, which shows that the increase in hours worked per capita due to increased college attainment is higher in the general equilibrium model than in the small open economy model. Higher earnings lead to higher labor tax revenues. Moreover, it also increases consumption and saving, which in turn results in both higher consumption and higher capital income tax revenues. The increase in government revenues from consumption, capital income, and labor taxation thus enables the government to reduce the labor tax rate.

Higher wages, however, also lead to higher Social Security benefits. The resulting increase in government spending thus partially offsets the reduction in the labor tax rate under general equilibrium. More importantly, the reduction in the interest rate in the general equilibrium model lowers government revenues from capital income taxation. Introducing higher college attainment in the model with decreasing fertility and increasing longevity therefore results in a larger increase in capital income tax revenues per capita in the small open economy model than under general equilibrium. We find that this additional increase in government revenues from capital income taxation results in a larger reduction in the labor tax rate in the small open economy model than in the general equilibrium model. In particular, as illustrated in Figure 16b, adding higher college attainment in the model with decreasing fertility and increasing longevity lowers the required increase in the labor tax rate by 8.3 percentage points in the general equilibrium model, but by 11.1 percentage points in the small open economy model. This shows that general equilibrium effects dampen the reduction in the labor tax rate due to higher college attainment by 35 percent.

The general equilibrium effects of higher capital accumulation leading to higher wages and lower interest rates have implications for welfare. As illustrated in Figures 17a and 17b, we find that the welfare gains, as measured by consumption equivalent variations, in the detrended model for 20-year-old consumers both with and without a college degree are lower under general equilibrium. In particular, for the 2100 projection, we find that adding increasing college attainment to the model with decreasing fertility and increasing longevity increases the welfare for a 20-year-old consumer with a college degree by 17.2 percentage points under general equilibrium, while it increases by 22.0 percentage points in the small open economy model. Similarly, higher college attainment increases the welfare for a 20-year-old consumer without a college degree by 16.5 percentage points under general equilibrium, but by 22.3 percentage points in the small open economy model. The higher welfare gain in the small open economy model follows from the fact that increased college attainment leads to a larger reduction in the labor tax rate in the small open economy model than in the general equilibrium model.

4.5 Sensitivity analysis

We have conducted a wide range of sensitivity analyses, and we find that our main results are robust. That is, the finding that higher college attainment lowers the required increase in the labor tax rate due to decreasing fertility and increasing longevity, that higher college attainment leads to welfare gains whereas decreasing fertility and increasing longevity lead to welfare losses, and that the fiscal and welfare implications of higher college attainment depend critically on general equilibrium feedback effects are robust to alternative parameterizations of the model. We limit our discussion here to two robustness checks. First, we study the effects of adding a labor force participation cost to better match the observed labor force participation rate in the data. Then we study the effects of removing government debt in the model. In both cases, we recalibrate the model to match the same targets as described in Section 3. The joint implications of increasing college attainment, decreasing fertility, and increasing longevity under different parameterizations of the model are given in Table 4.

Labor force participation cost The benchmark model presented in Section 3 overestimates the age-specific labor force participation rates in the data. Data from the Current Population Survey show that 79 percent of 20- to 64 year-olds and 16 percent of 65+ year-olds participated in the labor force between 2005 and 2009. The corresponding labor force participation rates in the benchmark model are 92 and 54 percent. This is partially driven by the fact that the model abstracts from fixed time costs of working and time loss due to sickness, both of which have been shown to affect labor force participation decisions. By overestimating the number of workers that contribute by paying labor taxes, the model underestimates the labor tax burden in the economy. To address this, we add a utility cost of working in the model. All consumers that choose to participate in the labor force suffer a utility cost, ι. We calibrate this cost to match average labor force participation rates for 20+ year-olds between 2005 and 2009. To ensure a balanced growth path, we assume that the utility cost grows at the rate of technological progress. A comparison of the labor force participation rate in the model and in the data is given in Figure 18. As illustrated in the graph, the model closely matches the observed labor force participation rates of 40+ year-olds, but continues to overestimate the labor force participation rates of 20- to 40-years-olds. This is partially due to the assumption that consumers enter the economy with zero assets.

Table 4 shows that the three channels of aging lead to similar changes in public health care spending per capita, Social Security spending per capita, and government interest payments per capita in the model with and without labor force participation costs. Moreover, the increase in both effective labor per capita and capital per capita are comparable in the two models. As a result, the increase in the wage rate and the reduction in the interest rate are also similar in the model with and without labor force participation costs. In terms of the tax implications, we find that the three channels of aging lead to a lower increase in consumption tax revenues and to a larger reduction in capital income tax revenues in the model with labor force participation costs. Consequently, the required increase in the labor tax rate due to higher college attainment, decreasing fertility, and increasing longevity is higher. While the government has to increase the labor tax rate by 2.5 percentage points to balance the budget in the benchmark model, it has to increase the labor tax rate by 4.1 percentage points in the model with labor force participation costs. These findings show that the benchmark model underestimates the negative fiscal implications of aging, but that the results are qualitatively robust to this alternative parameterization of the model.

No government debt Recall that interest payments on government debt account for 7.9 percent of tax revenues in the initial steady state of the benchmark model, and that the reduction in the interest rate due to the three channels of aging leads to a 56.1 percent reduction in interest payments on government debt. Lower interest payments on government debt thus partially mitigate the negative fiscal implications of aging. To better understand how government debt affects the fiscal implications of aging, we end this section by studying an alternative parameterization of the model with no government debt.

Table 4 shows that the reduction in government spending caused by lower interest payments on government debt reduces the required increase in the labor tax rate. In particular, the labor tax rate increases by 2.5 percentage points in the benchmark model, but by 5.2 percentage points in the model with no government debt. The higher increase in the labor tax rate in the model with no government debt reduces incentives to both work and save. Consequently, we find that effective labor per capita increases by an additional 0.8 percentage points in the benchmark model compared to the model with no government debt, and that capital per capita increases by an additional 18.3 percentage points. The relatively higher increase in capital per capita compared to effective labor per capita leads to an additional 4.9 percentage point increase in the wage rate and to an additional 0.7 percentage point reduction in the interest rate in the benchmark model compared to the model with no government debt. These price effects have implications for government tax revenues. On the one hand, the higher increase in the wage rate in the benchmark model leads to a larger increase in labor tax revenues. It also leads to a larger increase in consumption, and therefore a higher increase in consumption tax revenues per capita. On the other hand, the higher increase in the wage rate in the benchmark model leads to a higher increase in government spending on Social Security. More importantly, the higher reduction in the interest rate in the benchmark model has negative implications for capital income tax revenues, which decline by 8.2 percent in the benchmark model but increase by 2.3 percent in the model with no government debt.

5 Conclusion

While the literature has emphasized decreasing fertility rates and increasing longevity as important drivers of the increase in the old age dependency ratio, we argue that increasing college attainment is another key driver because college graduates have higher life expectancy than non-college graduates. Using a general equilibrium overlapping generations model with heterogeneous consumers, we show that the macroeconomic implications of increasing college attainment are different from those of decreasing fertility and increasing longevity. Most importantly, decreasing fertility and increasing longevity require the government to increase labor taxes, whereas increasing college attainment allows the government to reduce labor taxes. This follows because increasing college attainment leads to a more productive labor force, lower government spending on Medicaid and Emergency Relief, higher revenues from consumption taxation, capital income taxation, and labor taxation, and lower interest payments on government debt.

We also study the joint fiscal implications of the three channels of aging. In particular, we study the fiscal implications of introducing increasing college attainment into the model with decreasing fertility and increasing longevity. We show that adding higher college attainment to the model with decreasing fertility and increasing longevity lowers the required increase in the labor tax rate from 10.7 to 2.5 percentage points. Consequently, higher college attainment mitigates 77 percent of the required increase in the labor tax rate.

Finally, we show that the fiscal implications of aging depend critically on general equilibrium effects. We show that the reduction in the interest rate under general equilibrium lowers government revenues from capital income taxation. This dampens the reduction in the labor tax rate brought about by higher college attainment. In particular, adding higher college attainment to the model with decreasing fertility and increasing longevity allows the government to reduce the labor tax rate by 8.3 percentage points under general equilibrium, but by 11.1 percentage points in the small open economy model with a constant and exogenous interest rate. Hence, general equilibrium effects dampen the reduction in the labor tax rate due to higher college attainment by 35 percent.

In this paper, we performed comparative statics exercises in a model with balanced growth paths where the three channels of aging were exogenous. Focusing on balanced growth paths is restrictive. In particular, our results do not indicate how the U.S. economy will be affected by our three channels of aging between 2005 and 2100. Our welfare analysis does not take into account the effects of aging on generations already born in 2005, or the effects of aging on generations born during the transition. We leave it for future research to compute transition paths to perform such an analysis. Another worthwhile extension of our analysis would be to endogenize the three channels of aging.

References

Altig, D., A. J. Auerbach, L. J. Kotlikoff, K. A. Smetters, and J. Walliser (2001), "Simulating fundamental tax reform in the United States," *American Economic Review*, 91: 574–595.

Attanasio, O., S. Kitao, and G. L. Violante (2010), "Financing Medicare: A general equilibrium analysis," in J. B. Shoven (ed.), *Demography and the Economy*, Chicago: University of Chicago Press.

Auerbach, A. J., and L. J. Kotlikoff (1987), *Dynamic Fiscal Policy,* Cambridge: Cambridge University Press.

Castañeda, A., J. Díaz-Giménez, and J.-V. Ríos-Rull (2003), "Accounting for the U.S. earnings and wealth inequality," *Journal of Political Economy,* 111: 818–857.

Cole, H. L., S. Kim, and D. Krueger (2019), "Analysing the effects of insuring health risks: On the trade-off between short run insurance benefits versus long-run incentive costs," *Review of Economic Studies*, 86: 1123–1169.

Conesa, J. C., D. Costa, P. Kamali, T. J. Kehoe, V. M. Nygaard, G. Raveendranathan, and A. Saxena (2018), "Macroeconomic effects of Medicare," *Journal of the Economics of Ageing,* 11: 27–40.

Conesa, J. C., and D. Krueger (1999), "Social Security reform with heterogeneous agents," *Review of Economic Dynamics*, 2: 757–795.

De Nardi, M., E. French, and J. B. Jones (2010), "Why do the elderly save? The role of medical expenses," *Journal of Political Economy*, 118: 39–75.

De Nardi, M., S. İmrohoroğlu, and T. J. Sargent (1999), "Projected U.S. demographics and Social Security," *Review of Economic Dynamics*, 2: 575–615.

French, E. (2005), "The effects of health, wealth, and wages on labour supply and retirement behaviour," *Review of Economic Studies*, 72: 395–427.

Hubbard, R., J. Skinner, and S. P. Zeldes (1994), "The importance of precautionary motives in explaining individual and aggregate saving," *Carnegie-Rochester Conference Series on Public Policy*, 40: 59–125.

İmrohoroğlu, S., and S. Kitao (2012), "Social Security reforms: Benefit claiming, labor force participation, and long-run sustainability," *American Economic Journal: Macroeconomics*, 4: 96–127.

Jung, J., and C. Tran (2016), "Market inefficiency, insurance mandate and welfare: U.S. health care reform 2010," *Review of Economic Dynamics*, 20: 132–159.

Jung, J., C. Tran, and M. Chambers (2017), "Aging and health financing in the U.S.: A general equilibrium analysis," *European Economic Review*, 100: 428–462.

Kopecky, K. A., and T. Koreshkova (2014), "The impact of medical and nursing home expenses on savings," *American Economic Journal: Macroeconomics*, 6: 29–72.

Kotlikoff, L. J., K. Smetters, and J. Walliser (1999), "Privatizing Social Security in the United States–Comparing the options," *Review of Economic Dynamics*, 2: 532–574.

Kotlikoff, L. J., K. Smetters, and J. Walliser (2007), "Mitigating America's demographic dilemma by pre-funding social security," *Journal of Monetary Economics*, 54: 247–266.

Mendoza, E. G., A. Razin, and L. L. Tesar (1994), "Effective tax rates in macroeconomics: Cross-country estimates of tax rates on factor incomes and consumption," *Journal of Monetary Economics,* 34: 297–323.

Nakajima, M., and I. A. Telyukova (2018), "Medical expenses and saving in retirement: The case of U.S. and Sweden," Federal Reserve Bank of Minneapolis, Opportunity and Inclusive Growth Institute Working Paper 8.

Nishiyama, S., and K. Smetters (2007), "Does Social Security privatization produce efficiency gains?" *Quarterly Journal of Economics*, 122: 1677–1719.

Ozkan, S. (2014), "Preventive vs. curative medicine: A macroeconomic analysis of health care over the life cycle," Mimeo.

Palumbo, M. G. (1999), "Uncertain medical expenses and precautionary saving near the end of the life cycle," *Review of Economic Studies*, 66: 395–421.

Pashchenko, S., and P. Porapakkarm (2013), "Quantitative analysis of health insurance reform: Separating regulation from redistribution," *Review of Economic Dynamics*, 16: 383–404.

Scholz, J. K., and A. Seshadri (2016), "Health and wealth in a lifecycle model," Mimeo.

Table 1: **Parameters determined outside the model equilibrium**

Parameter		**Description**	**Value**
Life cycle			
J	Maximum life span	100 years	17
j_r	Retirement age	65 years	10
Preferences and indivisible labor			
γ	Consumption share in utility	French (2005)	0.574
σ	Risk aversion parameter	IES = 0.5	2.742
ℓ_p, ℓ_f, ℓ_e	Indivisible labor	75, 100, 125 perc. full emp.	0.225,0.300,0.375
Technology			
g_z	Productivity growth rate	Annual rate = 0.02	0.104
α	Capital income share	Standard	0.360
δ	Capital depreciation rate	Annual rate = 0.059	0.262
Idiosyncratic labor productivity			
ξ_1, ξ_2, ξ_3	Health-specific productivity		1,1,0
ϵ_{je}	Age-education-specific productivity	Conesa et al. (2018)	Online Appendix
Health insurance			
χ_P	Private insurance coinsurance rate	MEPS	0.229
χ_E	Employer insurance coinsurance rate	MEPS	0.229
χ_{CARE}	Medicare coinsurance rate	MEPS	0.500
χ_{CAID}	Medicaid coinsurance rate	MEPS	0.138
y^{CAT}	Categorical income limit	Kaiser Family Foundation	0.196
y^{MN}	Medically needy income limit	Kaiser Family Foundation	0.091
a^{MN}	Medically needy asset limit	Kaiser Family Foundation	0.041
Health care expenses and health transition probabilities			
m_{je}	Health care expenses		Online Appendix
$Q_{j,e}(h,h')$	Health transition probabilities		Online Appendix
Survival probabilities			
ψ_{jeh}	Age-education-health-specific surv. prob.	MEPS	Online Appendix
College attainment and 20-year-old population growth rate			
	Perc. of population with college degree	Census (average 1980–2005)	0.2276
$g_{n,2005}$	Population growth rate of 20-year-olds	U.N. (average 1980–2005)	0.0150
Taxes			
τ_c	Consumption tax rate	OECD (average 2005–2009)	0.047
τ_k	Capital income tax rate	OECD (average 2005–2009)	0.321

Table 2: **Parameters determined jointly in equilibrium**

Parameter	Description	Target (year = 2005–2009)	Value
θ	Choice of units for output	GDP pc = 1	1.260
β	Discount factor	Capital to annual output = 3	1.109
b_c	SS college replacement rate	Average SS benefits to GDP pc college = 0.293	0.741
b_{nc}	SS non-college replacement rate	Average SS benefits to GDP pc non-college = 0.244	0.607
$\underline{c}$	Consumption floor	Average food stamps = $\$1,227$	0.026
λ	Utility cost of Medicaid	Medicaid expenditure to health expenditure = 0.155	0.005
g_c	Government consumption per capita	Government consumption to output = 0.156	0.156
D	Government debt	Government debt to annual output = 0.545	1.180
	Eligible for employer insurance	Share with private or employer = 0.508	0.303
σ_η	Variance	Labor earnings Gini = 0.630	3.715
η_{top}	Productivity at the top	Labor earnings top 1 percent = 0.148	23.315
π_{top}	Probability at the top	Labor earnings top 10 percent = 0.435	0.013
ρ_n	Persistence	2-year persistence: Bottom 80 percent = 0.941	0.478
ρ_{top}	Persistence at the top	2-year persistence: Top 1 percent = 0.580	0.285

Table 3: **1980–2005 averages and 2100 projections for college attainment and fertility**

Parameter	**1980–2005 (average)**	**2100 (projection)**
Fraction of college graduates 25+	0.2276	0.6742
Population growth rate of 20-year-olds: g_n	0.0150	-0.0026

Figure 1: 2100 projection for age-specific probabilities (longevity)

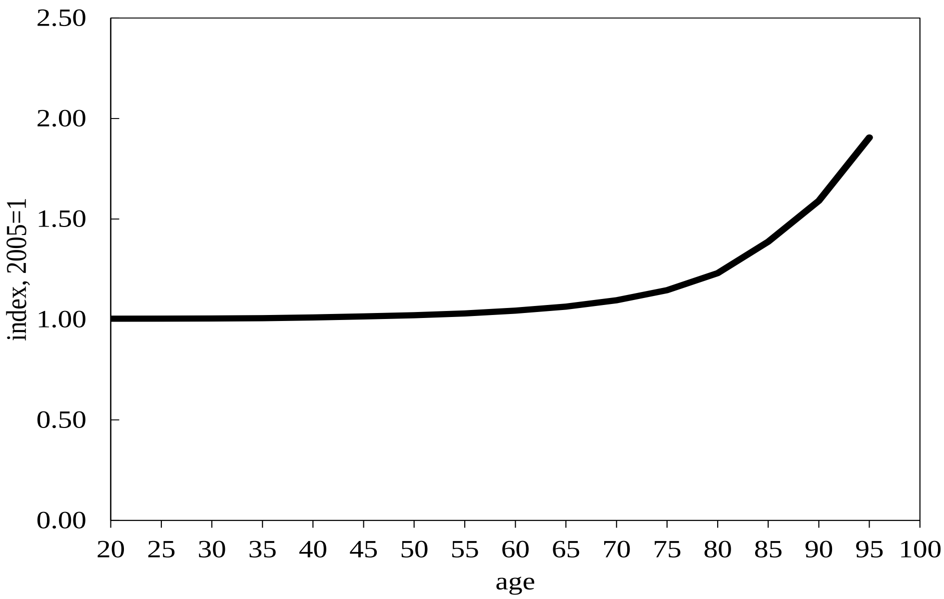


Figure 2: Old age dependency ratio

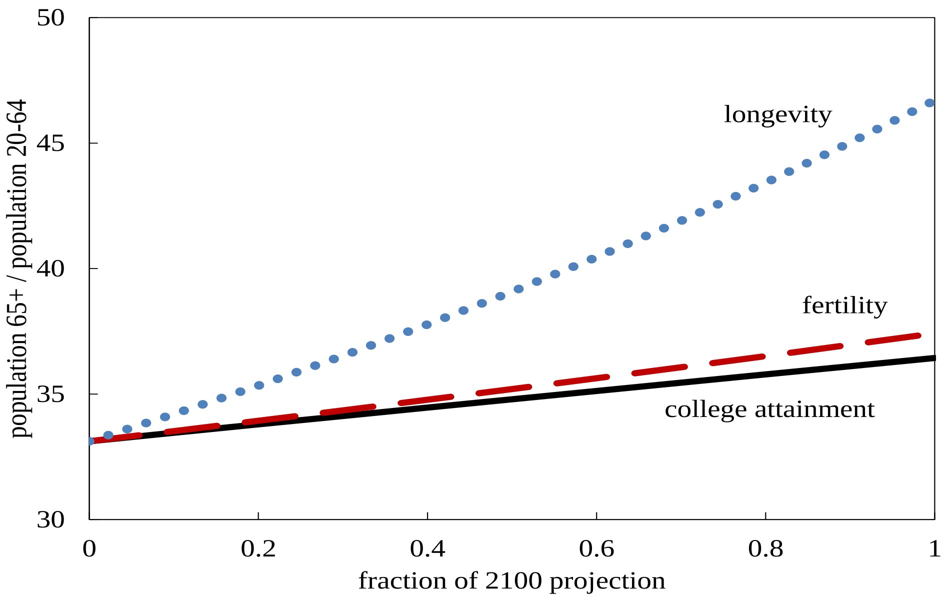


Figure 3: Labor tax rate, τ_ℓ

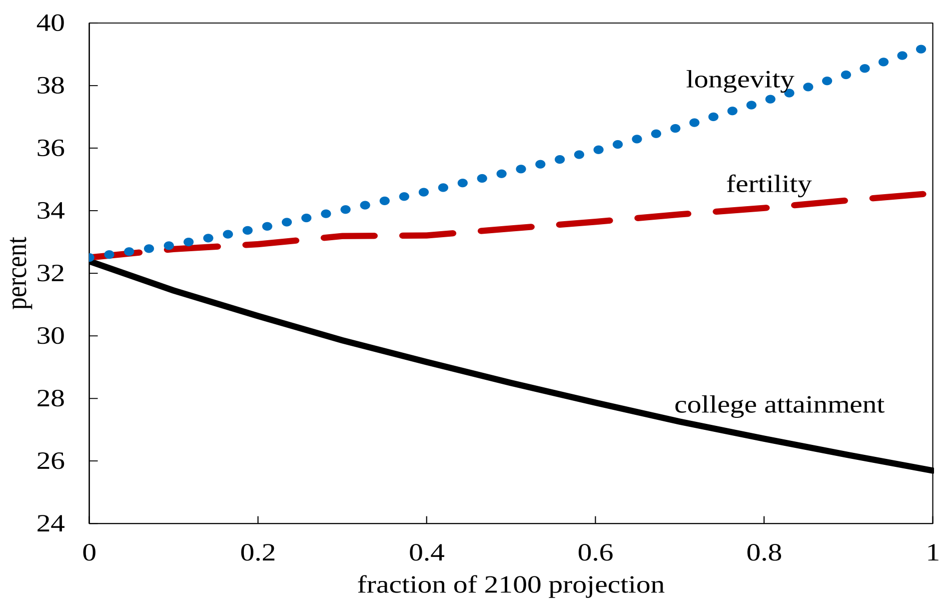
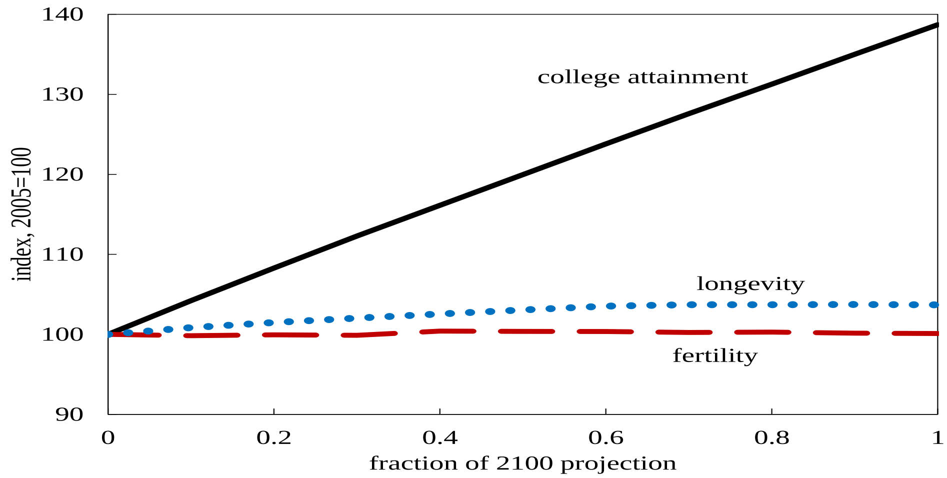
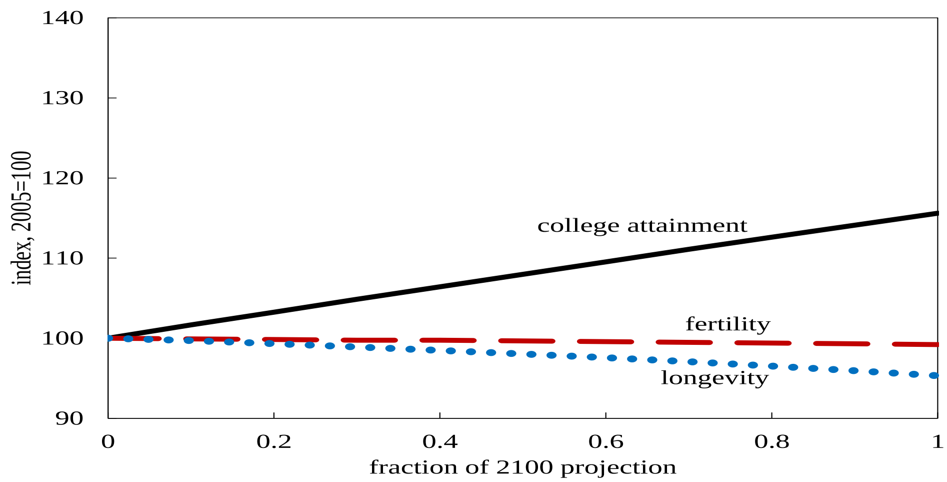


Figure 4: Capital per capita, effective labor per capita, and hours worked per capita

(a) Capital per capita



(b) Effective labor per capita



(c) Hours worked per capita

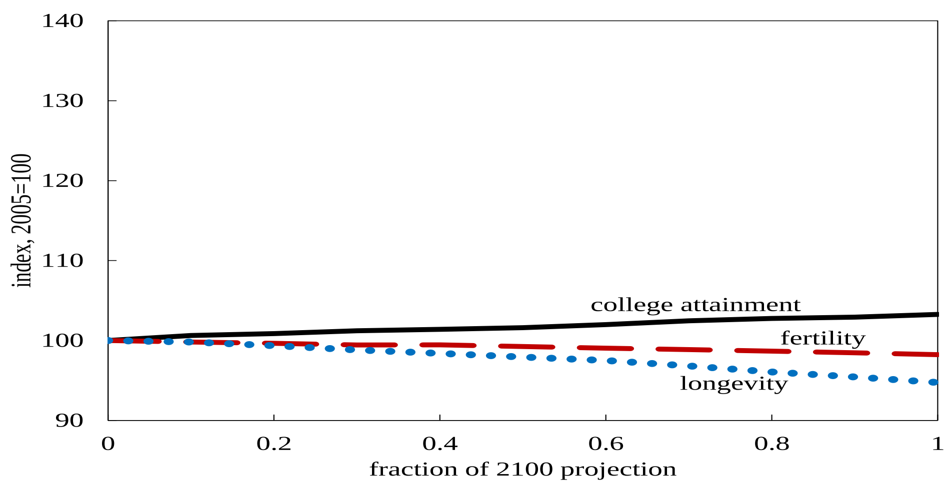
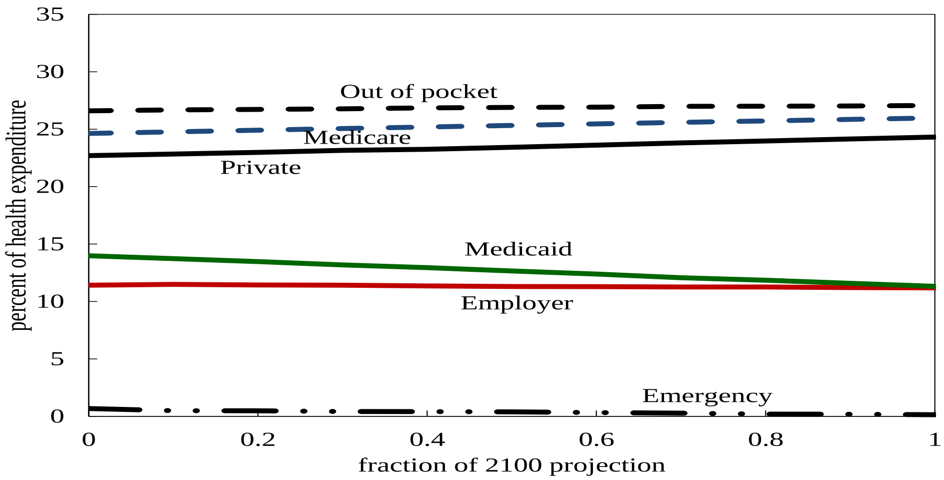
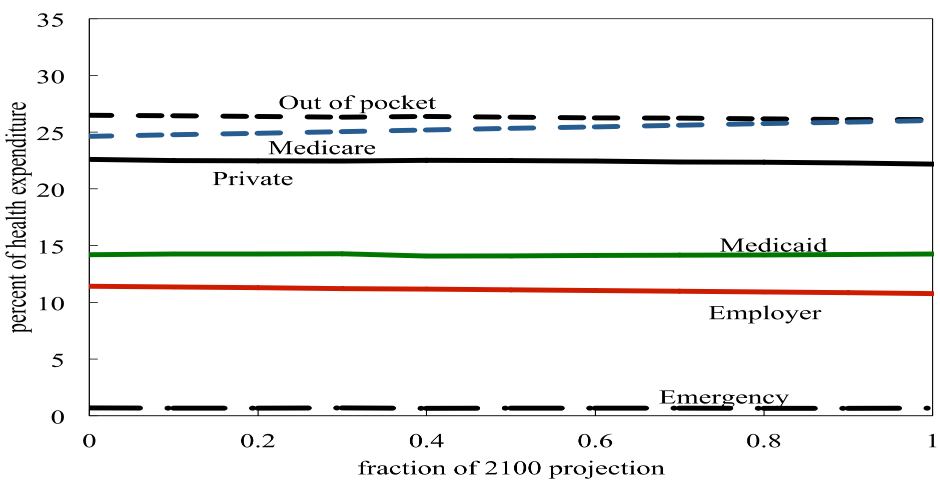


Figure 5: Health care expenditure distribution by provider

(a) College attainment



(b) Fertility



(c) Longevity

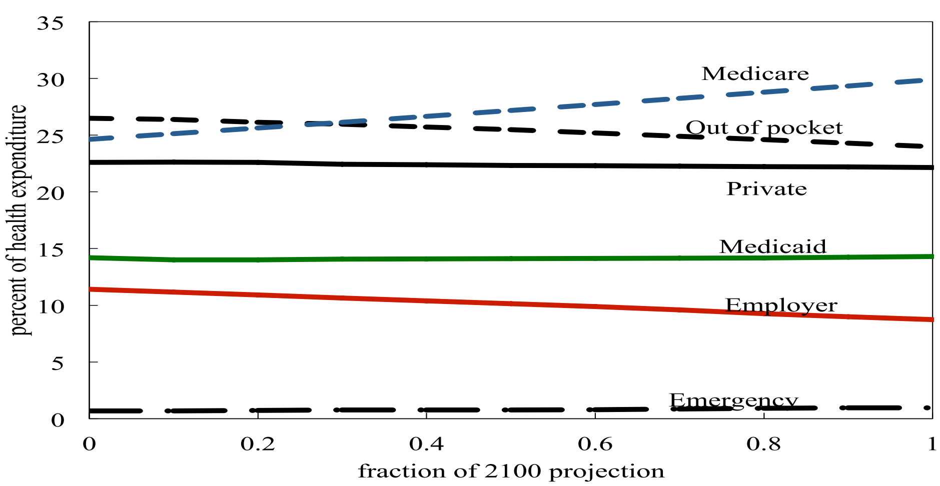
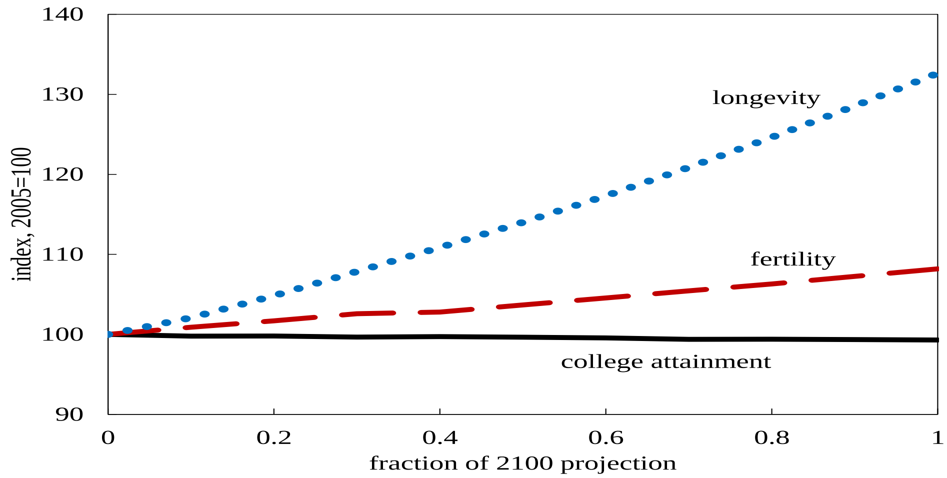
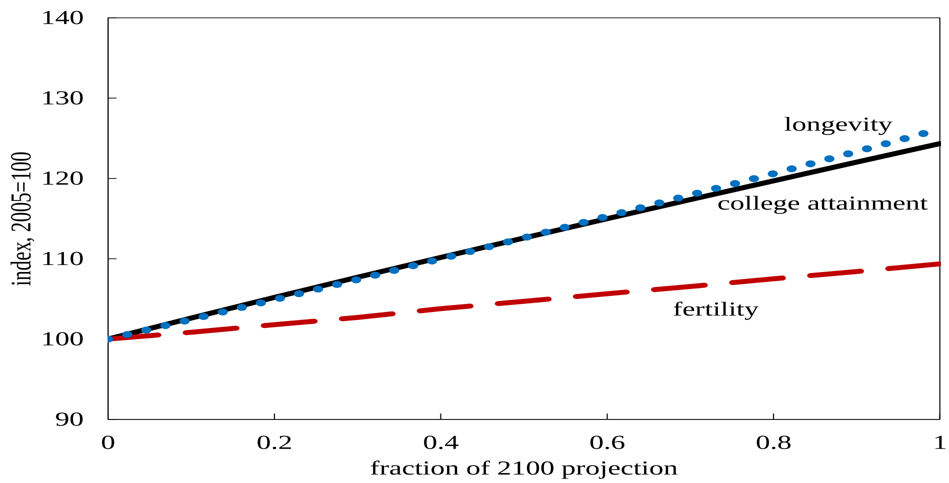


Figure 6: Government spending

(a) Public health care spending per capita



(b) Social Security spending per capita



(c) Interest payments on government debt per capita

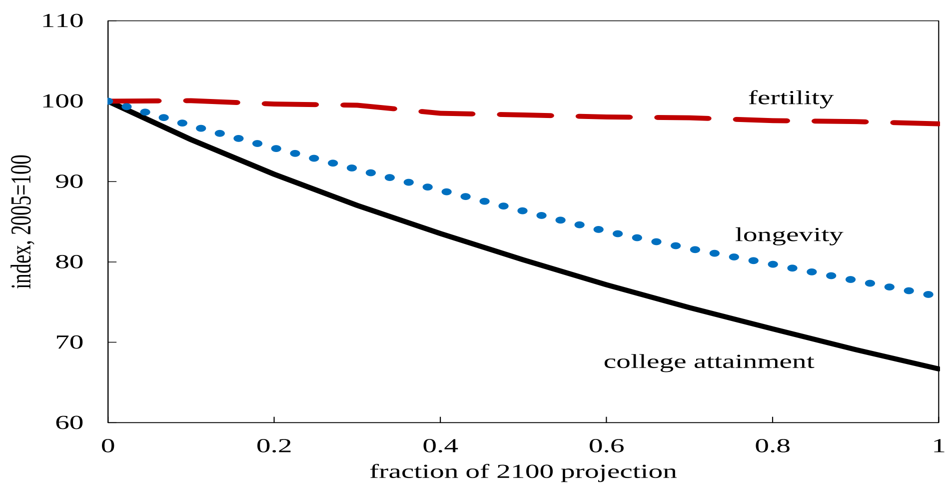
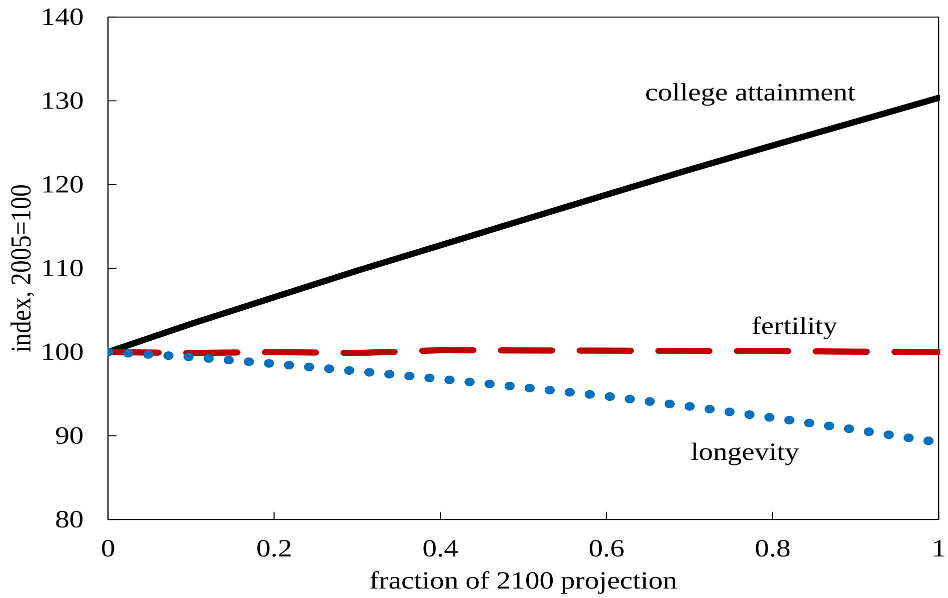


Figure 7: Government revenues from consumption and capital income taxation

(a) Consumption tax revenues per capita



(b) Capital income tax revenues per capita

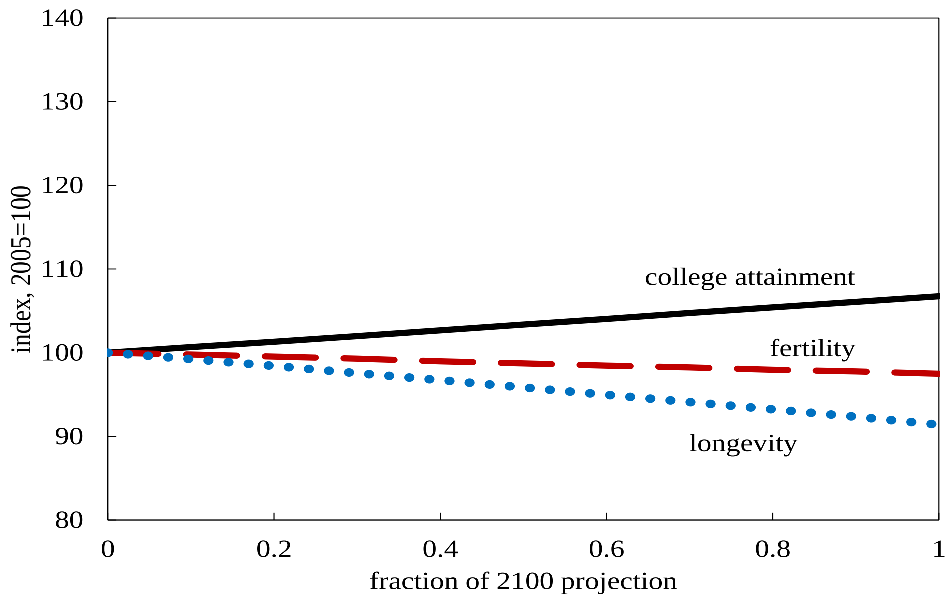


Figure 8: Wage rate, w

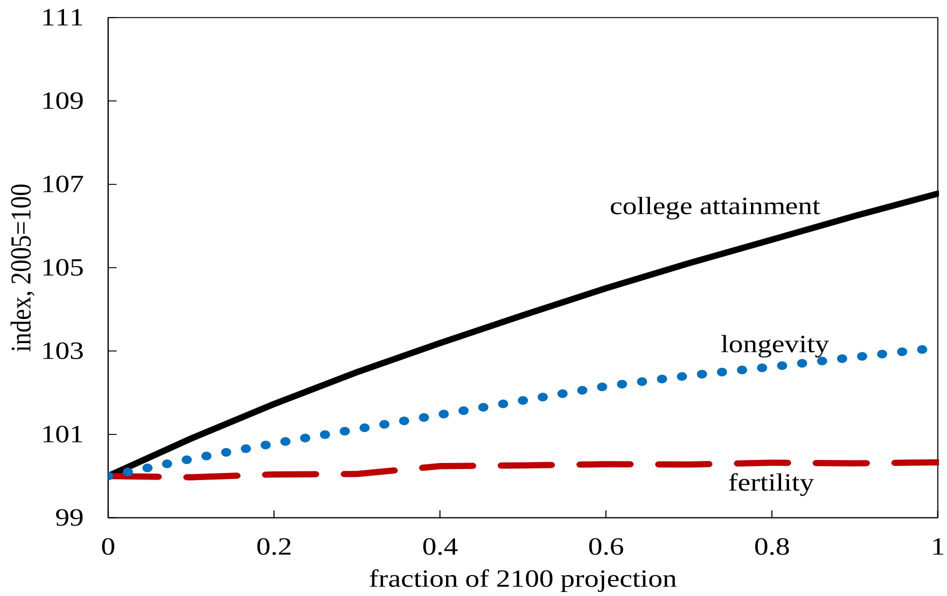


Figure 9: Interest rate, r

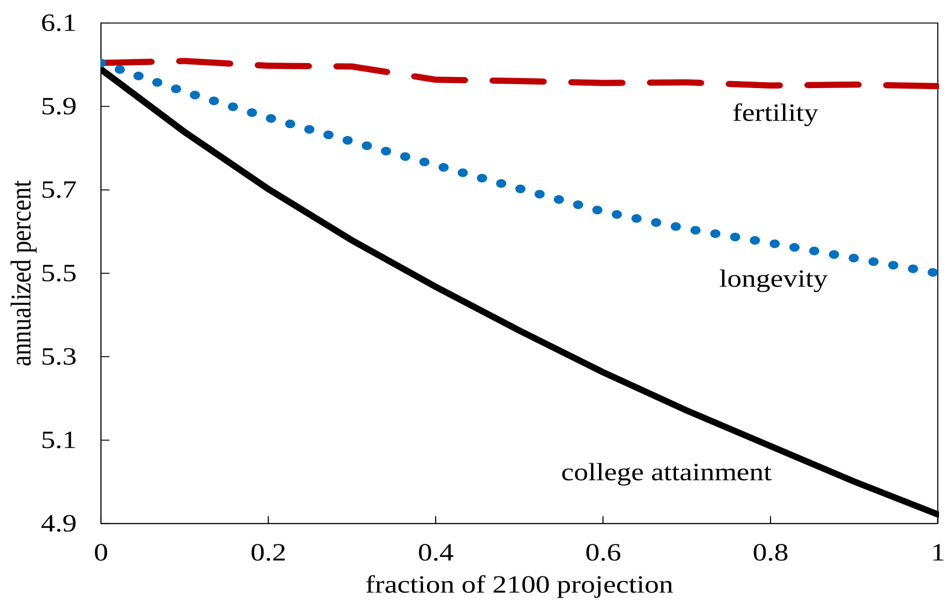
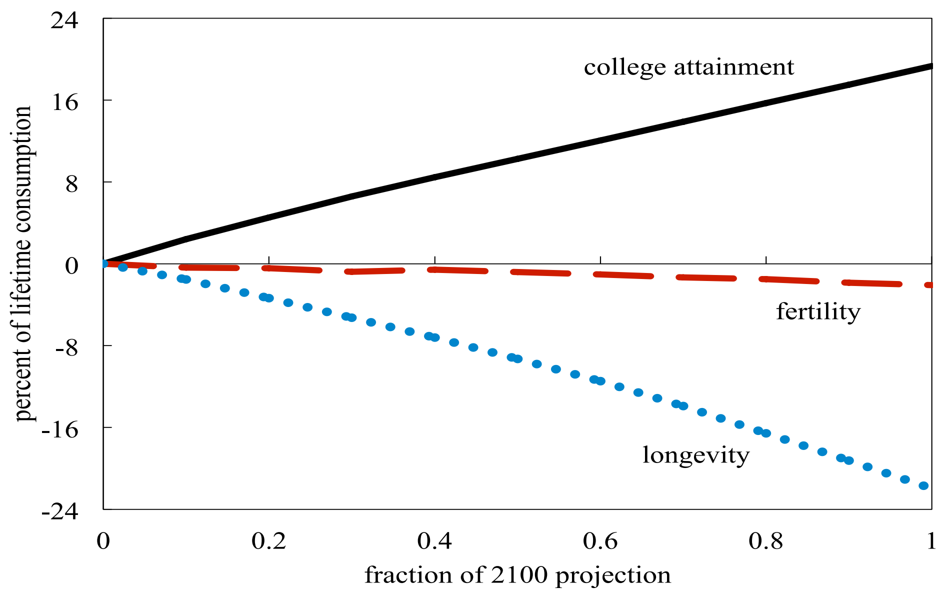


Figure 10: Lifetime consumption gains (losses) for a 20-year-old

(a) With college degree



(b) Without college degree

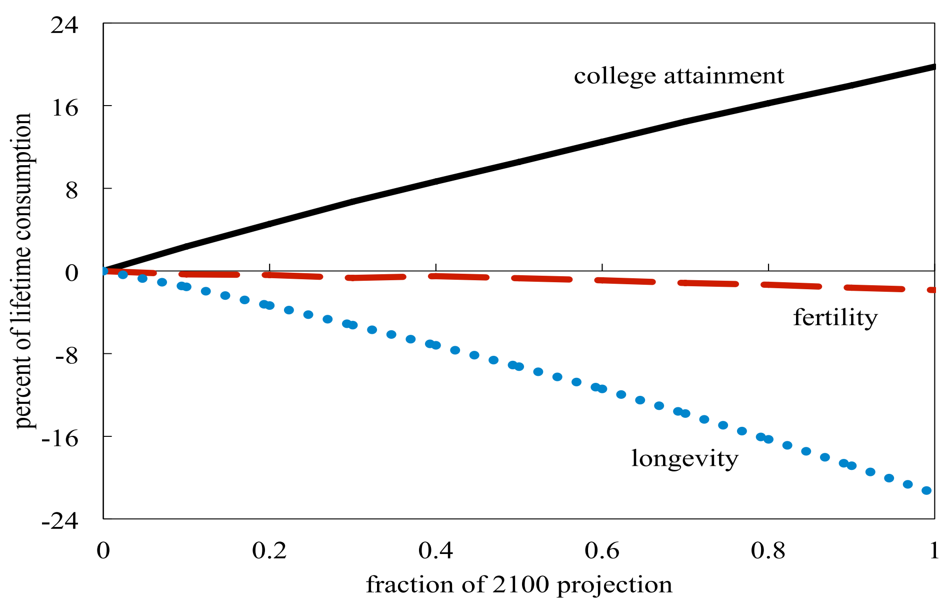
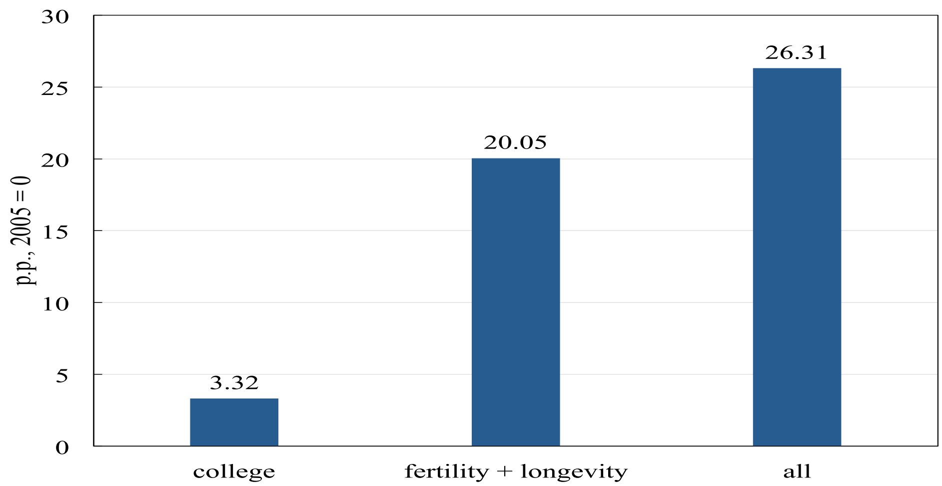
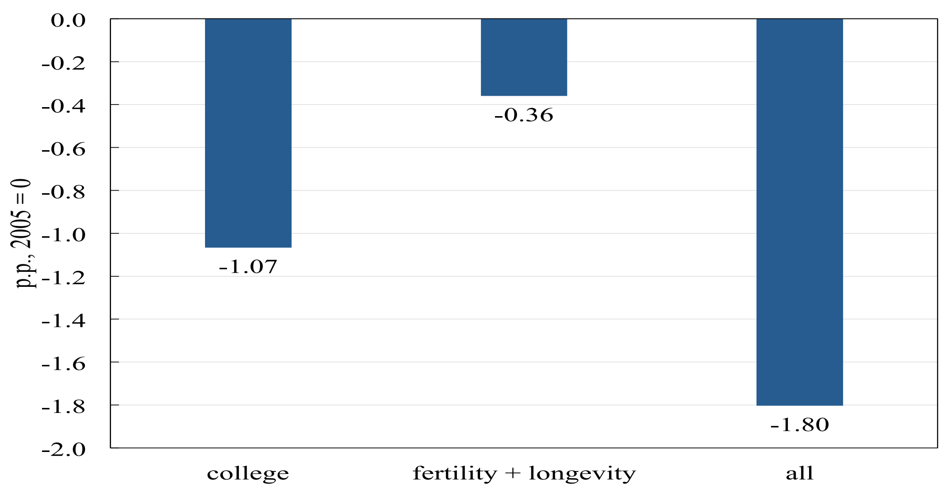


Figure 11: Decomposing interactions between college attainment, fertility, and longevity (part 1)

(a) Old age dependency ratio



(b) Interest rate, r



(c) Wage rate, w

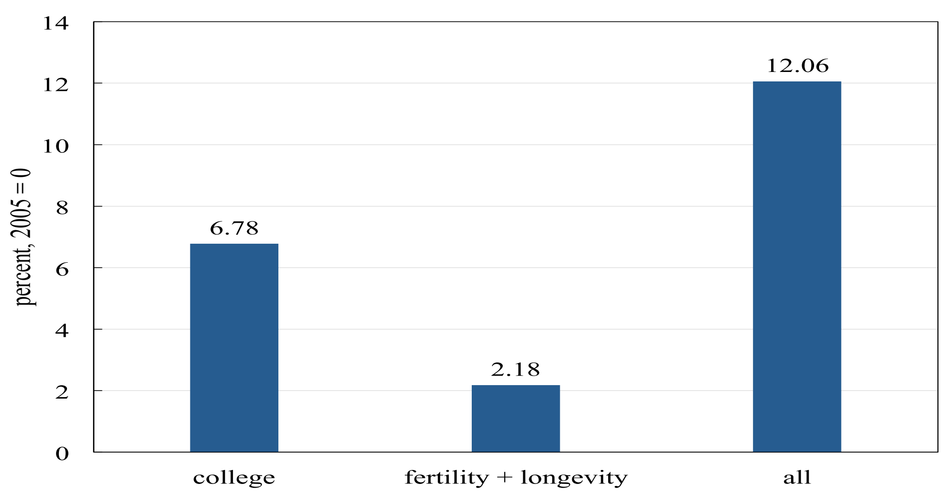
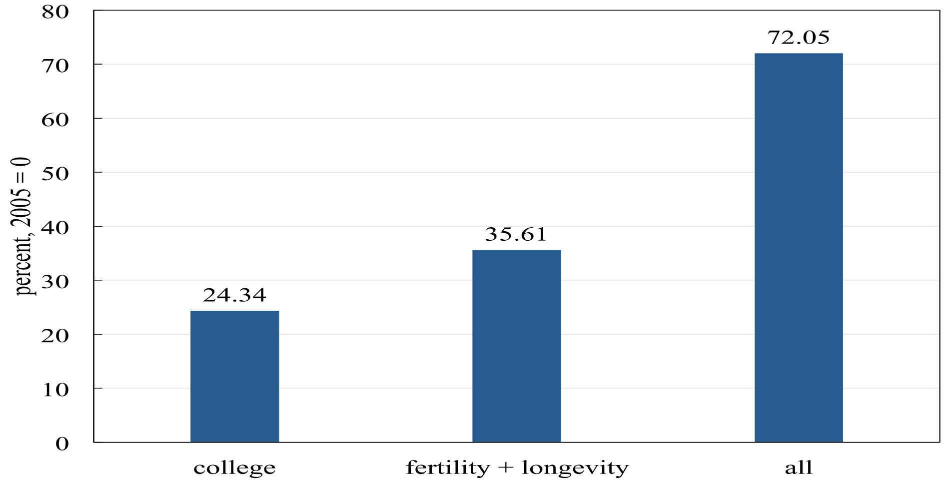
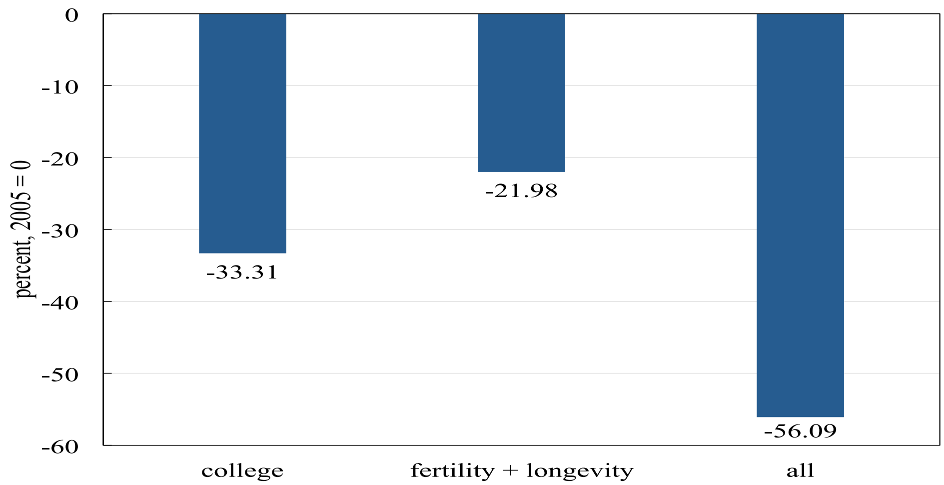


Figure 12: Decomposing interactions between college attainment, fertility, and longevity (part 2)

(a) Social Security spending per capita



(b) Interest payments on government debt per capita



(c) Public health care spending per capita

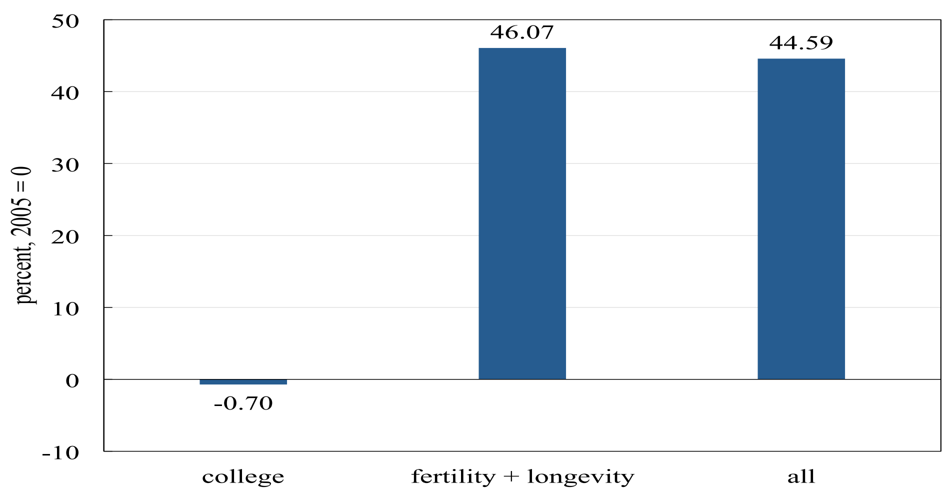
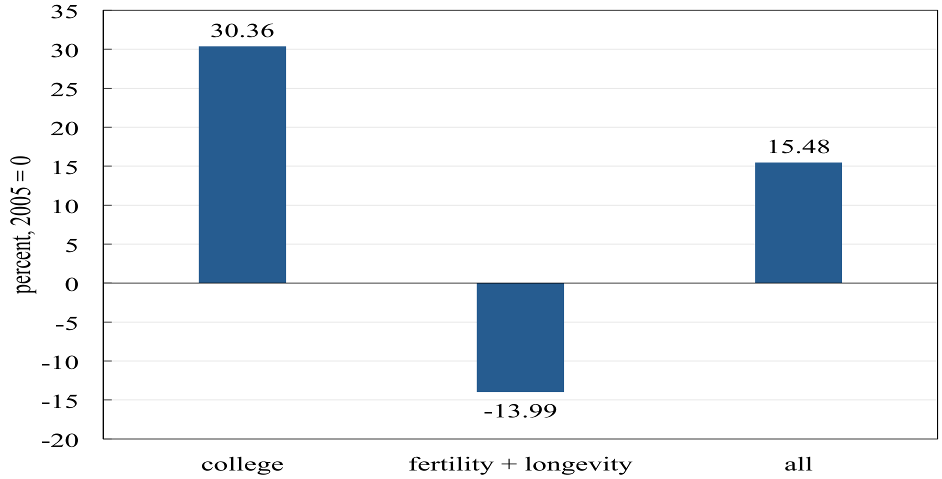
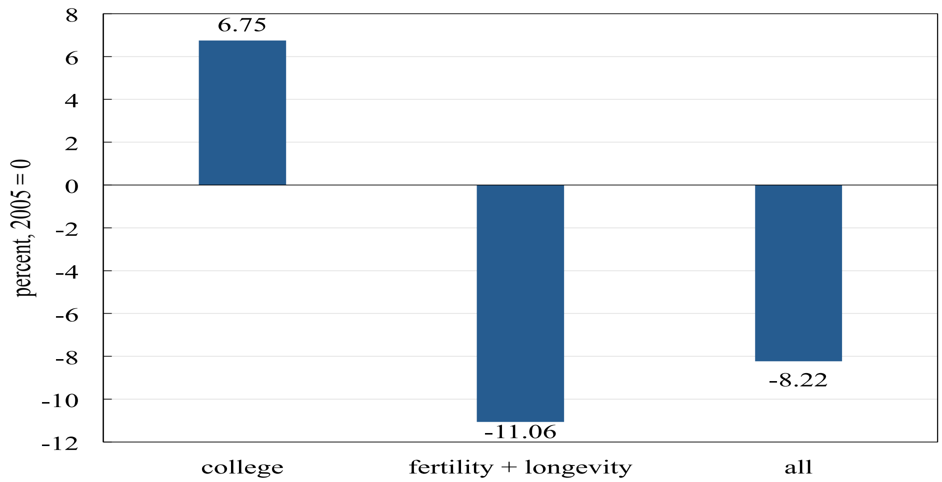


Figure 13: Decomposing interactions between college attainment, fertility, and longevity (part 3)

(a) Consumption tax revenues per capita



(b) Capital income tax revenues per capita



(c) Labor tax rate, τ_ℓ

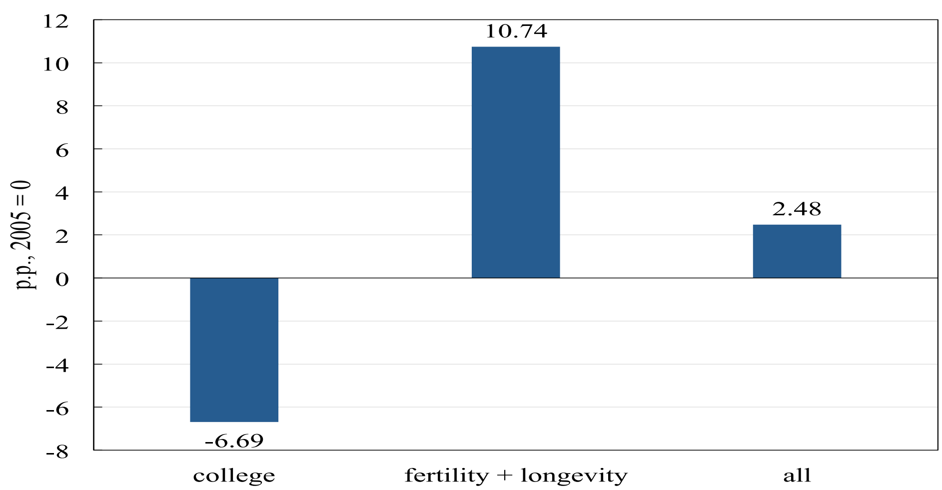
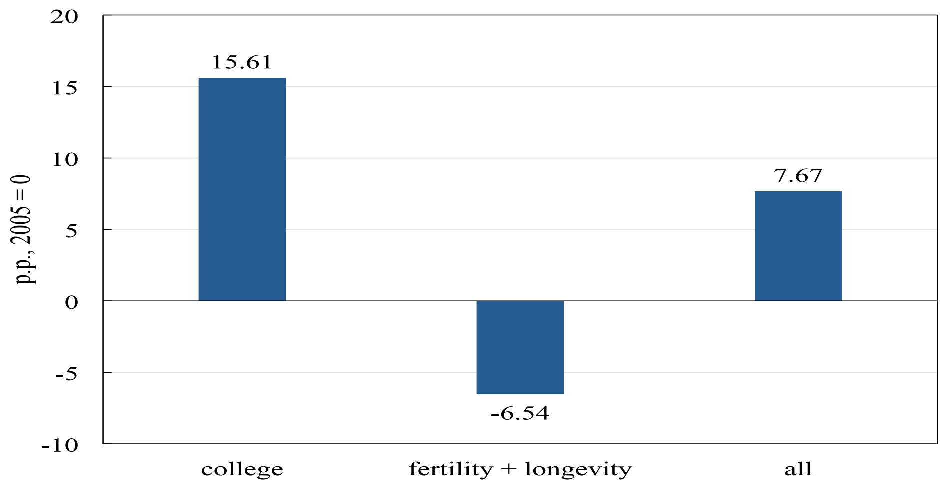
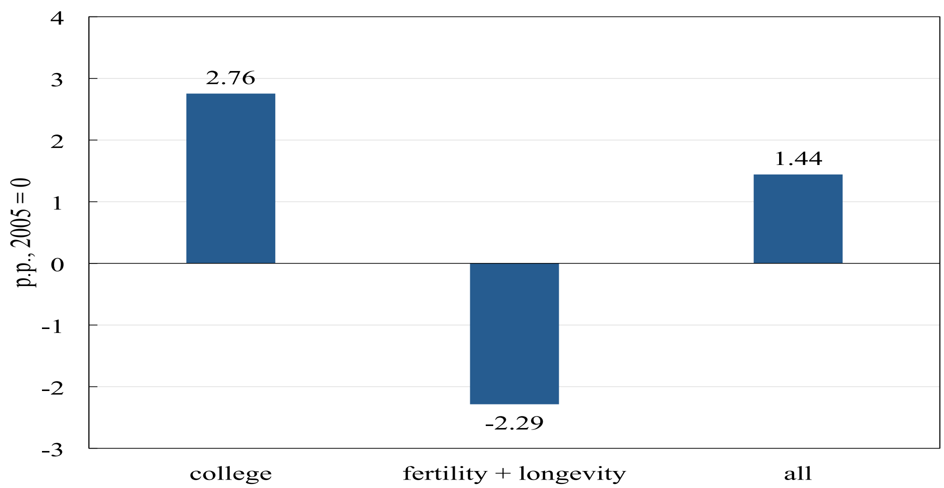


Figure 14: Decomposing interactions between college attainment, fertility, and longevity (part 4)

(a) Effective labor per capita



(b) Labor force participation rate by age (20- to 64-year-old consumers)



(c) Labor force participation rate by age (65+ year-old consumers)

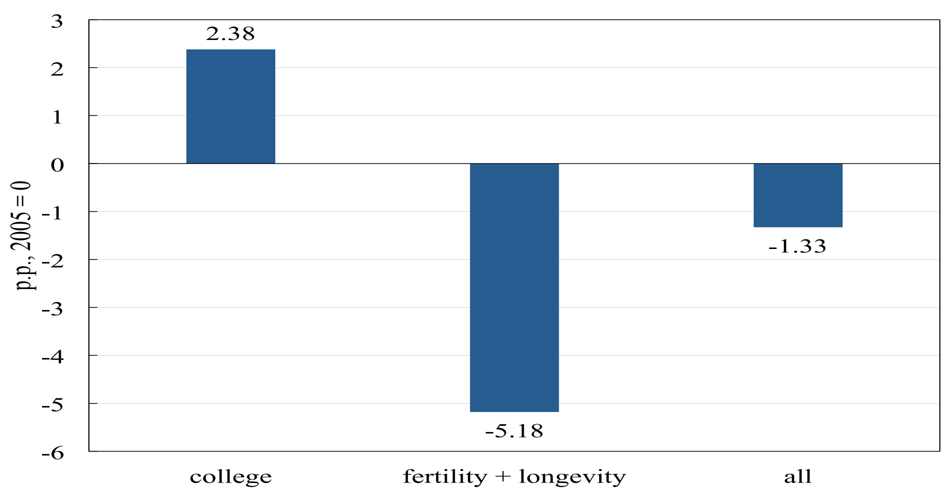
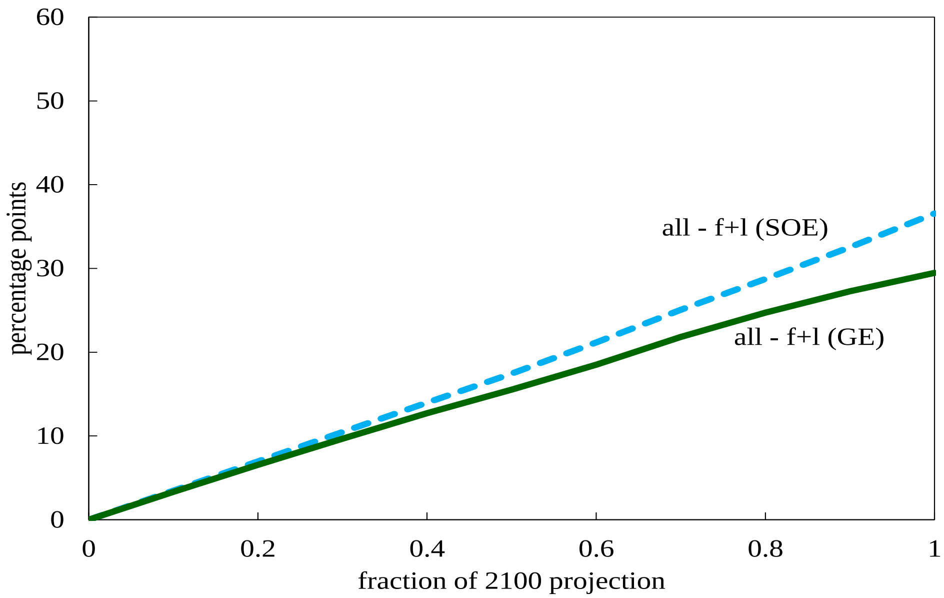


Figure 15: Consumption and capital income tax revenues

(a) Consumption tax revenues per capita



(b) Capital income tax revenues per capita

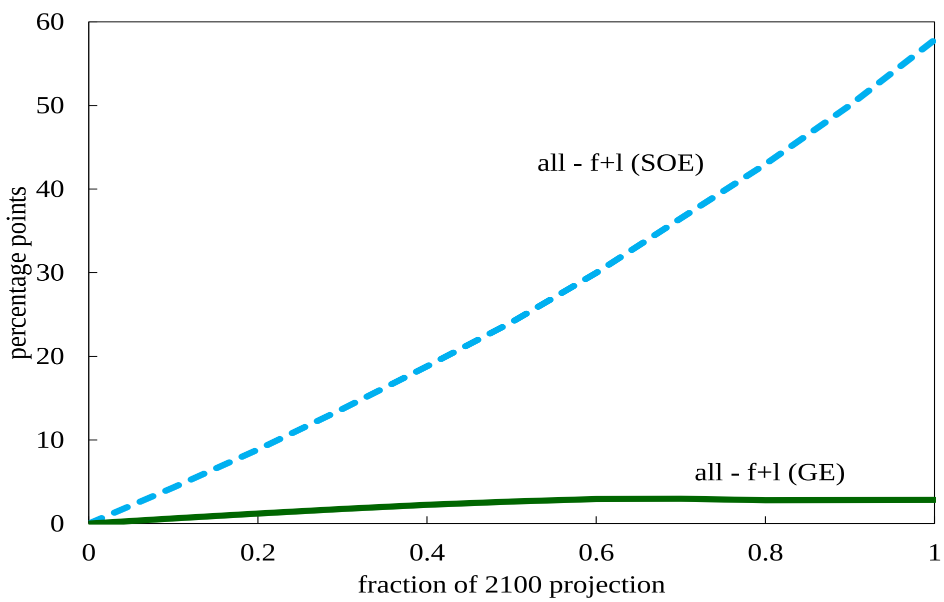
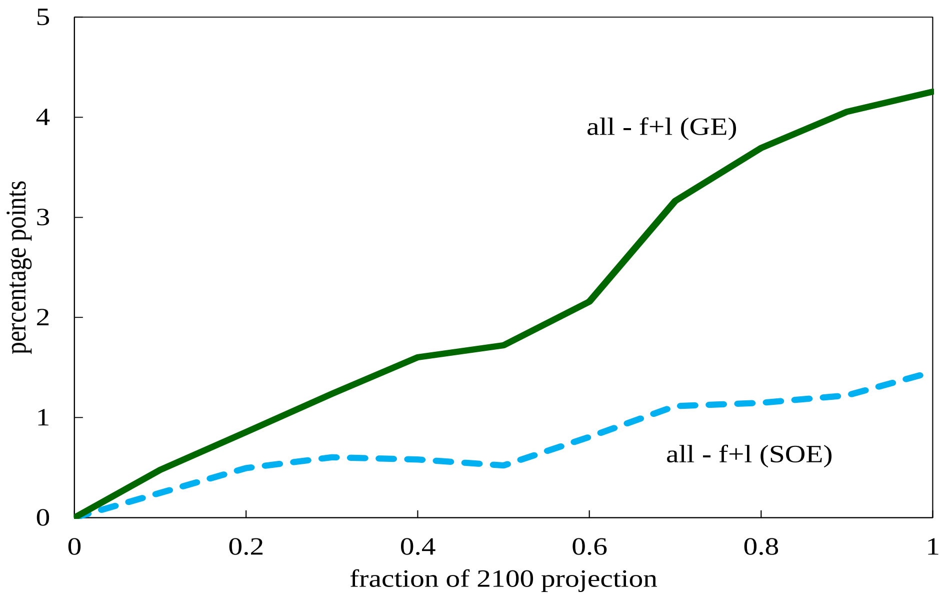


Figure 16: Hours worked per capita and labor tax rate

(a) Hours worked per capita



(b) Labor tax rate, τ_ℓ

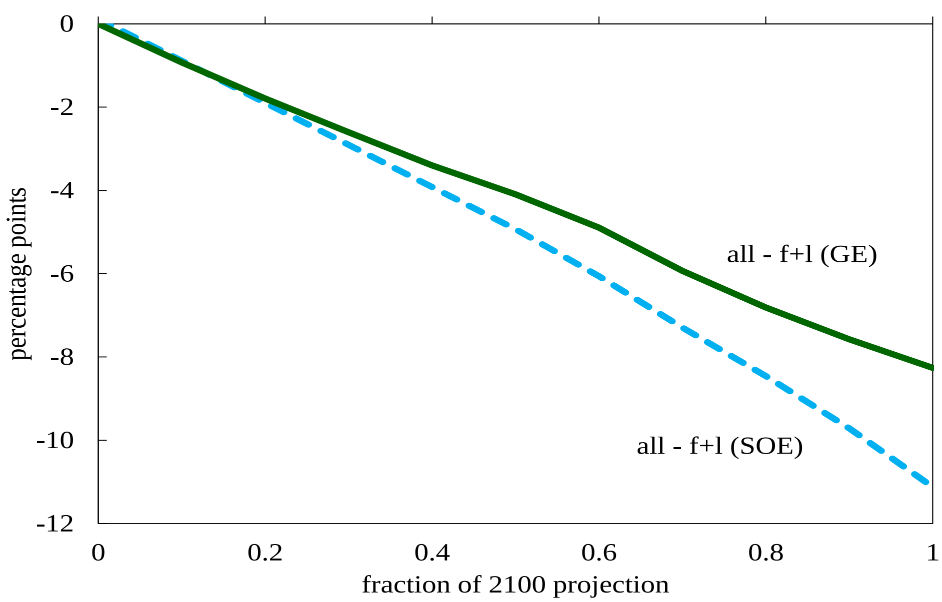
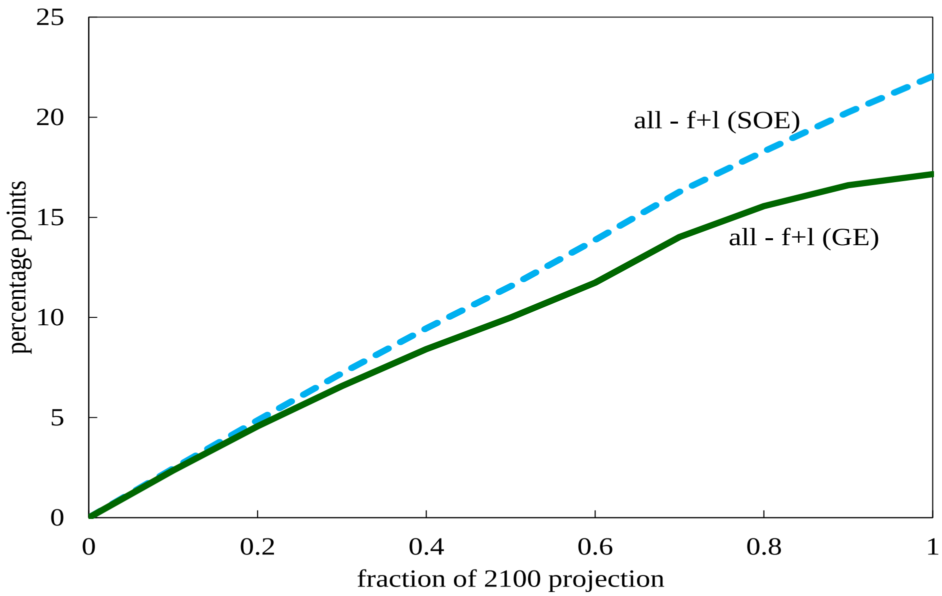


Figure 17: Lifetime consumption gains (losses) for a 20-year-old

(a) With a college degree



(b) Without a college degree

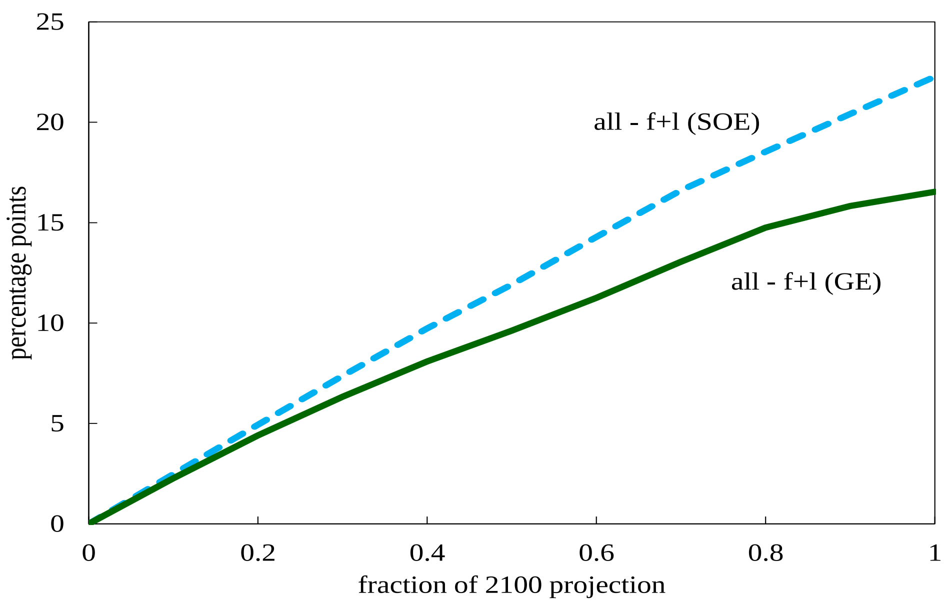


Figure 18: Robustness: model with labor force participation costs

(a) Labor force participation rate by age

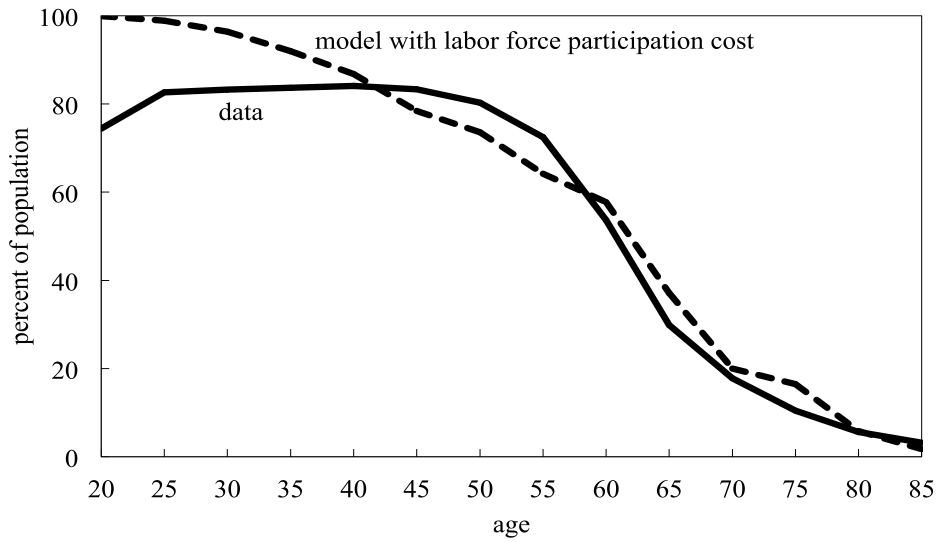


Table 4: Robustness: joint implications of college attainment, fertility, and longevity (all)

Variable (percent/p.p., 2005 = 0)	**Benchmark**	**Labor force part. cost**	**No gov. debt**
Old age dependency ratio	26.31	26.31	26.31
Social Security spending per capita	72.05	71.06	64.51
Public health care spending per capita	44.59	48.05	47.08
Consumption tax revenues per capita	15.48	10.67	10.74
Capital income tax revenues per capita	-8.22	-9.74	2.28
Interest payments on gov. debt per capita	-56.09	-54.38	n/a
Interest rate (annualized)	-1.80	-1.72	-1.12
Wage rate	12.06	11.41	7.15
Labor tax rate	2.48	4.11	5.19
Effective labor per capita	7.67	5.20	6.84
Capital per capita	47.73	42.03	29.42