The Growth-Cost of Demographic Change in Europe[*]

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February 15, 2019
Preliminary

Abstract
Since the early 1990's there have been persistent slowdowns in the growth rates of the four largest European economies: France, Germany, Italy, and the United Kingdom. This persistence suggests a low-frequency structural change is at work. Aging populations, both in terms of longer individual life expectancies and declining fertility have caused a shift in the age-cohort distribution. Growth accounting identifies the following five sources of economic growth: total factor productivity, capital accumulation, labor supply on the intensive and extensive margin, and population growth. Changing demographics affect all these five margins. The effects of aging populations on economic growth are also exacerbated by the pension systems in place. In order to fund increasing liabilities with a shrinking tax base, tax rates must increase to balance budgets. This will impose distortions to individual factor-supply choices, providing further headwinds for economic growth. We quantify the additional growth effects resulting from these distortions.

JEL Classification Codes: ....

Keywords: ....

[*]some expression of gratefulness to ppl who deserves it
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1 Introduction

Since the early 1990's there has been a slowdown in long run growth among Europe's largest economies. The differences in growth rates for these countries are also persistent. Changing demographics, in particular aging populations, is one feature that can have important implications for measured economic growth around the world and across countries. Increased life expectancy affects households' decisions over the life cycle, while shifts in the age-cohort distributions of populations affects the aggregation of these decisions. Europe's four largest economies: France, Germany, Italy, and the United Kingdom have all experienced substantial increases in life expectancy. The combination of declining fertility rates and increased life expectancy have at the same time shifted the age-cohort distributions. These increases in longevity and in the average age of the populations place an increasing burden on pay-as-you-go pension systems. This issue is particularly important in Europe, including among its four largest economies, which tend to have both generous pension systems and high levels of public debt. There is growing concern about the future consequences of these pension obligations. In this paper, we quantify the impact of these demographic changes on growth in Europe's four largest economies, including the additional frictions and distortions that result from the higher marginal taxes necessary to pay for the pension benefits of an aging society.

Traditional growth accounting allocates growth outcomes to five factors: total factor productivity growth, population growth and factor supply - specifically capital accumulation and labor supply on both the intensive and extensive margin. Between 1995 and 2015, Europe's four largest economies have seen substantial gains in longevity that impact this growth accounting. Between 1995 and 2015, life expectancy at birth increased from 77.3 to 80.4 years. Moreover, during the next 20 years, the United Nations project an increase from 81.8 to 84.2 years among the European G7 countries. Longevity gains together with lower fertility rates have shifted the age-cohort distribution to the right.

Increases in longevity affect individual factor supply decisions. An unexpected increase in individual life expectancy induces higher savings on the part of agents in order to smooth consumption over a longer time horizon. In addition, changes in life expectancy alter the labor supply decisions of households on with respect to how many years they work (the extensive margin) and how many hours on average they work (the intensive margin). These labor-supply decisions reflect a trade-off between incentives to save for a longer expected life span and the disutility of working when old.

Shifting age-cohort distributions affect the aggregation of these individual decisions. A rightward shift in the age-cohort distribution implies that more households may be in their highest savings years, thereby increasing the aggregate capital stock. Likewise, more households will enter the ages where they substantially decrease their labor supply. More subtly, shifts in the age-cohort distribution may affect measured total factor productivity. As a young population ages a greater fraction of the households will be in the most productive periods of their lives, thereby increasing measured TFP. As an older population ages, the reverse is true. Finally, there are strong general-equilibrium effects. The changes in aggregate factor supplies and TFP alter factor prices, which again affect individual decisions.

Pension systems exacerbate the growth effects of demographic change. As populations age, more households become eligible for retirement benefits, increasing the liabilities of governments. Coupled with a shrinking tax base as the relative number of working-age individuals decreases, tax rates must increase to balance government budgets. Changes in tax rates introduce additional frictions and distortions to individual saving and labor supply decisions and provide further headwinds for economic growth.

Using an overlapping generations model with a rich demographic structure, endogenous retirement, and a pay-as-you-go pension system, we find that past demographic change was a drag on economic growth in the four largest European economies. France fared the worst and the UK remained largely insulated. Over the next 20 years, however, Italy, Germany, and the U.K. will experience the worst drag from demographics. The primary channels through which this demographic change operates are capital accumulation and decreases in the employment-population ratio. In fact, the negative growth effects of demographic change operate almost exclusively through the extensive margin of labor supply. We find that decreases in the employment-to-population ratio largely outweighed increased savings historically. This suggests that demographic change is partially to blame for the economic slowdown in these European countries.

Moreover, incorporating a pension system is of first order importance for understanding the effects of demographic change even when pension reform is not the primary focus of the model. In fact, we find that the need to finance pension systems exacerbate the growth contributions of demographic change by 5.6% – 11.1% between 1995-2015, and by 8.3% – 55.6% from 2020-2040. This results from the fact that demographic changes will place a significant burden on pension systems in the coming years. While pension outlays as a fraction of GDP grew by less than 2 percentage points in all four countries from 1995-2015, we find that outlays will increase by 3 to 10 percentage points over the next 20 years. Indeed, all four countries will see their pension outlays as a fraction of GDP reach double digits by 2040, ranging from 12.7% in the UK to 25.4% in Italy.

Our model provides a laboratory to evaluate policy proposals to increase growth rates and balance government budgets. A crucial margin for welfare evaluations of policy proposals is the disutility of labor supply at different stages of the life cycle. In order to account for observed labor-supply choices on both the extensive and intensive margin, disutility of labor must increase strongly at old ages. This has immediate relevance for the welfare consequences of any policies that either incentivises or mandates labor-force participation at old ages. This paper is therefore closely related to the literature on aggregate labor supply, such as e.g. Erosa et al. (2012) and Erosa et al. (2016).

Previous studies have also recognized the importance of demographic change for capital accumulation. Backus et al. (2014), Henriksen and Lambert (2009), and Feroli (2003) investigate the effect of demographic change on international capital flows. Gagnon et al. (2016), Carvalho et al. (2016), and Ikeda and Saito (2014) show the impact of demographic factors on the real interest rate in the United States and Japan. All of these papers have focused on the demand for and supply of capital rather than all factor supplies and economic growth. Auclert and Malmberg (2018) studies how changing demographics may affect future growth, taking all decisions as given. Closest to this paper is Cooley and Henriksen (2018), which models capital and labor supply decisions and study the growth effects of demographic change in the U.S. and Japan in an otherwise frictionless model.

This paper is also closely related to the extensive literature on the implications of aging for the sustainability of social security systems based on multi-period overlapping generation models. See, for example, A.J. and Kotlikoff (1987), De Nardi et al. (1999), Fuster et al. (2007), Kotlikoff et al. (2007), Kitao (2014), Conesa and Garriga (2016), and İmrohoroğlu et al. (2016). These studies evaluate how aging is likely to increase the tax burden required to fund the social security system over a given period of time and how the resulting welfare cost could be mitigated through various reforms of the social security system.

The rest of the paper is organized as follows. Section 2 describes the long term growth and demographic trends in France, Germany, Italy, and the United Kingdom. Section 3 describes three versions of our pension system that we consider along with three different specifications for household preferences. Section 5 presents our historical decompositions and growth projections as well as our pension reform experiments. Section 6 concludes.

2 Growth and Demographic Change

Prior to the 1990's, Europe's four largest economies remained largely on par with one another. Beginning in 1990, however, these same countries saw a dramatic downward shift in GDP growth. Though France, Italy, and the United Kingdom rebounded slightly during the following several years, each converged to a flatter balanced growth path shortly thereafter. Furthermore, while France, Italy, and the United Kingdom remained on par with one another for several years, they quickly began growing apart in the mid to late 1990's as shown by Figure 1. Such changes in long-run growth could be due to many factors - one such factor is demographic change.

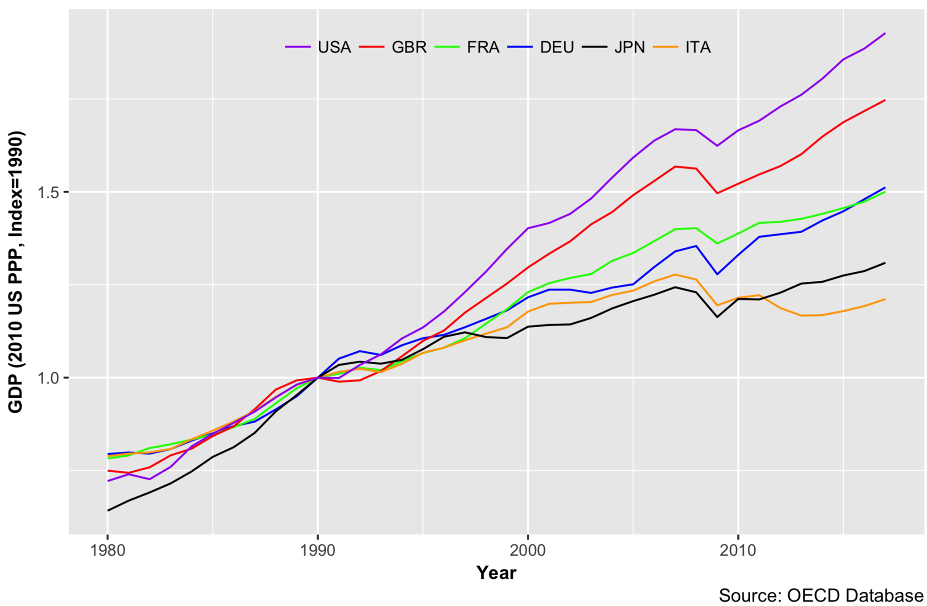
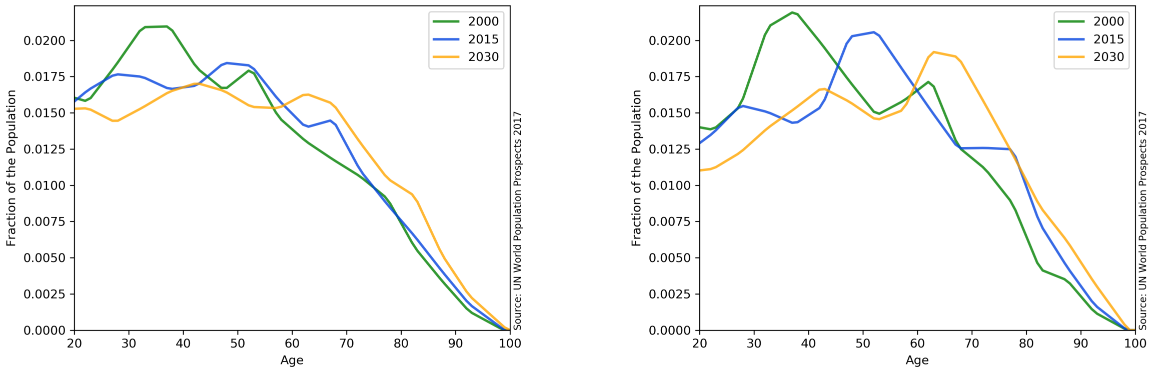


Figure 1: Aggregate Real GDP in G7 Economies Excluding Canada and Japan

Indeed, over this period the age-cohort distribution of these advanced economies began shifting rightward to varying degrees. Figure 2 illustrates this historical shift for the United Kingdom and Germany, respectively, and how they differ. Two characteristics stand out. First, it is clear that there has been a non-trivial shift in the age-structure of the population in each country. In both the United Kingdom and Germany, a combination of declining fertility rates and mortality rates has caused the population distribution to shift towards older individuals, a trend that is projected to continue for the forseeable future. Second, we see that the rightward shift in the cohort distribution was more drastic in Germany than in the United Kingdom. The differences in these trends imply that demographic factors played a greater role in accounting for the decline in German growth than for that in the United Kingdom.



(a) United Kingdom **(b)** Germany

Figure 2: Changing Cohort Distributions in United Kingdom and Germany

The trend in life expectancy at birth among the G7 nations stabilized during the 1990-1995 period as is shown in Figure 3. From 1995-2007, life expectancy at birth among the European G7 nations increased from an average of 77.3 to 80.4. UN projections of life expectancy among these nations continues this trend. Indeed, life expectancy is projected to increase from 81.8 to 84.2 among these same countries between 2015 and 2030.

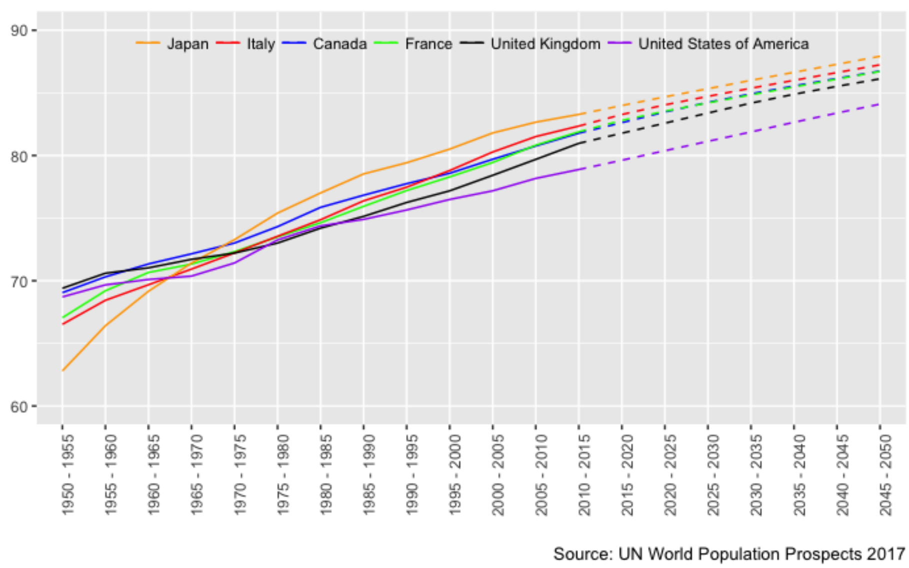


Figure 3: Life Expectancy at Birth in G7 Economies

The combination of increased life expectancy and shifting age-cohort distributions has several important implications for individual decision making and the aggregation thereof. Because life expectancies are increasing, individuals must plan for a longer time horizon than previously. Individuals must accumulate more assets during their working lives to carry themselves through a longer period in retirement. Because one of the primary means of acquiring additional assets is through labor income, this increased life expectancy implies that individuals may need to work longer hours and later in life to sustain their increased lifespan. The shift in cohort distributions changes how decisions made at the individual level are aggregated. That is, the rightward shift in the cohort distribution implies that these countries have and will continue to see an increase in the fraction of the population later in their working lives and thus with potentially higher levels of asset holdings depending on where along the demographic transition path a country lies. Additionally, an aging population could imply either a larger or smaller fraction of the population in the most productive years of their lives, again depending on where in the demographic transition each country finds themselves. Finally, increasing the fraction of the population at or above retirement age both increases the size of government outlays in the form of old age benefits and erodes the tax base from which these benefits can be funded, placing an increased tax burden on each member of the workforce.

All of these factors affect the aggregate capital stock, labor supply on both the intensive and extensive margin, and equilibrium prices, which in turn affect aggregate output (i.e. GDP) and the taxes necessary to finance old age benefits. Perhaps less obvious is the fact that this demographic change also affects measured TFP. As the cohort distribution shifts, so too does the average labor productivity of the workforce. This change in the average labor productivity would show itself in the form of TFP change in any growth accounting exercise. Generous pension systems also have implications for economic growth. As pension systems become more (less) generous, the incentive for individuals to accumulate more assets and work harder/longer during their lives as life expectancy increases is mitigated (amplified) . The increased tax burden resulting from an eroding tax base may hinder individuals' abilities to save, though they may incentivize indidivuals to work more depending on the structure of the tax system. The decrease (increase) in individual asset accumulation and in the intensive/extensive labor supply incentives mitigates (promotes) growth in output.

3 Model

Our model has a rich demographic structure that incorporates both changes in life expectancy and changes in fertility. Because the effects of demographic change operate through both the intensive and extensive margins of labor supply, we incorporate these features. Finally, in order to assess how pensions alter the growth effects of demographic change, our model incorporates a pay-as-you-go pension system with guaranteed old age benefits. In this section, we begin by presenting our simple benchmark economy without pensions, which is modeled as in Cooley and Henriksen (2018). Subsequently, we incorporate a simple pension system where old age benefits are constant and financed through either lump sum or distorting taxes. We decompose the growth effects of demographic change into a direct effect and an indirect effect operating throughthe increasing wedges necessary to finance increasing pension outlays. These environments allow us to discuss the extent to which pension systems matter in models of growth and the margins most affected by them. They also provide an environment for evaluating pension policy reforms.

3.1 Households

In each period, households receive lump sum accidental bequests, b_t, make a consumption-saving decision, and split one unit of time between leisure and labor supply in a frictionless labor market.

Households within each cohort differ due to exogenous idiosyncratic labor productivity shocks, which we assume follows an AR(1) process in logs given by

$$\log \eta_{i+1} = \rho \log \eta_i + \epsilon_{i+1} \tag{1}$$

where $\epsilon_i \sim \mathcal{N}\left(0, \sigma^2\right)$ is Gaussian white noise. Households differ between generations because of deterministic life cycle productivity differences, ψ_i. Households also make an endogenous and irreversible retirement decision. The productivity differences impact labor supply decisions throughout life. In particular, households who have received a series of high idiosyncratic productivity draws are more likely to remain in the workforce than those that received a series of poor draws.

Households also face a cost to participating in the labor force, θ_j, which we is convenx in age and can be calibrated to labor force participation rates at various ages. As in Cooley and Henriksen (2018) and Kitao (2014), we model the cost to participation in terms of leisure hours.[1]

The cost of labor force participation is given by the convex function:

$$\theta_i = \kappa_1 + \kappa_2 \cdot i^{\kappa_3} \tag{2}$$

[1] Ndiaye (2017) also incorporates a cost to participation that varies by cohort, though he models it as a utility cost rather than a cost to leisure hours.

where i denotes age.

This specification is convex in age and captures the idea that the cost of participation increases nonlinearly with age.

We assume that households maximize expected lifetime utility and have preferences over consumption and *effective leisure*. Moreover, we assume that utility is additively separable within and across periods, and that it takes an isoelastic form given by

$$u(c,h) = \frac{c^{1-\sigma}}{1-\sigma} + \chi \frac{(1-h-\theta_i \cdot I_p)^{1-\gamma}}{1-\gamma} \tag{3}$$

Here, σ denotes the elasticity of intertemporal substitution, $l = 1 - h - \theta_i \cdot I_p$ is effective leisure, and γ defines the curvature over effective leisure. Moreover, I_p takes a value of 1 if $h > 0$ and 0 otherwise.

In our benchmark model, we consider a frictionless model with no taxes and no pension systems. Thus, the household budget constraint is given by

$$c_{i,t} + a_{i+1,t+1} = (1+r_t)a_{i,t} + w_t \cdot h_{i,t} \cdot \psi_i \cdot \eta_{i,t} + b_t \tag{4}$$

Furthermore, note that the budget constraint of retired and working households are identical in this environment, but with $h = 0$ when retired. We also assume that households begin their economic lives with no assets and enforce a no-ponzi condition so that

$$a_{i_0,t} = 0 \qquad and \qquad a_{i_{max},t} \geq 0 \tag{5}$$

where i_{max} is the age at which the conditional survival probability, $s_{i,t}$, is 0 at time t. We maintain (5) throughout the paper.

3.2 Technology

We assume that a representative firm with constant returns to scale Cobb-Douglas production technology demands capital and labor, and produces a numeraire good for consumption in perfectly competitive markets. Thus, the firm's problem is given by

$$\max_{K_{d,t},L_{d,t}} \left\{ K_{d,t}^{\alpha} L_{d,t}^{1-\alpha} - r_t K_{d,t} - w_t L_{d,t} \right\} \tag{6}$$

where $0 < \alpha < 1$ is capital share, $K_{d,t}$ is aggregate capital demand, $L_{d,t}$ is aggregate labor demand measured in efficiency units, r_t is the real interest rate net of depreciation, and w_t is the real wage rate. Moreover, the aggregate capital stock evolves according to the usual law of motion,

$$K_{t+1} = (1-\delta)K_t + I_t \tag{7}$$

where δ is the depreciation rate and I_t is net investment.

3.3 General Equilibrium

An equilibrium in this environment is defined as follows:

1. Households choose savings, consumption, and labor supply on the extensive and intensive margins taking prices as given such that

   - Household's maximize lifetime utility:

   $$v_{LF}(i,a,\eta) = \max_{c,a',h} \left\{ u(c,h) + \beta \cdot s_i \cdot \mathbb{E}_{\eta'|\eta} \max \left\{ v_{LF}(i+1,a',\eta'), v_R(i+1,a') \right\} \right\}$$

   $$v_R(i,a) = \max_{a',c} \left\{ u(c,0) + \beta \cdot s_i \cdot v_R(i+1,a') \right\}$$

   - Decisions are aggregated to form aggregate supply of capital and labor measured in efficiency units:

   $$K_{s,t} = \sum_i x_i \int_{a \times \psi} a \cdot d\mu(a,\psi|i,t)$$

   $$L_{s,t} = \sum_i x_i \cdot \int_{a \times \psi} h \cdot \psi \cdot \eta_i \cdot d\mu(a,\psi|i,t)$$

   where x_i is the fraction of the population constituted by cohort i and $\mu(a,\psi|i,t)$ is the stationary joint distribution of a and ψ in time t for cohort i.

2. Firms maximize profits taking prices as given:

$$\max_{K_{d,t},L_{d,t}} \left\{ K_{d,t}^{\alpha} L_{d,t}^{1-\alpha} - r_t K_{d,t} - w_t L_{d,t} \right\}$$

3. Markets clear:

$$\{r_t, w_t\} \mid K_{s,t} = K_{d,t} \;\&\; L_{s,t} = L_{d,t}$$

3.4 Demographics

Our definition of general equilibrium shows that the conditional survival probability at each age and the age-cohort distribution in each period are sufficient statistics to capture demographics within our model. Several factors influence the evolution of a country's age-cohort distribution. First, changes in mortality rates reduce the number of deaths per year. Second, declines in a country's fertility rate reduces the degree to which aging cohorts are replaced by new, younger individuals. Both of these effects serve to shift the age-cohort distribution right. Lastly, a country's cohort distribution is affected by net migration flows, thereby shifting the cohort distribution either left or right depending on the mix of migrants.

Let $x_t \in \mathbb{R}^I$ denote the vector of length I where each element contains the fraction of the population of age i at time t. Each cohort is endowed with an age specific fertility rate, $f_{i,t}$, and a conditional survival probability, $s_{i,t}$, in each period. Moreover, denote $m_t \in \mathbb{R}^I$ as the vector of net migration of each age group in period t. Then the evolution of the cohort distribution within a given country is given by

$$x_{t+1} = \Gamma_t x_t + m_t \tag{8}$$

where,

$$\Gamma_t = \begin{bmatrix} f_{1,t} & f_{2,t} & f_{3,t} & \dots & f_{i,t} \\ s_{1,t} & 0 & 0 & \dots & 0 \\ 0 & s_{2,t} & 0 & \dots & 0 \\ \vdots & \vdots & \ddots & \ddots & \vdots \\ 0 & 0 & \dots & s_{I-1,t} & 0 \end{bmatrix} \tag{9}$$

Note that the cohort distributions used in our quantitative exercise do not necessarily equal the stationary distribution implied by Γ_t. Instead, we assume that individuals believe that the current demographic structure and therefore prices will persist in perpetuity. Thus, simulations should be interpreted as calculating steady states implied by each point along the demographic transition path.

Our model consists of I overlapping generations. We assume that households are ex-ante identical, enter their independent economic lives at age 20, and that no individual can live past age 120. Prior to age 20, households do not work, accumulate assets, or consume. Moreover, all households are born with $a_{i_0} = 0$ net assets.

At each age, i, households face mortality risk. Denoting s_i as the probability of surviving to age $i+1$ conditional on reaching age i, the unconditional probability of reaching age j is given by $s^j = \prod_{i=1}^{j-1} s_i$. Upon death, any assets saved from age i to $i+1$ are transferred equally across the remaining population in the form of lump sum accidental bequests, b_t.

3.5 Pension Systems

To investigate the growth effects of public defined-benefit pensions and their financing, we introduce a parsimonious pension system with guaranteed old age benefits. Here, we assume that households believe that current pension systems will persist indefinitely and that taxes are adjusted to balance government budgets period-by-period. Moreover, we take the level of real pension benefits to be constant and equal for each eligible household across cohorts above some eligibility age, I_R. In particular, define $\tau_{L,t}$ and t_t to be the labor tax rate and lump sum taxes levied on households, respectively, at time t.[2] The household budget constraint then becomes

$$c_{i,t} + a_{i+1,t+1} = (1-\delta)a_{i,t} + r_t \cdot a_{i,t} + (1-\tau_{L,t}) \cdot w_t \cdot h_{i,t} \cdot \psi_i \cdot \eta_{i,t} + b_t - t_t \cdot \mathbf{1}(i < I_R) + p_t \cdot \mathbf{1}(i \geq I_R) \quad (10)$$

where p_t is the level of real pension benefits and with r_t redefined to be the marginal product of capital rather than the net real interest rate. Moreover, we assume that lump sum taxes are levied only on those who are not eligible for old age benefits so that net transfers received in old age are not distorted by the financing of pension benefits. To close the model, define the budget constraint of the government to be

$$\sum_{i \geq I_R} \mathbf{x}_i \cdot p_t = \tau_{L,t} \cdot w_t \cdot L_t + T_t \quad (11)$$

where T_t denotes total lump sum tax revenues and where we have assumed that there is no additional government spending outside of pension outlays.

Pension systems augment the effects of demographic change on household decisions in two ways. First, the incentive to accumulate assets and work later in life as life expectancy increases is mitigated relative to the benchmark model as individuals receive transfers at old ages. Second, as a larger fraction of the population enters retirement, the total amount of pension outlays will increase. The increase in dependency ratios implies that tax rates must increase to balance the government's budget constraint as they are levied on a smaller fraction of the population. This further distorts individual decisions and thus factor supplies.

[2] The model can easily be extended to include capital income taxes, however, labor taxes are most relevant for financing old age benefits.

4 Calibration

We calibrate our benchmark model and the model with pension systems separately for Italy, Germany, France, and the United Kingdom using simulated method of moments. While we would prefer to calibrate our model to the 1990 economies, data limitations force us to rely on 1995 moments. The key margins of the model are the labor supply elasticities on both the intensive and extensive margin, and tax rate elasticities.

4.1 Preference Parameters

We calibrate preferences to match several key moments in the data in 1995. In particular, we set $\sigma = 1$ in order to obtain balanced growth preferences as in King et al. (1988). In addition, we fix the curvature on leisure to be $\gamma = 4$. The remaining preference parameters are the discount factor, β, household's weight on leisure, χ, and the cost to participation parameters, κ_1, κ_2, and κ_3. We set β to match the measured capital-output ratio for each country, δ to match the real interest rate, χ to match the average hours worked per year by working households aged 20-64, and $\{\kappa_1, \kappa_2, \kappa_3\}$ to match the labor force participation rate of those aged 60-64, aged 65-69, and the effective retirement age. The capital output ratio is calculated using data from the Penn World Tables 9.0 release through FRED, the real interest rate is calculated as the difference between the long term yield on 10 year government bonds and inflation, and the average hours worked is calculated as a weighted average of hours worked by age group where the weights are given by the relative size of each age cohort. Moreover, to maintain consistency between our model and the data, we calculate the the average effective retirement age within our model as a weighted labor market exit age starting at age 40 where our weights are the change in labor force participation between age i and $i + 1$ (Keese, n.d.). Data for long term yields and inflation are obtained through FRED, the labor force participation rates are obtained from the "lfsa_argan" variable in Eurostat, and the hours worked data and average effective retirement ages are obtained from the OECD database. Finally, we restrict participating households to work no less than 20% of their available time.

4.2 Technology and Productivity

Our production function is Cobb-Douglas form with an assumed capital share of $\alpha = 0.33$. We set the depreciation rate to match the 1995 real interest in each country, where we calculate the real interest rate as the return on 10 year long term government bonds less inflation. Each is taken from the OECD and World Bank, respectively, through FRED. As in Hansen (1993), we fix life cycle productivity, ψ_i, to be hump shaped as shown in Figure 4. Moreover, we assume that idiosyncratic labor productivity is quite persistent, with $\rho = 0.97$ and $\sigma^2 = 0.02$. Each is constructed from the PSID.

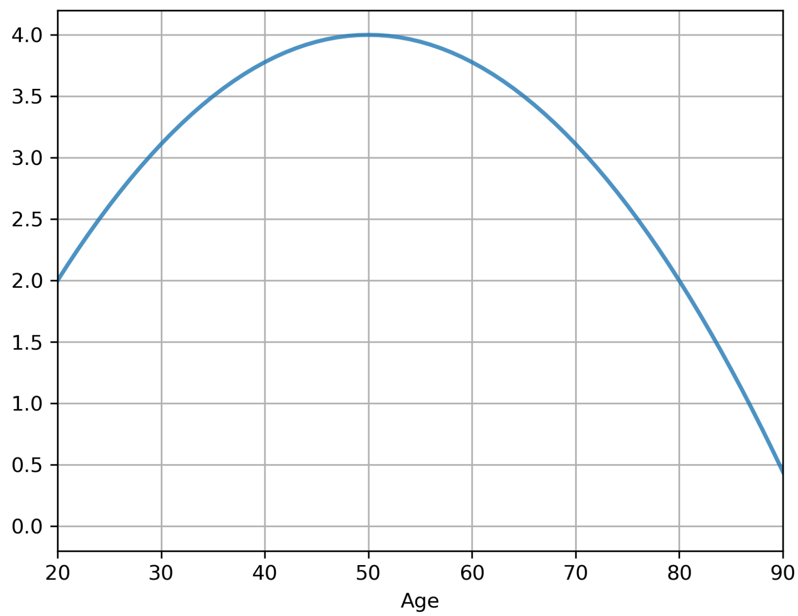


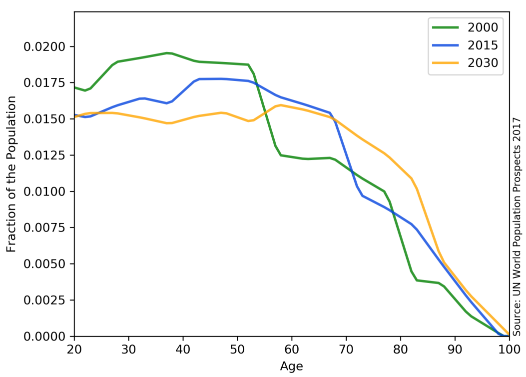
Figure 4: Age Specific Life-Cycle Productivity Profile

4.3 Pension System

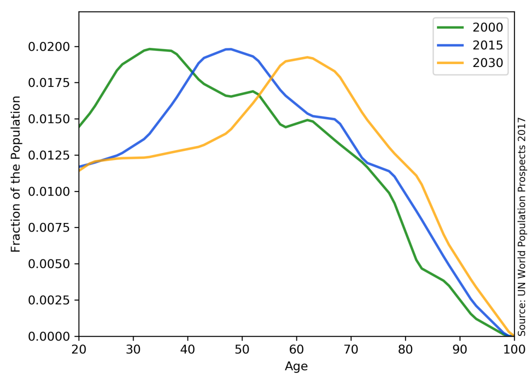
There are important differences in the public pension systems of the four European Economies we study. These are discussed in a paper by Erosa et al. (2012) and in SHARE the Survey of European health and retirement systems. For our purposes the important features of the retirement decision are driven by two parameters that determine the decision of the representative agent: the eligibility age, I_R, and the real old age benefits, p. The former is taken from the United Nations *Pensions at a Glance* 2002 release. In order to calibrate p_t, we match the level of pension expenditures in the form of non-means tested old age benefits by country as a percentage of GDP obtained from "spr_exp_pens" in Eurostat and assume that these old age benefits are evenly distributed among the eligible population. Ideally we would rely on average replacement rates, but this data is not readily available prior to 2002. We allow only one form of taxes to balance the government budget constraint at any given time. As a result, we calibrate two models with pension systems: a lump sum model and a labor tax model. In our main quantitative experiments, we fix p_t and allow the relevant tax rate to adjust to close the model. Finally, note that we fix $p_t = t_t = \tau_{L,t} = 0$ in our benchmark model without pension systems.

4.4 Demographics

What remains is to calibrate the model to match the demographics of each country. That is, we must calculate the conditional survival probabilities at each age and the size of each cohort. The cohort distributions are taken from the 2017 United Nations Population Prospects, which gives the cohort distribution in 5 year age bins. These cohort distributions for Germany and the United Kingdom are shown in Figure 2 and the cohort distributions for Italy and France are shown in Figure 5. We linearly interpolate between the center of each age bin and re-normalize the distribution to obtain 1 year cohort bins from age 20 to 120.



(a) France



(b) Italy

Figure 5: Changing Cohort Distributions in France and Italy

The conditional survival probabilities reflect the fact that households face a risk of death each period that alters their discount rate. These one-year survival probabilities are calculated as in Henriksen (2015) using life expectancy data obtained from the United Nations, which incorporates the fact that mortality rates are a function of both age and life expectancy at birth.

The full set of moments for each country are displayed below in Table 1. Appendix A gives the corresponding model moments and calibrated parameters for each country.

Table 1: Summary of 1995 Moments by Country

Moment	France	Germany	Italy	United Kingdom
LFPR for Ages 60-64	11%	19%	19%	37.2%
LFPR for Ages 65-69	3.0%	4.5%	6.3%	11%
Avg. Hours Worked for Ages 20-64	0.33	0.33	0.34	0.34
Effective Retirement Age	59.6	60.3	59.1	62
Real Interest Rate	5.75%	5.14%	6.96%	5.54%
Capital Output Ratio	3.23	3.55	4.02	3.02
Pension Outlays as a Fraction of GDP	9.9%	7.4%	10.2%	7.8%

5 Results

In this section, we present the results of our quantitative experiment. We fix the calibrated parameters of the model, adjust the conditional survival probabilities and cohort distributions, and perform both historical decompositions from 1995-2015 and future projections from 2020-2040 to determine the impact of demographic change on growth and pension systems. We assume a standard Cobb-Douglas production function given by,

$$Y = A \cdot K^{\alpha} \left(L \cdot h\right)^{1-\alpha} \tag{12}$$

We can further decompose the total growth effect into its constituent components by re-writing this expression as,

$$\frac{Y}{pop} = A \cdot \left(\frac{K}{L}\right)^{\alpha} \cdot \frac{L}{pop} \cdot h^{1-\alpha} \tag{13}$$

In (13), A is TFP, K is the aggregate equilibrium capital stock, L is the *number* of workers, and h is the average number of hours worked by those in the labor force. Thus, simple growth accounting yields

$$\gamma_{Y/pop} = \gamma_A + \alpha\gamma_{K/L} + \gamma_{L/pop} + (1-\alpha)\gamma_h \tag{14}$$

By decomposing the total effect of demographic change into its constituent components, we are able to identify which margins are most impacted and the policy reforms are likely to be most promising.

5.1 Growth Decomposition

We begin by decomposing the growth effects of demographic change using the benchmark. The benchmark economy serves as a comparison to past studies. In Section 5.2, we compare the benchmark model to the three remaining models to estimate the additional headwinds to growth resulting from pension systems. Table 2 shows the historical decomposition.

Table 2: 1995-2015 Annualizled Growth Rates

	$\gamma_{Y/pop}$	γ_A	$\alpha \cdot \gamma_{K/L}$	$\gamma_{L/pop}$	$(1-\alpha) \cdot \gamma_h$
United Kingdom					
Data	1.54	0.98	0.23	0.44	-0.10
Benchmark	0.05	0.03	0.08	0.03	-0.08
Lump Sum	0.04	0.03	0.07	0.001	-0.07
Labor Tax	-0.02	0.04	0.05	-0.02	-0.08
France					
Data	1.02	0.65	0.47	0.21	-0.30
Benchmark	-0.11	0.03	0.11	-0.17	-0.08
Lump Sum	-0.18	0.02	0.08	-0.22	-0.07
Labor Tax	-0.29	0.05	0.04	-0.30	-0.09
Germany					
Data	1.34	0.70	0.37	0.65	-0.38
Benchmark	-0.08	0.04	0.10	-0.12	-0.11
Lump Sum	-0.18	0.04	0.07	-0.19	-0.10
Labor Tax	-0.27	0.06	0.03	-0.23	-0.13
Italy					
Data	0.21	-0.16	0.44	0.17	-0.24
Benchmark	0.004	0.13	0.18	-0.16	-0.16
Lump Sum	-0.14	0.12	0.13	-0.23	-0.16
Labor Tax	-0.27	0.14	0.08	-0.31	-0.18

The benchmark model shows that demographic change was indeed a drag on historical growth for France and Germany while it boosted growth for Italy and the United Kingdom, albeit to a small degree. Relative to annualized growth in GDP per capita ranging from 0.21%-1.54% over this time period, the benchmark economy implies that historical growth would have been $5\% - x\%$ higher for France and Germany, but 0.20%-3% lower for Italy and the United Kingdom. The primary channels through which this effect operates is changes in the employment to population ratio, capital accumulation, and usual hours worked. Indeed, increases in life expectancy has caused individuals to increase their savings while rightward shifts in the age-cohort distribution implies that more households are in the highest savings portions of their lives. Moreover, as the average age of the workforce has increased, the average cost to participation has risen with the overall effect of decreasing hours worked. The primary drag on growth are declines in the employment/population ratio. As in the case of labor hours, the cost to participation increased sufficiently to cause much of the workforce to endogenously choose to retire. In addition, a larger fraction of the population lie in the right tail of the age-cohort distribution, where households have lower labor force participation.

Increases in life-expectancy and rightward shifts in the age-cohort distribution also affected total factor productivity. As young populations age, they begin to enter relatively more productive periods of their lives as indicated by the hump-shaped life-cycle productivity profile. The model also features an endogenous mechanism to generate TFP growth. Due to the persistence of idiosyncratic labor productivity, those who have received a series of high productivity draws early in life are more likely to remain in the labor force at older ages. Of note is the fact that TFP growth is positive while average hours worked have decline. This indicates that increases in the average cost to participation has dominated the increase in productivity described with respect to the intensive margin of labor supply.

In the future, this model implies that demographic change is projected to be a further drag on economic growth. Indeed, Table 3 shows that over the next 20 years, decreases in the employment to population ratio are projected to become more prominent while increases in capital accumulation are seen to decelerate. Moreover, the benchmark model indicates that Germany and Italy will face the most significant declines in growth.

5.2 Pension Effect Decomposition

Next, we compare the growth accounting exercise using our lump sum model to those discussed in the previous section. Here, we do not allow for distortionary taxes and allow only lump sum taxes to adjust to finance government outlays. This comparison allows us to estimate the growth headwinds faced as a result of simply receiving old-age transfers. Subsequently, we compare the labor and capital tax models to the model with lump sum taxes to estimate the growth effects of increasing distortions resulting from pension systems.

Both the historical decomposition and growth projections show that this model yields little qualitative difference from the benchmark model. Quantitatively, the provision of old-age transfers provides small headwinds for all countries except Germany, who faced an additional drag on historical growth of -0.10 percentage points annually. Over the next 20 years, however, these headwinds will largely fade for Germany as well. The primary channels through which the provision of these transfers operate are decreases in the employment to population rate and capital accumulation. Because households receive these transfers once they reach their respective eligibility

Table 3: 2020-2040 Annualizled Growth Rates

	$\gamma_{Y/pop}$	γ_A	$\alpha \cdot \gamma_{K/L}$	$\gamma_{L/pop}$	$(1-\alpha) \cdot \gamma_h$
United Kingdom					
Benchmark	-0.25	-0.009	0.05	-0.29	-0.004
Lump Sum	-0.25	-0.03	0.04	-0.30	0.04
Labor Tax	-0.36	-0.02	-0.01	-0.34	0.01
France					
Benchmark	-0.25	0.005	0.04	-0.31	0.01
Lump Sum	-0.20	-0.03	0.06	-0.31	0.08
Labor Tax	-0.34	-0.02	0.01	-0.38	0.04
Germany					
Benchmark	-0.49	0.05	0.09	-0.60	-0.04
Lump Sum	-0.51	-0.02	0.05	-0.61	0.06
Labor Tax	-0.75	0.01	-0.02	-0.73	-0.01
Italy					
Benchmark	-0.58	-0.05	0.13	-0.73	0.05
Lump Sum	-0.61	-0.09	0.09	-0.82	0.18
Labor Tax	-1.13	-0.05	-0.08	-1.09	0.09

age, the incentive to increase savings and work later in life to sustain one's retirement due to life expectancy increases is mitigated.

The model with labor taxes implies a more significant effect of pension systems on growth. As populations age, governments face increasing liabilities in the form of old age benefits, tax revenues will need to increase in order to balance their budget constraint. Moreover, the decline in the workforce implied by the rightward shift in the age-cohort distribution, necessitates that labor taxes rise. The increase in these distortions significantly depresses the employment/population ratio and further mitigates increases in capital accumulation. While the primary labor supply channel affected is the extensive margin, these increasing distortions further decrease the growth in average hours worked. Finally, these rising distortions increase TFP growth. As labor taxes rise, the productivity needed to remain in the workforce during old age does as well. Thus, the workforce that remains following a rise in labor taxes is more productive. This amplifies the self-selection mechanism discussed in Section 5.1. The net contribution to annual growth of these distortions ranges from -0.06 to -0.13 percentage points historically and -0.14 to -0.52 percentage points over the next 20 years.

5.3 Pension Reform

Having established the effects of aging populations and the channels through which it operates, we now turn to simple policy reforms aimed at insulating these four countries from their projected demographic change. We also establish the welfare effects of these reforms in terms of consumption equivalence of a newborn agent. In particular, given that savings rates and labor force participation rates are significantly impacted by aging populations and face the most prominent distortions as a result of financing pension outlays, one would like policy reforms that encourage capital accumulation and encourage more labor force participation in older cohorts. Pension reforms can accomplish both of these goals: decreasing the level of old age benefits may encourage capital accumulation by households, while increasing the eligibility age may encourage a longer working life. Here, we consider both of these reforms by assuming per-retiree pension outlays decrease by 5%-20% and that the eligibility age increases by 5 years by the year 2040 for each country considered.

Table 4 shows the result of reducing the amount of old age benefits received when in retirement for the labor tax model. The results for the lump sum model are shown inTable C.1. Table 5 shows the results of increasing the eligibility age for both models. Section 5.3 displays the constituent components of growth separately. Evidently, decreasing the level of pension benefits does in fact encourage additional capital accumulation, and to a lesser degree, encourages old age labor force participation. Two effects contribute to this. There is a direct effect in the form of decreased old age transfers. As the level of guaranteed transfers decreases, agents must rely on private savings more heavily to finance old age consumption. This causes savings rates to become more sensitive to increases in life expectancy. Second, there is an indirect effect operating through tax rates. Because the level of pension benefits and thus total pension outlays decreases, tax rates increase less. This reduces the disincentives to work, mitigating the decrease in the employment to population ratio. Depending on the extent of the reduction, such a reform can boost growth by 0.20-0.46 percentage points annually in the case of the Labor Tax model. The most prominent gains are observed for Italy while the most modest gains are seen for the United Kingdom. Moreover, these reforms are welfare improving, in some cases to a significant degree, as distortions in the 2040 economy are reduced. In France, Germany, and Italy, the median per-period consumption equivalent for newborns quickly rises over 1% as the extent of the reform increases. For significant benefits reductions, median consumption equivalents range from 2.20%-4.13%. The United Kingdom sees more modest welfare gains with consumption equivalen reaching 1.42% for 20% benefits reductions.

Except for the most significant reductions in pension benefits, increasing the eligibility age is more effective at promoting growth. Increasing the eligibility age operates through similar chan-

Table 4: Labor Tax Model: Projected Growth Rates for an $x\%$ Decrease in Benefits

	$\gamma_{Y/pop}$	$\Delta\gamma_{Y/pop}$	$\%CE$
UK			
5%	−0.30	0.06	0.37
10%	−0.26	0.10	0.75
15%	−0.24	0.12	1.10
20%	−0.16	0.20	1.42
France			
5%	−0.30	0.04	0.59
10%	−0.22	0.12	1.17
15%	−0.18	0.16	1.68
20%	−0.10	0.24	2.22
Germany			
5%	−0.67	0.08	0.63
10%	−0.62	0.13	1.21
15%	−0.54	0.21	1.81
20%	−0.50	0.25	2.38
Italy			
5%	−0.96	0.17	1.19
10%	−0.87	0.26	2.19
15%	−0.77	0.36	3.19
20%	−0.67	0.46	4.13

nels as reductions in pension benefits. First, as the eligibility age increases, the present value of old age transfers is reduced. This again implies that agents must rely more heavily on private savings for old age consumption. Second, as less of the population is eligible for any given level of benefits, government outlays and thus tax rates increase by less as populations age. These two effects serve again to further increase capital accumulation as life expectancies increase and mitigate the reduction in the employment to population ratio as populations age. Here again we see large welfare gains for these reforms with the largest gains coming from the labor tax model.

A direct implication of these results is that size-able reductions in pension benefits are a better approach to reform than increases in the eligibility age. While increasing the eligibility age may be a simpler solution for policy makers than re-structuring the provision of benefits, reducing pension benefits by 20% for example provides roughly the same boost to annual growth but with 37%-79% larger welfare gains. These additional welfare gains are a result of the cost to participation function. While both reforms decrease the level of distortions in the economy, increasing the eligibility age promotes labor force participation to a greater degree than decreases in benefits. These additional labor force participants incur the cost to participation late in life when it becomes highest.

Table 5: 2020-2040 Annualized Growth Rates for a 5 Year Increase Retirement Age

	$\gamma_{Y/pop}$	$\Delta\gamma_{Y/pop}$	$\%CE$
Lump Sum			
France	−0.15	0.05	−−
Germany	−0.41	0.10	1.05
Italy	−0.60	0.01	1.66
United Kingdom	−0.18	0.07	0.61
Labor Tax			
France	−0.11	0.23	1.24
Germany	−0.48	0.27	1.64
Italy	−0.75	0.38	3.01
United Kingdom	−0.18	0.18	1.00

6 Conclusion

Across Europe, populations have aged and will continue to age as life expectancy increases and fertility remains low. The average age of the aggregate population will continue to increase. Using a general equilibrium model with a rich demographic structure we investigate the extent to which this demographic change affects economic growth in the four largest European economies: France, Germany, Italy, and the United Kingdom. We find that the demographic transition was a significant drag on growth in France historically, whereas Italy and the United Kingdom were largely insulated from its effects. Moving foreward, however, the negative effects of an aging population will begin to bite in the United Kingdom, Germany, and Italy, while the impact in France will begin to moderate as they have already completed the most painful phase of the transition. The primary channels through which demographic change affects growth are changes in the aggregate capital stock per worker– due to a combination of increasing life expectancies and changing fraction of the population in the highest savings years of their lives– and, a decrease in the employment to population ratio due to a larger fraction of the population being in retirement.

Moreover, we find that pension systems are of first-order importance even when the counterfactual of interest is unrelated to pension reforms. In fact, we find that growth projections in previous studies that have largely ignored pension systems are quantitatively and, more importantly, qualitatively different from ours. We also find that financing pension outlays through labor taxes can exacerbate the effects of historical and projected demographic change by $5.6\% - 11.1\%$ and $8.3\% - 55.6\%$, respectively. We show that both decreasing the level of pension benefits and increasing the eligibility age of such benefits can in fact moderate the effects of an aging population with the latter being most effective. The quantitative magnitude depends critically on the calibration of key elasticity parameters, in particular with respect to old-age productivity and the evolution of disutility of labour as life expectancies increase. This paper also provides a laboratory to weigh incentives for late-life labour supply, which may stimulate economic growth against the disutility of working when old.

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A Calibration Results

Table A.1: Calibration Results

	$LFPR60-64$	$LFPR65-69$	$Retire.\ Age$	K/Y	$Avg.\ Hours\ Worked$
U.K.					
Data	0.37	0.11	62	3.02	0.34
Benchmark	0.55	0.053	62.6	3.06	0.31
Lump Sum	0.48	0.030	62.1	3.09	0.31
Labor Tax	0.47	0.035	61.9	2.91	0.31
France					
Data	0.11	0.03	59.6	3.23	0.33
Benchmark	0.23	0.026	59.3	3.42	0.26
Lump Sum	0.17	0.002	59.7	3.18	0.30
Labor Tax	0.23	0.008	60.0	3.18	0.28
Germany					
Data	0.19	0.045	60.3	3.55	0.33
Benchmark	0.38	0.031	61.0	3.66	0.28
Lump Sum	0.52	0.038	61.9	3.51	0.31
Labor Tax	0.39	0.030	61.2	3.30	0.28
Italy					
Data	0.19	0.063	59.1	4.02	0.34
Benchmark	0.22	0.01	59.3	4.16	−−
Lump Sum	0.18	0.001	59.4	4.17	0.31
Labor Tax	0.19	0.003	59.1	4.05	0.29

Table A.2: Model Parameter Values

	β	δ	χ	κ_1	κ_2	κ_3	p
U.K.							
Benchmark	0.944	0.055	0.2103	0.0506	0.00185	1.4088	–
Lump Sum	0.961	0.055	0.02758	0.00514	0.00211	1.3261	0.564
Labor Tax	0.956	0.055	0.335	0.006	0.002469	1.2862	0.548
France							
Benchmark	0.946	0.046	0.5199	0.0444	0.002038	1.3276	–
Lump Sum	0.955	0.046	0.389	0.0368	0.00130	1.4497	0.539
Labor Tax	0.958	0.046	0.389	0.042	0.002769	1.2091	0.515
Germany							
Benchmark	0.951	0.043	0.349	0.0496	0.001712	1.3975	–
Lump Sum	0.958	0.043	0.326	0.0470	0.002285	1.3287	0.556
Labor Tax	0.958	0.043	0.342	0.0469	0.003158	1.1968	0.544
Italy							
Benchmark	0.939	0.013	0.355	0.0498	0.00349	1.2004	–
Lump Sum	0.9509	0.013	0.272	0.0419	0.002643	1.2973	0.666
Labor Tax	0.952	0.013	0.410	0.00603	0.002791	1.2436	0.623

[**These need to be updated**]

B Pension Outlays

Table B.1: Percentage Growth in Pension Outlays

	U.K.	France	Germany	Italy
1995-2015				
Lump Sum	12.7%	−−	30.7%	−−
Labor Tax	−−	21.8%	30.7%	26.2%
2020-2040				
Lump Sum	23.4%	−−	28.7%	28.0%
Labor Tax	23.2%	17.8%	29.1%	29.7%

Table B.2: Outlays as a Fraction of GDP

	U.K.	France	Germany	Italy
1995				
Lump Sum	7.73%	−−	7.41%	−−
Labor Tax	−−	9.32%	7.3	10.0%
2015				
Lump Sum	8.7%	−−	10.45%	−−
Labor Tax	−−	12.2%	10.5%	13.7%
2020				
Lump Sum	9.3%	−−	12.7%	14.6%
Labor Tax	9.41%%	13.1%	11.2%	15.1%
2040				
Lump Sum	12.28%	−−	16.9%	21.73%
Labor Tax	12.73%	17.1%	16.4%	24.5%

C Policy Reforms

Table C.1: Lump Sum Model: 2020-2040 Annual Growth Rates for an $x\%$ Decrease in Benefits

	$\gamma_{Y/pop}$	$\Delta\gamma_{Y/pop}$	γ_A	$\alpha \cdot \gamma_{K/L}$	$\gamma_{L/pop}$	$(1-\alpha) \cdot \gamma_h$	$\%CE$
UK							
5%	−0.23	0.02	−0.02	0.05	−0.29	0.03	0.25
10%	−0.21	0.04	−0.02	0.06	−0.27	0.02	0.49
15%	−0.18	0.07	−0.02	0.07	−0.25	0.01	0.75
20%	−0.18	0.07	−0.01	0.07	−0.24	−0.01	1.00
France							
5%	−0.17	0.03	−0.03	0.07	−0.29	0.07	−−
10%	−0.15	0.05	−0.02	0.08	−0.28	0.06	−−
15%	−0.15	0.05	−0.01	0.08	−0.27	0.04	−−
20%	−0.15	0.05	−0.01	0.09	−0.26	0.03	−−
Germany							
5%	−0.49	0.02	−0.01	0.07	−0.60	0.05	0.38
10%	−0.47	0.04	−0.01	0.08	−0.59	0.03	0.75
15%	−0.45	0.06	0.01	0.09	−0.57	0.02	1.11
20%	−0.43	0.08	0.01	0.10	−0.56	0.01	1.51
Italy							
5%	−0.59	0.02	−0.08	0.11	−0.83	0.17	0.57
10%	−0.57	0.04	−0.07	0.12	−0.81	0.15	1.14
15%	−0.55	0.06	−0.06	0.14	−0.80	0.13	1.69
20%	−0.53	0.08	−0.05	0.16	−0.79	0.12	2.22

Table C.2: Labor Tax Model: Annualized Projected Growth Rates for an $x\%$ Decrease in Benefits

	$\gamma_{Y/pop}$	$\Delta\gamma_{Y/pop}$	γ_A	$\alpha \cdot \gamma_{K/L}$	$\gamma_{L/pop}$	$(1-\alpha) \cdot \gamma_h$	$\%CE$
UK							
5%	−0.30	0.06	0.02	0.02	−0.31	0.001	0.37
10%	−0.26	0.10	−0.01	0.03	−0.28	−0.003	0.75
15%	−0.24	0.12	−0.01	0.05	−0.27	−0.006	1.10
20%	−0.16	0.20	−0.01	0.08	−0.23	−0.007	1.42
France							
5%	−0.30	0.04	−0.02	0.02	−0.35	0.03	0.59
10%	−0.22	0.12	−0.01	0.06	−0.30	0.03	1.17
15%	−0.18	0.16	−0.008	0.07	−0.28	0.023	1.68
20%	−0.10	0.24	−0.005	0.10	−0.22	−0.02	2.22
Germany							
5%	−0.67	0.08	0.005	0.02	−0.69	−0.004	0.63
10%	−0.62	0.13	0.01	0.03	−0.66	−0.009	1.21
15%	−0.54	0.21	0.01	0.06	−0.60	0.01	1.81
20%	−0.50	0.25	0.01	0.08	−0.59	−0.02	2.38
Italy							
5%	−0.96	0.17	−0.05	0.02	−1.01	0.09	1.19
10%	−0.87	0.26	−0.04	0.02	−0.94	0.08	2.19
15%	−0.77	0.36	−0.04	0.06	−0.89	0.08	3.19
20%	−0.67	0.46	−0.04	0.10	−0.82	0.07	4.13

Table C.3: 2020-2040 Annualized Growth Rates for a 5 Year Increase Retirement Age

	$\gamma_{Y/pop}$	$\Delta\gamma_{Y/pop}$	γ_A	$\alpha \cdot \gamma_{K/L}$	$\gamma_{L/pop}$	$(1-\alpha) \cdot \gamma_h$	$\%CE$
Lump Sum							
France	−0.15	0.05	−0.01	0.02	−0.16	0.01	−−
Germany	−0.41	0.10	−0.002	0.06	−0.45	−0.02	1.05
Italy	−0.60	0.01	−0.07	0.05	−0.69	0.09	1.66
United Kingdom	−0.18	0.07	−0.02	0.02	−0.16	−0.02	0.61
Labor Tax							
France	−0.11	0.23	−0.004	0.02	−0.13	0.01	1.24
Germany	−0.48	0.27	−0.008	0.04	−0.49	−0.02	1.64
Italy	−0.75	0.38	−0.06	0.01	−0.78	0.07	3.01
United Kingdom	−0.18	0.18	−0.02	0.02	−0.17	−0.01	1.00