The demographics of structural change

Laurent Brembilla∗†
February 2018

Abstract

I study the impact of population aging on the process of structural change, defined as the composition shift of aggregate consumption. I first document that the lifecycle profile of the expenditure share of services is upward sloping, with a sharp increase of the slope at the retirement age. I then develop a multi-goods lifecycle model with home production consistent with this profile. Finally I incorporate this lifecycle model into a large scale overlapping generations model calibrated on US economy over the post-war period to make counterfactual experiments on demographic variables. The main effect is as follows. Aging reallocates resources from young ages, at which services are a luxury good, to old ages, at which they are a necessity good. This reduces the expenditure share of services for all individuals. Hence aging slows down structural change.

Keywords: aging, structural change
JEL classification: O41, I15, E13

1 Introduction

Aging and structural change are two notable trends of the postwar period in developed economies. Aging, a process driven by fertility and mortality rates declines, can be observed by the increase of the fraction

∗Université d’Evry, Paris-Saclay, 23 Bd François Mitterrand, 91 000 Evry FRANCE. E-mail address: laurent.brembilla@univ-evry.fr.
†I am grateful to Hippolyte d’Albis, Raouf Boucekkine, Shankha Chakraborty, Najat El Mekkaoui, Andreas Irmen and Gregory Ponthiere for their helpful comments. I thank Labex MME-DII for their financial support.
of elderly individuals. The ratio of individuals aged more than 65 to individuals aged between 20 and 65 has increased from 8.75% in 1955 to 14.5% in 2015 (see Figure 2). Structural change manifested over this period through a rising share of services in consumption from 39% in 1950 to 67% in 2015 in US (see Figure 1). It is considered since Kuznets (1966) as a central feature of the growth process, which means that the understanding of its determinants is an important issue to tackle for economists. This paper studies whether aging is one of these determinants.

Figure 1: US expenditure share of services. Source: BEA

Figure 2: US dependency ratio. Source: OECD database

There are three main effects that suggest a role for aging in the process of structural change. First, the consumption bundle of an individual varies with his age. As aging shifts the age distribution of the economy, it modifies the aggregate demand for each good. Second, lifecycle theory implies that demographic variables affect the intertemporal allocation of individuals’ resources. Individuals discount less future periods and so channel more resources, through higher savings or through higher contributions to a pension system, at older ages if their survival chances improve. Individuals also need to channel less resources during their
parenthood ages if they have fewer children. These intertemporal reallocations are synonymous with intratemporal reallocations of resources once utility per period is non-homothetic. Thus aging modifies individual consumption bundles, which also affects the aggregate demand for each good. Third, aging influences the composition of aggregate consumption through its general equilibrium consequences. Particularly, aging has an impact on the income level, which is considered since Kunzets (1966) as an important determinant of structural change.

To capture well the first effect, the lifecycle model I use must produce consumption bundles by age consistent with individual data. To the best of my knowledge, no paper documents such lifecycle profiles. My first contribution is to fill this gap. Using data from the consumption expenditure survey (CEX), I determine the lifecycle profile of the expenditure share of services. Then, I show that intratemporal preferences used by the structural change literature are inconsistent with this profile. Relying on a Beckerian view of services, I propose intratemporal preferences that are consistent with the lifecycle profile documented. The second channel is taken into account by incorporating these preferences in a lifecycle model with actual demographic data. Finally, this lifecycle model is embedded in an overlapping generations (OLG) model à la Auerbach and Kotlikoff (1987) to include general equilibrium effects. The model is calibrated to reproduce the evolution of the US aggregate consumption share of services over 1950-2015 and is then used to make counterfactual experiments on the demographic variables: What is the contribution of mortality rates declines to the evolution of the aggregate expenditure share of services? What is the contribution of the fertility rate change? What is the joint impact of these two demographic phenomena?

By answering these questions I contribute to three strands of the literature. First, I complement a literature that discusses preferences to use in multi-goods growth models to generate structural change. Boppart (2014) highlights the consistency of PIGLOG preferences with a balanced growth path for aggregate variables and a rising expenditure share on services. Herrendorf et al. (2014) show that a utility function with constant elasticity of substitution between goods and subsistence levels can replicate well the joint evolution of aggregate consumption expenditure, consumption shares and relative prices for US over 1945-2015. Comin et al. (2017) introduce preferences that yield non-linear Engel curves over a large range of income levels. All these preferences are consistent with aggregate patterns of structural change. My contribution is to underline that one of their common features, the convex Engel curves they imply for services, is at odds with the lifecycle pro-
file of the expenditure share of services I document. Indeed, this profile reveals that individuals reduce their consumption expenditures during their retirement, while their expenditure share of services increases.

I also complement the structural change literature by highlighting a new determinant of this process. Traditional determinants include the relative price change between goods and services due to technological progress differences and the income level increase that modifies the relative demand between goods featuring different income elasticities.\footnote{This literature is thoroughly reviewed in Herrendorf et al. (2014).} Other determinants include female employment (Ngai and Petrongolo 2017), technological progress in home production (Moro et al. 2017) and population growth (Leukhina and Turnovsky 2015). As Leukhina and Turnovsky (2015) also highlight a demographic factor, fertility, as a driver of structural change, it is the closest to this paper. Several differences distinguish my work from theirs. First, they focus on the fertility rate, while I study the role of the fertility rate as well as that of mortality rates. Second, and more importantly, they study the process of structural change in England over 1750-1900, while I study this process in US over 1950-2015. Different channels of interaction between demographic variables are at play in the two cases. In Leukhina and Turnovsky (2016), the main channel relies on the use of land as a fixed factor of production of the farming good. Given the production function estimates of Valentinyi and Herrendorf (2008), the relative supply between goods and services in terms of consumption expenditures is equal to the TFP ratios which is unlikely dependent on demographic variables. Rather I point out demand side channels, the population and the reallocation effects, as a source of interaction between aging and structural change between the goods and services sectors. Given that Leukhina and Turnovsky (2016) use a representative agent model, these demand side channels are absent from their framework.

Finally, I complement a large literature on the economic consequences of aging. Economists consider aging as a source of important economic changes. There are several attempts to better understand the impact of aging on the growth process. On the theoretical side, Bloom et al. (2003), Chakraborty (2004) and Zhang and Zhang (2005) note that aging induces individuals to save more and thus stimulates physical capital accumulation. Acemoglu and Restrepo (2016) argue that the labor scarcity created by aging spurs technological innovations that sustain economic growth. d’Albis (2007) challenges the positive impact of aging on economic growth. He shows that in a multi-period OLG model, the relationship is no more monotonic. Boucekkine et al. (2004) and Ludwig et al. (2012) also discuss the growth consequences of aging in a frame-
work in which individuals invest in their human capital. My contribution with respect to these papers is to study the consequences of aging on a phenomenon, structural change, which is central to the growth process. In the presence of structural change, new channels through which aging affects economic growth appear. Thus the paper offers new insights on the consequences of aging in terms of income.

Section 2 emphasizes the channels of interaction between aging and the composition of aggregate consumption. In section 3, I determine the lifecycle profile of the expenditure share of services using CEX data. In section 4, I present a utility function that is consistent with this profile. In section 5, I present the quantitative model and the results of the counterfactual experiment. Section 6 concludes.

2 Theoretical considerations

The goal of this section is to highlight the channels through which aging affects the aggregate consumption share. For this, I discuss a standard multi-goods model embedded in a realistic demographic structure. I also discuss other possible channels of interaction.

I start by examining the role of aging in the individual decision problem. An individual lives up to age $T > 0$. His survival probability between ages $a$ and $a + 1$ is $q_{a,a+1}$. Parenthood ages, $P$, are a subinterval of $[0, T]$, during which the individual lives with $n$ children. The individual derives utility from the consumption of $N \in \mathbb{N}$ different goods. He also possibly directly derives utility from the number of his children, however I assume that preferences over the number of children are separable from the preferences over the consumption goods. During parenthood ages, the individual derives utility for each good $i$ only from a fraction $s(n)$ of his consumption level of good $i$, with $s(n) < 1$ and $s'(n) > 0$. He takes the prices as given. His return on savings at age $a$ is $\frac{1+r_a}{\lambda+(1-\lambda)q_{a,a+1}}$. Where $\lambda \in [0,1]$ captures the degree of imperfection of the annuity market, $r_a$ is the interest rate at time $a$.

To maximize his lifetime expected utility under the budget constraints, the individual first chooses at each age his consumption bundle given his total level of consumption expenditures. Then, at each age $a$, the expenditure share on good $i$ writes: $x_{a,i} = f_a(E_a, P_a)$, where $E_a$ is the level of consumption expenditure at age $a$, $P_a$ is the price vector of the $N$ goods at time $a$. The function $f_a(.,.)$ possibly depends on $a$ if we allow utility per period to differ with age. It would directly depend on $n$ if the scale factor $s(n)$ was different across goods. It would also directly

\footnote{For notational convenience, I assume that the individual is born at time 0, so much that age and time are equal.}
depend on \( n \) if preferences over goods and children were not separable because the marginal rate of substitution between consumption goods would depend on \( n \). Thus, here the only possible impact of aging on the consumption expenditure share \((x_{a,i})_{(a,i)}\) is through its impact on the total level of consumption expenditures:

\[
\frac{\partial \ln(x_{a,i})}{\partial q_{a,a+1}} = \frac{\partial E_a}{\partial q_{a,a+1}} (\zeta_{a,i} - 1) \tag{1}
\]

and

\[
\frac{\partial \ln(x_{a,i})}{\partial n} = \frac{\partial E_a}{\partial n} (\zeta_{a,i} - 1) \tag{2}
\]

With \( \zeta_{a,i} \) the expenditure-elasticity at age \( a \) of good \( i \). Hence the impact of aging on consumption shares is opposite for luxury and necessity goods. The direction of the impact is given by the impact of the demographic variables on the level of consumption expenditures at age \( a \), which in turn is determined by solving the intertemporal problem of the individual.

Suppose first that there is no annuity market, \( \lambda = 1 \). The Euler equation states that the growth rate of \( E_a \) between two periods positively depends on the survival probability between the two periods, \( q_{a,a+1} \). In our framework and in the absence of an annuity market, the lifetime resources of the individual do not depend on survival probabilities. If \( q_{a,a+1} \) increases, then the growth rate of \( E_a \) between \( a \) and \( a + 1 \) increases, while other growth rates are unchanged. This necessitates a decrease of the initial expenditure level, \( E_0 \), for the lifetime budget constraint to be fulfilled. Consequently there exists a pivot age \( \hat{a} \) such that \( E_{a'} \) decreases (resp. increases) if \( a' \) is smaller (resp. greater) than \( \hat{a} \) following an increases of \( q_{a,a+1} \). Hence a survival probability shift at a particular age modifies consumption bundles at any age, and the direction of the change is age-dependent. It spurs young individuals to consume more necessary goods and old individuals to consume more luxury goods. In presence of a perfect annuity market, \( \lambda = 0 \), the direction of the change is no more age-dependent. The Euler equation is now independent on the survival probabilities, hence the growth rate of consumption expenditures between two consecutive ages is unaffected by changes of survival probabilities. The amount of lifetime resources diminish with higher survival probabilities, because these ones reduce the return on assets. Thus, an increase of the survival probability at a particular age reduces consumption expenditures at any age in the same proportion. In the imperfect annuity case, \( \lambda \in (0,1) \), the two scenari can occur. The growth rate of consumption expenditures between two consecutive ages increases in the survival probability and the lifetime resources diminish.
with survival probabilities. Thus consumption expenditures at young ages diminish. If they diminish sufficiently and if future consumption growth rates increase sufficiently, consumption expenditures at old age can increase.

I now examine the impact of the number of children, \( n \), on the consumption expenditures profile \( (E_a)_{a \in [0,T]} \). This impact can only occur through the scaling factor \( s(n) \). Suppose first the individual is no more parent, \( a \in [\max(P) + 1, T - 1] \). Then, the Euler equation at this age is no more dependent on \( n \) because the scaling factor is equal to 1. Thus, for two consecutive periods not belonging to \( P \), the growth rate of consumption expenditures does not depend on \( n \). This is also the case for two consecutive periods during the parenthood period. Indeed, the scaling factor is similar to a discount factor of consumption in parenthood periods. As this additional discount factor is the same for all periods in parenthood, the Euler equation is independent on the scaling factor. However, the Euler equation does depend on the scaling factor for the transition between non-parenthood to parenthood and inversely. Suppose \( \min(P) > 0 \), hence the individual is not initially a parent. At age \( \min(P) - 1 \), an increase of \( n \) spurs the individual to increase his next period consumption expenditures to offset the increase of the scaling factor. Thus the growth rate of consumption expenditures increases in \( n \) at age \( \min(P) - 1 \). The reverse occurs at age \( \max(P) \), if it is assumed smaller than \( T \). These growth rate shifts imply that \( n \) modifies the profile \( (E_a)_{a \in [0,T]} \). Using the fact that lifetime resources do not depend on \( n \), we deduce that consumption expenditures increase during parenthood ages, while either consumption expenditures before parenthood or consumption expenditures after parenthood must decrease. Therefore, a fertility change modifies consumption bundles, and the direction of this change is age-dependent.

The main insight of this analysis lies in equations (1) and (2): the intertemporal reallocation of resources due to aging create an intratemporal reallocation of resources once intratemporal preferences are non-homothetic. Non-homotheticity is a common and documented feature of preferences over different goods (Herrendorf et al. 2014). Thus, aging modifies the consumption bundle of individuals. The direction of these consumption changes can be broadly characterized in our stylized multi-goods lifecycle framework. However, additional effects can be at play. They are linked to the fact that lifetime resources of an individual can change with demographic variables, even in the absence of an annuity market. First, an individual can modify his labor supply at the intensive margin. In the next sections, I include such a decision and I argue that it is important to understand the lifecycle profile of the consumption
expenditure shares. Second, an individual can increase his labor supply at the extensive margin by postponing his retirement age if his life expectancy increases. This tends to increase consumption expenditures at any age. In my quantitative section, I do not include a retirement decision, because over our period of interest, 1950-2015, the retirement age has not change by much. Consequently it is unlikely that it plays a large role in the change of consumption shares. Third, the Ben-Porath effect stipulates that individuals invest more in their human capital if they live longer. This implies that consumption expenditures would increase if survival probabilities increase. However, Cervellati and Sunde (2013) show that the Ben-Porath effect occurs following middle-age survival improvements. On the contrary, survival improvements in retirement period do not increase shooling time. Over 1950-2015, survival improvements due to aging mostly occured at old ages. Thus, I do not expect a large Ben-Porath effect over my period of interest, which justifies not to incorporate human capital decisions in our framework.

I now turn briefly to the impact of aging on the relative aggregate demand between goods in partial equilibrium. Previous analysis underlines that demographic factors, $\tilde{q} = (q_{a,a+1})_{a<T}$ and $n$, affect consumption levels. So I explicitly mention this dependance by writing the consumption level of good $i$ by an aged $a$ individual belonging to cohort $c$ as $c_{i,c,a}(n, \tilde{q})$. then the aggregate relative demand between good $i$ and $j$ at time $t$ writes:

$$D_{i,j}^t = \frac{\sum_{c+a=t} L_{c,a} c_{i,c,a}(n, \tilde{q})}{\sum_{c+a=t} L_{c,a} c_{j,c,a}(n, \tilde{q})}.$$  (3)

Where $L_{c,a}$ is the number of cohort-$c$ individuals aged $a$. (3) allows to visualize the two partial equilibrium effects mentioned in the introduction. Aging affects $D_{i,j}^t$ because it affects individual consumption levels $c_{i,c,a}(n, \tilde{q})$. Aging also affects $D_{i,j}^t$, because demographic variables determine $L_{c,a}$ the size of the different groups of the population. Caracterizing the dependence of $D_{i,j}^t$ with respect to demographic variables is out of reach without further assumptions. However, there is an extreme case that it is worth mentioning. It is well-known that $D_{i,j}^t$ simplifies in case intratemporal preferences are homothetic and identical among all individuals. The first assumption implies that for any individual $(c, a)$, the ratio of consumption levels of goods $i$ and $j$ only depends on the relative price between good $i$ and $j$, $\frac{c_{i,c,a}(n, \tilde{q})}{c_{j,c,a}(n, \tilde{q})} = f_{c,a}(\frac{P_i}{P_j})$. The second assumption implies that the function $f_{c,a}(., .)$ is the same across all individuals $(c, a)$. Then, $D_{i,j}^t = f(\frac{P_i}{P_j})$ and the relative aggregate demand between goods is independent on demographic variables. This result is the aggregate counterpart of equations (1) and (2), which state that the individual lifecycle
problem is independent on demographic variables if and only if individual preferences do not depend on age and are homothetic. Hence $D_{t}^{i,j}$ does not depend on demographic variables under identical and homothetic preferences because the two partial equilibrium effects of aging are neutralized under this assumption. The composition change of the population due to aging does not affect $D_{t}^{i,j}$ because all individuals choose the same consumption bundle. On the contrary, if we abstract from homothetic preferences, then the ratio of consumption levels of goods $i$ and $j$ for an individual $(c,a)$ is also a function of the total consumption expenditure level, $E_{c,a}$: $\frac{c_{i,c,a}(n,\tilde{q})}{c_{j,c,a}(n,\tilde{q})} = g(E_{c,a}, \frac{p_{c+a}^{i}}{p_{c+a}^{j}})$. Hence this ratio is different across individuals for two reasons. $E_{c,a}$ is age-dependent, individuals at a different point of their lifecycle have different expenditure levels. $E_{c,a}$ is cohort-dependent, because individuals belonging to different cohorts face different prices. Hence the composition change of the population effect operates under non-homothetic preferences. Relaxing the assumption of identical preferences across individuals is obviously the alternative way to make $D_{t}^{i,j}$ dependent on demographic variables. The following proposition summarizes these results:

**Proposition 1** The relative aggregate demand between goods is invariant with respect to aging for any price vector if and only if intratemporal preferences are homothetic and identical across individuals.

Given that the non-linearity of Engel curves is well-documented (see among others Herrendorf et al. (2013)), Proposition 1 justifies our research question that is to quantitatively assess the contribution of aging to the process of structural change.

3 The lifecycle profile of the expenditure share of services

I use data from the Consumer Expenditure Survey (CEX), more precisely the NBER CEX extracts that include the waves from 1980 to 2003. Households that report consumption expenditures in the four quarters are conserved and I compute their annual consumption expenditures for each category. The number of categories is equal to 46. I adopt the definition of services and goods of the BEA and I classify consumption expenditures into these two categories. 3 The exact classification is given in Appendix A. Before doing this aggregation, I deflate each category expenditure into constant dollars using its consumer price index (CPI).

3 A good is a tangible commodity that can be stored or inventoried. A service is a commodity that cannot be stored and inventoried and that is usually consumed at the place where it is purchased.
Otherwise, changes in the consumption bundle over the lifecycle would also be due to the change of the relative price between goods and services, in addition to the effect of age. Then I follow the strategy of Aguiar and Hurst (2013) to identify age effects from cohort and family effects by estimating the following equation:

\[
\log(share_i) = \beta_0 + \beta_{age} Age_i + \beta_{coh} Cohort_i + \beta_{Fam} Family_i + \epsilon_i
\] (4)

\(share_i\) is the share of service expenditure in total consumption expenditures of household \(i\), \(Age_i\) is a vector of age dummies, \(Cohort_i\) a vector of cohort dummies. \(Family_i\) is a set of household composition controls. Using equivalence scales instead of household composition controls does not affect the results. \(\beta_{age}\) is my coefficient of interest.

Figure 3 plots my results. The expenditure share of services is upward-sloping over the lifecycle. The slope is changing around age 65, which is precisely the mean retirement age of the sample. Before retirement, the expenditure share of services increases weakly in age, while its increase is much more pronounced after retirement.

Figure 3: Lifecycle profile of the expenditure share of services

This lifecycle profile can be deduced from Figures 4 and 5, in which I respectively plot the lifecycle profile of services expenditures and total consumption expenditures. These profiles are obtained by regressing equation (4) with the adequate outcome variable.

Figure 5 is the well-documented lifecycle profile of consumption expenditures, which is inverted U-shaped.\(^4\) Figure 4 shows that services expenditures closely track total consumption expenditures before retirement, with a similar inverted-U shaped profile, while this is no more

the case after retirement. Indeed, after retirement, the level of service expenditures is increasing, while the total level of consumption expenditures keeps decreasing. This is in accordance with the sharp increase of the expenditure share of services after retirement documented by Figure 3. Figure 3 and Figure 5 imply that the nature of services changes over the lifecycle. Services are a luxury good for individuals aged between 25 and 55, while services are a normal good for individuals aged more than 55. In appendix A, I repeat this exercise while I exclude health expenditures. I find very similar lifecycle profiles, which shows that health expenditures do not drive the increase of the expenditure share of services in retirement period.

4 A multi-goods framework with home production

4.1 Standard preferences and the lifecycle profile of the share of services expenditure

In this subsection, I explain why this lifecycle profile cannot be replicated by lifecycle models with preferences used by the structural change literature. Let $P_S, P_G, E$ be respectively the price of services, the price of goods, the level of consumption expenditures. Boppart (2014) Comin et al. (2017) or Herrendorf et al. (2013) all consider a per-period indirect utility, $(P_S, P_G, E) \rightarrow V(P_S, P_G, E)$ such that the expenditure share of services, $x_S = \frac{1}{E} \cdot \frac{\partial V}{\partial P_S}$ is increasing in $E$. Consequently, a lifecycle model incorporating these preferences predicts that the lifecycle profile of $x_S$ mirrors that of $E$. This means that if my lifecycle model replicates the documented lifecycle profile of $E$ (Figure 5), then it cannot replicate the documented lifecycle profile of $x_S$ (Figure 3).
4.2 A multi-goods framework with home production

To reconcile theory with the empirical evidence of Figure 3, I need to specify preferences such that:

- The slope of the age-profile of the expenditure share of services increases at the retirement age.
- The expenditure share of services increases in consumption expenditure during working period.
- The expenditure share of services decreases in consumption expenditure during retirement period.

With respect to the first point, I draw on Aguiar and Hurst (2013). These authors show that the lifecycle profile of consumption expenditures differs by item depending whether these goods are amenable to home production or not. The goods that can be home-produced, with time and market expenditures as substitutable inputs, know a sharp decline at retirement. As individuals retire, the price of their time falls, and their market expenditures decline. Here I also rely on a Beckerian view of consumption by considering services as a composite good produced with time and market expenditures. Examples of services category in the CEX include: barbershops, beauty parlors, health clubs, food on-premise, alcohol on-premise, transportation. These services all require both market expenditures and time, and these inputs are complements. At the time of retirement, the price of time falls, which spurs individuals to spend more on services, as market expenditures and time are complements to home produce services. Note also that as work productivity peaks at around age 50, the price of time of individuals starts falling before retirement. This explains why the expenditure share of services does not decrease from age 55 to 65 while total consumption expenditures decline.

With respect to the second point, I rely on non-homothetic preferences used in structural change literature that generate an expenditure elasticity of services greater than 1 as long as individuals work a positive amount of time.

I now show that the combination of these two ingredients, non-homothetic preferences and home production of services, implies that the services expenditure share can decrease in consumption expenditure in retirement period (hence the third point). To ease the exposition, let us assume the following parametric forms:

\[ u(c_G, c_S, l) = (b(c_G - \bar{c}_G)^\epsilon + (1 - b)f(c_S, l)^\epsilon)^{\frac{1}{\epsilon}} \]  \hspace{1cm} (5)
\[ f(c_s, l) = \left((c_S + \tau_S)^{\sigma_S} + \chi l^{\sigma_S}\right)^{\frac{1}{\sigma_S}} \]  

(6)

Where \(\tau_G, \tau_S, \chi, b \in [0, 1]\) are constants. \(c_G\) is the consumption level of goods, \(c_S\) is the consumption level of services. \(l\) is non-working time, \(l \in [0, \overline{l}]\). I view \(l\) as a mix between leisure time and time dedicated to the home production of services. Hence preferences (5) can be viewed from two different perspectives. Leisure and services are not separable, or services are home-produced with market expenditures and time. Note that if \(\chi\) is equal to 0, then my per period utility function coincides with a CES specification with subsistence consumption levels \(\tau_G\) and \(\tau_S\), as in Herrendorf et al. (2013). My view that market expenditures and time are complements to home produce services leads me to impose that \(\sigma_S\) is negative. By definition of the retirement period, the time spent to home produce services is fixed to \(\overline{l}\), and the intratemporal problem of the individual writes:

\[
\max_{c_G, c_S} u(c_G, c_S, \overline{l})
\]

(7)

Subject to \(P_G c_G + P_S c_S \leq E\).

Where \(E\) is total consumption expenditure. There are two forces that shape the dependence of the expenditure share of services, \(P_S / E\) with respect to \(E\). The first effect is due to subsistence levels, \(\tau_G\) and \(\tau_S\). Market expenditures are not necessary to consume services, while they are necessary for goods. Thus, for a low expenditure level, it is optimal not to spend resources on services. As \(E\) grows, it is optimal to spend a positive amount of resources on services, the expenditure share of services increases. This is the traditional effect due to subsistence levels, which is particularly strong for low expenditure levels. The non-separability between time and services expenditures generates a second non-homotheticity in the utility function (5), when leisure time is fixed to \(\overline{l}\). If an individual wants to spend more on services, because \(E\) increases, he also wants to spend more time to home produce services, as time and market expenditures are complements. As an individual cannot increase his time to home produce in retirement period, this reduces the marginal utility of service expenditure. In the extreme case where time and services expenditures are perfect complements, the marginal utility of service expenditures is null, and an individual does not increase his expenditure on services if \(E\) increases. This effect also depends on the elasticity of substitution between services and goods. If services and goods are complements, then an individual increases his consumption of goods and services at the same time. As the only way to increase consumption of services during retirement is through higher market expenditures, expenditures on services also increase. Then, the direction
of this second effect is ultimately given by a comparison between the
elasticity of substitution between the two types of consumption and the
elasticity of substitution between time and market expenditures. I obtain
the following result:

**Proposition 2** Let \((c_G, c_S)\) the consumption bundle that solves (7). Assume \(\epsilon > \sigma_S \). \(\frac{p_{cs}}{E}\) is inverted U-shaped in \(E\).

Proposition 2 shows that the nature of services, luxury or necessity,
depend on the level of expenditures. Hence preferences (5) can be con-
sistent with the results of Figures 3 and 5.

5 The quantitative model

In this section, I embed my lifecycle model into a large-scale OLG model
that I calibrate to US economy on the period 1950-2015. Demographic
variables are exogenous. I then quantify their impact on the composition
of aggregate consumption.

5.1 The model economy

5.1.1 Firms

There are three sectors in the economy: the goods producing sector
\((G)\), the investment sector \((I)\) and the sector of services \((S)\). The in-
vestment good is taken as the numéraire. As my interest is to study the
composition of aggregate consumption, I follow a consumption based ap-
proach. Valentinyi and Herrendorf (2008) estimate Cobb-Douglas pro-
duction functions for this approach that I borrow here:

\[
Y_{Gt} = A_{Gt}K_{Gt}^{\alpha}L_{Gt}^{1-\alpha} \\
Y_{St} = A_{St}K_{St}^{\alpha}L_{St}^{1-\alpha} \\
Y_{It} = A_{It}K_{It}^{\alpha}L_{It}^{1-\alpha} 
\]

Where \(Y_{it}\) is the final output of good \(i \in \{G, S, I\}\) at time \(t\), \(K_{it}\) the
capital stock, \(L_{it}\) effective labor, and \(A_{it}\) the total factor productivity
(TFP). As documented by Herrendorf and Valentinyi (2008), the capital
intensity of good and services sectors is equal, and is noted \(\alpha \in (0,1)\).
\(\alpha_I\) is the capital intensity of the investment sector. To the best of my
knowledge, the literature does not provide evidence of a significant im-
pact of demographic variables on TFP levels, thus I assume that their
evolution is exogenous:

\[
A_{it+1} = (1 + g_t)A_{it} 
\]
Factors of production are perfectly mobile across sectors and are paid at their marginal product. This implies the following equalities:

\[ w_t = P_{Gt}A_{Gt}(1 - \alpha)k_{Gt}^\alpha = P_{St}A_{St}(1 - \alpha)k_{St}^\alpha = A_{It}(1 - \alpha)k_{It}^\alpha \]  

(12)

\[ r_t + \delta = P_{Gt}A_{Gt}\alpha k_{Gt}^{\alpha-1} = P_{St}A_{St}\alpha k_{St}^{\alpha-1} = A_{It}\alpha I k_{It}^{\alpha-1} \]  

(13)

where \( k_{it} \) is capital to labor ratio of sector \( i \) and \( \delta \) is the depreciation rate of capital. (12) and (13) imply that the capital to labor ratios are equal across the two consumption sectors (hence \( k_{1t} = k_{2t} \)). Moreover, the relative price of consumption goods is equal to the ratio of TFP levels: \( \frac{P_{Gt}}{P_{St}} = \frac{A_{St}}{A_{Gt}} \).

5.1.2 Timing and demographics

A period of the model corresponds to five years. Each individual enters the economy at the age of 20 and lives up to 17 periods, or age 105. Given that the mean retirement age has not changed by much during my period of interest (1950-2015), I fix the retirement age to 65, which corresponds to period 10.\(^5\) Each cohort-\(c\) individual lives with his \( n_c \) children from age 30 to age 50 or equivalently from period 2 to period 5. During these parenthood ages, he derives utility from a fraction \( s(n_c) = \frac{1}{(1 + \phi n_c)^{\omega}} \) of the household consumption level, with \( 0 < \phi, \omega < 1 \). This expression of the scale factor, borrowed from Greenwood et al. (2003), introduces a scale effect in household consumption. For a member of cohort \( c \), the probability to survive between period \( a \) and period \( a + 1 \) is noted \( q_{c,a} \), while the unconditional probability to reach period \( a \) is noted \( S_{c,a} \). The number of cohort-\(c\) individuals who reach period \( a \) is noted \( L_{c,a} \).

5.1.3 Individuals

Each individual maximizes expected lifetime utility, with the per period utility function given by (5). For a cohort-\(c\) individual, this writes:

\[ U_c = \sum_{p=0}^{16} \beta^p S_{c,p} \frac{u(s_p(n_c)c_{G,c,p}, s_p(n_c)c_{S,c,p}, l_{c,p})^{1-\gamma}}{1-\gamma} \]  

(14)

Where \( \beta \) is the discount factor and \( \gamma \) is the inverse of the intertemporal elasticity of substitution and \( s_p(n_c) = \mathbb{1}_{1<p<6}(s(n_c) - 1) + 1 \). \( c_{G,c,p} \) and \( c_{S,c,p} \) are consumption expenditures at the household level. There is

\(^5\)Prettner and Canning (2014) show that in a perpetual youth model, the retirement age increases with life expectancy contrary to what happened in US and other OECD countries. They conclude that political constraints impede these adjustments. Then I take here these political constraints as given.
no annuity market. Government taxes unexpected bequests and redistribute them equally across individuals. The budget constraints read:

$$\forall p \leq 9, a_{c,p+1} = (a_{c,p} + T_{c+5p}^B)(1 + r_{c+5p}) + (1 - \tau_{c+5p})z_{c,p}w_{c+5p}(l - l_{c,p}) - P_{S,c+5p}c_{S,c,p} - P_{G,c+5p}c_{G,c,p} - M_{c,p} - T_{c+5p}^H$$ (15)

$$\forall p \geq 10, a_{c,p+1} = (a_{c,p} + T_{c+5p}^B)(1 + r_{c+5p}) + B_{c+5p} - P_{S,c+5p}c_{S,c,p} - P_{G,c+5p}c_{G,c,p} - M_{c,p}$$ (16)

and $a_{c,0} = 0$. Where $a_{c,p}$ denotes the level of assets in period $p$, $(z_{c,p})_{p=0,9}$ is a vector of age-efficiency weights, $T_{c+5p}^B$ is the amount of unexpected bequests distributed at time $c + 5p$. $B_{c+5p}$ is the pension income level at time $c + 5p$, which is financed through a tax on the wages at rate $\tau_{c+5p}$, $M_{c,p}$ is level of health expenditures. $T_{c+5p}^H$ is a lump-sum tax on working-aged individuals to finance health expenditures of old individuals. Finally, $l$ is total amount of time available in a period for each individual.

### 5.1.4 Retirement system

The pension system is a simple pay-as-you-go system. Independently on its age, each retiree receives a pension income which is proportional to the current mean labor income in the economy. Given a replacement rate, $\psi$, the tax rate is determined so as to balance the budget. More precisely at time $t$:

$$\tau_t w_t \sum_{a=0}^{9} z_{t-5a,a} L_{t-5a,a} = \psi \sum_{a=0}^{9} \frac{z_{t-5a,a} L_{t-5a,a}}{L_{t-5a,a}} \sum_{a=0}^{16} L_{t-5a,a}$$ (17)

This implies that the tax rate is proportional to the dependency ratio, $\tau_t = \psi \frac{\sum_{a=0}^{16} L_{t-5a,a}}{\sum_{a=0}^{9} L_{t-5a,a}}$. And the pension income level at time $t$ is given by:

$$B_t = \psi w_t \sum_{a=0}^{9} z_{t-5a,a} L_{t-5a,a} \sum_{a=0}^{16} L_{t-5a,a}$$

### 5.1.5 Health expenditures

Individual health expenditures, $M_{c,p}$, are driven by two factors. First, biological factors require that an individual spends more and more resources for his health along the lifecycle. Second, medical innovations shift upward the lifecycle profile of health expenditures. Thus, I assume that $M_{c,p} = m_{c+5p}(1 + g^H)^p$, where $m_{c+5p}$ captures the state of medical technology at time $c + 5p$ and $g^H$ is the growth rate of health expenditures along the lifecycle. Part of these health expenditures are publicly financed for retired individuals. They are financed through a lump-sum tax on working aged individuals, which is determined to balance the budget.
5.1.6 Equilibrium

My definition of an equilibrium is standard. Each cohort chooses his consumption levels and time to home-produce services to maximize expected lifetime utility (14) subject to the budget constraints (15) and (16). The demand for labor and capital by firms is given by equations (12) and (13). The budget of the government is balanced and markets clear.

5.2 Calibration

I want to compare the dynamics of my model with respect to the evolution of US economy on the period 1950-2015. In this aim, I simulate the transitional dynamics from a fictive steady-state in 1800 to a second fictive steady-state in 2400. These two steady-states differ through their demographic and technological variables. Then, I compare the dynamics of my model on the period 1950-2015 to that of US economy. In a second time, I resimulate the model blocking demographic variables and I compare the result to my first simulation.

Demographic data: I merge different sources to obtain complete demographic data, survival probability and initial cohort size, for cohorts 1840 to 2050. I use survival probabilities for both sexes. In Haines (1994), I obtain these survival probability for cohorts 1840 to 1900. They are given for intervals age of 10 years, so I interpolate a Gompertz-Makeham law of mortality to obtain these numbers for an interval age of 5 years. Details are given in Appendix. For cohorts 1905 to 2050, I use data from Bell et al. (1992). Once cohort plus age is greater than 2015, the data is obviously a projection. Figure 6 reports the survival curve of three different cohorts.

![Figure 6: Survival curve for different cohorts](image)
Initial cohort size is collected in the database of the US census for cohorts 1840 to 1990. For future cohorts, I use the projections of the UN database. The number of children, $n_c$, for each cohort $c$, is computed to be coherent with cohort sizes. Hence \( \frac{L_{c-20}}{L_{c}} \), because individuals have their children in period 2. This means that children who died before age 20 do not reduce the consumption of the parent.

**Firms:** The values of $\alpha$ and $\alpha_I$ are obtained or computed from Valentinyi and Herrendorf (2008). These authors estimate production functions with capital and labor as inputs for five sectors: agriculture, manufactured consumption, services, equipment investment and construction investment. Consistently with my final consumption approach, I use their capital share in purchaser price with their aggregated input-output table to compute the capital share of the sector producing goods (hence agriculture and manufactured consumption). I find a capital share of the goods sector equal to 0.35, which is also that of services, as specified by production functions (8) and (9). Hence $\alpha = 0.35$. I obtain $\alpha_I = 0.28$ directly in Valentinyi and Herrendorf (2008). I use an annual depreciation rate of physical capital equal to 3.8% as in Ludwig et al. (2012), which implies $\delta = 17.6\%$. The ratio of TFP growth rates of goods and service sector coincides with the growth rate of the relative price of services and goods. I compute the average growth rate of the relative price of services and goods over 1950-2015 from BEA. I obtain $1 + g_G = 1.0831(1 + g_S)$. Initial TFP levels are normalized.

**Preferences:** I set the inverse of the intertemporal elasticity of substitution, $\gamma$, to 2 as in Conesa et al. (2009). I choose $\epsilon = -0.5318$ to get the same elasticity of substitution between goods and services as in Kehoe et al. (in press). This value is halfway to literature estimates. I use the age-income profile ($z_{c,a}$) of Coeurdacier et al. (2015) for all cohorts. Indeed, these authors compute this profile from CEX data and observe it is invariant over time. The amount of time available each period is normalized to 1, $\bar{l} = 1$. Relative to home production, I use a value close to the estimate of Fang and Zhu (2017) for the elasticity of substitution between market expenditures and time. This gives $\sigma_S = -0.8$. I obtain the values of $\phi$ and $\omega$ in Greenwood et al. (2003). $\beta$ is chosen to match a realistic capital to output ratio, around 3. This yields a discount rate slightly greater than 1, which is in accordance with lifecycle models in which mortality rates are taken into account (see Heer and Irmen (2014)). Finally, the replacement rate of the pension system, $\phi$, is set to 0.4 as in Aguiar and Hurst (2013).
Health expenditures: Dalgaard and Strulik (2014) compute the growth rate of health expenditures over the lifecycle in several countries and obtain a value equal to 2%. This gives me a value for $g^H$. The medical technology terms $(m_t)_{t \in [1800,2400]}$ are computed for the model to reproduce the ratio of total health expenditures to total consumption expenditures from 1930 to 2015. The values are obtained from the BEA. Before 1900, health expenditures are assumed to be null. Between 1900 and 1930, the ratio of health expenditures to consumption expenditures is the interpolated value. After 2015, this ratio is assumed to pursue its post-war trend. The Resolution subsection below gives more details on the way the terms $(m_t)_{t \in [1800,2400]}$ are computed.

Other calibrated parameters: There remains to assign a value to $(\chi, b, c_S, c_S; g_G, g_I)$. $g_G$ and $g_I$ are chosen on a grid centered around the values found by Moro and Leon-Ledesma (2017) to match the evolution of the aggregate consumption expenditures. $(\chi, b, c_S, c_S)$ are chosen over a large grid to minimize the distance between the actual aggregate expenditure share of services and the model counterpart over the period 1950-2015. Let $S_t^{data}$ and $S_t(\chi, b, c_S, c_S)$ denote respectively the aggregate expenditure share of services in the data at time $t$ and the model counterpart. $(\chi, b, c_S, c_S)$ are chosen to minimize the following objective:

$$\sum_{t=1950}^{2015} (S_t^{data} - S_t(\chi, b, c_G, c_S))^2$$

Resolution: The algorithm to solve the model is standard. I make a guess for the values of capital stock per worker in the investment sector, pension income, the amount of unexpected bequests and the total level of consumption expenditures at each time. With the level of consumption expenditures and the share of health expenditures in consumption expenditure, I can obtain the aggregate level of health expenditures at each time and then I can compute the technology terms and the lifecycle profile of health expenditures each individual faces. I then solve the individual’s problem for each cohort. For this, I make an initial guess of the level of assets at the beginning of last period and I iterate backward through the Euler equation. In working period, the Euler equation can be solved analytically, so that I use an endogenous grid method (Carroll 2006) to speed up the computation. I also gain speed by using a parallelization routine to compute individual variables for different cohorts. Finally, I update my guesses with a Gauss-Siedel procedure as in Ludwig (2007). Details of the computation are given in Appendix.
5.3 Results

Backfitting: I examine the performance of the model with respect to data. The model replicates well the trajectory of the aggregate consumption expenditure (in terms of the investment good) and that of the aggregate expenditure share of services, the variable of interest (Figures 8 and 9). Note that matching the pattern in the data with my OLG model is much more challenging than with a representative agent model. To gauge how successful the model is to replicate individual behavior, I plot the lifecycle profile of the expenditure share of services of the cohort 1950 (Figure 10). The model overpredicts the increase of this share initially, but the change of the slope at the time of retirement is well captured. Moreover, the model is able to reproduce the changing nature of services along the lifecycle. Therefore my model appears as a reliable laboratory to examine the impact of demographic variables on the evolution of the aggregate expenditure share of services.

Figure 7: Relative price between services and goods

Figure 8: Aggregate real consumption expenditures

Figure 9: Aggregate expenditure share of services
Experiment: I now assume that each cohort faces the demographic variables of the cohort 1840, the oldest cohort for which we have data. All other parameters are unchanged. Figure 11 reports the evolution of the aggregate expenditure share of services of this counterfactual economy. It reveals that aging tends to diminish the expenditure share of services. The decrease between the two scenarios varies from 8.55% in 1950-1955 to 1.41% in 2010-2015.

To understand the result, we need to assess how each of the three effects previously outlined affects the expenditure share of services. The first effect is due to the change of the composition of the population. Figure 10 indicates that old individuals have a higher expenditure share of services than young individuals. Hence aging tends to increase the aggregate expenditure share of services through this effect. The second effect is due to the reallocation of resources over the lifecycle. Aging implies that individuals postpone their consumption expenditures at older ages. Then, the impact on the expenditures share of services is obtained by equations (1) and (2). At older ages, services are a necessity goods,
so the expenditure increase at these ages reduces the expenditure share of services at old ages. At younger ages, services are a luxury good, so the expenditure decrease at these ages also reduces the expenditure share of services at young ages. Hence aging increases the expenditure share of services of all individuals through this effect, which positively impacts the aggregate expenditure share of services.

Figure 12: Labor supply differences (Baseline-experiment)

Figure 13: Consumption expenditure differences (Baseline-experiment)

Figure 14: GDP per capita difference (Baseline-experiment)

Figure 15: Expenditure share differences (Baseline-experiment)

The third effect is due to market prices change. Aging stimulates physical capital accumulation as it induces individuals to save more. Moreover aging stimulates labor supply. Indeed, as individuals spend less during young ages, and so less on services, they spend less time to home-produce because time and market expenditures are complement.
Thus individuals supply more labor (see Figure 12). These inputs'supply increases are stronger than the population increase due to aging, which implies that aging stimulates income per capita (Figure 14). These supplementary resources change individuals’ consumption bundles differently according to their ages: the expenditure share of services increases for young individuals, while it diminishes for old individuals. Hence the third effect has an ambiguous impact on the aggregate expenditure share of services. We can observe the total impact of the second and the third effects by comparing the individual expenditure share of services in the two scenarios (Figure 15). These two effects combined tend to reduce the individual expenditure share of services. Then Figure 11 implies that the change of the population composition has a smaller impact than these two combined effects.

6 Conclusion

This paper assesses the contribution of demographic variables, fertility and mortality rates, to the evolution of the composition of aggregate consumption. For this, I develop a life-cycle model with consumption of goods and services and home production. Home-production, or non-separability between leisure and service expenditures, is a key ingredient to obtain a lifecycle profile of the expenditure share of services consistent with empirical evidence. Indeed, the empirical evidence I present reveals that services are a luxury good for working-aged individuals and a necessity good for retirees. Standard multi-goods preferences without home production are not consistent with this fact. I then incorporate my lifecycle model into an OLG structure calibrated to US economy on post-war period. The model replicates well the evolution of the aggregate expenditure share of services and is used to make counterfactual experiments on demographic variables. These ones reveal that aging diminishes the aggregate expenditure share of services, up to 8.55%. The dominant effect is as follows. Aging reallocates resources from young ages, at which services are a luxury good, to old ages, at which services are a necessity good. This reduces the expenditure share of services of all individuals.

References


94-107.


7 Appendix A

Consumption categories that are considered as goods in the CEX data are: food-off premise, tobacco products, alcohol off-premise, clothing and shoes, jewelry and watches, toilet articles and preparations, furniture and durable household equipment, nondurable household supplies and equipment, fuel oil and coal, ophthamic products and orthopedic appliances, new and used motor vehicles, tires, tubes accessories and other parts, gasoline and oil, books and maps, magazines, newspapers, other nondurable toys, recreation and sports equipment. Other categories are considered as services. I now exclude health expenditures and I repeat the estimations of section 3. Figures 16 to 18 plots the results.

Hence our results are robust to the exclusion of health expenditures.

8 Appendix B

In this section, I derive the Euler equation of the individual’s problem. We redefine household consumption level as indiviuadl consumption by absorbing scale factors into the price of goods and services. The la-
Figure 16: Lifecycle profile of the share of service expenditures

Figure 17: Lifecycle profile of service expenditures

Figure 18: Lifecycle profile of consumption expenditures

grangian associated to this problem writes:

\[ \mathcal{L}_c = \sum_{a=0}^{16} \beta^a_s \frac{u(c_{G,c,a}, c_{S,c,a}, l_{c,a})^{1-\gamma}}{1-\gamma} \]

\[ + \sum_{a=0}^{9} \lambda_a ((a_{c,a} + T_{c+5a})(1+r_{c+5a}) + (1-\tau_{c+5a})z_{c,a}w_{c+5a}(\bar{l} - l_{c,a}) - P_{S,c+5a}c_{S,c,a} - P_{G,c+5a}c_{G,c,a} - a_{c,a+1}) \]

\[ + \sum_{a=10}^{16} \lambda_a ((a_{c,a} + T_{c+5a})(1+r_{c+5a}) + B_{c+5a} - P_{S,c+5a}c_{S,c,a} - P_{G,c+5a}c_{G,c,a} - a_{c,a+1}) \]

(19)

I focus on an interior solution for \( c_S \) and \( l \). The first-order conditions write:

\[ \lambda_a = \lambda_{a-1}(1 + r_{c+5a}) \]

(20)
\beta^g S_{c,a} u_1(c_{G,c,a}, c_{S,c,a}, l_{c,a}) u(c_{G,c,a}, c_{S,c,a}, l_{c,a})^\gamma = \lambda_a P_{G,c+5a} \tag{21}

\beta^g S_{c,a} u_2(c_{G,c,a}, c_{S,c,a}, l_{c,a}) u(c_{G,c,a}, c_{S,c,a}, l_{c,a})^\gamma = \lambda_a P_{S,c+5a} \tag{22}

\beta^g S_{c,a} u_1(c_{G,c,a}, c_{S,c,a}, l_{c,a}) u(c_{G,c,a}, c_{S,c,a}, l_{c,a})^\gamma = \lambda_a w_{G,c+5a} (1 - \tau_{c+5a}) z_{c,a} \tag{23}

During retirement period, (23) and (22) imply:

\[ l_{c,a} = (c_{S,c,a} + C_S)(w_{G,c+5a} (1 - \tau_{c+5a}) z_{c,a}) \frac{1}{\sigma_{\mu} - \gamma} \tag{24} \]

Then, this relationship with (21) and (22) gives a linear relationship between \(c_{G,c,a}\) and \(c_{S,c,a}\). Then, we express marginal utility of goods as a function only of \(c_{S,c,a}\). Then, the Euler equation:

\[ \beta q_{a,a+1}(1 + r_{c+5a}) \frac{P_{G,c+5a+5}}{P_{G,c+5a}} = \frac{u_1(c_{G,c,a}, c_{S,c,a}, l_{c,a})}{u_1(c_{G,c,a+1}, c_{S,c,a+1}, l_{c,a+1})} \tag{25} \]

implies a linear relationship between \(c_{S,c,a}\) and \(c_{S,c,a+1}\). During retirement period, we obtain the Euler equation by combining (21) and (22) with \(l_{c,a} = l\). We obtain a (non-linear) equation linking \(c_{S,c,a}\) and \(c_{S,c,a+1}\). Pratically, I work with a 30 points grid for the guess on the asset level in period 16. I then solve the model backward through the Euler equation. The code is in Python and is available upon request.