

Generational Connections, Population Aging, and Sustainable Consumption

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Abstract

As their populations age, Japan, the United States, and many other countries face challenging economic prospects. Due to important intergenerational linkages, members of every generation will be affected. Saving may prove to be insufficient and old-age support systems fiscally unsound. Here we assess the proportional reduction in consumption across all ages that would be required to attain long-term sustainability. We use a simulation model together with the most extensive data ever compiled to analyze the connections between age structure and the economy. Our goal is to root our analysis in these rich empirical measures of age specific economic behavior which provide a straightforward interface with the population age distribution. This approach contrasts with more theoretical models incorporating feedbacks and endogenous behavior while requiring different kinds of assumptions. Sustainability requires both cross-sectional aggregate balance each year and longitudinal balance for each birth cohort. Specifically, we ask: “Are the baseline age profiles of consumption, labor income, savings, and intergenerational transfers sustainable in a hypothetical demographic steady state that would result from fixed fertility and mortality rates? To what extent would the age profile of consumption have to be altered to achieve sustainability?” Sustainability is calculated for each country using conditions as of three dates: several decades ago (1984 Japan and 1990 US), 2019, and 2065. We find that the intergenerational economies in Japan and the US were close to sustainable at the earlier

date, but became seriously unsustainable by 2019. An even greater shortfall would occur given expected fertility and mortality rates for 2065. We discuss reasons for the deterioration in sustainability-- population aging, differences in economic behavior, and public policy. Given 2019 conditions long run sustainability in Japan would require a 15% reduction in consumption (relative to labor income with an underlying upward trajectory from expected productivity growth). With the projected fertility and mortality conditions of 2065 a 19% reduction would be required to achieve sustainability. For the US the corresponding reductions would be 9% for 2019 and 12% for 2065 conditions.

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Introduction

Many countries are experiencing population aging without precedent. People are having fewer births and living into their 70s, 80s, and beyond. The questions addressed in this paper: “Will they be able to maintain their standards of living? If not, how sharp a decline in consumption will be required?” Saving that was sufficient in the past may no longer suffice when life expectancy is reaching higher levels. Compounding that problem is the deteriorating finances that characterize old-age transfer systems. The number of elderly who rely on publicly-funded programs is rising sharply relative to the number of taxpayers who fund such programs.

A potentially useful response to population aging is for people to work longer. This has happened in both Japan and the United States, but this is only a partial solution. Greater reliance on intergenerational transfers can shift resources across age groups, but does not increase the total resources available. People will have to consume less and save more. Thus, aging will lead to substantial downward pressure on consumption.

The simulation model presented in this paper shows how consumption would change in response to aging, slowing population growth, and policies related to demographic changes. We assume that all cohorts rely exclusively on resources they generate over their lifetime, rather than on wealth passed on by previous generations or by debt passed on to future generations. We assume that standards of living for one age group are not achieved at the expenses of members of other age groups. All boats rise or fall together.

The analysis uses National Transfer Accounts (NTA) showing how Japan and the United States balance their cross-sectional lifecycle accounts with consumption funded by labor income, transfers, and asset-based reallocations at every age. We use a simulation model to show how lifecycle accounts balance

from a longitudinal perspective relying on intergenerational transfers and saving. Consumption that can be funded over the lifecycle of a representative cohort is said to be sustainable.

In Japan and the US consumption was sustainable in the past. At present, current consumption falls well-short of sustainability. And in the future, sustainability will likely be further out of reach. Three factors account for this conclusion. First, life expectancy is rising in both countries leading to an increase in years spent consuming relative to years spent producing. People are working more at older ages, but retirement is still a growing segment of the lifecycle. Second, spending at older ages is rising relative to spending at prime adult ages. Spending on health and long-term care is behind this change. Third, old-age support systems are eroding and will erode further in the future. Due to low fertility and higher life expectancy, the number who count on benefits is rising relative to the number who provide them.

This paper presents a model developed to simulate the path of sustainable consumption for a representative cohort and for the population, as a whole. The model incorporates the effects of demographic factors, baseline age patterns of consumption and labor income, the extent to which countries rely on transfers and asset-based reallocations to fund the needs of children and seniors, the rates of return on assets, and the rates of productivity growth.

Our model is distinctive in several ways. First, it relies heavily on macro-level cross-sectional and intertemporal constraints that govern flows over the lifecycle. Second, it defines and uses sustainability to model consumption for cohorts and the economy as a whole. Third, it relies on observed age profiles rather than assumptions about optimizing behavior to guide consumption and labor income. Fourth, it models the entire lifecycle, from birth to death, recognizing inter-dependency across all generations. Fifth, the model recognizes the importance of reallocation systems that shift resources from one age group to another and from one time to another.

Implementation relies on data for Japan and the United States. Extensive use is made of National Transfer Accounts (NTA) data some of which has been updated and used here for the first time.

Historical and contemporaneous data are used to show how changes over the last three decades have led to a decline in sustainability over this period. Projections are used to show that further decline in sustainable consumption can be expected.

Aging is leading to greater challenges in Japan than in the US for several reasons. As compared with the US, Japan is experiencing more severe aging and depends more heavily on transfers to support seniors. Although Japanese seniors consume less than Americans relative to their labor income, Japanese consumption by seniors has shifted sharply higher in recent years. A final factor is that rates of return to capital are low in Japan, as compared with the US, increasing the costs of accumulating sufficient assets to support consumption in retirement in Japan. Aging will bring its challenges to the US, as well, but they are less serious than in Japan.

The paper is organized in five sections. The first section reviews theoretical foundations on which the current study builds. The second section presents a formal model of sustainable consumption building on overlapping generation (OLG) and lifecycle frameworks. The third section presents simulations used to assess the impact of aging on sustainable consumption and to analyze how policies that affect support systems and fertility will influence outcomes. The fourth section considers how the introduction of bequests and other forms of wealth would affect the results. The fifth section discusses other issues and concludes.

Foundations

The importance of intergenerational linkages in the macroeconomy was widely recognized with the development of overlapping-generation (OLG) models. Samuelson's (1958) consumption-loan model demonstrated how pay-as-you-go transfer systems can arise in the absence of capital markets. He

introduces the “biological rate of interest” that depends on population and productivity growth.

Diamond (1965) extended this framework to include capital accumulation, showing how public debt and social security affect intergenerational welfare in an economy with overlapping cohorts. Subsequent OLG formulations (Tobin 1967, Willis 1988) explored how saving and demographic structure jointly determine equilibrium interest rates. Auerbach and Kotlikoff’s *Dynamic Fiscal Policy* (1987) introduced detailed age structures and rich fiscal institutions to analyze tax and transfer policies across realistic lifespans.

More recent studies (Cutler, Poterba et al. 1990, Feldstein and Liebman 2002, Diamond 2004, Sheiner 2023, U.S. Office of Management and Budget 2023) have used OLG frameworks to evaluate the sustainability of old-age support systems under population aging and fiscal stress. Related analysis for Japan by İmrohoroğlu, Kitao, and Yamada (2017) uses a calibrated OLG model to assess fiscal sustainability and pension reform.

Lee (1994a, 1994b) provides the most comprehensive conceptual foundation for modeling detailed age structure, intergenerational transfers and other macroeconomic outcomes. Lee, Mason, and others build on these concepts to develop National Transfer Accounts (NTA) providing the conceptual and empirical foundation for the work presented here (Lee and Mason 2011, United Nations Population Division 2013).

Several recent studies have relied on NTA concepts and data to analyze the economic effects of population age structure. Lee and Mason (2011) and Mason and Lee (2006) pioneered the use of NTA to explore how demographic change influences saving and capital accumulation, leading to a “second demographic dividend.” Subsequent work by Lee, Mason, and collaborators has incorporated NTA data into cohort-based, macro-simulation models to assess fiscal sustainability, the evolution of support ratios, and the long-term economic implications of aging (Lee and Mason 2010, Mason 2015). Other

researchers have developed closely related frameworks linking NTA with general equilibrium or OLG-type simulations. Sánchez-Romero and colleagues (Sánchez-Romero, Fernández-Villaverde et al. 2013, Sánchez-Romero, Fernández-Villaverde et al. 2022) combine NTA with dynamic microsimulation and computable OLG models to examine public-transfer reform, pension sustainability, and intergenerational equity. Sánchez-Romero, Ogawa, and Matsukura (2013) apply similar methods to Japan using a CGE model with realistic demography to analyze the effects of age structure and bequest behavior on intergenerational wealth transfers. Hammer, Prskawetz, and Freund (2015) use an NTA-based macro-simulation model to evaluate how changes in fertility, mortality, and labor supply affect economic growth and generational welfare. Collectively, these studies demonstrate how NTA-based simulation models can quantify the macroeconomic and intergenerational consequences of demographic change.

The Model

The foundations of sustainable consumption consist of two parts. First, current flows address the cross-sectional connection between current consumption and economic resources: labor income, transfers, and asset-based reallocations. Second, lifecycle wealth addresses the longitudinal connection between consumption and resources for a representative cohort. Current flows are addressed first and then we turn to wealth.

Current flows

Current flows consist of four components as modeled and estimated in National Transfer Accounts:

- *Consumption*: Public and private consumption of health, education, the rental value of owner-occupied housing, and other public and private consumption.
- *Labor income*: Earnings and self-employment labor income, estimated as two-thirds of mixed income. Age profiles include an estimate of the value of unpaid family workers.

- *Transfers*: Public and private transfers. Public transfers at each age consist of cash and in-kind transfers received less taxes and obligations incurred due primarily to debt financing. Private transfers consist of transfer inflows and outflows between and within households.
- *Asset-based reallocations*: asset income in excess of saving; or asset income plus dis-saving.
 - Asset-income: Private and public asset income. Private asset income is equal to the net operating surplus, a portion (one third) of mixed income, income from owner-occupied housing, and property income. Public asset income is comprised of the public operating surplus, if any, and public property income including interest on public debt.
 - Saving: Public and private saving.

Aggregate flows are adjusted to match System of National Accounts data to the extent possible and assigned to age using methods described in the NTA manual. The manual can be downloaded from the UN (United Nations Population Division 2013) or the NTA website (www.ntaccounts.org).

Age-based economic flows fall into four lifecycle phases. The first two phases, childhood and childrearing, are closely linked. Children produce little through their labor and must fund consumption relying heavily on transfers and, to a limited extent for older children, on asset-based reallocations. During the childrearing phase, adults produce more through their labor than they consume, with the surplus devoted heavily to funding the needs of children.

The third and fourth phases of the lifecycle emphasize old-age needs. During the third phase, labor income exceeds consumption and the surplus is used to accumulate assets for retirement and to fund transfers that support seniors. During the fourth and final phase of life, seniors rely on transfers and asset-based reallocations to fund the gap between their consumption and labor income.

Lifecycle phases are conveniently identified by average flows, but the reality is that these phases overlap. The simulation model presented below is a simplified version of reality, however, and we

assume that surplus resources during the second phase are used to fund the needs of children while surplus resources during the third phase are used to fund old-age needs.

Economic flows are governed by important aggregate constraints. In the absence of net transfers from the rest of the world, aggregate transfer inflows must equal outflows. Net transfers are zero. Transfers are used to redistribute resources across age groups, but they cannot be used to increase resources for one age group without reducing resources for another. Asset-based reallocations are also constrained at the aggregate level. Setting aside international capital flows, aggregate credit must be zero. Thus, aggregate asset-based reallocations are constrained by the return to capital and the extent to which income is saved or dissaved. Saving influences the path of assets and, hence, asset income over the lifecycle.

Wealth

Wealth is analyzed over the lifecycle of a representative cohort consisting of all individuals born in year t_0 , at age 0, and surviving to the maximum age ω in year $t_0 + \omega$. Their wealth at any age x can be viewed retrospectively, determined by consumption and labor income from birth to age x : the accumulation of additional wealth at each age and the returns to those accumulations. Or wealth can be viewed prospectively determined by the present value of anticipated economic flows of consumption and labor income between age x and the end of life.

Given steady state assumptions assumed here relevant features of the representative cohort apply to all cohorts.

Wealth comes in two forms, assets and transfer wealth $W(x, t_0) = A(x, t_0) + W^T(x, t_0)$ (Willis 1988, Lee 1994a, Lee 1994b). Assets are defined following standard practice while transfer wealth is defined as the present value of net transfers for the representative cohort over the lifecycle.

The composition of wealth is important because: (a) the composition of assets and transfer wealth vary considerably over the lifecycle; (b) the rates of return to assets differ from the rates of return to transfer wealth; (c) the composition of wealth reflects differences in public policy that distinguish Japan from the US and from many other countries.

Age-profiles of wealth share broad similarities. During the first phase of the lifecycle, childhood, wealth declines from zero at birth, reaching a trough. During the second phase, childrearing, lifecycle wealth recovers using the surplus of labor income over consumption. At the end of the second phase, lifecycle wealth is zero and lifecycle resources are no longer devoted to childrearing. Wealth rises during the third phase as lifecycle surpluses are devoted to accumulating wealth, both in the form of assets and transfer wealth. During the fourth phase, wealth declines funding old-age needs. Assets at the end of life may be non-zero due to uncertainty about the age at death, but we assume that individuals rely on costless annuities (Yaari 1965) so that each cohort ends life with zero assets.

Sustainable consumption

Sustainable consumption was defined by Solow in his 1992 lecture, “An Almost Practical Step Toward Sustainability”:

“Sustainability is maintaining the capacity to provide the same standard of living for future generations that we provide for ourselves.”

Solow did not explicitly incorporate technological progress in his formulation but we define sustainability assuming that successive generations realize the benefits of productivity growth. Solow’s formulation is extended here to incorporate the lifecycle. Our definition:

Sustainability is achieved when: a) standards of living for successive generations rise in line with productivity growth; and b) resources generated by successive generations (labor income, assets, and transfers) are sufficient to maintain standards of living at every age.

Transfers do not play a role in Solow's formulation, but they are central to sustainability when the lifecycle is introduced

Consumption is sustainable if successive generations are self-sufficient. Cohorts do not consume more by relying on bequests from previous generations and, in like fashion, do not provide bequests to, nor impose debts on, future generations. Wealth at the beginning and at the end of life is zero:

Sustainability is achieved when:

$$W_0 = W_\omega = 0.$$

As noted earlier, accidental bequests are ruled out because individuals rely on lifetime annuities (Yaari 1965). Below, we discuss how introducing intentional bequests would influence the results.

The Simulation model

The simulation model is based on the following assumptions:

- The population is stable and closed to immigration; age-specific fertility and mortality rates are fixed and, hence, the population growth rate and population age structure are constant.
- The rate of labor productivity growth is constant.
- The economy is closed.
- The levels of consumption and labor income change, but the age patterns do not.
- There are no bequests.
- Reallocation shares (net transfers versus asset-based reallocations) are exogenous; shares for childrearing and for old-age needs differ.

A population achieves stability, after a period of time, if age-specific fertility and mortality rates are fixed. This results in a constant rate of population growth and a fixed age structure. A representative

cohort is traced from its birth year, t_0 , until year $t_0 + \omega$ by which time all cohort members will have died. The population of the cohort is designated as $N(x, t_0 + x)$ where:

$$N(x, t_0 + x) = B(t_0)L(x) \quad (1)$$

$B(t_0)$ is births in year t_0 and $L(x)$ is person years lived at each age by a birth cohort, a standard life table mortality measure. The number of births and the population of each age grow at rate n .

Per capita labor income at age x for the cohort is:

$$y^l(x, t_0 + x) = (1 + \lambda)^x y^l(x, t_0) \quad (2)$$

where λ is the annual rate of productivity growth; i.e., the rate at which the per capita age profile shifts over time, and $y^l(x, t_0)$ is the per capita labor income age profile in year t_0 .

Per capita sustainable consumption is:

$$c(x, t_0 + x) = \beta^* (1 + \lambda)^x c(x, t_0) \quad (3)$$

where λ is the annual rate of productivity growth, and $c(x, t_0)$ is the per capita consumption age profile in year t_0 . The simulation model is used to solve for the sustainability ratio, β^* .

Lifecycle wealth for children and for childrearing adults is calculated prospectively from birth to age x^* :

$$W(x, t_0 + x) = \sum_{z=0}^{x^*} (1 + r_1)^z [YI(z, t_0 + z) - \beta^* C(z, t_0 + z)] \quad (4)$$

$$W(0, t_0) = W(x^*, t_0 + x^*) = 0.$$

where $W(x, t_0 + x)$ is lifecycle wealth of the year t_0 cohort of age x in year $t_0 + x$ and r_1 is the rate of return to wealth over the age range 0 to x^* . Wealth is 0 at birth and at the end of the childrearing phase.

Wealth over the third and fourth phases is calculated prospectively as:

$$W(x, t_0 + x) = \sum_{z=0}^{\omega-x^*} (1+r_2)^{-(\omega-z)} [\beta^* C(x+z, t_0+x+z) - Yl(x+z, t_0+z)] \quad (5)$$

$$W(\omega, t_0 + \omega) = W(x^*, t_0 + x^*) = 0.$$

where $W(x, t_0 + x)$ is lifecycle wealth of the year t_0 cohort of age x in year $t_0 + x$, r_2 is the rate of return to wealth over the third and fourth phases of the lifecycle, and x^* is the age at which the accumulation of retirement wealth first begins.

Reallocations and the rates of return

The rates of return to wealth vary over the lifecycle because the composition of wealth (assets versus transfer wealth) varies over the lifecycle. The rate of return to assets is exogenous while the rate of return to transfers is $n + \lambda$, the rate of population growth plus the rate of productivity growth, the biological rate of interest. If individuals “invest” in transfers they receive returns governed by the number of people and the per capita resources of those providing transfers. Thus, the rate of return to wealth is:

$$r = r_A(1 - w_T) + (n + \lambda)w_T \quad (6)$$

where r_A is the rate of return to assets, $(1 - w_T)$ is the share of lifecycle deficits funded by asset-based reallocations, and w_T is the share funded by transfers. The rate of return to wealth for the child/childrearing phases depends on the reallocation shares for those phases while the rate of return to wealth depends on the reallocation share for the pre-retirement/retirement phases of the lifecycle.

Equilibrium

Equilibrium is defined by two sets of conditions. The first is the lifetime balance condition. For all cohorts, wealth at the beginning of life, at the age of transition, x^* , and at the end of life must be zero:

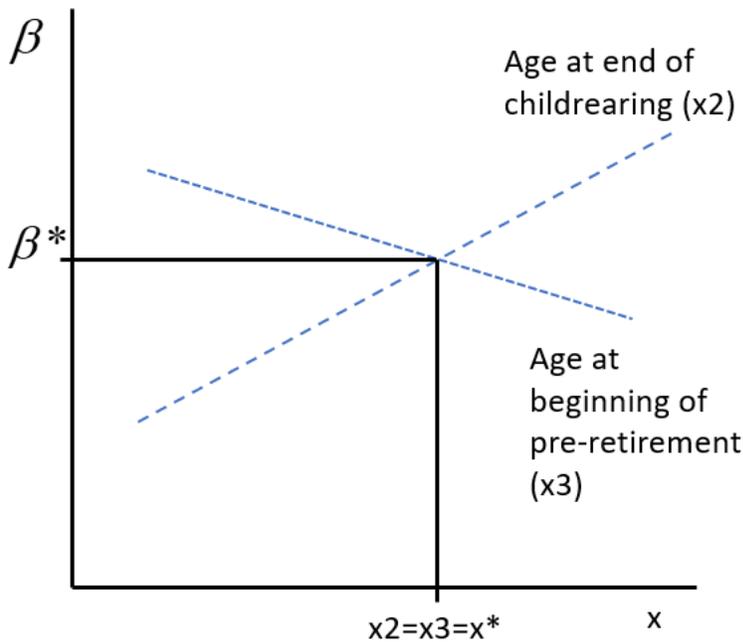
$$W(0) = W(x^*) = W(\omega) = 0. \quad (7)$$

The second condition is the lifecycle transition condition. The lifecycle is characterized by a transition from lifecycle debt, or negative wealth, to positive lifecycle wealth. The age at which this transition occurs is endogenously determined by:

$$x^* = x_2(\beta^*) = x_3(\beta^*). \quad (8)$$

A graphical representation of the equilibrium transition age is shown in Figure 1. With an increase in consumption ratio, β , childrearing is completed later and the accumulation of old-age resources begins earlier. We solve for the equilibrium by calculating the values of x_2 and x_3 given values of beta and searching for the outcome that satisfies the equilibrium conditions in equations 7 and 8.

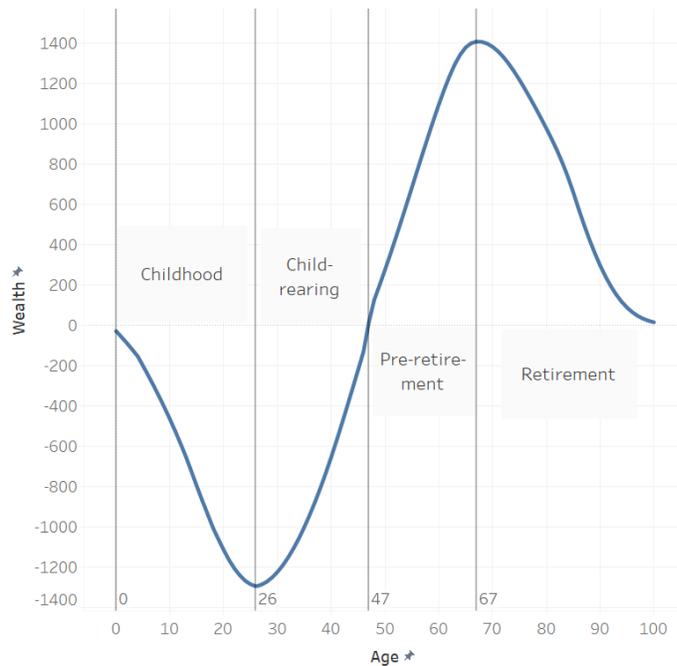
Figure 1. Equilibrium sustainable consumption ratio, β^* , and transition age (x^*).



Source: Constructed by authors.

The equilibrium lifecycle of wealth realized when both conditions are met is shown in Figure 2.

Figure 2. Sustainable lifecycle of wealth illustrated.



Note. Values are based on the US 2019 baseline scenario. Wealth is expressed as a percentage of core labor income for members of a birth cohort. Core labor income is the average of per capita labor income for those 30-49. Source: constructed by authors.

The Simulations

Data

The analysis draws heavily on National Transfer Accounts described in the NTA manual. (United Nations, 2013; Lee and Mason, 2011). The methods have been extensively evaluated as described in these publications. Research teams in over 80 countries continue to assess the methods and the applicability to the institutions and data available in their own countries. Detailed methods and data are reported on a country-by-country basis. The NTA manual is over 200 pages long and cannot be incorporated in detail in this paper.

Ogawa and Matsukura, based at the Nihon University Population Research Institute (NUPRI), pioneered the development of NTA in Japan producing complete accounts at five-year intervals for 1984 to 2009 (Ogawa, Mason et al. 2009, Ogawa, Mason et al. 2012). More information about these data is available

on the NTA website www.ntaccounts.org. New estimates have been produced by Fukai, Fukuda, and other collaborators based at the National Institute of Population and Social Security Research (IPSS) and the University of Tokyo (Fukai, Fukuda et al. 2024). These estimates are available at <https://www.ipss.go.jp/projects/NTA/index.html>. NUPRI estimates were used for 1984 and IPSS estimates for 2019 are used in this paper. Revised estimates for 2019 constructed by IPSS in consultation with the authors of this paper. The most recent estimates are based on the National Accounts, annual reports of the National Pension Service, surveys and reports produced by education and health ministries, reports on Social Security costs by IPSS, the Family Income and Expenditure Survey, the National Survey of Family Income, Consumption and Wealth, the *Population Estimates* by the Statistics Bureau. Similar data sources were used for 1984.

The construction of US NTA is led by Lee and Donehower at the Center for the Economics and Demography of Aging (CEDA) at the University of California, Berkeley (Lee and Donehower 2022). US estimates draw on the Current Population Survey (March supplement), the Consumer Expenditure Survey, the Medical Expenditure Panel Survey, National Center for Education Statistics, Census for 1990 data and the American Community Survey for 2019, and other data. Data are combined using propensity score matching.

The age profiles of consumption and labor income for 1984 and 2019 for Japan and 1990 and 2019 for the US are available on the NTA website: www.ntaccounts.org. Although US NTA data have been estimated for 2020 and later, these data are not used so as to avoid the effects of COVID19.

Input data for three baseline scenarios are reported in Table 1 and Table 2. The first two baselines rely on data for Japan 1984 and 2019 and the US 1990 and 2019. The third baseline rely on projected demographic values for 2065 and NTA estimates for 2019. Sources and methods for the data in the remaining columns in Table 1 and Table 2 are described below.

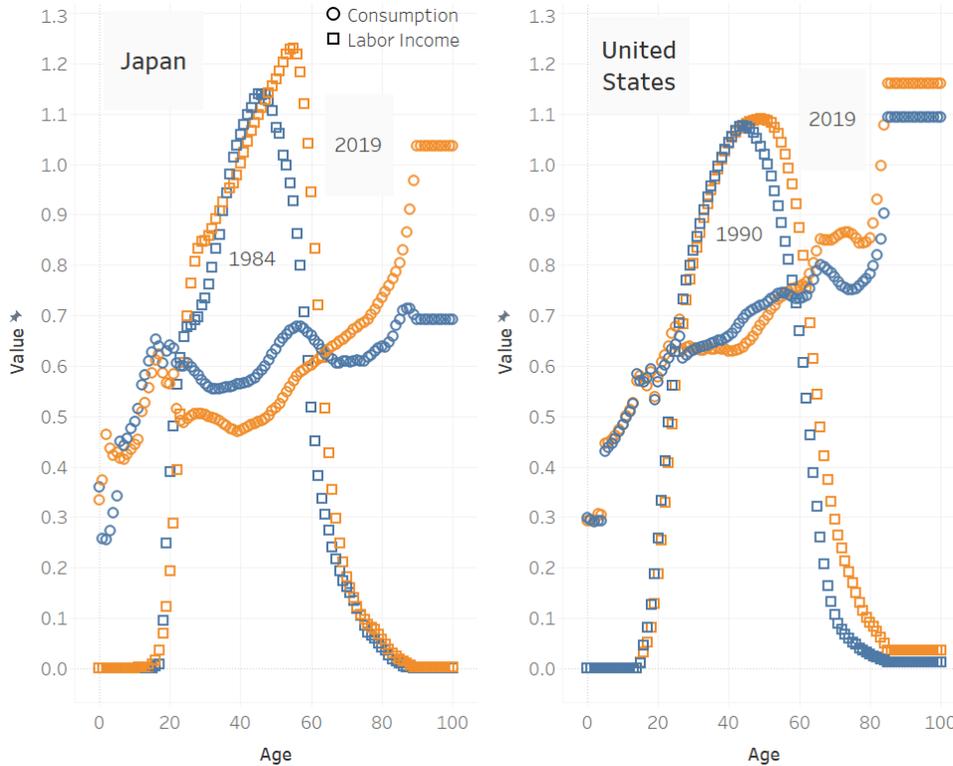
Table 1. Baseline input values for Japan and the United States: NTA data, demographic data, and productivity growth rates.

Scenario	NTA Data			Demographic data			Productivity growth rate (%)
	NTA profile year	Child transfer share (%)	Old-age transfer share (%)	Life expectancy at birth	Total fertility rate	Population growth rate, SS (%)	
<i>Japan</i>							
1984	1984	100	73.0	77.5	1.78	-0.551	1.4
2019	2019	100	43.3	84.4	1.32	-1.548	1.4
2065	2019	100	43.3	90.3	1.4	-1.352	--
<i>United States</i>							
1990	1990	97.0	32.6	75.4	2.1	0.0	1.0
2019	2019	93.4	27.1	78.9	1.7	-0.704	1.0
2065	2019	93.4	27.1	85.2	1.6	-0.906	--

Sources. The sources of NTA per capita age profiles of consumption and labor income for Japan in 1984 and 2019 and for the US in 1990 and 2019 are described in the text; 2065 profiles are based on 2019 estimates. Child and old-age transfer shares are based on NTA estimates of age profiles of transfers and asset-based reallocations. See text for the calculation method. Life expectancy at birth is a summary measure of mortality; age-specific survival rates are used in the simulation. These are estimates for 1984/1990 and 2019 for Japan and the US and projected values for 2065 (UN 2024). The Total Fertility Rates for those years is taken from UN (2024). The steady-state (SS) population growth rate is calculated from the Total Fertility Rate as $\ln(\text{TFR}/2.1)/30$ where 2.1 is replacement fertility and 30 is assumed to be the generation length. Productivity growth rates are estimated for the 1984-2019 interval in Japan and 1990-2019 interval in the US, with methods and source described in the text and the appendix. Productivity growth for 2019-2065 is assumed to be identical to the observed rates of productivity growth.

Age profiles of real per capita labor income and consumption are shown in Figure 3. Values are standardized for each country and year by dividing the age-specific values by the average of per capita labor income in the 30-49 age range. The standardization facilitates comparisons but has no effect on the simulations. We refer to the 30-49 year age group as core ages throughout the paper.

Figure 3. Standardized cross-sectional per capita consumption and labor income by age, Japan, 1984 and 2019 and the US, 1990 and 2019. All values are expressed relative to core labor income, the average per capita income of those 30-49. Blue markers used for earlier date; orange markers for later date.



Source: See text.

The shapes of the age profiles for Japan changed considerably over the thirty-five-year period tracked. Standardized labor income and consumption both shifted upward at older ages. Per capita consumption at the core ages shifted downward possibly in response to the rise of old-age dependency. Other factors that affected Japan’s consumption profile include the introduction of long-term care insurance, rising costs for health and long-term care, and a rise in the percentage of seniors living in one-person households. The US experience between 1990 and 2019 was different than Japan’s. Like Japan, US labor income shifted upward at older ages. Standardized consumption at young ages changed very little in the US. Consumption at older ages shifted upward in the US, but by less than in Japan. And consumption at core ages shifted downward in the US, but by less than in Japan.

The child transfer share summarizes reallocations that support those in the 0 to $x1$ age range, where $x1$ is the last young age at which consumption exceeds labor income. (Note that $100 - Child_share$ equals the share of asset-based reallocations).

$$Child_share = \frac{100 \sum_{x=0}^{x1} T(x,t)}{\sum_{x=0}^{x1} T(x,t) + \sum_{x=0}^{x1} RA(x,t)} \quad (9)$$

The transfer shares for seniors are calculated in similar fashion as the ratio of aggregate transfers to aggregate age reallocations for those older age groups where consumption exceeds labor income:

$$OA_share = \frac{100 \sum_{x=x4}^{\omega} T(x,t)}{\sum_{x=x4}^{\omega} T(x,t) + \sum_{x=x4}^{\omega} RA(x,t)} \quad (10)$$

T is aggregate net transfers and RA is aggregate asset-based reallocations. The deficit age ranges are defined for children as 0 to $x1$ and for seniors as $x4$ and older.

The reallocation systems for children are similar in Japan and the US with transfers playing a dominant role (Table 1). In Japan, both in 1984 and 2019, 100% of reallocations for children were funded by transfers. In the US transfers funded 97.0 percent of child reallocations in 1990, but by 2019, transfers accounted for 93.4% of reallocations to children with increased reliance on debt. Note that childhood includes young adults in their mid-20s.

The old-age support systems in Japan and the US both rely on a relatively balanced approach to funding the old-age gap between consumption and labor income. In 2019, 43.3% of reallocations were comprised of transfers in Japan as compared with 27.1% in the United States. In both countries seniors relied more on asset-based reallocations than on transfers to fund old-age needs. Japanese

reallocations have changed more in recent decades than US reallocations. In 1984 Japan, 73% of old-age reallocations were funded by transfers as compared with 32.6% in 1990 US.

Demographic estimates and projections of the total fertility rate and age-specific survival rates (single-years of age) for Japan and the US are taken from the UN World Population Prospects 2024 (United Nations Population Division 2024). Mortality is measured using life table data, person-years of life (L_x), by single years of age from 0 to 100+. Mortality is summarized in Table 1 using life expectancy at birth, but the simulations use survival data by single years of age. Fertility, the Total Fertility Rate (TFR), is used to calculate the steady-state rate of population growth (see Table 1 notes).

Due to its low fertility and high life expectancy, Japan's population is growing more slowly and is older than any other major country. US population growth is expected to turn negative but the decline will be less rapid than in Japan. If immigration plays a role in the future, US population growth may well be more rapid than shown in Table 1. The demographic differences between Japan and the US are expected to persist.

Productivity growth is based on the observed changes in per capita labor income between 1984 and 2019 in Japan and between 1990 and 2019 in the US. Productivity growth is estimated using the annual rate of growth of the lifetime real labor income for a synthetic cohort:

$$\lambda = \left(\frac{\sum_x L(x, t2) yl(x, t2)}{\sum_x L(x, t1) yl(x, t1)} \right)^{t2-t1} - 1 \quad (11)$$

The survival rates for 2019 were used for both Japan and the US to avoid including the impact of increased survival on years worked. This effect is captured by the impact of changes in survival on the working-age population. Details of the methods are presented in the appendix in Tables A1 and A2.

Rates of return to wealth

The final simulation model inputs, rates of return to wealth, are described in Table 2. The rates of return to wealth vary over the lifecycle depending on the child and old-age reallocation shares (equation 9 and 10 and Table 1), the rates of return to assets and to transfers on the rates of return to assets and transfers and the reallocation shares. The rates of return to assets are assumed to be constant and exogenous, reflecting long-term market conditions (Jorda et al., 2019). The rate of return to transfer wealth is $n + \lambda$, the rate of population growth plus the rate of productivity growth. Children who rely on transfer debt accumulate an obligation paid to successive generations. The size of the obligation depends on growth rates in the number of children relative to the number of providers and productivity. In similar fashion, transfers to support seniors yields a return that depends on growth in the number of seniors relative to the number of providers and productivity.

Rates of return for Japan and the US are shown in Table 2. The biological interest rates are similar in Japan and the US. Although the population growth rate is lower in Japan the rate of productivity growth is higher. The return to capital is higher in the US than in Japan. Combining these factors, the rates of return for reallocations to children and for reallocations to seniors are higher in the US than in Japan.

Reallocations to seniors in the US are favored because they earn a high rate of return. A dollar invested in old-age needs returns almost 5% per year in the US as compared with 2.3% per year in Japan.

Table 2. Rates of return to wealth for children and seniors. Values are calculated as the weighted sums of the biological interest rates and the rates of return to assets with weights equal to the reallocation shares.

Scenario	Bio interest rate (%)	Rates of return to assets (%)	Rates of return	
			Children	Seniors
1984	0.85	4.23	0.85	1.76
2019	-0.15	4.23	-0.15	2.33
2065	0.05	4.23	0.05	2.42
1990	1.00	6.58	1.17	4.76
2019	0.30	6.58	0.71	4.88
2065	0.09	6.58	0.52	4.82

Notes: Rates of returns to assets are post-1980 rates of return to assets (bonds, bills, equity, and housing) from Jorda et al. (2019) reported in Table XII, p.54.

Baseline simulations

Simulation results for Japan and the United States for the 2019 inputs (Figure 4 and Table 3) can be summarized by four findings.

First, current consumption levels are unsustainable in Japan and in the United States. The sustainability ratio, β , is less than 1 in both countries.

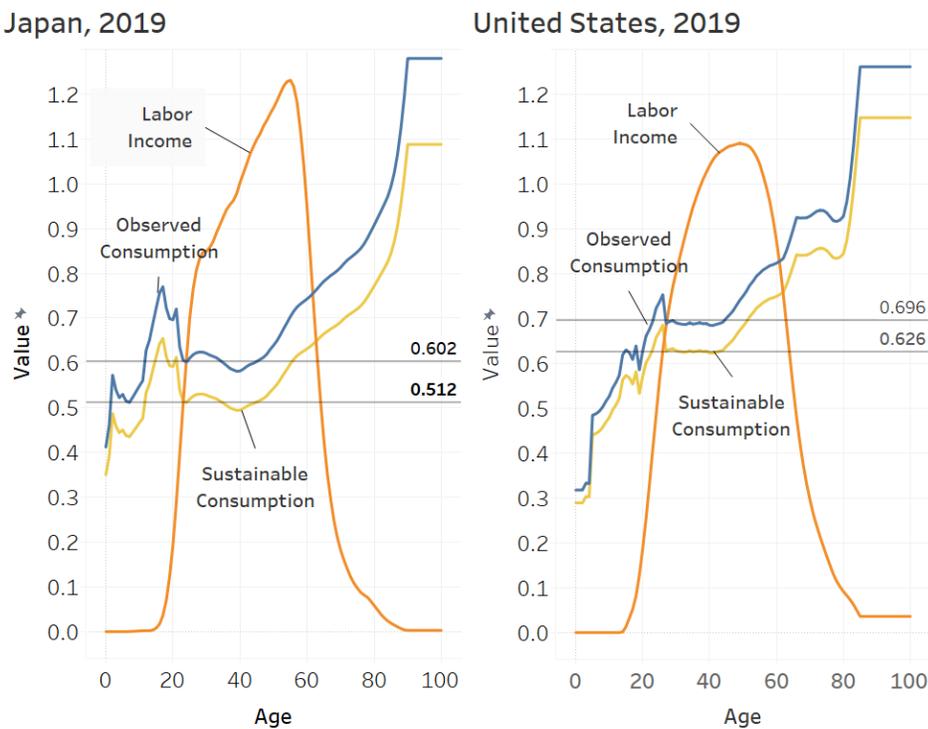
Second, the differences between current and sustainable consumption are large. In Japan, a reduction in per capita consumption by 15% would be required to reach sustainability. Achieving sustainability in the US would require a reduction in per capita consumption by 9%.

Third, the gap between current and sustainable consumption is greater in Japan than in the United States.

Fourth, the shortfall is greater in Japan than in the US even though current per capita consumption is already substantially lower relative to labor income in Japan than in the US. Current consumption is 60.2% of labor income at ages 30-49 in Japan as compared with 69.6% in the US.

A number of factors account for the particular challenges being faced by Japan, as compared with the United States as shown in Tables 1 and 2: unfavorable demographics with slower population growth due to lower fertility and higher life expectancy; heavier reliance on transfers to support old-age needs; and lower returns to assets.

Figure 4. Per capita labor income, consumption, and sustainable consumption, Japan and the US in 2019 relative to core labor income (per capita value for the 30-49 age ranges). Horizontal lines show the core per capita consumption (average consumption for 30-49-year-olds) relative to core labor income.



Sources: See text for observed 2019 profiles. Sustainable consumption profiles calculated by the authors.

The second set of baseline simulations, reported in Table 3, use historical values as inputs – 1984 for Japan and 1990 for the United States (Table 1 and Table 2). These results are of particular interest

because they show consumption was sustainable or nearly-so in the past. In Japan, the sustainability ratio was 0.97 in 1984 and, in the United States, the ratio was 1.0.

Many factors led to the loss of sustainability over the last thirty to thirty-five years. Observed consumption increased in both countries between 1984/1990 and 2019 relative to labor income (Table 3). Demographic conditions shifted in unfavorable ways with a decline in fertility and a rise in life expectancy for both countries. Somewhat offsetting these factors in Japan was its increased reliance on asset-based reallocations to fund old-age needs. The reforms to old-age support systems were not sufficient, however, to offset other changes.

The third baseline simulations address the implications of anticipated demographic change. In both countries, life expectancy is projected to increase. Fertility is projected to decline in the US and to rise slightly in Japan. In both countries, further drops in the sustainability ratio are projected. In Japan, per capita sustainable consumption is projected to drop by 18.9% as compared with current levels. In the US, sustainable consumption is projected to drop by 12.1% as compared with current values.

Table 3. Simulated measures of consumption, three simulations for Japan and the United States.

		Ratio of sustainable to observed consumption	Observed core consumption relative to core labor income	Sustainable core consumption relative to core labor income	Unsustainable core consumption relative to core labor income	Unsustainable as a percentage of core consumption
Japan	1984	0.97	0.572	0.555	0.017	3.0
United States	1990	1.00	0.662	0.662	0.000	0.0
Japan	2019	0.85	0.602	0.512	0.090	15.0
United States	2019	0.91	0.696	0.633	0.063	9.1
Japan	2065	0.81	0.602	0.488	0.114	18.9
United States	2065	0.88	0.696	0.613	0.084	12.1

Source: Calculated by authors. Notes. Core consumption is average per capita consumption for those 30-49 relative to labor income for those 30-49. Unsustainable consumption is observed consumption less sustainable consumption. See Tables 1 and 2 for input values.

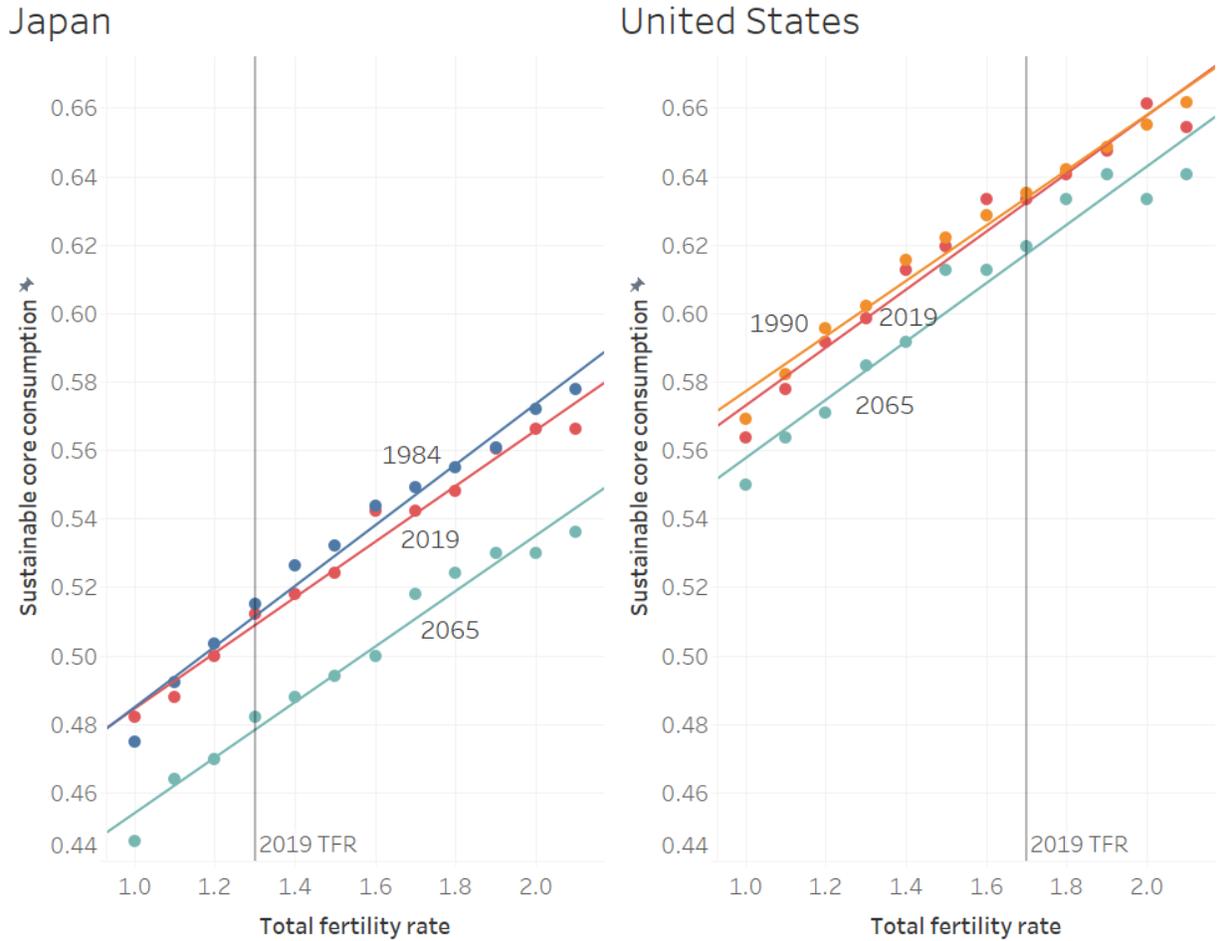
Many factors contributed to changes in sustainable consumption and the differences between Japan and the United States. In the next section, the connections between fertility and old-age support systems and sustainable consumption are explored in more detail by varying fertility and old-age transfers shares holding all other inputs fixed. These two variables are of particular interest because they are actionable.

Total Fertility Rate

Given other 2019 conditions in Japan, a decline in the total fertility rate (TFR) from 2.0 to 1.0 would lead to a decline in sustainable core consumption (mean consumption for ages 30-49) relative to core labor income from 0.566 to 0.482, a 16% decline in per capita consumption applicable to all ages. The partial effect of a change in the TFR is very similar in all Japanese scenarios with a decline in the TFR from 2 to 1 yielding a decline in sustainable core consumption by 0.088 given 1984 conditions and 0.081 given 2019 and 2065 conditions. The partial effects of the same change in the TFR in the US are very similar equal to 0.081 given 1990 conditions to 0.085 given 2019 and 2065 conditions (based on the slopes of the regression lines in Figure 5).

Considered from an historical perspective, changes in the TFR holding all other factors constant have a notable effect on sustainable consumption. The decline in TFR in Japan from 1.8 to 1.3 between 1984 and 2019, a change of 0.5, leads to a decline in sustainable core consumption of between 0.04 or 0.05 or roughly a 10 percent decline in consumption at all ages. The change in the TFR in the US between 1990 and 2019 was 0.4 births per woman producing a decline in core sustainable consumption of roughly 0.03 and approximately a 5% decline in consumption at all ages (Figure 5).

Figure 5. The simulated impact of the total fertility rate on the ratio of sustainable per capita consumption to per capita labor income for persons 30-49. Japan using 1984, 2019, and 2065 baseline inputs and for the United States using 1990, 2019, and 2065 baseline inputs.



Note: See Tables 1 and 2 for baseline inputs. Source: Constructed by authors.

Figure 5 raises several additional points. First, at any given level of fertility, sustainable consumption is higher in the US than in Japan. Several factors account for this: in the US life expectancy is lower, rates of return to capital are higher, and reliance on asset-based reallocations to support seniors is higher than in Japan. Second, given any TFR sustainable consumption did not change between 1984 and 2019

in Japan or between 1990 and 2019 in the US. In both Japan and the US changes in factors other than the TFR had effects, but those effects cancelled out. In Japan, reduced reliance on old-age transfers offset increased consumption at older ages and increased life expectancy. In the US, a small decline in reliance on old-age transfers offset modest gains in life expectancy and old-age consumption.

Old-age Reallocation

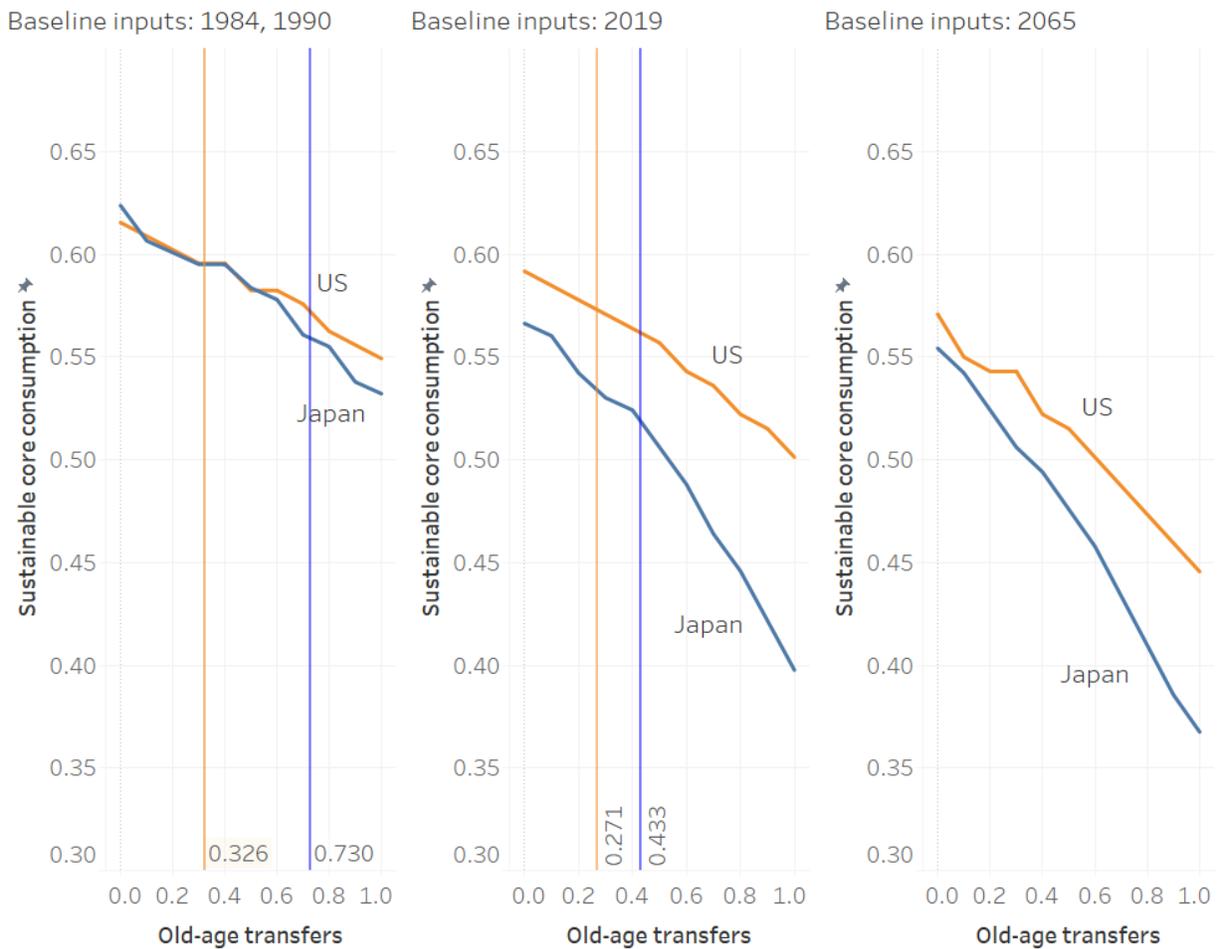
In 1984 Japan relied heavily on transfers to fund old-age deficits but that is no longer the case. By 2019 transfers were 43% of the old-age deficit rather than the 73% share estimated for 1984. The US has seen much smaller changes over the last three decades with old-age transfers dropping from 33% in 1990 to 27% in 2019 (Table 1).

The effects of reallocations on sustainable consumption are shown in Figure 6 given the historical conditions (1984 for Japan and 1990 for the US), current conditions (2019), and projected conditions (2065).

The difference in sustainable consumption between Japan in 1984 and the US in 1990 can be explained entirely by Japan's greater reliance on old-age transfers – 73.0% in Japan vs 32.6% in the US. Had the reallocation system in Japan been the same as the US system, core sustainable consumption would have been about 59% of core labor income in both countries.

Given 2019 conditions the costs of relying heavily on old-age transfer systems would be very high in both Japan and the US, but especially in Japan. Full reliance on old-age transfers would reduce core sustainable consumption from 57% to 40% of core labor income. In the US, the change would have been from 59% to 52% of core labor income. The adverse impact of rapid aging combined with heavy reliance on transfer systems was a key reason for instituting reforms to public transfer systems in Japan.

Figure 6. The simulated effect of changes in the old-age transfer share on per capita sustainable consumption relative to per capita labor income, 30-49 age group, Japan baseline inputs for 1984, 2019, and 2065 and US baseline inputs for 1990, 2019, and 2065. The observed old-age transfer shares for Japan in 1984 and 2019, respectively, were .730 and .433, and for the US were .326 and .271, respectively.



Note: See Tables 1 and 2 for baseline inputs. Source: Constructed by authors.

The simulated effects of old-age transfer shares on sustainable consumption are greater given 2065 conditions as compared with 2019 conditions. A shift from full reliance on asset-based reallocations to

full reliance on transfers in Japan would lead to a simulated decline in sustainable consumption by 21 percent. In the US, a shift from fully embracing asset-based reallocations to fully embracing transfers would lead to a simulated decline of sustainable consumption by 12 percent, from 57 percent to 45 percent of core labor income.

Shifting away from old-age transfer systems appears to be attractive. The benefits may be elusive, however, because of transition issues. If we had always relied entirely on asset-based reallocations rather than entirely on transfers, then we would have had much higher sustainable consumption in both countries, particularly given 2019 and 2065 conditions. Given an historical reliance on transfer systems for the elderly, however, it would be very costly to transition toward asset-based reallocations, because they impose a double burden on current generations expected to fulfill obligations to current seniors and to save to meet their own old-age needs.

A second issue is that relying on asset-based reallocations requires strong financial systems and an ability on the part of consumers to engage in long-term planning.

Bequests, extensions and other issues

Consumers may supplement their resources relying on bequests or other forms of wealth. This could arise if earlier generations consumed below sustainable levels, saved more, and created wealth that could be passed on to their descendants. In some countries wealth is high because of resource endowments. Negative wealth is a possibility if countries have incurred foreign debt obligations.

The concept of sustainability can be extended to incorporate bequests (or other forms of wealth that are passed on from generation to generation). Suppose B/YI is the ratio of total bequest wealth to total labor income. To maintain a sustainable or steady-state level of bequests, wealth must grow at the

same rate as aggregate labor income, $(1 + \lambda)(1 + n)$. If the return on wealth, $1 + r$, exceeds $(1 + \lambda)(1 + n)$, the surplus can be sustainably consumed (McCarthy et al. 2022).

There are a number of other ways that the model could be improved. The model de-emphasizes decision-making, based on optimizing behavior, that might influence labor income and consumption. We assume that lifetime labor income will continue to grow at the same rate as in the past few decades, reflecting, in part, decisions by workers to delay their retirement. Likewise, we assume that the shape of the age profiles will not shift. Introducing decision-making in the model would provide a richer understanding of the implications of population aging. Perhaps workers will not choose to increase their work effort to the extent that they have in past. Perhaps consumption will shift in favor of seniors and at the expense of children or working-age adults (Preston 1984). These possibilities are not considered here.

The steady state assumptions in this model emphasize the fundamentals that determine the eventual effects of aging but not the timing. Introducing population dynamics into the model would allow an assessment of the speed with which sustainability is achieved.

Sustainable consumption is heavily influenced by choices about whether to rely on transfers or asset-based reallocations to fund old-age needs. Public policies and private decision-making for Japan and the US are incorporated into the simulation model using the reallocation shares. Additional policy analysis could rely on showing how specific proposed policies would influence reallocation shares and, hence, sustainable consumption.

Another factor that affects sustainable consumption is immigration. Historically, immigration to the US has been high while it has been low in Japan. The future of immigration appears to be quite uncertain in light of political changes in both Japan and the US. In the short-run restricting immigration will slow

growth in the labor force and reduce taxes that support old-age systems (Smith and Edmonston 1997).

In the long run, immigration has a limited impact on age structure (Goldstein 2009).

The analysis presented here is confined to aggregate or per capita flows, but outcomes likely vary considerably by economic status. Those who are poor rely heavily on transfers while high-income individuals rely more on asset-based reallocations. Thus, the poor may be more vulnerable to the effects of aging. Old-age transfer systems could be reformed to increase net transfers to impoverished seniors.

Conclusions

Aging and slower population growth will depress consumption relative to labor income. Because people will live longer, they will have insufficient retirement assets requiring them to reduce consumption and save more. Because the number of retirees will increase relative to the number in the working ages, governments must implement reforms that raise taxes, reduce benefits, or some combination of the two. The combined effects of changes in public policies and private decision-making are uncertain. Some generations may bear a greater share to the cost of aging than others, but overall consumption will be adversely affected by aging.

Prospects for Japan are dim because of its severe aging, its high old-age consumption, and its low rates of return to wealth. Reduced reliance on old age transfer systems has been helpful, and additional changes appear to be likely. Per capita benefits to seniors could be increased in order to maintain their standard of living. Taking this path, however, would mean even greater sacrifice on the part of younger generations.

Aging will have a smaller impact on standards of living in the United States. Fertility is higher and life expectancy is lower in the US than in Japan. Thus, even without higher immigration, aging would be less

severe in the US. The US is advantaged in other ways. Old-age support systems emphasize asset-based reallocations and lower transfers. Moreover, the rate of return to assets is relatively high in the US benefiting asset-based old-age support systems. In one important respect, the US is disadvantaged as compared with Japan and other countries. Spending on health care, particularly among seniors, is very high in the US. Taking all factors into consideration, aging will also lead to lower consumption in the US.

Japan and the United States are not isolated cases. Many other countries now have low or very low fertility, high life expectancy, rapid population aging, and rely heavily on old-age transfers. Downward pressure on consumption can be expected for them.

These findings are based on a simulation model that adheres to observed age-patterns of consumption and labor income, reallocation shares (transfers and asset-based reallocations) estimated separately for children and seniors, cross-sectional flow constraints embodied in NTA methods, and longitudinal constraints imposed by the simulation model. Demographic variables, growth in labor productivity, and rates of return to capital influence the outcome. The model identifies the levels of consumption that are sustainable for the economy, as a whole, and for every cohort. In the long-run consumption cannot exceed resources available from labor income, transfers, and asset-based reallocations over the lifecycle. Policies that lead to higher fertility and greater reliance on assets to support old-age needs can reduce the gap between current and sustainable consumption. In both countries, however, population aging is likely to create downward pressure on per capita consumption.

These conclusions should be considered in light of other considerations. First, per capita consumption will grow more slowly over the coming decades it is unlikely to decline because productivity growth will more than offset the adverse effects of aging. Second, that people are enjoying more years at the end of their lives is a positive development.

Appendix

Productivity growth

Measures of growth in labor productivity are reported for Japan in Table A.1 and the US in Table A.2. All values are based on real labor income for 1984 and 2019 in Japan and 1990 and 2019 for the US. Labor income per person is reported as a matter of information but is not suitable for this analysis because it is affected by changes in population age structure during the periods in question.

Table A.1. Labor productivity growth, Japan, 1984 to 2019

	Labor income		Growth Rate (%)
	2019	1984	
Labor income per person 15 and older	3,063	2,158	1.00
Average labor income of persons 30-49	4,601	3,124	1.11
Lifetime labor income, synthetic cohort			
1984 survival rates	192,277	117,544	1.41
2019 survival rates	198,460	120,884	1.42
2065 survival rates	201,976	122,731	1.42

Thousands of yen, 2019 prices.

Average labor income of persons 30-49 controls for age structure by using the simple average of per capita labor income by single-years-of-age in the core 30-49 age range. The rates of growth over the time intervals measure changes essentially due to increases in wages measured as the real per capita labor income of persons at the core working ages.

The synthetic cohort measures include the impact of real wages plus the impact of an increased per capita supply of labor that have occurred primarily at older ages. This is a measure of expected lifetime labor income and the annual growth rates of those values.

Table A.2. Labor productivity, US, 1990 to 2019.

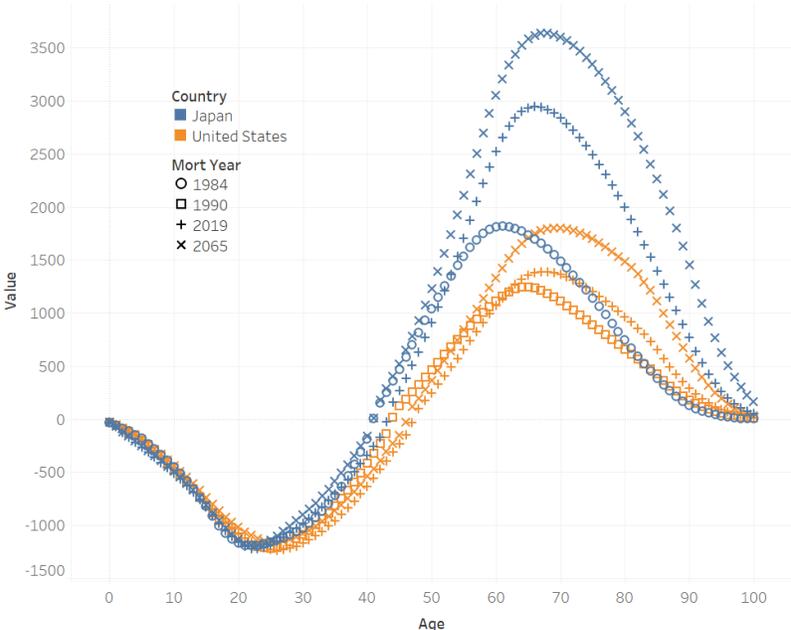
	Labor income		Growth Rate (%)
	2019	1990	
Labor income per person 15 and older	51.2	39.9	0.86
Average labor income of persons 30-49	75.5	61.9	0.69
Lifetime labor income, synthetic cohort			
1990 survival rates	3,040	2,259	1.03
2019 survival rates	2,993	2,257	0.98
2065 survival rates	3,182	2,368	1.02

Thousands of dollars, 2021 prices.

Sustainable Wealth

The sustainable wealth profiles for the three baseline scenarios for Japan in 1984, 2019, and 2065 and the United States in 1990, 2019, and 2065 are shown in Figure A.1.

Figure A.1. Sustainable wealth for a birth cohort as a percentage of core labor income, Japan and the United States, three baseline scenarios. See Tables 1 and 2 for details about the three baseline profiles.



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