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Aging, Population Projections, and Public Pensions

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Aging, Population Projections, and Public Pensions *

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Abstract

This paper investigates the long-term implications of demographic aging for public pension sustainability, using population projections from both international and national sources. Drawing on the 2024–2100 United Nations World Population Prospects (UN WPP) as well as forecasts from the Social Security Administration (SSA), U.S. Census Bureau (CB), Congressional Budget Office (CBO), and Japan's National Institute of Population and Social Security Research (IPSS), I document substantial cross-country variation in projected old-age dependency ratios. In addition, there is a large range of forecasts produced by different assumptions on fertility and immigration. I calculate a key forward-looking metric—the number of full retirement age (FRA) postponements required to maintain the 2023 dependency ratio through 2100. I show that advanced economies like Japan, having aged much earlier, face more modest required adjustments, while many middle-income countries will need much sharper policy shifts. I further demonstrate the sensitivity of unfunded pension liabilities to alternative demographic projections in the U.S. and Japan, and quantify the impact of Japan's 2004 macroeconomic slide reform on long-run fiscal sustainability. The results underscore the importance of proactive pension reform—particularly in developing economies entering demographic transition with limited time and institutional and fiscal capacity.

Keywords: Aging, population projections, old age dependency ratios, postponements of retirement age, unfunded obligations

JEL: E62, E63, H6

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1 Introduction

The economic and fiscal consequences of demographic aging are among the most pressing challenges facing advanced and emerging economies alike. Japan has long been viewed as the archetype of a rapidly aging society, with a rich body of research analyzing its pension reforms and macroeconomic adjustments. A consistent theme in this literature is that the long-run sustainability of public finances in aging societies often hinges on substantial policy measures, including large increases in taxation or significant structural reforms to pension systems.

This paper broadens the lens to consider how demographic aging will affect public pension systems across a diverse set of countries: Japan, the United States, the United Kingdom, France, Germany, Italy, Spain, Denmark, China, Korea, India, Brazil, and Türkiye. Using the 2024–2100 UN WPP as a consistent international benchmark, along with official projections from domestic agencies in the U.S. and Japan, I assess the trajectory of old-age dependency ratios (OADR) and their implications for pension sustainability.

The core contribution is a simple but transparent fiscal metric: the number of times a country must postpone its FRA by one year every five years—starting in 2029—to maintain the 2023 OADR through 2100. This approach provides a simple metric to compare pension pressures across countries at different stages of the demographic transition.

Recent studies have highlighted a sharp and often underappreciated fertility decline in middle-income countries, accelerating their transition into aged societies. While countries such as Japan and Denmark have already implemented significant pension reforms, many emerging economies have yet to take comparable steps. In these contexts, aging-related fiscal stress may prove more acute due to weaker institutional capacity and a narrower window for gradual reform.

This paper also contributes to the literature on pension financing by quantifying how alternative population forecasts influence the present value of unfunded pension obligations in the U.S. and Japan. The analysis incorporates both the level of population aging and specific reform measures—such as Japan's 2004 macroeconomic slide, which indexed pension benefits to demographic and economic factors, substantially lowering long-run liabilities.

The paper is organized as follows. Section 2 discusses the related literature. Section 3 documents the timing and the extent of aging in advanced and middle-income countries using a common indicator, the dependency ratio. Section 4 displays the implications of alternative assumptions on fertility and net immigration on the old-age dependency ratios. Section 5 compares Japan to other countries about the timing of aging demographics. Section 6 calculates the number of postponements of the FRA as another measure of aging demographics. Unfunded obligations of the public pensions in the US and Japan are presented in Section 7 and Section 8 concludes.

2 Related Literature

Japan has long served as the canonical case of rapid population aging, and a large body of research has analyzed the fiscal responses and macroeconomic consequences of this demographic shift. A common conclusion in the literature is that achieving long-run fiscal sus-

tainability in the face of rising old-age dependency may require significant tax increases—on the order of 30 or more percentage points—particularly to finance escalating public pension and healthcare expenditures.[1] Although a substantial portion of this projected fiscal burden stems from healthcare spending—particularly long-term care (LTC)—the challenge posed by public pensions remains central to the economic effects of aging.

This paper examines the fiscal implications of demographic change with a specific focus on public pension systems in a broad set of countries: Japan, the United States, the United Kingdom, Denmark, France, Germany, Italy, Spain, China, Korea, India, Brazil, and Türkiye. The analysis draws on the United Nations World Population Prospects (WPP), which offers a consistent, internationally comparable dataset for evaluating long-term demographic trends. While population projections are inherently uncertain, the WPP provides alternative fertility scenarios to account for this uncertainty and highlight plausible bounds for future aging dynamics.

To quantify the fiscal adjustment needed to sustain current pension system dependency ratios, I use a simple metric: the number of years by which a country's full retirement age (FRA) must be postponed in order to stabilize its old-age dependency ratio at the 2023 level. This forward-looking metric allows for a transparent comparison of the magnitude of pension-related adjustments across countries at different stages of the demographic transition.

Recent research underscores the urgency of this analysis. Fertility rates and birth counts have fallen sharply in many middle-income countries—often more rapidly than in advanced economies—raising concerns that these nations may face a more compressed and severe aging challenge in the decades ahead (Fernández-Villaverde 2025). In parallel, the widening gap between GDP per capita and GDP per working-age adult highlights the economic distortions introduced by demographic shifts. While countries such as Japan have experienced stagnating GDP per capita, their productivity per worker has remained relatively strong, underscoring the distinction between headline growth and labor-market fundamentals (Fernández-Villaverde, Ventura, and Yao 2025). Furthermore, Hayashi (2025) attributes much of Japan's long-run growth slowdown to aging-induced declines in total factor productivity (TFP), suggesting that the macroeconomic drag from aging extends beyond simple labor supply effects.

While Japan has already undergone the bulk of its demographic transition and has implemented several rounds of pension reform, many middle-income countries are just beginning to confront the fiscal consequences of aging. Given their relatively limited institutional capacity and smaller time window for gradual policy adjustment, the challenges these countries face may ultimately prove more severe than those experienced by early-aging advanced economies.

[1] For fiscal suatainability in Japan, see Doi (2008), Doi, Hoshi, and Okimoto (2011), İmrohoroğlu and Sudo (2011), Braun and Joines (2015), Kitao (2015), Hansen and İmrohoroğlu (2016), İmrohoroğlu, Kitao, and Yamada (2016), and Hansen and İmrohoroğlu (2023).

3 Aging Demographics

3.1 Aging in Japan

The National Institute of Population and Social Security Research of the Ministry of Health, Labour and Welfare has been publishing detailed population estimates and projections since 1997. Figure 1 shows the dependency ratios, the ratio of the number of individuals 65 and older to that between 20 and 64, from these projections.

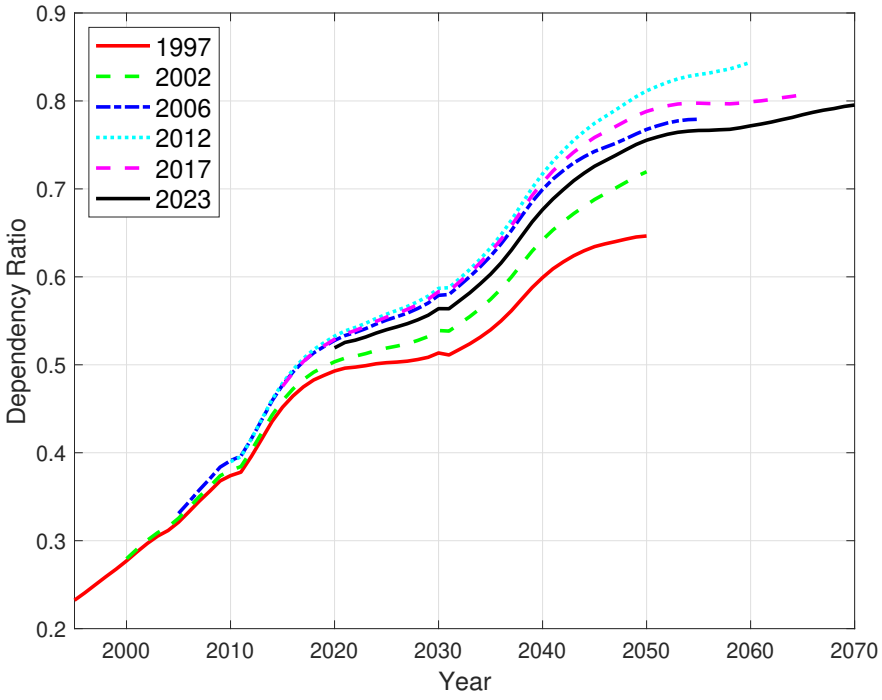

Figure 1: Dependency Ratios Implied by the Six IPSS Waves

The first wave in 1997 started significant academic and political discussions about pension reform and with the more pessimistic second wave of forecasts in 2002, Japan undertook the 2004 pension reform with its 'macroeconomic slide'. The indexation of benefits to average wages was reduced and the replacement ratio (fraction of some notion of income received as public pension benefits) started to decline over time to also reflect the expanding size of beneficiaries and declining size of taxpayers. The third wave in 2007 was even more alarming with the fourth wave in 2012 being the most pessimistic of projections. The last two waves in 2017 and 2023 have been better than the previous ones but the number of births in 2024 turned out to be less than even the most pessimistic projections of fertility and aging concerns remain on the forefront of public discussions.

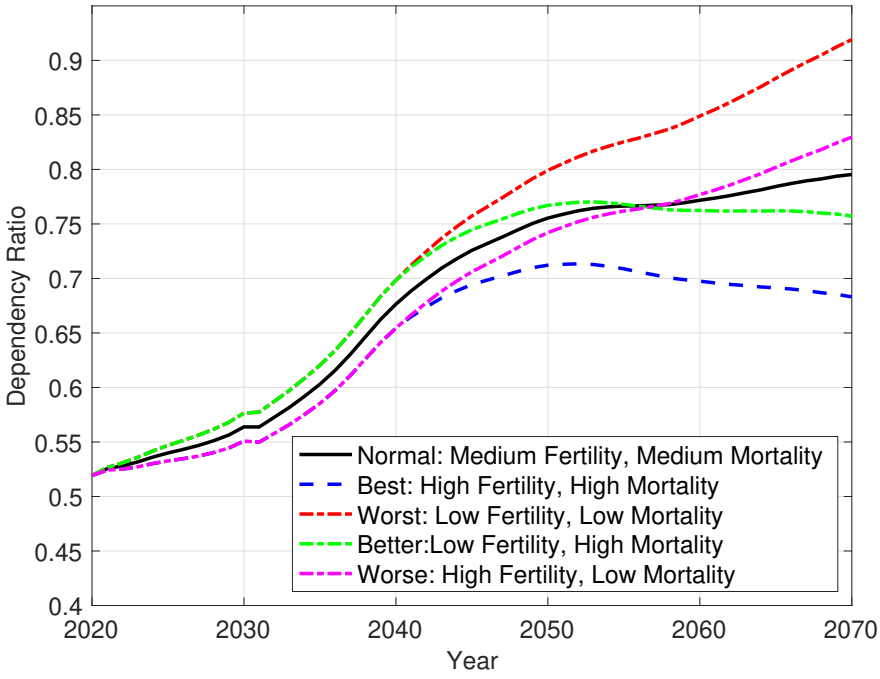

Figure 2: 2023 Wave and Alternative Mortality and Fertility Assumptions

Figure 2 presents the old-age dependency ratios implied by various versions of the most recent 2023 wave of IPSS population projections. According to the official Japanese projections, the old-age dependency ratio is expected to rise from about 52% in 2023 to about 80% by 2100 according to the medium fertility and mortality assumptions. However, there is a wide range of values implied by different mortality and fertility assumptions. By 2050, the difference in the dependency ratios can be 10 percentage points depending on the most optimistic or pessimistic realizations; by 2100 the difference can grow to exceed 20 percentage points.

Figure 3 shows the dependency ratios from the UN population projections for Japan. Using the medium case, the dependency ratio is expected to rise to about 78% by 2100, not that far off from the IPSS projections. The range of the dependency ratios, however, are enormous: almost 60 percentage points. The medium case assumes a total fertility rate (TFR) of about 1.2 for Japan in 2023, rising eventually to 1.47 by 2100. The high TFR case adds 0.5 percentage points where as the low TFR case subtracts 0.5 percentage points from the eventual value, and, hence the very large range for the old-age dependency ratio.

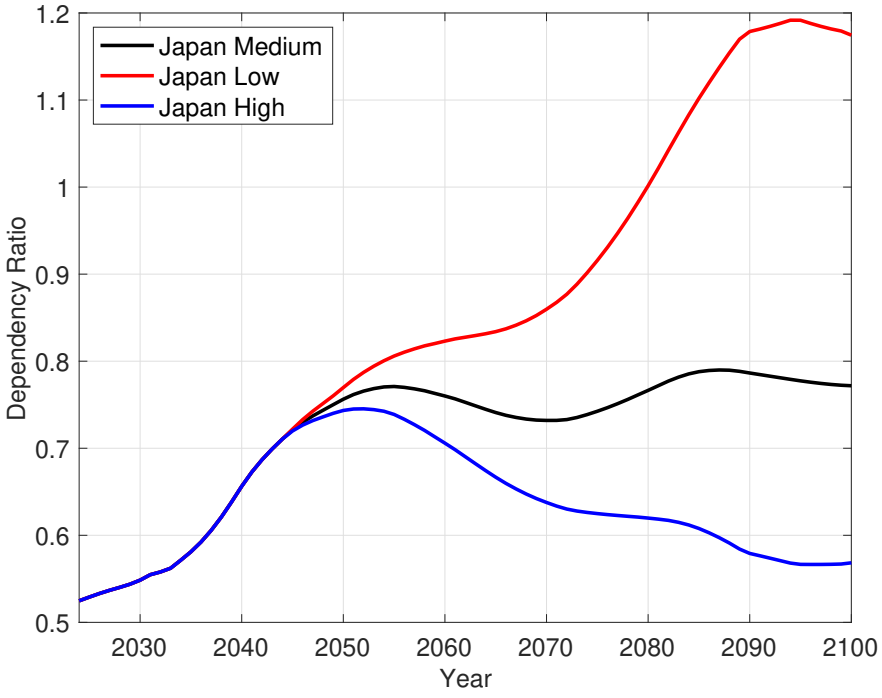

Figure 3: Old-Age Dependency Ratio from the UN WPP

This uncertainty highlights two problems. First, it is very difficult to get the fertility right. Second, it is useful to consider alternative projections, especially a country's own official forecasts. In addition, if recent declines in fertility turn out to be more long-lasting than initially considered even the medium projections may prove to be too optimistic about the extent of demographic aging.

3.2 Aging in the U.S.

For the U.S., there are at least four institutions that publish population estimates and projections: the CBO, the SSA, the CB, and the UN WPP. Their estimates and projections, however, seem quite different. To begin with, consider their total population estimates for 2022 and 2023 in Table 1.[2]

	CBO	SSA	Census	WPP
2022	339.7	339.2	333.3	341.5
2023	342.8	341.0	334.9	343.5

Table 1: Total Population Estimates

[2] Board of Trustees, Federal Old-Age and Survivors Insurance and Federal Disability Insurance Trust Funds (2024) reports details of the data and assumptions behind the SSA's evaluation of the health of the social security system in the U.S. Here are the sources for the data used in this paper: SSA population projections, CBO Demographic Outlook: 2025 to 2055, CB Population Projections, UN WPP 2024 Revision, IPSS Population Projections for Japan.

The discrepancies, which can be as large as 2.5%, arise from differences in fertility and net immigration assumptions. Figure 4 by the CBO shows that the CB has the lowest (medium) estimates, the CBO is somewhere in the middle where as the SSA has the highest total population estimates.

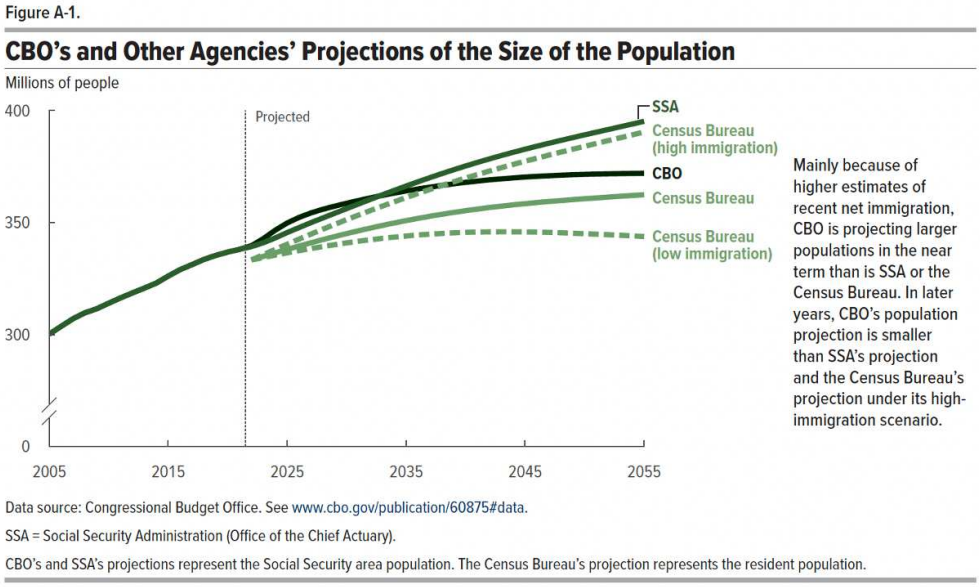

Figure 4: CBO Population Projection Comparison

In addition to these differences in total population estimates, the projections by age for future cohorts also differ as shown in Figure 5. Note that the dependency ratio used by the CBO is obtained by the ratio of 65 and older individuals to the number of individuals between ages 25 and 64. As a result, the dependency ratios by CB and UN are re-calculated to match this definition.

Regarding the fertility assumptions, CBO and CB use 1.6 from 2024 through 2055. UN starts at 1.62 in 2024 and quickly converges to 1.64 though 2055. SSA starts at 1.7 in 2024 and converges to 1.9 by 2031. Regarding net immigration forecasts, SSA has the highest numbers, followed by the CBO; the CB has the lowest net immigration projections in their medium forecasts.

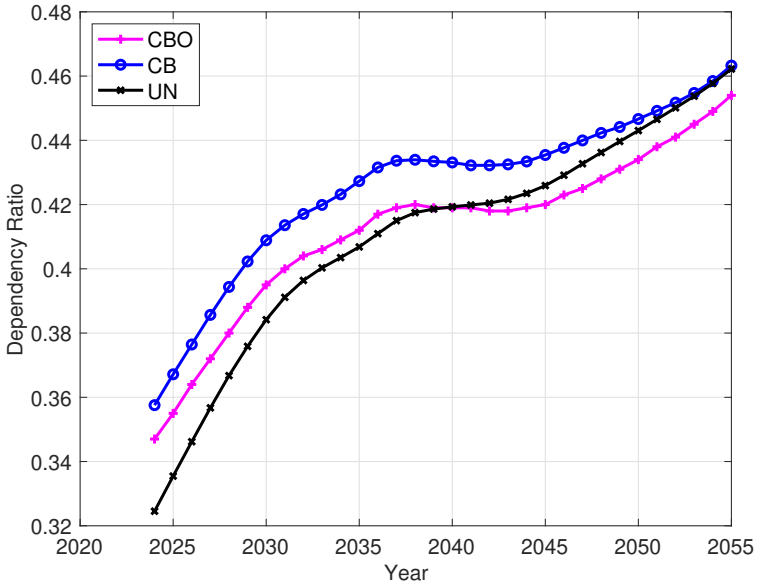

Figure 5: CB, CBO, and UN

CBO cuts off their projections at 2055 and use a definition of old-age dependency different from one that I use through the paper, namely the number of individuals who are 65 and older divided by the number of individuals between the ages 20 and 64. Fortunately, SSA, UN, and CB have projections by age from 2024 through 2100 and Figure 6 displays the dependency ratio from three different sources for United States.

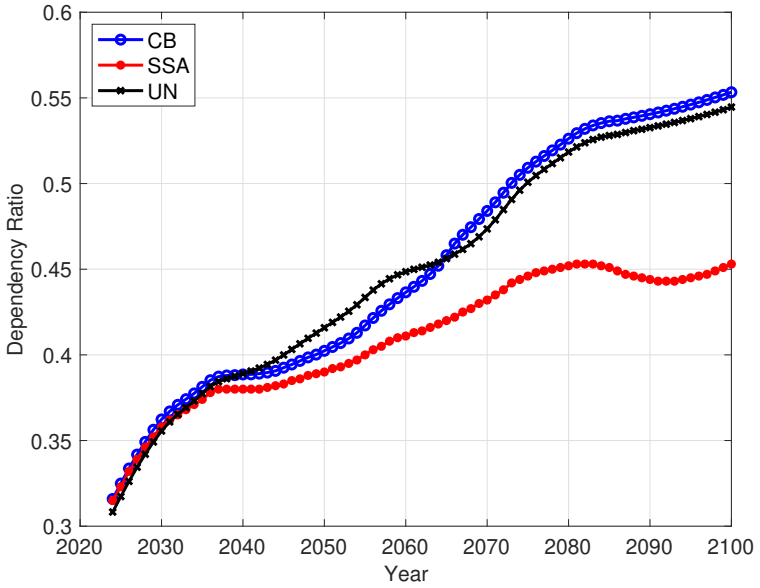

Figure 6: SSA, CB, and UN

The projections by the CB and UN are very similar with the dependency ratio eventually reaching about 55% in 2100, from about 32% in 2024. The projections by the SSA, on

the other hand, are markedly optimistic and the dependency ratio gets to about only 45% by 2100. Clearly, this would have significant implications on the health of the Trust Fund and the unfunded obligations of social security.

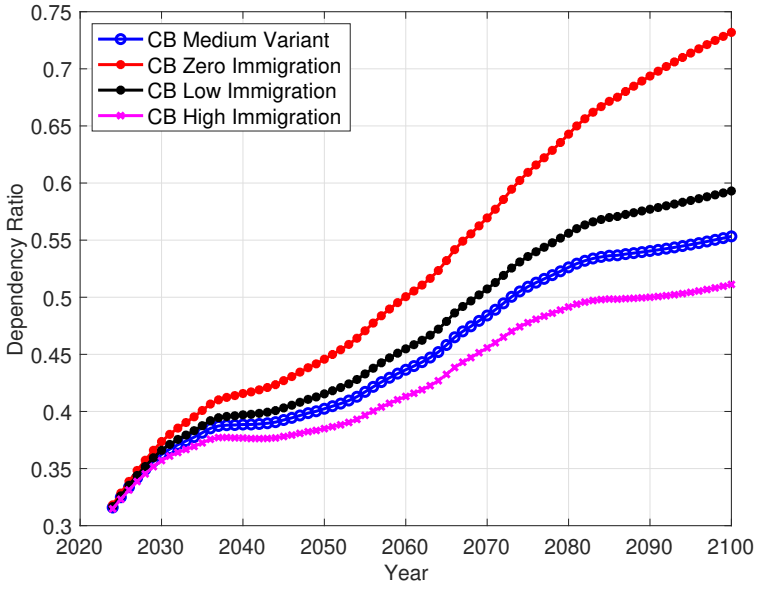

Figure 7: Census Bureau Population Projections

In addition to their medium population projections, the CB also publishes their zero-, low-, and high-immigration population forecasts. Figure 7 shows the dependency ratios implied by all four projections. The range of values depends significantly which immigration assumption will be closer to the realized in the next few decades; the difference between the high-immigration and zero-immigration dependency ratios is about 25 percentage points by 2100.

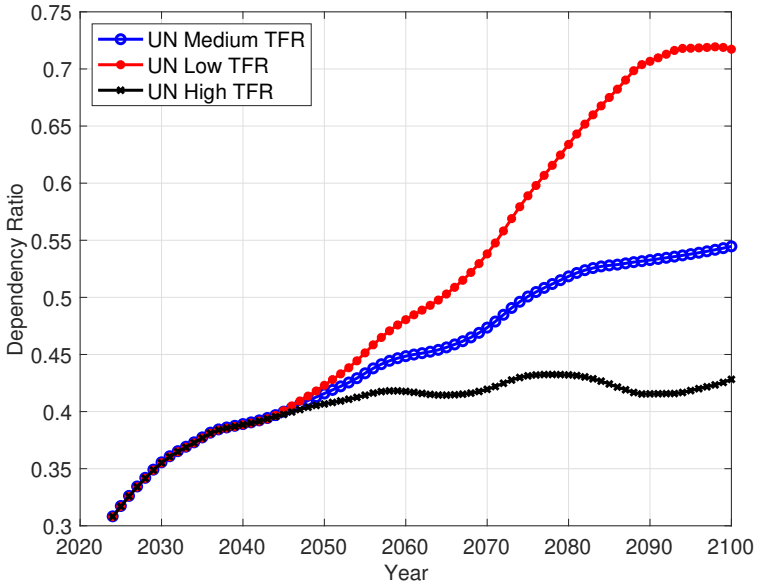

Figure 8: UN WPP

The range of dependency ratios is even larger for the US with the UN estimates. Between the high and low immigration cases, there is a 30 percentage point difference, as Figure 8 indicates. The projections by the SSA also produce a 30-percentage point range in the dependency ratio according to Figure 9. However, the more striking feature of the SSA population forecasts is the overall optimism with their intermediate and low cost projections. These are very different from those made by the UN and the CB.

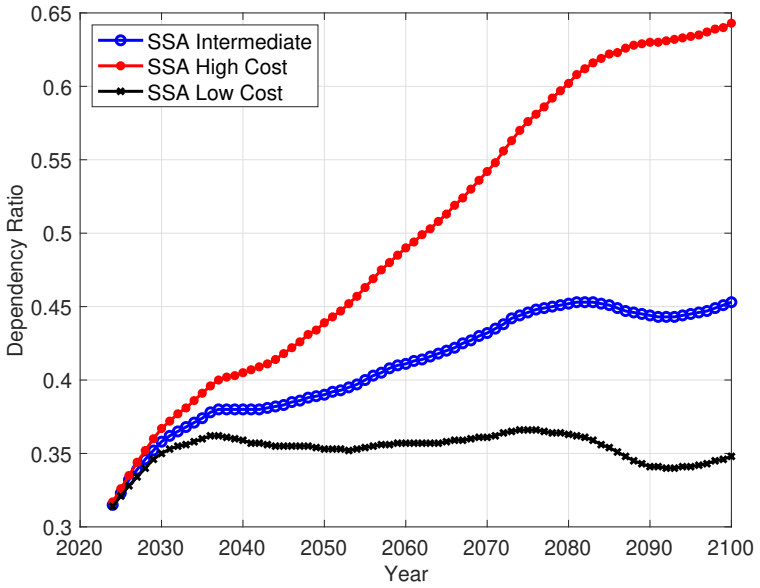

Figure 9: SSA Projections

3.3 Advanced and Middle-Income Countries and UN Projections

Advanced Economies In the previous section, we saw that the dependency ratios implied by the CB and the UN population projections are quite similar for the U.S. In this section, we use the UN projections on a group of European countries to compare the forecasts of aging within a relatively homogeneous group of advanced economies to that of Japan.

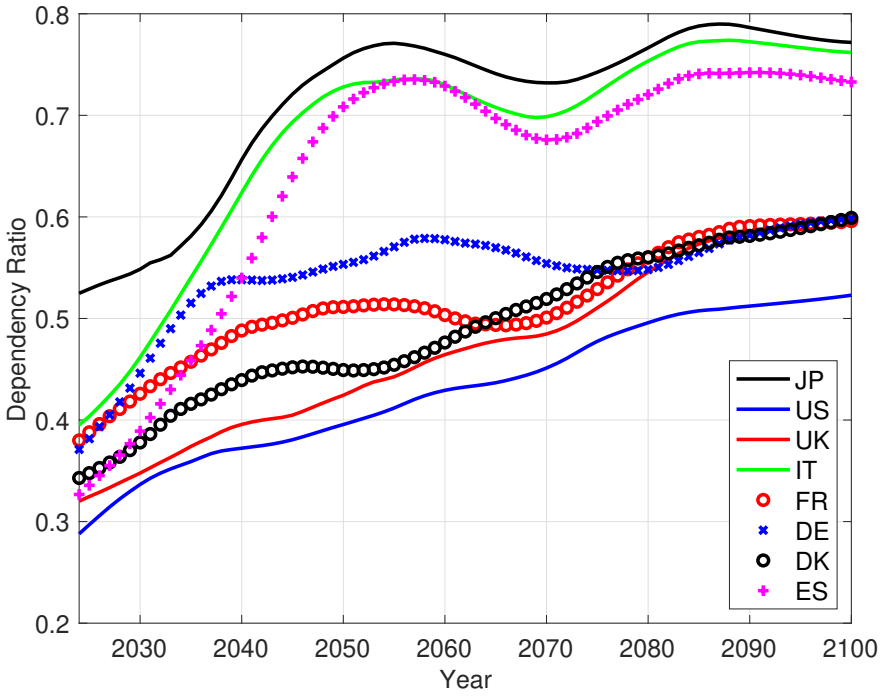

Figure 10: Dependency Ratios in Advanced Economies

Figure 10 displays the implied dependency ratios for Japan, US, UK, Italy, France, Germany, Denmark, and Spain, using the medium forecasts from the UN WPP. Japan is the outer envelope leading the aging process among this group of countries but Italy is right behind, followed closely by Spain. Note that Spain starts relatively young but quickly catches up with Italy by 2050s.

The US is the youngest of the group. UK, Denmark, France and Germany show some heterogeneity but remarkably converge to the same dependency ratio by 2100. Since the current FRA is different in these countries, some are closer to fiscal sustainability than others. For example, the current law in Denmark raises the FRA to 70 by 2040 (and 74 by 2100 if further aging occurs) where as the statutory retirement age in France is 64.

Developing Countries China and India are the two most populous countries in the world. Furthermore, China has had a relatively low fertility rate and a one-child policy for decades. In this section, we use the UN WPP data to describe the path of dependency rates in China, India, Brazil, Korea and Türkiye, relative to Japan.

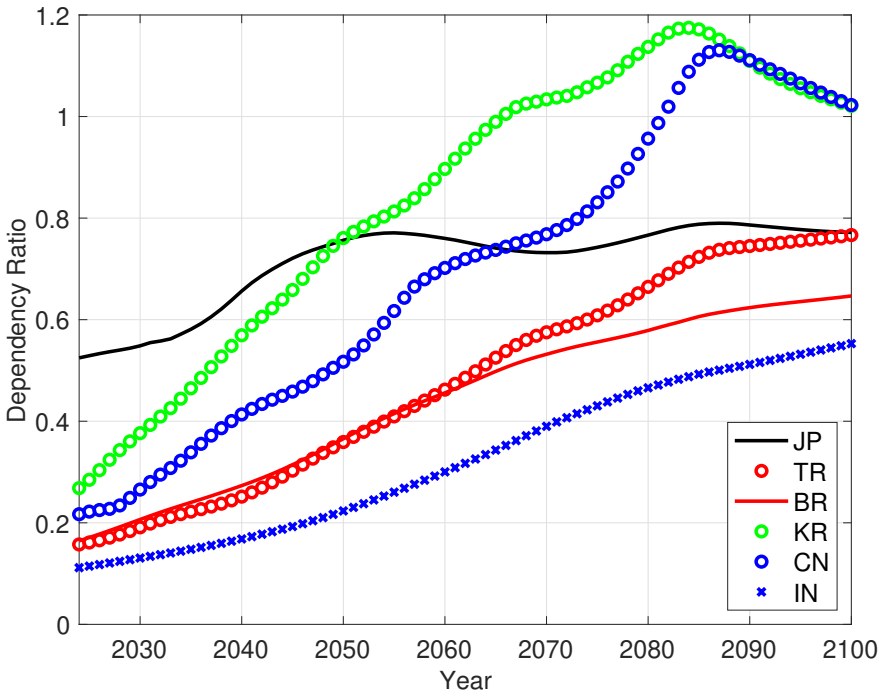

Figure 11: Dependency Ratios in Middle-Income Countries

Figure 11 shows the dependency ratio in Japan as the solid black curve, starting at about 52% in 2024 and rising to about 80% by 2100. One of the most notable features of Figure 11 is how young China and Korea are in 2024 relative to Japan and how fast they are projected to overtake Japan in terms of their aging. Korea, in particular, is expected to overtake Japan in 2050. In fact, according to the UN forecasts, both countries will have dependency ratios far in excess of unity in the 2080, indicating the most severe aging and the accompanying burden on public pension systems anywhere in the world.

India has the youngest population in this group but is still expected to experience a more than tripling of its dependency ratio by 2100, similar to what Brazil is projected to become. Finally, although very young in 2024 relative to Japan, Türkiye is projected to age rapidly and catch up with Japan eventually in 2100. Public pension systems in these developing countries have recently been formed and the FRA is quite different across them, as low as 50 for women with blue collar jobs in China, to eventually 65 in the future in Korea and Türkiye.

3.4 Fertility Rates

A critical assumption that determines the age distribution in these population projections is the total fertility rate which has been declining across all countries in the world. Table 2 summarizes the TFR assumptions on the countries used in this paper by the UN WPP in four snapshots.

Table 2: Total Fertility Rates

	2024	2050	2075	2100
Brazil	1.614	1.559	1.575	1.578
China	1.013	1.184	1.283	1.345
Denmark	1.517	1.574	1.600	1.614
France	1.636	1.647	1.652	1.646
Germany	1.448	1.538	1.572	1.597
India	1.962	1.765	1.712	1.693
Italy	1.206	1.349	1.425	1.478
Japan	1.217	1.349	1.434	1.472
Korea	0.734	1.026	1.191	1.296
Spain	1.221	1.362	1.442	1.483
Türkiye	1.621	1.616	1.612	1.611
UK	1.551	1.549	1.575	1.595
US	1.622	1.643	1.642	1.647

The 2024 TFRs range from a low of 0.734 in Korea to a high of 1.962 in India. The assumption about future values for most countries is that the TFR will converge to about 1.6, with Korea and China reaching about 1.3. Spain is expected to have its TFR rise from 1.2 to about 1.5. It is unclear what the underlying reasons are for the path of these projected fertility rates but they are absolutely critical in affecting the dependency ratios in the future. Figure 12 shows the medium TFR assumptions used by the UN WPP.

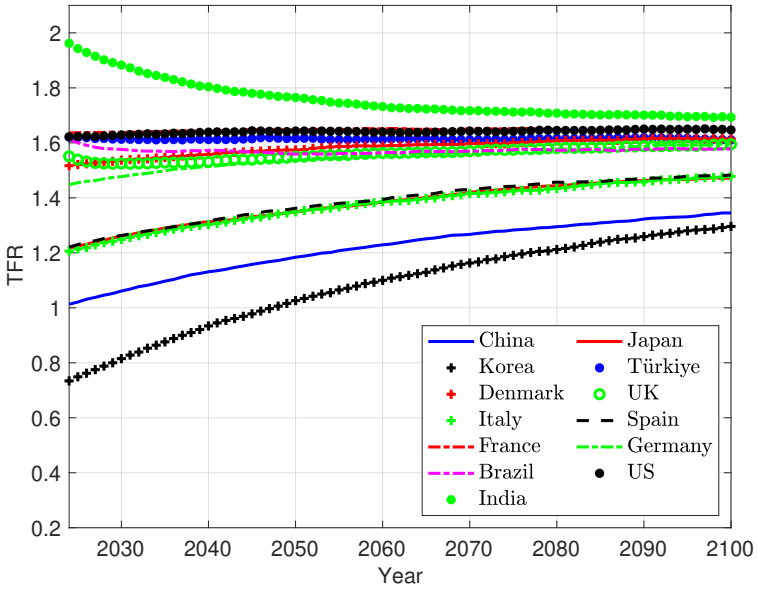

Figure 12: Total Fertility Rates

4 Range of Projections in the UN WPP Data

In this section we display the range of dependency ratios using the UN WPP data for the countries under consideration. Figure 13 shows the measure of aging for Japan and the U.S.

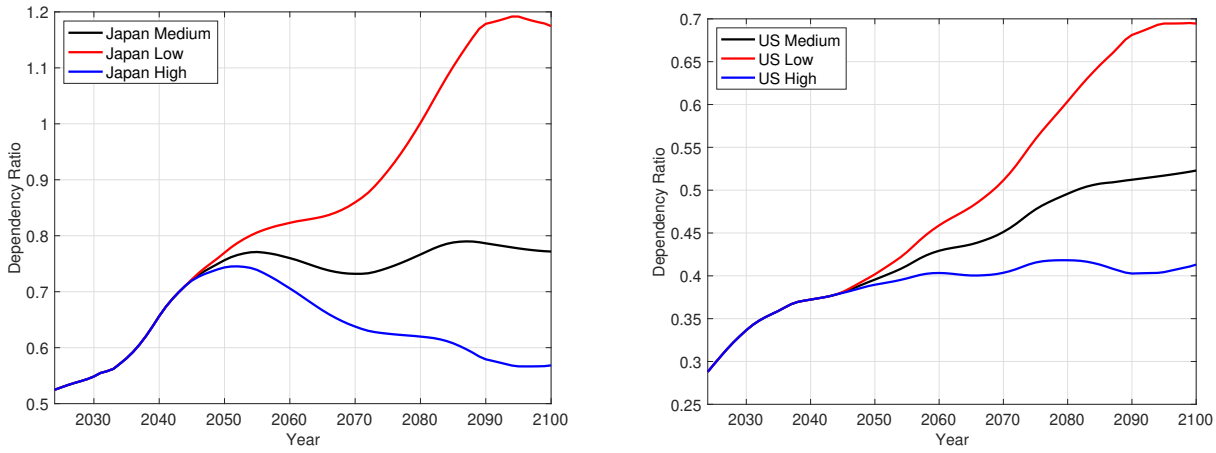

Figure 13: Old-Age Dependency Ratios in Japan and the U.S. from UN WPP

The range of values for the dependency ratio is especially large for Japan, going from a slight increase in 2100 from the current 2024 value of 52% if fertility rises 0.5 percentage points, to a very high 120% if fertility declines by 0.5 percentage points from its recent, already low value.

Figure 14 shows the dependency ratios in the U.K. and Italy, where as Figure 15 displays the measures for France and Germany.

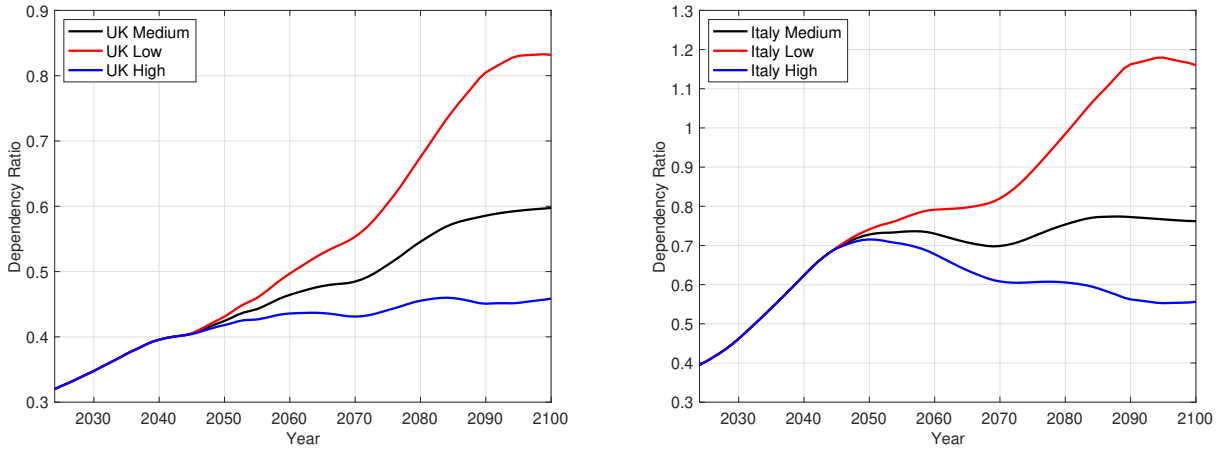

Figure 14: Old-Age Dependency Ratios in the U.K. and Italy from UN WPP

The demographics of the U.S. and the U.K. are fairly similar, so are those in Denmark, France and Germany. Italy and Spain are closer to that of Japan as mentioned earlier, with Türkiye converging to the level of Japan eventually.

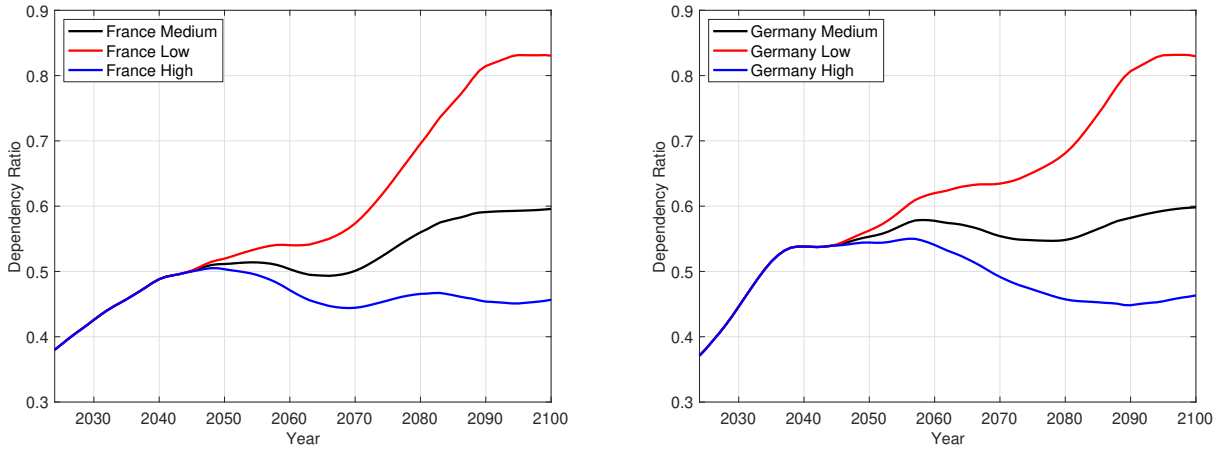

Figure 15: Old-Age Dependency Ratios in France and Germany from UN WPP

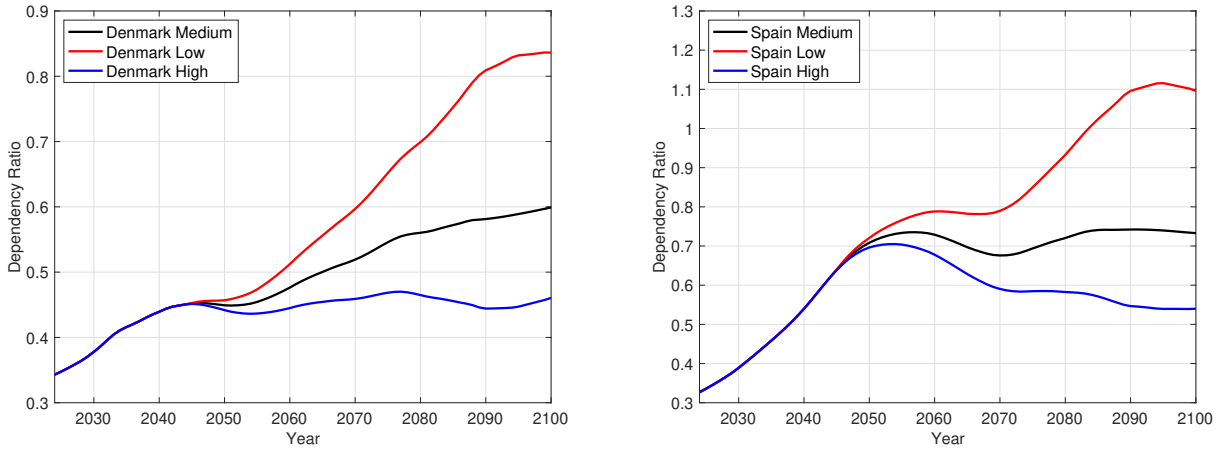

Figure 16: Old-Age Dependency Ratios in Denmark and Spain from UN WPP

Denmark, France and Germany all converge to about 60% old-age dependency ratio by 2100, starting below 40% in 2024. Spain starts even younger at below 35% dependency ratio in 2024 but is projected to converge to above 70% by 2100.

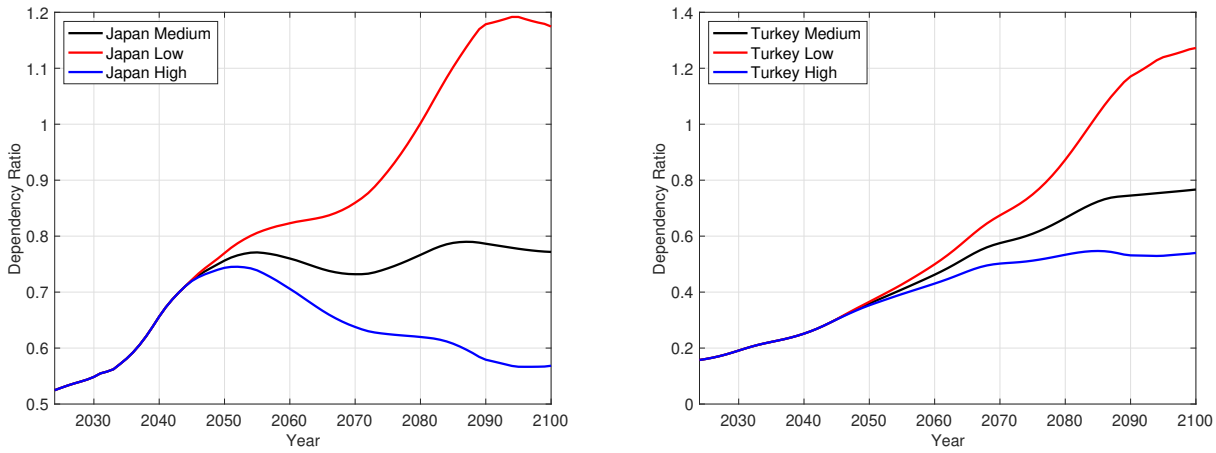

Figure 17: Old-Age Dependency Ratios in Japan and Türkiye from UN WPP

Brazil and India start out at very young, with low levels of dependency ratios in 2024 but are both projected to age rapidly and approach 0.5-0.6, more than tripling their measures of aging, shown in Figure 18. Türkiye is nearly one-third younger in 2024 compared to Japan but is projected to catch up with Japan in 2100.

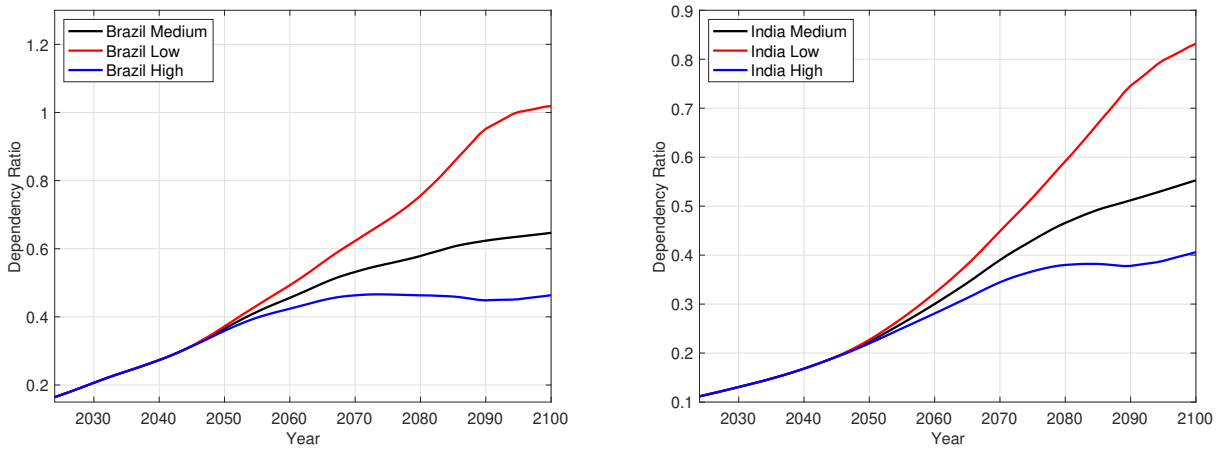

Figure 18: Old-Age Dependency Ratios in Brazil and India from UN WPP

China and Korea face the harshest aging processes, starting at very low levels of dependency ratios but more than quadrupling them by 2100. If the UN projections turn out to be even remotely realistic, all of these developing countries will be facing severe fiscal consequences.

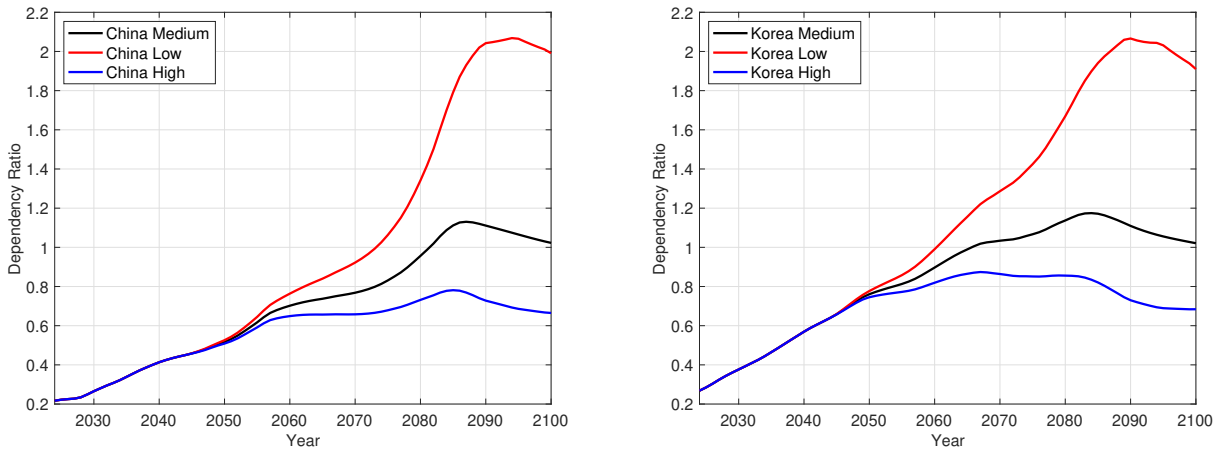

Figure 19: Old-Age Dependency Ratios in China and Korea from UN WPP

5 Catching up with Japan

Table 3 examines the timing of the aging processes, using the dependency ratios, the number of 65 and older individuals divided by the number of individuals between the ages of 20 and 64, of the list of countries relative to that in Japan. Column two lists the values of the dependency ratios in 2023. Japan is the highest at 0.5217 and India the lowest at 0.1087, with the advanced economies in between and the developing countries below them and above India.

Table 3: Dependency Ratio in 2023

	2023 DepRatio	Been There	There Yet?
Japan	0.5217	2023	2023
Italy	0.3883	2012	2034
France	0.3718	2010	2054
Germany	0.3629	2009	2036
Denmark	0.3378	2007	2071
Spain	0.3179	2006	2039
UK	0.3148	2005	2077
US	0.2784	2002	2099
Korea	0.2534	1999	2038
China	0.2085	1994	2050
Brazil	0.1582	1984	2068
Türkiye	0.1534	1984	2065
India	0.1087	1970	2093

The third column lists the year Japan had passed the 2023 dependency ratio of each

country. Japan was in Italy's 2023 position back in 2012 and in India's shoes back in 1970. The last column of Table 3 shows the year each country is projected to catch up with Japan's current, 2023, dependency ratio. Italy, Germany, Korea, and Spain are within 15 years of reaching the current aging measure of Japan; most countries are further away from Japanification in this regard.

6 Postponing the Retirement Age

Another way to assess the timing and the magnitude of the aging problem is to consider a hypothetical postponement of the FRA in an attempt to keep the dependency ratio relatively low, say at its 2023 level. In particular, in this section we ask 'how many postponements of the FRA does it take for each country to maintain its dependency ratio at the current, 2023, level?'

Following De Nardi, İmrohoroğlu, and Sargent (1999), we raise the FRA by one year every five years starting in 2029 until the eventual dependency ratio in 2100 comes down to the 2023 level. Figure 20 from De Nardi, İmrohoroğlu, and Sargent (1999) indicates that one needed 11 postponements from an FRA of 65 to an eventual FRA of 76, using the actual demographic data from mid-1990s.

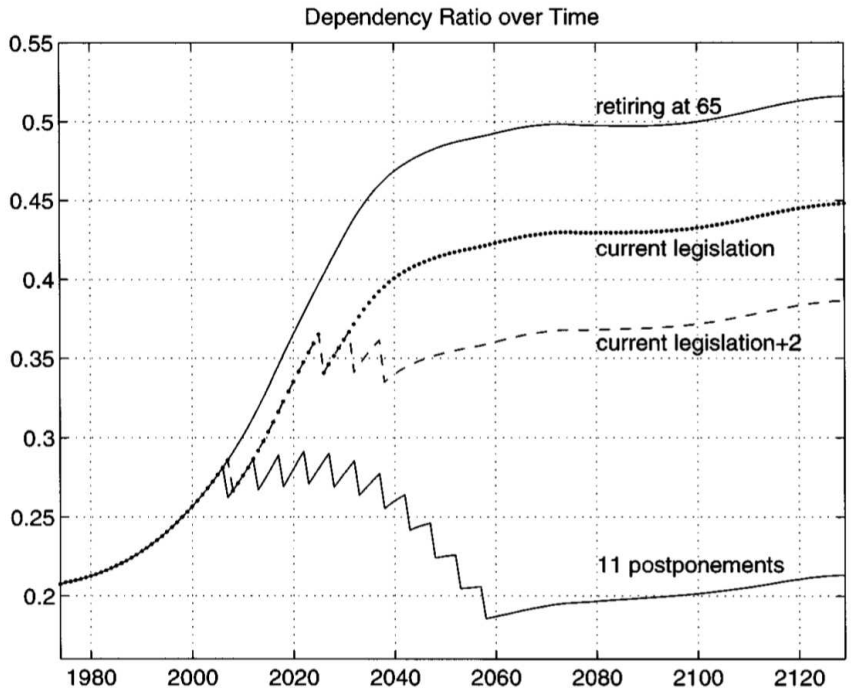

Figure 20: Figure 1 from De Nardi, İmrohoroğlu, and Sargent (1999)

Using the current CB and the UN projections, Figure 21 shows that the FRA has to increase to 76 or 77 to bring the 2100 ratio of the number of individuals 76 or 77 and older to that of the individuals between 20 and 75 or 76, to the value in 2024. Note that we start

from the current FRA of 67 so that the dependency ratio in 2024 is the ratio of the number of individuals 67 and older to that between 20 and 66, and, then raise the FRA by one every five years starting in 2029 and so on.

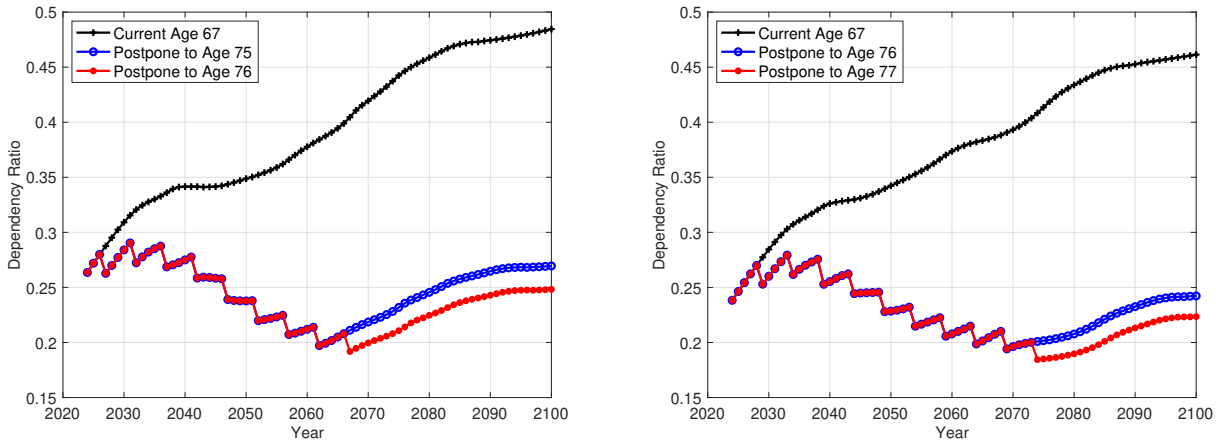

Figure 21: Postponing the FRA in the U.S.

Using the low and zero immigration variants of the UN projections yield somewhat higher postponements in Figure 22.

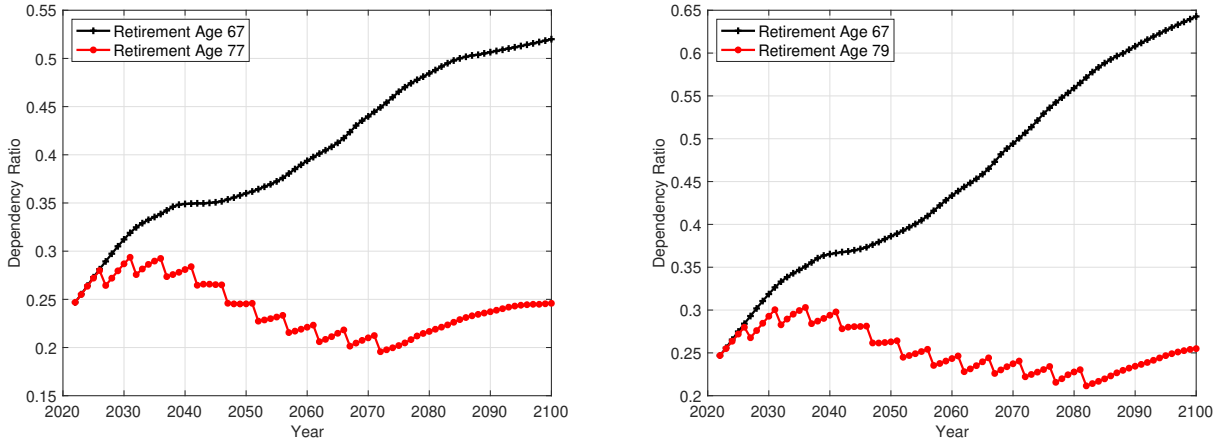

Figure 22: Postponing the FRA in the U.S.

When the SSA projections are used to assess the aging in the US, the outcome is far more optimistic than that under the CB or the UN. Figure 23 shows that only 5 postponements are needed in the US to bring the eventual old-age dependency ratio back to its initial value. Since SSA is the official US government entity that determines the health of the Trust Fund and all aspects of social security, it is useful to compare SSA's forecasts with those from other sources.

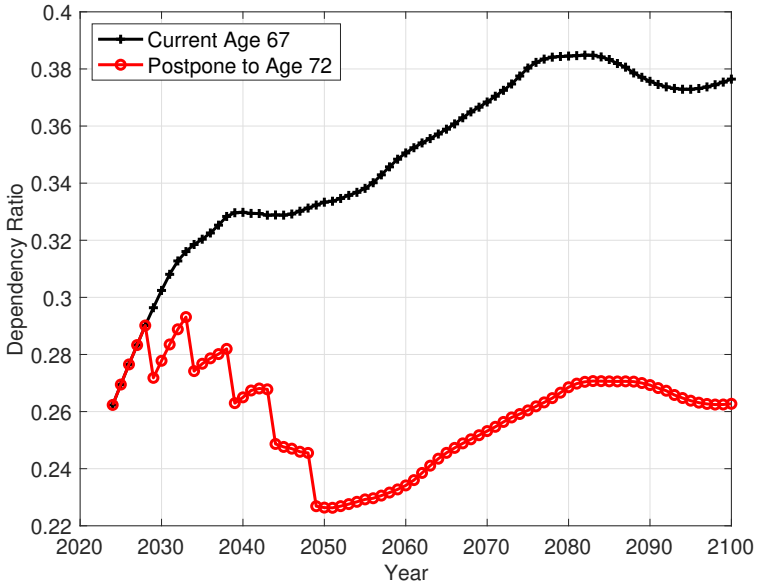

Figure 23: Postponing the FRA in the US with SSA Projections

Given SSA's assumption of 1.9 for fertility going forward, it is not surprising that the number of postponements is significantly lower than those from using the CB or UN's projections. In this sense, SSA has the most optimistic outcome for the future health of social security compared to the population projections from other sources.

Figure 24 shows that the number of postponements in Japan from the current FRA of 65 is a much smaller increase to about age 71.5. Both the official Japanese government projections (IPSS) and the UN WPP give the same result for Japan. The reason for the smaller number of postponements is that Japan has already aged significantly and a few postponements go a long way to re-establish the 2024 dependency ratio.

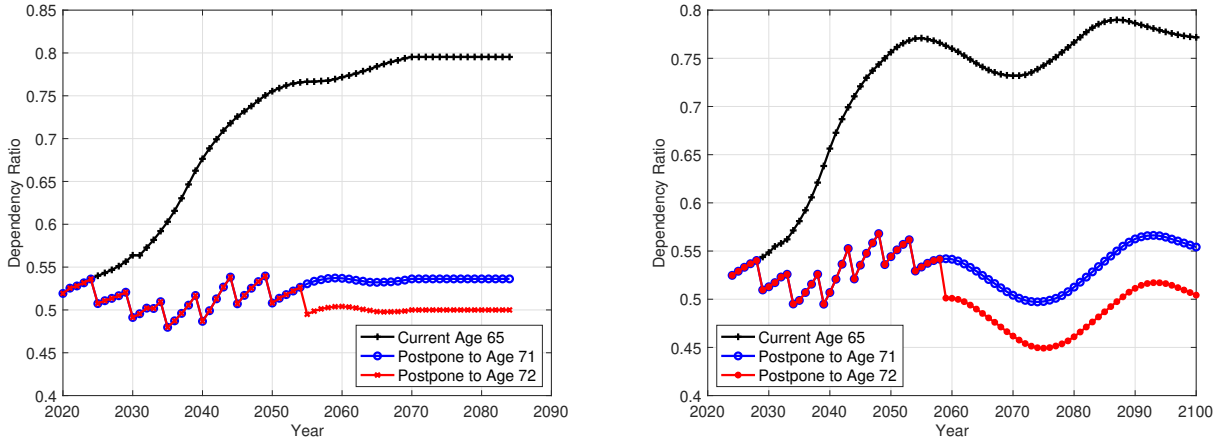

Figure 24: Postponing the FRA in Japan

Denmark has its FRA projected to rise to 70 by 2040, and perhaps to 74 by 2100, but Figure 25 suggests that increasing the FRA to about 75.5 may be needed.

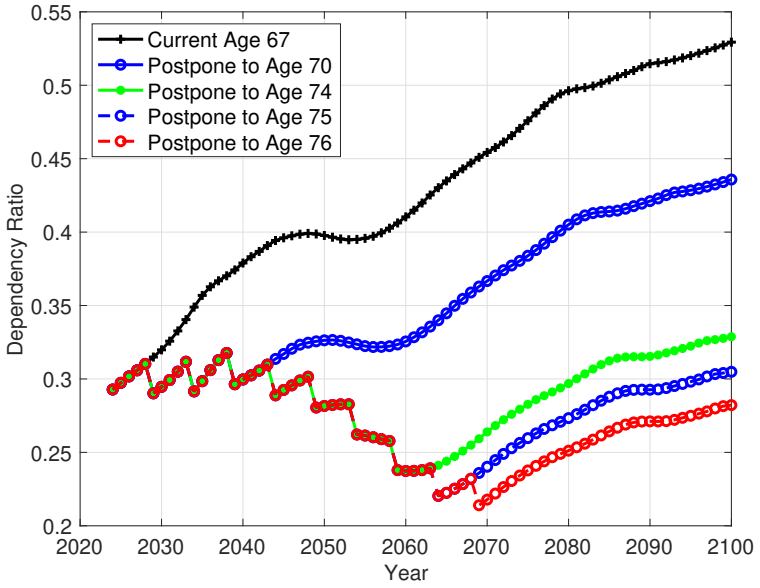

Figure 25: Postponing the FRA in Denmark

France and Germany require 7 and 8 postponements, respectively as shown in Figure 26.

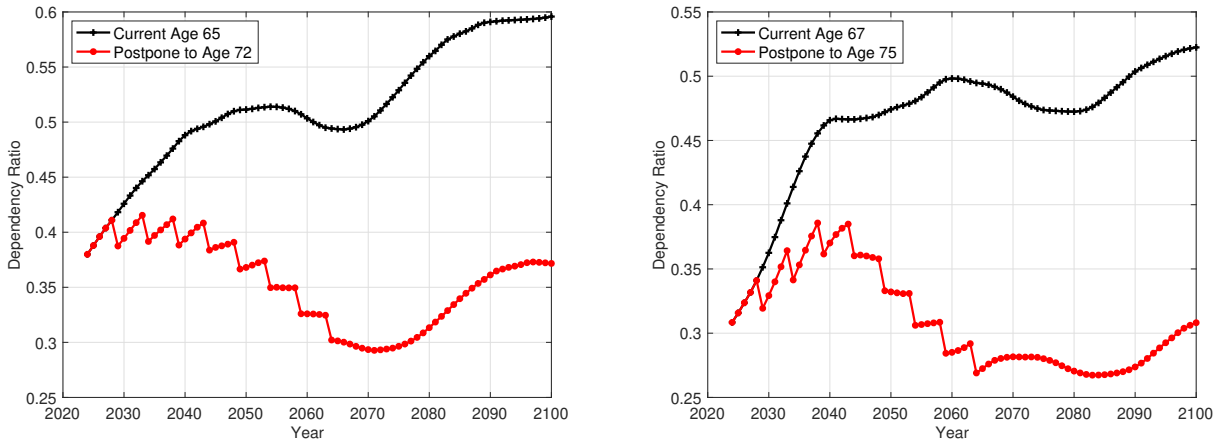

Figure 26: Postponing the FRA in France and Germany

Italy and Spain, on the other hand, need more postponements with 11 and 13, respectively.

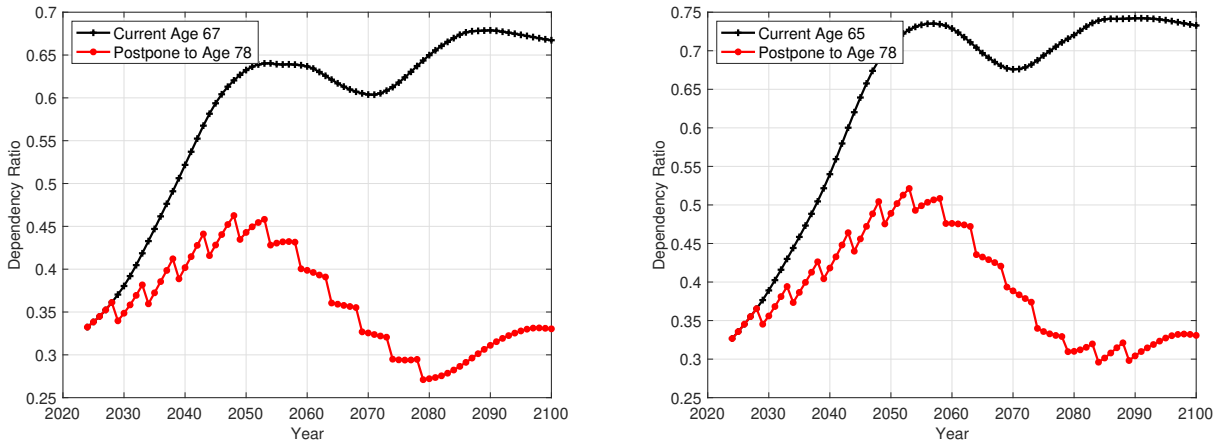

Figure 27: Postponing the FRA in Italy and Spain

UK is similar to the US with a needed postponement of about 10 in the FRA according to Figure 28.

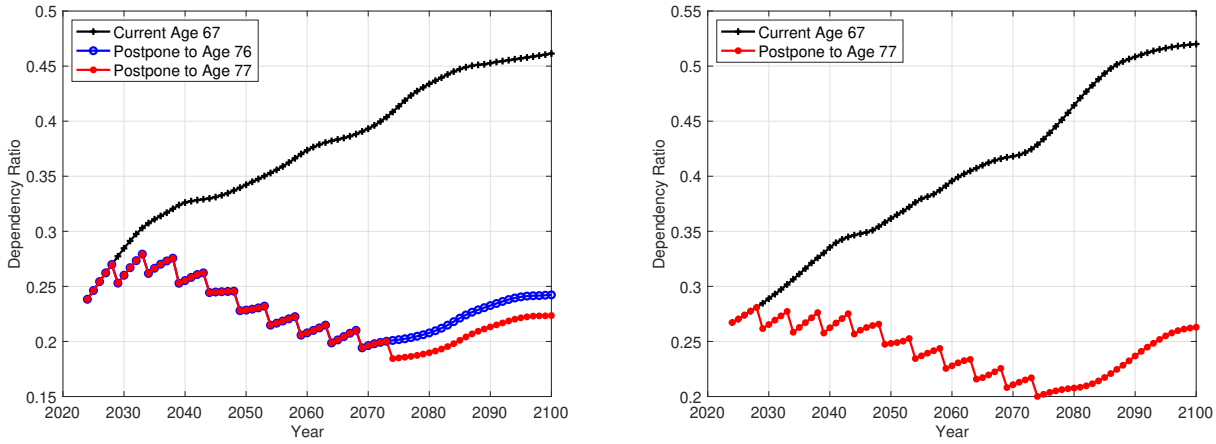

Figure 28: Postponing the FRA in the US and UK

India starts as the youngest country in 2024 and its current FRA of 60 requires an increase to 79 with 19 postponements eventually as shown in Figure 29.

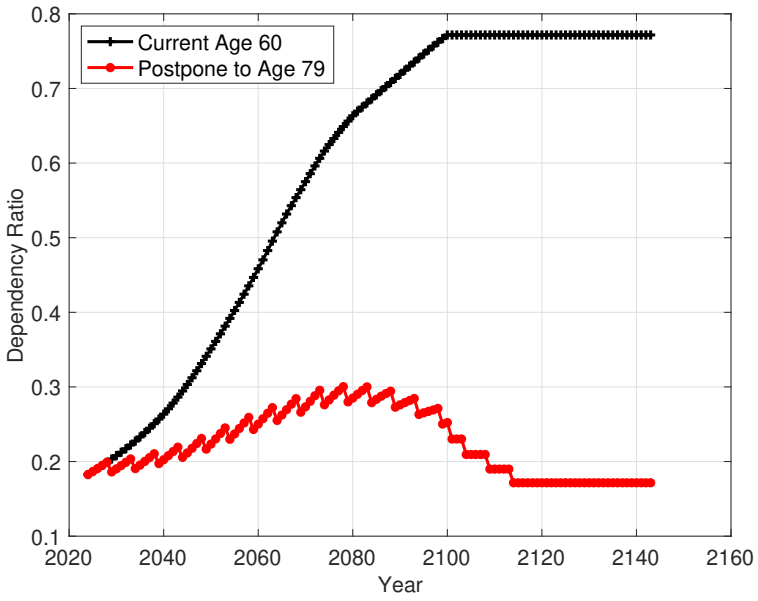

Figure 29: Postponing the FRA in India

Brazil and Türkiye are also among the younger countries and consequently need large postponements at 17.5 and 19, respectively, according to Figure 30.

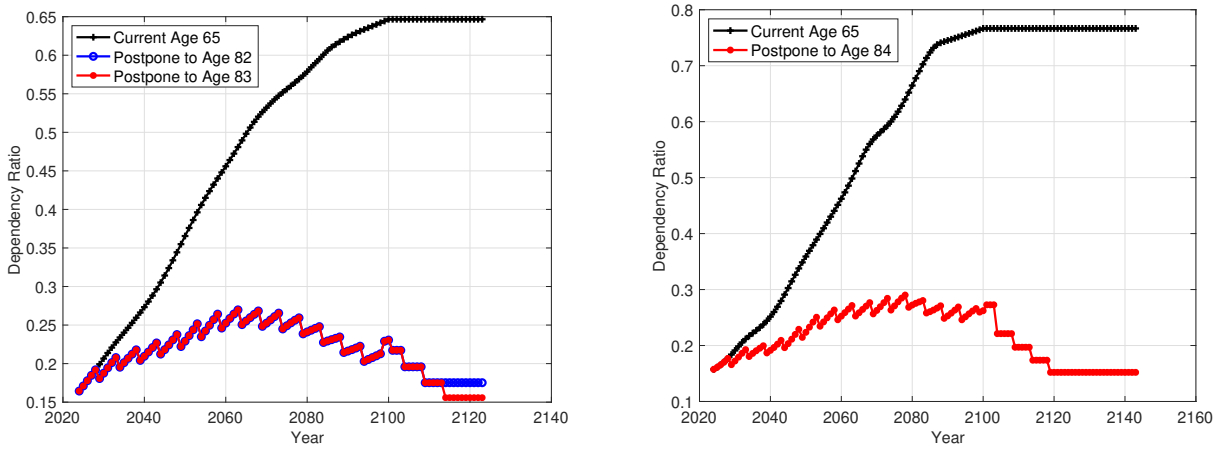

Figure 30: Postponing the FRA in Brazil and Türkiye

China and Korea are not only among the youngest but their TFRs are also among the lowest projected. As a result, their postponements are 23.5 and 20, respectively, as shown in Figure 31.

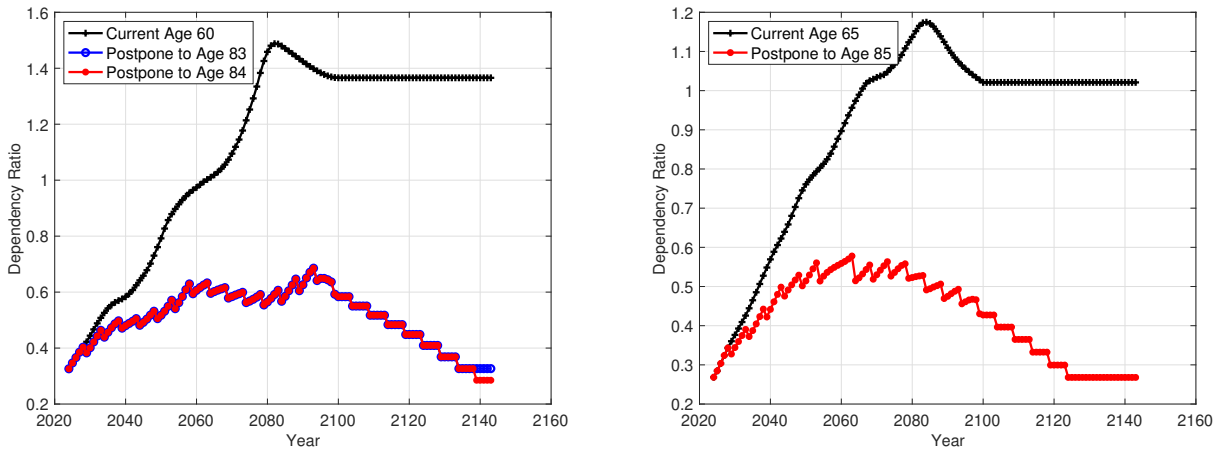

Figure 31: Postponing the FRA in China and Korea

Of course, we do not think these postponements will ever take place. Rather, these measures put into context which countries are aging at which point in time and where their FRAs are now relative to their current dependency ratios. Furthermore, the generosity of the public pension programs is also critical in addition to the imbalance provided by demographic aging.

Figure 32 shows the correlations between the number of postponements (in the horizontal axis in both panels) and the 2024 TFR (left panel) and the 2024 dependency ratio (on the right panel). There is a strong negative correlation between the level of aging in 2023 as measured by the dependency ratio and the number of postponements needed to bring the eventual dependency ratio back to its 2023 level. In addition, the countries with the lowest TFRs face much higher postponements.

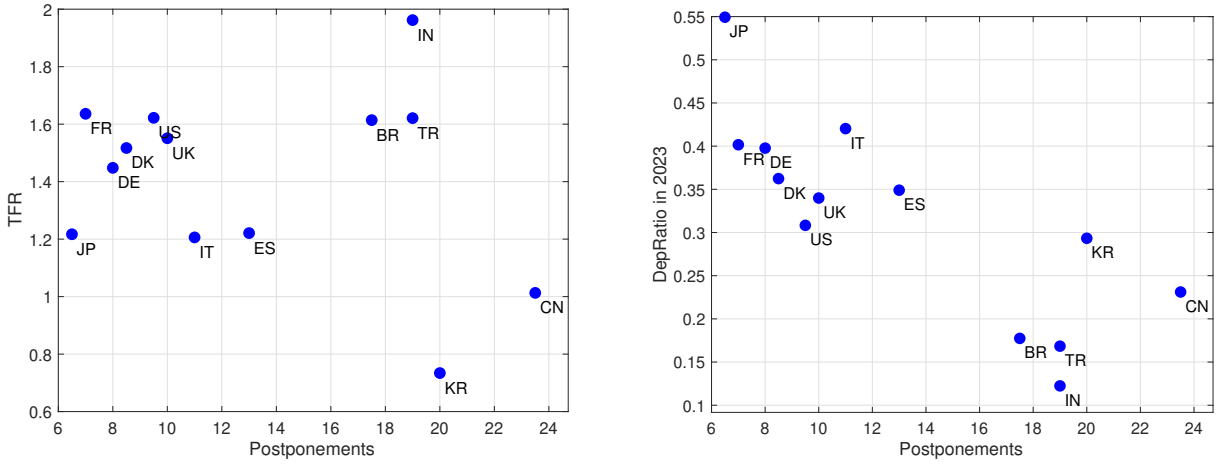

Figure 32: 2024 TFR and Dependency Ratio, and Postponements

7 Unfunded Obligations of Public Pensions in the U.S. and Japan

According to Office of the Chief Actuary, Social Security Administration (2024), the value of the unfunded obligations in year t_0, UO_{t_0}, over the valuation period (e.g., from year t_0 to year t_n) is calculated as:

$$UO = PV[\text{Cost}] - PV[\text{Income}] - \text{Trust Fund}_{t_0} \tag{1}$$

where:

- $PV[\text{Cost}] = \sum_{t=t_0}^{t_n} \frac{C_t}{(1+r)^{t-t_0}}$ is the present value of projected Social Security costs,
- $PV[\text{Income}] = \sum_{t=t_0}^{t_n} \frac{I_t}{(1+r)^{t-t_0}}$ is the present value of projected non-interest income (payroll taxes, income taxes on benefits),
- Trust Fund_{t_0} is the trust fund balance at the beginning of the valuation period,
- r is the real discount rate,
- C_t is the total cost (benefits + administrative expenses) in year t,
- I_t is the total non-interest income in year t.

In the most recent 2024 Trustees Report, the evaluation period is the 75-year period from 2023 to 2098. Since I have data through 2100, I will use the formula 1 from 2024 through 2100.[3]

The SSA's detailed methodology incorporates time-varying assumptions for interest rates, inflation, productivity, and labor market and demographic dynamics, in addition to the discount rates used in the PV calculations. Furthermore, they use administrative data and their own population projections. My estimates abstract from these in favor of simplicity and transparency. Furthermore, I will apply the simple method to data on Japan as well.

***UO* of Social Security in the U.S.** To evaluate the sensitivity of public pension unfunded obligations to alternative demographic projections, this section presents a set of back-of-the-envelope calculations based on 2023 figures from the Social Security Administration (SSA). Specifically, I begin with the total net payroll tax income of $1,054.1 billion and total scheduled benefits of $1,227.4 billion reported for the Old-Age and Survivors Insurance (OASI) program in 2023. Using the SSA estimates of the working-age population (ages 20–64) at 197.995 million and the retirement-age population (ages 65 and older) at 60.877 million, I calculate a per capita income contribution from workers of $5,324 and a per capita benefit cost to retirees of $20,162.

[3] I abstract from the revenue from taxation of benefits and the interest earnings on the Trust Fund in calculating the income, and, ignore the administrative expenses to calculate the costs. Also, I only consider the OASI program and leave the disability insurance (DI) and health insurance (HI) programs out of this analysis.

Applying these per-person income and cost estimates to SSA's population projections from 2024 through 2100, I compute annual total income and benefit cost streams. I then calculate the present value (as of 2023) of these income and cost streams using a constant real discount rate of 2.0%, and subtract the present value of total income (payroll taxes) plus the OASI Trust Fund balance at the end of 2023 ($2.6 trillion) from the present value of total costs (benefits), following equation 1. This yields an estimated unfunded obligation of **$23.3 trillion** for 2023 which is 84% of GDP. This simple estimate is broadly consistent with the 2024 Trustees Report, which places the 75-year unfunded obligations of the OASI program at **$22.6 trillion**.

To assess the impact of different demographic projections, I replicate the same exercise using the SSA's alternative forecasts as well as those from the UN and CB and report the results in Table 4.

Table 4: Unfunded Public Pension Obligations of U.S. Social Security

SSA	low cost	intermediate	high cost
	$16.9	$23.3	$30.7
	60.8%	84.0%	110.9%
UN	low TFR	medium TFR	high TFR
	$24.3	$27.5	$30.0
	87.8%	99.2%	108.2%
CB	medium	low	zero
	$25.7	$26.1	$26.8
	92.8%	94.1%	96.7%

$ trillion; as a percentage of 2023 GDP

SSA's own population forecasts yield a large range for the unfunded obligations of social security. For example, the difference between the 'low cost' and 'high cost' UOs are more than 50% of GDP. In addition, the population projections of SSA are markedly more optimistic than those from the UN and the CB as shown in Figure 6. The implications of this difference on the UOs are not small; the CB's and the UN's medium population projections produce more than 8 and 15 percentage points of GDP, respectively. The range of UO estimates from the CB population projections (with medium, low and zero immigration variants) is fairly small where as that from the UN projections is in between those from the SSA and the CB. These findings underscore the substantial fiscal sensitivity of pension obligations to the underlying demographic forecasts.

UO **of Public Pensions in Japan** In fiscal year (FY) 2023, Japan collected ¥39.7 trillion (premiums paid by individuals and employers across the Employees' Pension (Kōsei Nenkin) and National Pension (Kiso Nenkin) systems), with ¥11.3 trillion in subsidies from the government. Part of the 2004 and 2009 pension reforms in Japan involved the government subsidizing 50% of the basic pension portion (Kiso Nenkin) and some operating and administrative expenses from general tax revenues. I will allocate this subsidy to the financing of

the pensions and also provide the income of the system without the subsidy.[4] Dividing the total revenue into the public pension by the number of 20-64 year old individuals gives a per-person income of ¥586,376 excluding the government subsidy and ¥753,279 including the subsidy.[5]

Japan's total public pension benefits disbursed—combining both the National Pension (basic) and Employees' Pension Insurance—amounted to approximately ¥53.4 trillion in FY 2023, about 9% of GDP for 2023. Dividing this number by the number of 65+ individuals gives a per-person public pension benefit of ¥1,511,891. Given per-person cost and income of the public pension program in Japan, we can now use various population projections to calculate the *UO* of the Japanese system. Table 5 shows the estimates (as a percentage of 2023 GDP) using the UN and the official IPSS population projections.

Table 5: Unfunded Public Pension Obligations

		no subsidy	w/subsidy
IPSS worst	No Slide	136.8%	79.3%
	Slide to 2050	70.6%	13.1%
	Slide to 2100	46.6%	−10.8%
IPSS medium	No Slide	117.2%	58.2%
	Slide to 2050	53.8%	−5.2%
	Slide to 2100	31.0%	−28.0%
IPSS best	No Slide	96.8%	36.0%
	Slide to 2050	36.2%	−24.7%
	Slide to 2100	14.6%	−46.3%
UN low	No Slide	128.3%	74.7%
	Slide to 2050	66.9%	13.3%
	Slide to 2100	46.1%	−7.5%
UN medium	No Slide	119.6%	62.2%
	Slide to 2050	57.2%	−0.2%
	Slide to 2100	35.8%	−21.6%
UN high	No Slide	102.6%	41.2%
	Slide to 2050	40.8%	−20.5%
	Slide to 2100	19.6%	−41.7%

As a percentage of 2023 GDP.

Using the IPSS population projections, the unfunded obligations of the Japanese public pension system range from 96.8% of GDP to 136.8% of GDP with no 'slide', slightly higher than those for the U.S. The range is slightly smaller with 102.6% and 128.3% of GDP with the UN population forecasts.

However, these calculations for Japan so far ignore the significant reforms of 2004 called the 'macroeconomic slide'. In addition to raising the payroll taxes from about 13.58% in 2004 to 18.3% by 2017 (which is implicitly reflected in my calculations as I am using

[4] I will abstract from the investment return of ¥3.6 trillion for FY 2023.

[5] The estimates of the 20-64 and 65+ populations in 2023 are 67,704,000 and 35,320,000, respectively.

the 2023 payroll taxes), the benefits were reduced to reflect the decline in the number of taxpayers and the rise in longevity, decreasing the benefits approximately by 0.8% each year (for the basic pension, until about 2047 with further declines to 2057 under certain conditions).[6]

I implement the macroeconomic slide of 2004 by reducing the per-person benefit by 1 percentage point starting in 2024 until 2050. With the slide stopping in 2050, the unfunded obligations are now 36.2% of GDP to 70.6% of GDP using the range of IPSS projections, and, 40.8% to 66.9% of GDP with the UN population forecasts. In other words, the macroeconomic slide reform seems to have reduced the unfunded obligations of the Japanese public pension system by more than 60 percentage points of GDP over an approximately 50-year horizon.

In addition, when the government subsidy is taken into account, the IPSS range for Japan's UO is -24.7% to 13.1%, and UN's range reduces to -20.5% to 13.3%. These indicate substantial reductions in the fiscal burden of public pensions achieved by the macroeconomic slide. If the slide were to be extended beyond 2050 to 2100, the unfunded liabilities become even smaller without the government subsidy and with subsidy there are negative UOs.

These calculations suggest that the reforms of the 2004 created significant fiscal space for Japan as far as public pensions are concerned, and, both the advanced and middle-income countries can learn from Japan's approach to dealing with demographic aging. The sooner a government acts the more contained will be the fiscal burden. For example, if the U.S. undertook a macroeconomic slide like Japan that starts in 2024 and reduces cost per retiree by 1% each year until 2050, the unfunded liability, using SSA's intermediate population projections, would decrease from 84.0% to 37.0%; extending this slide to 2100 would deliver an UO of only 16.8%.[7]

8 Concluding Remarks

Demographic aging will increasingly define the macroeconomic landscape of the 21st century. This paper has documented the scale and heterogeneity of the aging process using internationally comparable data from the UN WPP and national statistical agencies. A key insight is that while aging is a global phenomenon, its fiscal consequences will vary sharply depending on each country's demographic starting point, institutional readiness, and willingness to implement reform.

The number of retirement age postponements needed to stabilize the old-age dependency ratio serves as a simple yet powerful proxy for required fiscal adjustment. This measure reveals that Japan, having aged early and already enacted meaningful pension reform, faces a comparatively modest path forward. In contrast, middle-income countries such

[6] See İmrohoroğlu, Kitao, and Yamada (2016) for the estimates of the decline in the replacement ratio in Japan as a consequence of the implementation of the 2004 macroeconomic slide.

[7] Note that my analysis has been descriptive and simple accounting. To evaluate the economic and welfare effects of policies, one needs a quantitative general equilibrium model with overlapping generations in which individuals respond to changes in their demographic and fiscal environment by re-optimizing their consumption, saving, and labor supply decisions and markets and budget constraints add up properly. This is on-going research.

as China, Türkiye, and Brazil will need far more aggressive adjustments, with some requiring retirement age increases of nearly 20 years over the century.

Estimates of unfunded public pension obligations further underscore the sensitivity of fiscal projections to population assumptions. In the U.S., switching from SSA to Census Bureau projections raises the long-term fiscal gap by over $2 trillion. Meanwhile, Japan's experience with the macroeconomic slide reform highlights how automatic benefit indexation can materially improve long-term sustainability.

The findings of this paper suggest three broader implications. First, demographic projections are not destiny, but they must be taken seriously in designing long-term fiscal policy. Second, countries that delay reform are likely to face more abrupt and politically difficult adjustments later. Third, automatic stabilizers—such as indexation rules tied to demographic trends—can serve as powerful tools in pension reform, especially where institutional capacity for ongoing adjustment is limited.

Future research might explore how varying institutional structures across countries affect the political economy of pension reform, or assess how complementary policies—such as immigration or family policy—can mitigate demographic headwinds. For now, the evidence is clear: demographic aging demands fiscal foresight, and the window for gradual adjustment is closing fastest in the places where it is needed most.

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