Supplying Safety to an Aging World: Demographics, Debt, and Risk Premia*

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Abstract

By raising the share of life spent in retirement, demographic aging shortens the duration of individuals' labor earnings relative to their consumption horizons. Since labor income is relatively safe, its shortening duration increases households' desire for safe bonds and lowers their capacity to bear equity risk. Slower population growth reinforces these effects. A consequence of aging is therefore a lower safe rate, with the risk premium rising to make aging investors willing to absorb the risk. In a two-country model in which Foreign ages more severely, Home households (which we identify with the U.S.) optimally supply safe bonds and take leveraged equity positions, as they are in the better *relative* position to do so. As a result, Home's equity premium rises by more than Foreign's, consistent with the evidence. Quantitatively, we find that demographic changes since 1980 have lowered the world safe rate by 71 basis points and raised the U.S. equity premium by 251 basis points (compared with 49 basis points abroad). Aging can therefore lower safe returns globally while raising the compensation required to bear equity risk – particularly in the "younger" country, which is better placed to absorb such risk and becomes the global safe asset issuer.

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1 Introduction

In this paper, we study the equilibrium allocation of risk between two countries that differ in their aging patterns – with one country aging "more severely" than the other, in the sense that its population growth rate declines by more and its residents spend a greater fraction of their lives in retirement. Since labor income is relatively safe, shorter working lives relative to total lifespans raise the desire to save in safe assets, like bonds, that can replace such income in retirement (Merton, 1971). Aging can therefore be expected to lower safe rates, while pushing up the equity premium. This can be seen as a reflection of the fact that an older population is less suited to bear risk, meaning the risk premium must rise to make investors willing to bear it (Kopecky and Taylor, 2022).

Our particular contribution is to analyze this dynamic in an open economy, where aging is more severe in Foreign than in Home (which, empirically, can be associated with the U.S.). In such a setup, we show that the relatively younger Home households are better placed to take on equity risk, while issuing safe bonds to the rest of the world, where aging has hit harder. Home (U.S.) households therefore take a leveraged equity position, functioning like "the world's venture capitalist" (Gourinchas and Rey, 2007). Our paper thus links observed patterns in global imbalances, safe rates, and risk premia to cross-country differences in demographic forces. In this sense, our paper can be understood as "Merton meets Gourinchas and Rey".

It has long been debated whether secular movements in safe rates of interest and risk premia reflect changes in growth, market structure, or risk. Over the past few decades, real safe rates have fallen significantly, while the pre-tax return on private capital has remained broadly stable in the U.S. – implying a rising equity premium, at least in the U.S. (Gomme et al., 2015; Farhi and Gourio, 2018; Reis, 2022). The stability of the return on capital sits uneasily with the "global saving glut" hypothesis (Bernanke, 2005), as that should lower risky rates of return alongside risk-free ones. It is similarly hard to reconcile with a simple productivity or capital-deepening story. Consequently, the widening wedge between safe and risky returns is widely interpreted as a rising price of risk.

What has driven this rise? The leading explanations are incomplete in important ways. Farhi and Gourio (2018) show that the joint behavior of safe rates, risky returns, and equity premia can be reconciled by allowing disaster probabilities to drift upward over time. But disaster risk is notoriously hard to measure, and attempts to do so find little evidence that it has risen (Papanikolaou, 2018). Marx et al. (2021) conclude that "a large increase in the risk aversion of investors, or a growing weight of risk-averse investors" is necessary to match the data, but this merely relocates the puzzle: what caused risk aversion to rise?

Invoking secular changes in a structural parameter risks turning it into a free parameter, a criticism that Farhi and Gourio (2018) themselves acknowledge.[1] Eggertsson et al. (2021) attribute these trends to rising markups, but this explanation is sensitive to contested measurement (Basu, 2019; De Loecker et al., 2020; Raval, 2023) and may be quantitatively overstated in the presence of intangible capital (Farhi and Gourio, 2018). Reis (2022) develops a theory based on rising misallocation of investment due to financial frictions. Each of these accounts appeals to forces that are difficult to observe or measure, or that themselves need explaining.

This paper argues that a different, more measurable trend can explain the observed patterns. *Aging* – characterized by falling population growth rates, longer expected lifetimes, and individuals spending a greater fraction of their lives in retirement – increases the demand for safe financial wealth in a way that lowers the safe rate and pushes up the equity risk premium. Rather than treating a higher price of risk as a primitive, we connect it to demographics – a force that is directly observable and precisely measured, and whose secular trend is widely acknowledged – through safe-asset issuance and investor balance sheets.

Starting on the measurement front, we first document how (a) the risk premium appears to have risen by more in the U.S. than elsewhere, while (b) aging has hit harder outside the U.S., in the sense that the fraction of life spent in retirement has risen by more there. Consequently, non-U.S. individuals' "retirement-duration gaps" – the expected duration of their consumption stream minus the expected duration of their labor earnings – have widened by more.

Motivated by these observations, we develop a model to understand how these patterns might be linked. We first study a small country (consisting of two types of agents: stockholders and nonstockholders) that ages in isolation, with the interest rate held fixed at r^*. If this country can "import" all the desired safe assets from abroad, demographics will not have any impact on the risk premium. But that no longer holds when some of the bonds need to be supplied domestically, by the limited set of stockholders. In that case, they are asked to take on a leveraged equity position, which – given that they are aging too – does not appeal to them *a priori*. To make them willing to hold equity on a leveraged balance sheet, they need to be compensated with a higher risk premium, which creates a link from demographic forces to asset prices.

We then move to a two-country model to study how risk is shared in an open economy

[1] Farhi and Gourio (2018) present their explanation as semi-structural, noting that "allowing these parameters to vary over time flexibly suggests they are not microfounded and invariant to policy. Yet we find the results useful because deeper explanations need to be consistent with the changes of parameters implied by our approach" (p. 217).

equilibrium. In our main experiment, we mimic the empirical pattern in which the U.S. has aged less than other parts of the world. This places U.S. households in a better relative position to take on risk and to supply safe assets to the rest of the world (whose *relative* demand for safe assets is stronger). In equilibrium, the "younger" U.S. economy becomes the safe asset issuer while investing more in equity. Although it is in the better relative position to do so, it ends up loading on risk while not being entirely free from domestic aging pressures, and must therefore be compensated with a higher equity risk premium. Quantitatively, we find that demographic changes since 1980 have lowered the world safe rate by 71 basis points and raised the U.S. equity premium by 251 basis points (compared with 49 basis points abroad).

Related literature. Our paper builds on several strands of previous work. First, we deploy the insight of Merton (1971) that human capital is bond-like in nature (see Bodie et al., 1992; Campbell et al., 2001; Viceira, 2001; Cocco et al., 2005 for other prominent contributions to this vast literature; Gomes (2020) offers a survey). Taking this point to an international two-country setup, we show that the country with the larger retirement-duration gap ("Foreign" in our labeling) has a stronger incentive to accumulate the safe asset – to replace the flow of labor income (which, relative to the duration of the consumption stream, is quicker to peter out in Foreign). In equilibrium, Home therefore becomes the safe asset issuer: its residents have a comparative advantage in this role because their relatively safe labor income covers a larger share of the lifetime over which consumption must be financed.

Our paper also relates to the literature aimed at explaining who becomes the global safe asset issuer, which in practice has been the U.S. in recent history. Caballero et al. (2008), Mendoza et al. (2009), and Maggiori (2017) show how this outcome can result from the U.S. being more financially developed, but do not explain why the U.S. is characterized by a greater level of financial development. In our setup, the country with the shorter retirement-duration gap becomes the safe asset issuer, which is consistent with the observation that U.S. individuals tend to spend a shorter fraction of their lives in retirement.[2] The savings that are being channeled to the U.S. in this way (looking for a relatively safe rate of return, to proxy fading labor income) may furthermore have contributed to the U.S.'s superior level of financial development (Ordóñez and Piguillem, 2019), at which point the channel – originally rooted in differential aging patterns – would obtain an extra kick by also launching the financial development channel. This brings us to the Gourinchas and Rey (2007) characterization of the U.S. as "the world's

[2]In practice, other factors, such as country size (Hassan, 2013) and debt volume (He et al., 2019), are likely to be important as well when it comes to determining who will become the global safe asset issuer, but we abstract from those here.

venture capitalist" – in the sense of the U.S. mostly issuing safe debt, while simultaneously investing in riskier assets – with our paper explaining this outcome by cross-country differences in the duration embedded in human wealth, which tends to be relatively safe in nature.

More generally, we build on the voluminous literature exploring the impact of demographics on various rates of return. Most research in this area has focused on the depressing effect that aging can have on the safe rate of return (Domeij and Flodén, 2006; Krueger and Ludwig, 2007; Ferrero, 2010; Carvalho et al., 2016; Rachel and Smith, 2017; Eggertsson et al., 2019; Rachel and Summers, 2019; Gagnon et al., 2021; Lisack et al., 2021; Bárány et al., 2023; Carvalho et al., 2025; Rachel, 2025; Auclert et al., 2025, 2026). By building a stochastic model that offers both safe and risky investment options, we are instead interested in the implications aging might have for the *risky* rate of return – and the implied risk premium. There is a small literature studying this question from a closed-economy perspective (Ang and Maddaloni, 2005; Kopecky and Taylor, 2022)[3], but – to the best of our knowledge – ours offers the first open-economy analysis. In doing so, we show how cross-country differences in aging patterns shape global imbalances and differential trends in risk premia.

On the risk-premium front, our paper relates to the broader literature observing that safe rates of return appear to have fallen by more than risky rates – implying a widening risk premium (Gomme et al., 2015; Farhi and Gourio, 2018; Reis, 2022; Blanchard, 2023). A global saving glut would push down the returns on all assets alike, which is hard to reconcile with the stability of risky returns; Caballero et al. (2017a,b) therefore attribute these trends to excess demand specifically for safe assets. Our mechanism provides a demographic source for this excess demand: as households spend more of their lives in retirement, aging raises the demand for safe assets in particular, rather than for assets in general. The widening risk premium is best established for the U.S. (to which the aforementioned papers apply), with our analysis suggesting that this trend is also *most pronounced* in the U.S. Our model attributes this international divergence to U.S. households having taken on more risk over the years (acting like "venture capitalists", in the sense of Gourinchas and Rey (2007)), with the higher U.S. risk premium compensating them for doing so.

Outline. Section 2 presents the motivating evidence. Section 3 develops a partial

[3]An earlier literature (Mankiw and Weil, 1989; Abel, 2001; Brooks, 2002; Abel, 2003; Geanakoplos et al., 2004) asked whether aging trends could translate into lower-frequency dynamics in asset prices. The idea was that prices would peak as "boomers" were financially preparing themselves for retirement (accumulating assets), with prices falling again as these households entered retirement, where they might sell their assets to finance consumption. Empirically, however, Poterba (2001) found that retirees do not dissave much in retirement, making an "asset market meltdown" less likely from this perspective.

equilibrium model to illustrate the core mechanism. Sections 4 and 5 introduce and quantify the two-country model. The appendices give the derivations and further details of the quantitative exercises.

2 Motivating evidence

This section presents two motivating observations that our model will later connect in a causal way. Focusing on the period since 1980, from which point on demographics are generally thought to have influenced rates of return (Carvalho et al., 2016; Gagnon et al., 2021; Lisack et al., 2021; Carvalho et al., 2025; Rachel, 2025), we first show that the risk premium appears to have increased more in the U.S. than elsewhere. Second, we document how the fraction of life spent in retirement has risen by more among non-U.S. households. This means that they are, on average, characterized by a greater retirement-duration gap (defined as the expected duration of their consumption stream, which only ends upon death, minus the expected duration of their labor income stream, which ends upon retirement).

2.1 Trends in risk premia

While there are several papers pointing out that the U.S. risk premium has risen over time (Gomme et al., 2015; Farhi and Gourio, 2018; Reis, 2022), less is known about whether this finding extends to other countries.

To shed light on this issue, we turn to the Macro History Database (Jordà et al., 2017, 2019), which provides us with the relevant data for 18 major economies.[4] From it, we calculate country-level risk premia as the total risky rate of return (which combines rates of return on equity and housing – the latter being an important vehicle for retirement savings), minus the t-bill rate as a proxy for the safe rate. The resulting series is naturally noisy, as it is affected by unforeseen shocks, which are not reflected in the ex-ante risk premium. So to get at underlying trends, we work with a 15-year moving average of current and past outturns (but results are robust to other smoothing approaches).

Our main takeaway from Figure 1 is that, since 1980, the risk premium has risen by more in the U.S. This finding, also visible in Kopecky and Taylor (2022) (who exclude housing and solely look at the return on equity), follows when basing inference on a PPP-weighted average (see panel (a)), while looking at a simple, equal-weighted average

[4]The dataset includes: Australia, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, U.K., U.S.

yields the same message (see panel (b)). Over the full 1980–2020 sample, the non-U.S. realized premium actually trends downward. That decline is heavily concentrated in the early part of the sample, however. From 1990 onward, the risk premium rises again – albeit by less than what is observed for the U.S. Overall, the picture is one of international divergence, with the rise in risk premia most pronounced for the U.S.

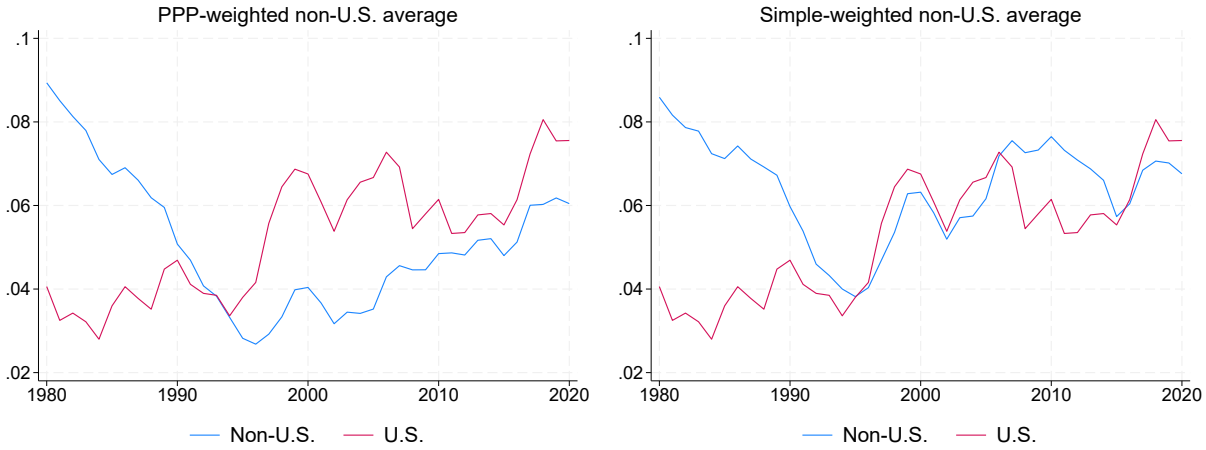


Figure 1: Risk premium developments over 1980–2020: U.S. versus non-U.S.
Notes: Risk premium series are first smoothed at the country level by taking a 15-year moving average of current and past outturns. Data are from the Macro History Database (Jordà et al., 2017, 2019). Non-U.S. composite consists of the non-U.S. countries mentioned in footnote 4.

At this stage, and despite the smoothing applied, one might worry about the reliance on realized returns; conceptually, looking at *expected* returns – which are not distorted by unforeseen shocks that happen to hit in-sample – is more appropriate. This is exactly the exercise done by Corsetti et al. (2025). Because of the heavier data requirements associated with the underlying Gordon growth formula, they are confined to the post-1997 sample period and lose information on the return to housing, as well as part of the cross-country dimension (they have to limit themselves to the G7 economies). The key message nevertheless remains: in ex-ante terms too, the risk premium is found to have risen by more in the U.S. than in other economies.

2.2 Trends in life expectancy and retirement age

A second dimension along which the U.S. and other major economies have been characterized by differential trends is the fraction of time spent in retirement. This can be analyzed using the OECD's "Pensions at a Glance" database, which contains data on "effective retirement ages" and "expected years after retirement" for the 18 major economies

underlying Section 2.1 (as listed in footnote 4). The OECD data are broken down by gender, but below we focus on aggregates obtained after taking a simple average between males and females.

Life expectancy at retirement – calculated as the sum of the effective retirement age and expected years after retirement – has risen significantly across countries: somewhat more in the non-U.S. part of our sample, but the U.S. is not far behind.

There is, however, substantial cross-country heterogeneity in whether those additional years are spent working or in retirement. Since 1980, the time spent in retirement has risen by 4.8 years in the non-U.S. part of our sample; this is almost equal to their total increase in life expectancy over that period (+5.4 years), meaning that nearly all of the additional life years gained are being "consumed" in retirement. By contrast, U.S. households have been more inclined to stretch the length of their working careers (retiring later in life), meaning that their expected years after retirement have risen by less (by 1.3 years to be precise, compared to life expectancy having risen by 4.4 years since 1980).

As a result of these developments, the fraction of time spent in retirement has risen most in the non-U.S. part of our sample. There, it rose from 0.210 in 1980 to over 0.25 in 2024 (a relative increase of nearly 20 percent). In the U.S., by contrast, it has remained relatively constant – moving only marginally, from 0.211 to 0.215. This means that the retirement-duration gap, that part of life where consumption needs to be financed from past savings and associated returns, has widened by more in the non-U.S. part of our sample.

An important country not covered by the OECD database is China. But there too, available evidence suggests that the majority of life years gained have been added to time spent in retirement. Since the 1950s, Chinese statutory retirement ages have been fixed at 55 and 60 years for women and men, respectively – meaning that life years gained over time have primarily been adding to years after retirement.[5] Only in 2025 has China embarked on a reform trajectory to increase the statutory retirement ages by 3 years (over a 15-year transition period), to 58 years for women and 63 years for men.

In the remainder of this paper, we build a model to show how differences in these demographic trends may be a driver of our first motivating observation – that the U.S. risk premium has risen by more than that in other countries.

[5] According to the UN World Population Prospects database, Chinese life expectancy at 65 has risen by 4.8 years since 1980 – with most of these life years gained thus having been added to retirement.

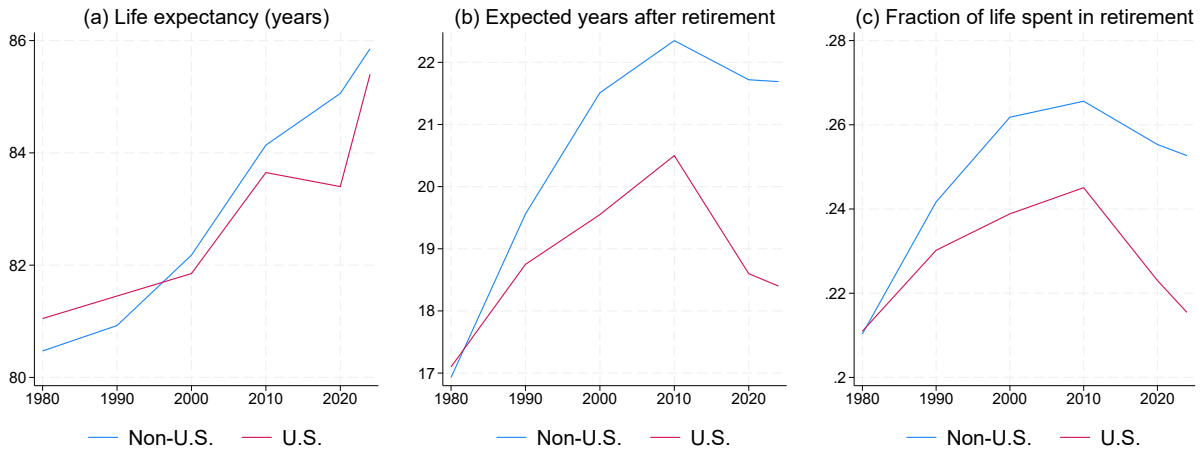


Figure 2: Demographic developments over 1980–2024: U.S. versus non-U.S.
Notes: Data are from the OECD's "Pensions at a Glance" database. Non-U.S. composite consists of the non-U.S. countries mentioned in footnote 4.

3 A fixed-rate benchmark

To clarify the mechanism, we start by studying aging, first defined as individuals spending a larger fraction of their life in retirement, at a fixed world safe rate, r^*. (In a subsequent step, we will also incorporate the impact of lower rates of population growth.) One can think of this analysis as applying to the non-U.S. part of our sample, which, as documented in Section 2.2, has aged more. Section 4 will generalize the analysis to two countries, effectively adding the U.S. and endogenizing the safe rate. A key feature of our environment is limited stock-market participation: nonstockholders can hold only bonds, so stockholders alone must hold the risky asset.

We model aging as a decline in mortality while holding the duration of labor income fixed. This approximates the experience of the non-U.S. part of our sample, where increases in longevity have mostly translated into longer retirements because the effective retirement age has not kept pace with life expectancy. Financing a longer retirement from the same labor-income stream increases demand for safe bonds, as they form the closest substitute for the waning labor-income stream (which is also relatively safe in nature) – an insight that goes back to Merton (1971).

To satisfy this "Mertonian" demand for safe income, new bonds may be issued by local non-U.S. stockholders or by an external party, such as the U.S., which lies outside this partial-equilibrium analysis until Section 4. This distinction determines who bears risk. If local stockholders issue the bonds, the same risky asset must be held on a more leveraged balance sheet. Because local stockholders are also aging, and so share the

Mertonian desire to save in bonds, they are *a priori* unwilling to take on this leverage, and the equity premium must rise to compensate them. If the bonds are supplied externally, local stockholders need not issue additional debt and this balance-sheet channel is absent; as Section 4 shows, it is then the premium in the country *issuing* the safe debt that rises. Appendix A contains the derivations for this section, while Appendices B and C cover the transition dynamics and the population-growth extension.

3.1 Demography, labor income, and household balance sheets

The demographic structure follows Yaari (1965) and Blanchard (1985). Households die at the constant rate $\delta > 0$, have no bequest motive, and hold wealth through actuarially fair annuity accounts. Newborns enter without financial wealth. With stationary population, the density at age $a \geq 0$ is $\delta e^{-\delta a}$, and expected remaining life is always $1/\delta$.

We take the evidence that labor income is safer than capital income (Campbell et al., 2001; Davis and Willen, 2013; Lustig et al., 2013; Guiso and Pistaferri, 2020) to the extreme and assume that labor income is locally riskless.[6] Labor income declines with age at rate $\chi > 0$, so a household can be thought of as retiring smoothly rather than at a discrete date. Writing the aggregate wage bill as W, earnings at age a are

$$w(a) = W\frac{\delta + \chi}{\delta}e^{-\chi a}, \qquad \int_0^\infty w(a)\delta e^{-\delta a}\, da = W,$$

where the factor $(\delta + \chi)/\delta$ normalizes aggregate earnings to W. A useful object for the analysis that follows is the *retirement-duration gap*, which we define as

$$\Delta \equiv \frac{1}{\delta} - \frac{1}{\chi + \delta} = \frac{\chi}{\delta(\chi + \delta)} > 0. \tag{1}$$

This gap compares the expected consumption horizon, $1/\delta$, with the expected duration of labor earnings, $1/(\chi+\delta)$. Aging widens it: households must bridge a longer period, during which they no longer earn much labor income, while still having to finance consumption (which they do by drawing on past savings and the associated returns). In particular, if mortality falls while $\chi+\delta$ is held fixed, the gap widens one-for-one with expected lifetime.

Since wages are locally riskless and the safe rate is fixed, aggregate human wealth, the

[6]The results generalize to the case in which labor income follows a diffusion process. The relevant condition is that wage risk is lower than the risk embedded in asset returns. Introducing wage risk does not alter the main economic mechanism, but substantially increases the algebraic complexity.

present value of expected labor income, is

$$\mathcal{H}(\delta, \chi, W) = \frac{W}{r^* + \chi + \delta}. \tag{2}$$

This is the human-wealth analogue of the Gordon growth formula. Raising any term in the denominator, be it the safe rate, the rate at which earnings decline (i.e., how quickly households retire), or mortality, shortens the duration of the wage claim and lowers its present value.

At birth, a household is permanently assigned to be a stockholder or a nonstockholder, $k \in \{S, N\}$. Stockholders have population share π_S, so type-specific wage bills and human wealth are

$$W_S = \pi_S W, \qquad W_N = (1 - \pi_S) W, \qquad \mathcal{H}_S = \pi_S \mathcal{H}, \qquad \mathcal{H}_N = (1 - \pi_S)\mathcal{H}. \tag{3}$$

Type is assigned at birth, independently of age and earnings, so stockholders and nonstockholders share the same age–earnings profile and each type's human wealth is just its population share of the aggregate. Making the split permanent is a simple way of capturing the concentration of equity ownership and consumption exposure in the data (Mankiw and Zeldes, 1991; Attanasio et al., 2002; Brav et al., 2002).

Let $\mathcal{B}_N$ denote local nonstockholders' bond holdings. Their financial wealth consists entirely of bonds, $\mathcal{F}_N = \mathcal{B}_N$, including bonds issued locally and abroad. Their total safe wealth is $\mathcal{T}_N = \mathcal{B}_N + \mathcal{H}_N$: bond holdings plus human wealth.

The local Lucas tree, which we take to represent equity, is in unit supply and pays $D_t\, dt$. Dividends follow a driftless geometric Brownian motion, driven by the standard Brownian motion Z_t:

$$\frac{dD_t}{D_t} = \sigma_D\, dZ_t, \qquad \sigma_D > 0. \tag{4}$$

Let P be the ex-dividend value of the tree and $\mathcal{B}_S \leq 0$ local stockholders' bond position. Negative values denote borrowing, and debt outstanding is $-\mathcal{B}_S$. Their financial wealth, total wealth, leverage, and risky share are

$$\begin{aligned} \mathcal{F}_S &= P + \mathcal{B}_S, \quad \mathcal{T}_S = P + \mathcal{B}_S + \mathcal{H}_S, \\ \mathcal{L}_S &= \frac{P}{P + \mathcal{B}_S}, \quad \theta_S = \frac{P}{P + \mathcal{B}_S + \mathcal{H}_S}. \end{aligned} \tag{5}$$

Financial leverage $\mathcal{L}_S$ scales the risky position by the tree's value net of safe debt. Meanwhile, the risky share θ_S scales the risky position by total wealth, human wealth included.

3.2 Household optimization and bond supply

Household problems. A household of type $k \in \{S, N\}$, either a stockholder (S) or a nonstockholder (N), has CRRA period utility with coefficient $\gamma_k > 0$,

$$v_{\gamma_k}(c) = \begin{cases} \dfrac{c^{1-\gamma_k}}{1-\gamma_k}, & \gamma_k \neq 1, \\ \log c, & \gamma_k = 1, \end{cases}$$

where log utility is the limiting case as $\gamma_k \to 1$. Each household type also has its own discount rate ρ_k. Conditional on being alive at date t, a household survives for another u years with probability $e^{-\delta u}$, so the expected lifetime utility of a type-k household is

$$\mathcal{U}_k\Big(\{C_{k,t+u}\}_{u\geq 0}\Big) = \mathbb{E}_t \int_0^\infty e^{-(\rho_k+\delta)u}\, v_{\gamma_k}(C_{k,t+u})\, du, \qquad k \in \{S, N\}. \tag{6}$$

Mortality acts like additional impatience: it raises the household's effective discount rate from ρ_k to $\rho_k + \delta$.

Nonstockholders hold only annuitized bonds. Their problem is

$$\begin{aligned} V_N(\mathcal{F}_{N,t}, \mathcal{H}_N) = &\sup_{\{C_{N,t+u}\}_{u\geq 0}} \mathcal{U}_N, \\ \text{subject to} \qquad & d\mathcal{F}_{N,t} = \Big[(r^* + \delta)\mathcal{F}_{N,t} + W_N - C_{N,t}\Big]dt. \end{aligned} \tag{7}$$

Surviving households earn $r^* + \delta$: in addition to the safe rate, they receive the mortality credit $\delta\mathcal{F}_{N,t}$, financed by the wealth of those who die.

A stockholder chooses consumption and the amount $\mathcal{E}_{S,t}$ invested in the risky tree. The residual position, $\mathcal{F}_{S,t} - \mathcal{E}_{S,t}$, is held in bonds and may be negative, in which case the stockholder issues bonds. Because only stockholders can hold the tree, market clearing requires $\mathcal{E}_{S,t} = P_t$. Their bond position is then $\mathcal{F}_{S,t} - \mathcal{E}_{S,t} = \mathcal{B}_{S,t}$, so local debt issuance appears as borrowing on the stockholder balance sheet.

Write the cum-dividend tree return as $dR_t = \mu_R dt + \sigma_R dZ_t$. Risk taking is subject to a leverage penalty

$$\Phi_S = \frac{\psi_S}{2}(\mathcal{L}_S - 1)^2, \qquad \tau_S = \frac{\partial \Phi_S}{\partial \mathcal{L}_S} = \psi_S(\mathcal{L}_S - 1),$$

whose marginal charge τ_S applies to each unit of risky holdings. The proceeds are returned to stockholders in proportion to their total wealth, $\alpha_S \mathcal{T}_{S,t}$ with $\alpha_S = \theta_S \tau_S$.

We interpret τ_S as a reduced-form wedge that measures the shadow cost of leveraged risk bearing. There are multiple microfoundations one can give. One interpretation can

be that the wedge stands in for regulatory, margin, or capital constraints on leveraged balance sheets, such as those of specialized local intermediaries whose constraints affect required returns (Gârleanu and Pedersen, 2011), or for slow-moving capital (Duffie, 2010). Alternatively, it can stand in for compensation for non-Gaussian losses in crisis periods. Finally, it can also capture additional risk aversion beyond the standard preferences we use in this model. We do not model these frictions explicitly. In the calibration, the wedge is the additional expected return stockholders require to hold the risky tree. Building on the recent literature on "intermediary asset pricing" (see Haddad and Muir, 2026 for a review), we use this leverage wedge to match the observed equity risk premium.

Taking τ_S, α_S, and ξ_t as given, the stockholder's problem is[7]

$$\begin{aligned} V_S(\mathcal{F}_{S,t}, \mathcal{H}_S) &= \sup_{\{C_{S,t+u}, \mathcal{E}_{S,t+u}\}_{u\geq 0}} \mathcal{U}_S, \\ \text{subject to} \qquad d\mathcal{F}_{S,t} &= \Big[(r^* + \delta)\mathcal{F}_{S,t} + \mathcal{E}_{S,t}(\mu_R - r^* - \tau_S) + (\alpha_S - \xi_t)\mathcal{T}_{S,t} + W_S - C_{S,t}\Big]dt \\ &\quad + \mathcal{E}_{S,t}\sigma_R\, dZ_t. \end{aligned} \tag{8}$$

In words, stockholder wealth earns the annuitized safe return plus the tree's excess return net of the leverage charge; it also receives labor income and the rebate net of the external payment, and is drawn down by consumption. Because the rebate equals the charge in equilibrium, $\alpha_S \mathcal{T}_{S,t} = P_t \tau_S$, the wedge changes the incentive to bear risk but takes no resources away from stockholders.

The consumption rules for each household type are

$$\begin{aligned} C_{N,t} &= m_N \mathcal{T}_{N,t}, \qquad m_N \equiv \delta + \frac{\rho_N + (\gamma_N - 1)r^*}{\gamma_N}, \\ C_{S,t} &= m_S(D_t, \mathcal{B}_{N,t})\, \mathcal{T}_{S,t}. \end{aligned} \tag{9}$$

Each type consumes a fraction of its total wealth. Because the rules are linear in wealth, they aggregate within type, which is why we work with type totals throughout. The nonstockholder propensity m_N depends only on mortality, preferences, and the imposed safe rate. The stockholder propensity m_S has no closed form under CRRA preferences and is solved numerically together with the tree price. Under log utility the consumption rules reduce to $C_{k,t} = (\rho_k + \delta)\mathcal{T}_{k,t}$.

The stockholder portfolio condition determines the risk premium below, while nonstockholder saving determines safe bond demand. Aggregating the nonstockholder bud-

[7] Stockholders also make an external payment $\mathcal{X}_t = \xi_t \mathcal{T}_{S,t}$ to the rest of the world, where each household takes the rate ξ_t as given.

get across survivors and deaths gives

$$\dot{\mathcal{B}}_{N,t} = r^* \mathcal{B}_{N,t} + W_N - C_{N,t}. \tag{10}$$

Although survivors earn $r^* + \delta$, aggregate bond holdings earn only r^*, because the mortality credit redistributes wealth within the sector. Mortality still affects saving through consumption, with a lower mortality rate lengthening the planning horizon and reducing consumption relative to total wealth.

Fixing earnings duration. Our main longevity experiment is designed to approximate the experience of the non-U.S. part of our sample, where increases in life expectancy have mainly added to years spent in retirement. As a result, the average duration of the labor income stream ("earnings duration") has remained relatively constant – beginning at the start of one's working life, and ending when the individual reaches 60–65 years of age. In our framework, where households retire gradually (to maintain analytical tractability), earnings duration is given by $1/(\chi + \delta)$. Consequently, when we lower mortality δ, thereby increasing expected lifetimes, we raise χ one-for-one, so that $\chi + \delta$, and therewith earnings duration and human wealth $\mathcal{H}$, stays at its initial level:

$$\underline{\chi} + \underline{\delta} = \overline{\chi} + \overline{\delta} \Longleftrightarrow \overline{\chi} = \underline{\chi} + \underline{\delta} - \overline{\delta}, \tag{11}$$

where underlines denote initial values and overlines final values. This removes the windfall that would arise if longer lives also lengthened working careers: the present value of the wage stream, and hence $\mathcal{H}_S$ and $\mathcal{H}_N$, is unchanged. Stationary nonstockholder bond holdings are then

$$\mathcal{B}_N^*(\delta) = \mathcal{H}_N \frac{r^* + \gamma_N \chi - \rho_N}{\gamma_N \delta + \rho_N - r^*}. \tag{12}$$

Suppliers of bonds. Initially, all bonds held by nonstockholders are issued by local stockholders, so $\underline{\mathcal{B}}_N = -\underline{\mathcal{B}}_S = \mathcal{B}_N^*(\underline{\delta})$. A share $\omega \in [0, 1]$ of any subsequent increase is supplied from abroad at the world safe rate, and the remainder by local stockholders, whose bond position becomes

$$\mathcal{B}_S = \underline{\mathcal{B}}_S - (1 - \omega)(\mathcal{B}_N - \underline{\mathcal{B}}_N).$$

We can now establish the following result.

Lemma 1 (Longevity raises bond demand and local borrowing)**.** *Suppose stationary bond holdings are positive and stable, i.e., $r^* + \gamma_N \chi - \rho_N > 0$ and $\gamma_N \delta + \rho_N - r^* > 0$. Holding $\chi + \delta$ fixed,*

so that human wealth $\mathcal{H}_N$ is unchanged, a decline in mortality raises nonstockholders' stationary bond holdings, and local stockholders borrow the share $1-\omega$ of the increase:

$$\frac{d\mathcal{B}_N^*}{d\delta} = -\frac{\gamma_N[\mathcal{B}_N^*(\delta)+\mathcal{H}_N]}{\gamma_N\delta+\rho_N-r^*} < 0, \qquad \frac{d\mathcal{B}_S^*}{d\delta} = -(1-\omega)\frac{d\mathcal{B}_N^*}{d\delta}. \tag{13}$$

Intuitively, a lower δ widens the retirement-duration gap Δ: the same human wealth must now finance consumption over a longer expected lifetime. Households respond by consuming a smaller fraction of their wealth and holding more bonds, which must replace a labor income that ends well before they die.

3.3 Local debt issuance and the equity risk premium

Lemma 1 shows that longer lives raise local debt whenever $\omega < 1$. We now show how this debt raises the equity premium. Under CRRA preferences, the stockholder problem (8) yields the portfolio condition that pins down the equity risk premium (ERP) required to hold the tree:

$$\text{ERP} \equiv \mu_R - r^* = \underbrace{\psi_S(\mathcal{L}_S-1)}_{\text{leverage wedge, } \tau_S} + \underbrace{\gamma_S\theta_S\sigma_R^2}_{\text{risk compensation}} + \underbrace{(\gamma_S-1)\sigma_D D v_D \sigma_R}_{\text{intertemporal hedging}}. \tag{14}$$

The leverage wedge is zero when stockholders finance the tree entirely out of their own financial wealth ($\mathcal{L}_S = 1$), and it grows as more borrowing is used to support the same risky position, at a rate set by ψ_S. Conventional risk compensation, the second term, is the familiar product of risk aversion γ_S, exposure θ_S, and return variance σ_R^2. The last term captures intertemporal hedging: stockholders want to hedge changes in future investment opportunities, and v_D measures how their continuation value responds to dividends. This term can have either sign, vanishes under log utility, and is small in our calibration. Appendix A.6 derives the full pricing system.

Local debt is what links the demand for bonds to the equity premium. When local stockholders issue the additional bonds that nonstockholders demand, they continue to hold the entire tree, so the same risky position is financed with more borrowing. The leverage of stockholders rises, which then causes their share of risky assets in their portfolio to also rise. Finally, as the stockholders are more leveraged, this affects the volatility of returns. As a result, every term of (14) is affected. The effects of these three channels depend on the response of the tree price, since any price change revalues stockholders' balance sheets. To track this response, we write the price as $P(D, \mathcal{B}_S; \delta, \omega)$, with $P_B = \partial P/\partial \mathcal{B}_S$ its derivative with respect to the stockholder bond position; $P_B > 0$ then

means that additional borrowing *lowers* the tree's price. We begin with leverage.

Proposition 2 (Local debt raises leverage)**.** *Suppose stockholder financial wealth is positive, $P + \mathcal{B}_S > 0$. Then*

$$\frac{\partial \mathcal{L}_S}{\partial(-\mathcal{B}_S)} = \frac{P - \mathcal{B}_S P_B}{(P + \mathcal{B}_S)^2} > 0 \tag{15}$$

whenever $\mathcal{B}_S P_B / P < 1$. In particular, this condition holds at a fixed price and whenever borrowing does not raise the tree price, $P_B \geq 0$. Higher local debt therefore raises leverage and, since $\tau_S = \psi_S(\mathcal{L}_S - 1)$, the leverage wedge.

The numerator shows the two ways debt raises leverage. First, at a fixed price, additional debt reduces stockholders' financial wealth without changing their risky position. Second, if borrowing also lowers the tree price, financial wealth falls by as much as the tree itself, which is a larger proportional fall because the tree is partly debt-financed, so leverage rises further. More generally, the condition $\mathcal{B}_S P_B / P < 1$ allows the tree price to rise in response to borrowing, provided that response is not large enough to overturn the balance-sheet effect. A transparent sufficient condition is $P_B \geq -1$: one additional unit of safe debt cannot raise the market value of the tree by more than one unit. It excludes the extreme case in which borrowing raises the tree price by more than the debt itself, so that leverage *falls*. Equivalently, this condition implies that debt issuance cannot mechanically create stockholder net worth.[8]

Next, consider how safe debt changes stockholders' risky asset holdings.

Proposition 3 (Local debt and risky asset holdings)**.** *Suppose stockholders' other wealth, human wealth net of debt, is positive, $\mathcal{H}_S + \mathcal{B}_S > 0$. Then*

$$\frac{\partial \theta_S}{\partial(-\mathcal{B}_S)} = \frac{P - (\mathcal{H}_S + \mathcal{B}_S) P_B}{(P + \mathcal{B}_S + \mathcal{H}_S)^2}. \tag{16}$$

Higher local debt raises the share of stockholders' wealth held in the risky asset if and only if it lowers the tree price proportionally less than it lowers their other wealth, $P_B / P < 1/(\mathcal{H}_S + \mathcal{B}_S)$. In particular, it does so at a fixed tree price.

Safe debt changes stockholders' risky asset holdings through their balance sheet. The risky share compares the tree with the rest of stockholders' wealth, their human wealth net of debt. When stockholders issue additional safe debt, they continue to hold the entire tree, so the rest of their wealth falls one-for-one and a larger fraction of their wealth is tied

[8] Proposition 2 does not require $P_B \geq 0$: a modest positive price response to borrowing (in particular: $-1 < P_B < 0$) is compatible with rising leverage. In the quantitative solution $P_B > 0$ at the steady state, so the condition holds with room to spare.

up in the risky asset. Issuing safe debt thus concentrates risk on stockholders' balance sheets. If borrowing also lowers the tree price, stockholders' risky position shrinks, which can then offset the effect of increased leverage. Therefore, the proposition shows that the risky share rises if and only if the tree price does not fall too much in response to borrowing.

Finally, we consider how safe debt affects the riskiness of the tree itself.

Proposition 4 (Local debt and return volatility)**.** *The volatility of the cum-dividend return equals dividend volatility times the price-dividend elasticity,*

$$\sigma_R = \sigma_D \frac{DP_D}{P}. \tag{17}$$

Local debt therefore affects return volatility only through this elasticity,

$$\frac{\partial \sigma_R}{\partial(-\mathcal{B}_S)} = \sigma_D \frac{\partial}{\partial(-\mathcal{B}_S)} \left(\frac{DP_D}{P} \right), \tag{18}$$

so higher local debt raises return volatility if and only if it makes the tree price more sensitive to dividends.

Debt makes the price more sensitive to dividends through a feedback loop on stockholders' balance sheets. Suppose a negative dividend shock lowers the tree price. Stockholders' debt does not change, so the whole loss falls on their financial wealth, $P + \mathcal{B}_S$, which drops by proportionally more than the price. As leverage rises, the leverage wedge rises as well. As a result, stockholders require a higher return to hold the tree. With more debt outstanding, financial wealth is smaller relative to the tree, so a given price change moves leverage by more. Prices end up moving more than dividends, which is why return volatility rises although dividend volatility has not changed.

Differentiating the premium (14) with respect to local debt collects these channels:

$$\frac{\partial \text{ERP}}{\partial(-\mathcal{B}_S)} = \underbrace{\frac{\partial \tau_S}{\partial(-\mathcal{B}_S)}}_{\text{leverage-wedge channel}} + \underbrace{\gamma_S \sigma_R^2 \frac{\partial \theta_S}{\partial(-\mathcal{B}_S)}}_{\text{asset-allocation channel}} + \underbrace{2\gamma_S \theta_S \sigma_R \frac{\partial \sigma_R}{\partial(-\mathcal{B}_S)}}_{\text{volatility channel}} + \underbrace{(\gamma_S - 1)\sigma_D D \frac{\partial(v_D \sigma_R)}{\partial(-\mathcal{B}_S)}}_{\text{intertemporal hedging}}. \tag{19}$$

The first term is the change in the shadow cost of leverage, which is positive by Proposition 2. The next two split conventional risk compensation: the asset-allocation channel changes stockholders' exposure at a given return variance, and is positive at a fixed tree price by Proposition 3; the volatility channel changes the risk borne at a given exposure, and is positive when debt makes the price more sensitive to dividends (Proposition 4). The

final term allows hedging demand to adjust with investment opportunities and vanishes under log utility.

Lemma 1 and the three propositions together trace how longer lives reach the equity premium. A decline in mortality raises nonstockholders' demand for bonds. When $\omega < 1$, local stockholders meet part of this demand by borrowing, so they hold the same tree with more debt. This raises their leverage and the leverage wedge, concentrates risk on their balance sheets, and can make the tree's return more volatile, each of which raises the return stockholders require to hold the tree. Longer lives therefore raise the equity premium through the debt they lead stockholders to issue. When $\omega = 1$, the rest of the world supplies the additional bonds, local debt is unchanged, and this channel is shut.

3.4 Illustrative calibration

We discipline the household, demographic, and dividend parameters using the non-U.S. part of our sample, where the fraction of a lifetime spent in retirement has risen most (Section 2.2). The initial mortality and earnings-decline rates imply an expected remaining lifetime of about 59 years and a survival-adjusted duration of earnings of about 20 years, so households must finance several decades of consumption after their labor income has largely run down. The external share ω plays a different role. Setting $\omega = 0.70$ places 30 percent of the additional bond demand generated by increased longevity on local non-U.S. stockholder balance sheets at the imposed world safe rate; the remaining 70 percent is supplied externally. We choose an intermediate value between full local supply ($\omega = 0$) and full external supply ($\omega = 1$), and Section 3.6.2 reports results across a wide range of values.

Based on empirical evidence in Chien and Naknoi (2015), we set the stockholder share to 30%, so that equity risk is borne by a minority of households. We set dividend-growth volatility to 12.0%, a rounded value of the 11.6% annual volatility of GDP-weighted real dividend growth for the five non-U.S. G6 economies with available equity observations over 1970–2020; Appendix A.5 reports results at the unrounded estimate.[9]

We set initial local stockholder debt, and hence nonstockholders' initial bond holdings, equal to 145 percent of output. This is somewhat higher than observed central government debt-to-GDP ratios, to reflect that some safe assets are issued by local, quasi-public, or non-governmental entities, such as government-sponsored or government-owned utilities and highly rated corporations.

[9]The series comes from the Jordà–Schularick–Taylor Macrohistory Database (Jordà et al., 2017, 2019). It contains no usable Canadian equity-return observations. We do not impute them; annual GDP weights are renormalized across France, Germany, Italy, Japan, and the United Kingdom.

Table 1 summarizes the two-step calibration procedure. First, we choose the nonstockholder discount rate ρ_N so that nonstockholders wish to hold exactly this stock of bonds, that is, so that their bond holdings have zero drift in equation (10). Second, given the resulting balance sheet, we choose the leverage sensitivity ψ_S so that the initial equity risk premium equals 5 percent, which we use as a stylized benchmark. The stockholder discount rate ρ_S governs stockholder consumption; we set it to a conventional value of 4%.

Table 1: Non-U.S. calibration

Object	Value	Source
World safe rate, r^*	2.70%	Macro History Database (Jordà et al., 2017, 2019)
Initial mortality and earnings decline, $\underline{\delta}, \underline{\chi}$	1.69%, 3.39%	Calibrated to longevity trends
Stockholder share, π_S	30%	Chien and Naknoi (2015)
Nonstockholder CRRA coefficient, γ_N	4.00	Standard value in the literature
Stockholder CRRA coefficient, γ_S	1.50	Moderate risk aversion, below γ_N
Dividend volatility, σ_D	12.00%	Macro History Database, five-country estimate (rounded)
Initial local stockholder bond position / initial output, $\underline{\mathcal{B}_S}/\underline{Y}$	-145.00%	Set above central government debt/GDP
Initial equity risk premium	5.00%	Stylized benchmark
Nonstockholder discount rate, ρ_N	12.23%	Calibrated to stationary bond holdings
Leverage sensitivity, ψ_S	0.0666	Calibrated to premium target

Notes: $\underline{Y}$ denotes initial output, which serves as a fixed denominator in the tables. Negative stockholder bond positions denote borrowing. Appendix A.5 reports the parameter–target mapping, participation comparisons, and discount-rate and target diagnostics.

Table 2 reports the initial stationary moments. With return volatility of about 13.2 percent and moderate risk aversion, conventional risk compensation accounts for only 42.9 percent of the 5 percent premium; the leverage wedge accounts for the remaining 57.1 percent. Stockholders initially finance about 30 percent of the tree with debt, a leverage ratio of 1.43.

Table 2: Initial stationary moments

Moment	Model value
Equity risk premium, ERP	5.00%
Decomposition of Equity Risk Premium	
Leverage-wedge component	2.85 percentage points
Risk-compensation component	2.14 percentage points
Intertemporal-hedging component	0.00 percentage points
Financial leverage, $\mathcal{L}_S$	1.43
Risky allocation, θ_S	82.07%
Return volatility, σ_R	13.20%

Notes: The decomposition of the equity risk premium corresponds to the three terms in equation (14). Risky allocation is the tree value relative to stockholders' total wealth, including human wealth. Return volatility is the annualized local conditional standard deviation of the cum-dividend return on the non-U.S. risky tree, $\sigma_R = \sigma_D DP_D/P$, evaluated at the stationary state.

3.5 Longer retirement spells and the equity risk premium

We now lower mortality permanently to increase the retirement-duration gap by four years, close to the increase in expected years after retirement in the non-U.S. sample since 1980 (Section 2.2). As explained in Section 3.2, we raise χ so that earnings duration, and therewith human wealth, is unchanged; the additional years are spent entirely in retirement, with individuals continuing to retire "at 65" (recall our discussion around equation (11)). Expected remaining lifetime rises from about 59 to 63 years, while the earnings-weighted average timing of future labor income, $1/(\chi + \delta)$, stays at about 20 years; in terms of the model's parameters, mortality falls from 1.689 to 1.582 percent and χ rises from 3.393 to 3.500 percent.

Nonstockholder bond holdings rise by 19.67 percentage points of initial output, as households save more to finance a longer retirement from a labor income stream of unchanged duration. With $\omega = 0.70$, local stockholders supply 5.90 percentage points of these bonds and the rest of the world the remaining 13.77. Because local stockholders continue to own the entire tree, their leverage rises from 1.43 to 1.49.

Local stockholders are themselves aging: their retirement-duration gap also widens, which strengthens their own "Mertonian" demand for safe income to replace a labor income stream that now fades sooner relative to their consumption horizon. To make them nevertheless willing to hold the more leveraged, riskier tree position, the ERP needs to rise, by 50.4 basis points in this calibration. Table 3 shows that most of this increase, 42.4 basis points, comes from the leverage wedge, with a further 8.6 basis points from

higher return volatility.

Table 3: Impact of increased longevity in the non-U.S. benchmark

Object	Initial	Final (longevity)
Equity risk premium, ERP	5.00%	5.50%
Nonstockholder bond holdings / initial output, $\mathcal{B}_N/\underline{Y}$	145.00%	164.67%
Local stockholder bond position / initial output, $\mathcal{B}_S/\underline{Y}$	-145.00%	-150.90%
Financial leverage, $\mathcal{L}_S$	1.43	1.49
Risky allocation, θ_S	82.07%	82.11%
Return volatility, σ_R	13.20%	13.46%
Decomposition of Equity Risk Premium (basis points)		
Leverage-wedge contribution		42.43
Asset-allocation contribution		0.09
Volatility contribution		8.57
Intertemporal-hedging contribution		-0.67
Total		50.42

Notes: Negative stockholder bond positions denote borrowing. The retirement-duration gap increases by four years. The aggregate wage bill is held fixed and χ is adjusted to hold human wealth fixed. The leverage sensitivity ψ_S is held fixed across equilibria. The decomposition uses arithmetic endpoint averages: changes in the hedging loading enter the hedging contribution, while changes in return volatility enter the volatility contribution (Appendix A.6). Return volatility is the annualized local conditional standard deviation of the cum-dividend return.

3.6 Extensions and robustness

As robustness checks, we extend the benchmark in three directions. First, we recognize that demographic change is driven not only by increases in longevity but also by lower population growth. Next, we discuss how the results vary with who supplies the additional bonds, and we conclude with transitional dynamics.

3.6.1 Slower population growth

Populations age not only because people live longer but also because fewer are born: with slower population growth, the population is older on average even if no one's lifetime changes. Building on Buiter (1988), we add this second source of aging to our longevity experiment. It works through the same mechanism: an older population demands more bonds, local stockholders meet part of this demand by borrowing, and the equity premium rises.

We start population growth at 0.50 percent per year and recalibrate the nonstockholder discount rate and leverage sensitivity to the same bond-holdings and equity-premium

targets as in Section 3.4, holding them fixed thereafter. We first apply the longevity experiment of Section 3.5 at this growth rate and then lower population growth to zero.[10] Appendix C gives the derivations and reports the three allocations.

Slower population growth raises the average age of households, equal to $1/(n + \delta)$, and an older population holds, on average, more bonds per person for two reasons. First, newborn households enter without financial wealth, so fewer births mean fewer households that have yet to accumulate savings. Second, older households have seen their earnings decline for longer and therefore have a stronger "Mertonian" demand for safe bonds to replace their fading labor income. These forces make nonstockholder bond holdings rise by a further 21.06 percentage points of initial output, from 162.86 to 183.93 percent. Local stockholders supply 6.32 percentage points of this additional debt while continuing to hold the entire tree, and their leverage rises from 1.49 to 1.58 as the additional borrowing and the fall in the equity price reduce their financial wealth.

An older population therefore finds equity less attractive to hold. Lowering population growth from 0.50 to 0.00 percent raises the ERP from 5.47 to 6.16 percent, adding 69.4 basis points to the 46.9 basis points generated by longer retirement spells alone. Lower population growth rates thus reinforce the effect of spending more of one's life in retirement.[11] Table 4 summarizes the two steps and their combined effect.

3.6.2 External bond supply and the local equity premium

Our benchmark places 30 percent of the additional bond demand on local stockholder balance sheets. As a robustness check, we repeat the longevity experiment of Section 3.5 while varying the share ω of additional bonds supplied by the rest of the world over $[0.40, 1]$, the range over which our numerical solution is validated. The financial calibration and initial debt are held fixed over the experiment.

Figure 3 shows that the equity premium response falls as the external share of debt supplied by the rest of the world rises. It is 50.4 basis points at the benchmark $\omega = 0.70$ and 31.8 basis points when 80 percent of the additional bonds come from abroad. At the limit where all debt is supplied from abroad, the equity premium response is essentially zero. Appendix Table 11 decomposes the response of the equity premium.

Therefore, we see that the impact of demographic aging on the equity premium depends on who supplies the additional bonds. The external share determines how much of the additional demand becomes local debt: the more bonds come from abroad, the less

[10] The growth rates are illustrative; Section 4 calibrates population growth to the data.

[11] The additional population-growth effect is measured from the post-longevity allocation, with prices and returns evaluated at the steady-state dividend and nonstockholder bond holdings at their zero-drift value.

Table 4: Longevity and population slowdown: Decomposition of Equity Risk Premium

Variable and unit	Longevity increase ($\underline{x} \to x^L$)	Population after longevity ($x^L \to \overline{x}$)	Combined change ($\underline{x} \to \overline{x}$)
A. Changes in prices and balance sheets			
Equity risk premium, ERP, basis points	+46.89	+69.40	+116.29
Financial leverage, $\mathcal{L}_S$, ratio points	+0.06	+0.08	+0.14
Local stockholder debt, $-\mathcal{B}_S$, percent change	+3.70	+4.20	+8.05
Stockholder financial wealth, $\mathcal{F}_S$, percent change	-8.94	-10.84	-18.81
Nonstockholder bond holdings / initial output, $\mathcal{B}_N/\underline{Y}$, percentage points	+17.86	+21.06	+38.93
Risky allocation, θ_S, percentage points	-0.01	+0.07	+0.06
Equity-return volatility, σ_R, percentage points	+0.23	+0.45	+0.69
B. Decomposition of Equity Risk Premium (basis points)			
Leverage wedge	+39.89	+55.24	+95.13
Risky allocation	-0.02	+0.19	+0.17
Return volatility	+7.60	+15.18	+22.79
Intertemporal hedging	-0.58	-1.21	-1.80
Total ERP change	+46.89	+69.40	+116.29

Notes: $\underline{x}$, x^L, and $\overline{x}$ are the Initial, Longevity, and Final values of a variable x. Longevity column: four-year longevity increase at $n = 0.005$. Stocks are per member of the total population and divided by initial per-capita output in every column. Percent changes are measured from the start of each step and compound across steps; basis-point and ratio changes add. Panel B decomposes each column separately, using that column's endpoint averages, so its allocation, volatility, and hedging terms need not add up across columns.

local stockholders need to borrow and the smaller the rise in their leverage. At $\omega = 1$, bond demand rises by just as much, yet local balance sheets are unchanged and the premium barely moves. In the two-country model of Section 4, we allow bonds to flow across countries endogenously, and the split of bond supply between Home and Foreign stockholders is an equilibrium outcome.

3.6.3 Transitional dynamics

The comparisons so far are between stationary equilibria, after households have fully adjusted their savings. As a final robustness check, we examine how the response unfolds over time, in the spirit of Farhi and Gourio (2018), since demographic change takes decades and asset prices are forward-looking. We consider the same four-year increase in the retirement-duration gap, now announced unexpectedly at date zero, with the world safe rate fixed and $\omega = 0.70$. Bond holdings and debt accumulate only gradually, as nonstockholders save and stockholders issue the matching debt, whereas the tree price is

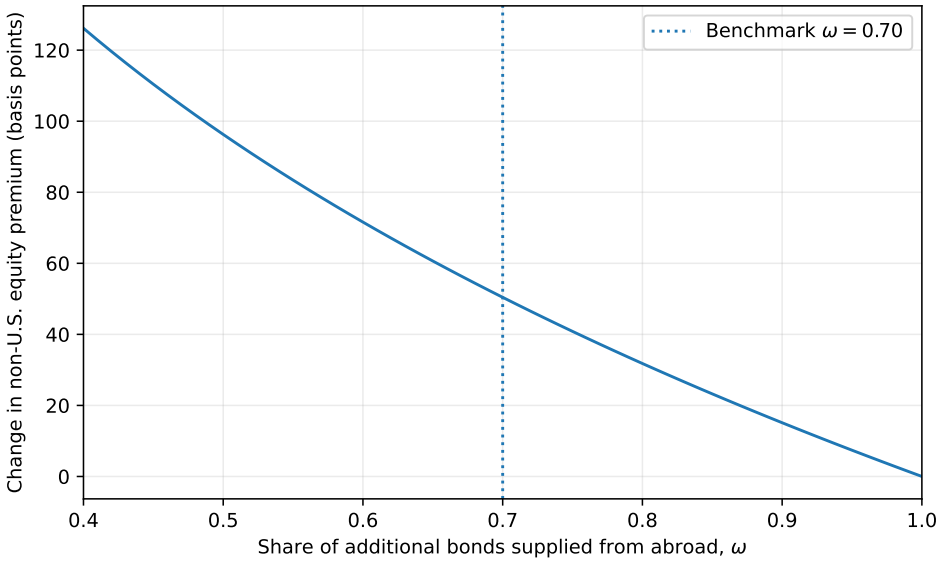


Figure 3: External bond supply and the non-U.S. equity premium

Notes: The figure reports the change in the non-U.S. equity premium following the four-year longevity increase, as the share ω of additional bonds supplied from abroad varies. At $\omega = 1$, all additional bonds are supplied from abroad. The financial calibration and initial debt are held fixed. Results are shown over the range for which the numerical solution is validated.

free to jump on impact.

The premium adjusts in two stages. On impact, before any additional bonds have been accumulated, the ERP rises from 5.00 to 5.13 percent. This jump of 13.2 basis points is about 26 percent of the long-run effect. The rest of the increase is gradual: ten years on, the ERP stands at 5.25 percent, against 5.50 percent in the long run. Since nonstockholder bond holdings take 17.5 years to close half of the gap to their new stationary level, the premium adjusts faster than the balance sheets that drive it.[12]

The equity premium jump on impact is driven by households' anticipation. Investors foresee longer lives and also the borrowing stockholders will do to meet the extra bond demand, and the tree price falls immediately. Since the stock of debt takes time to adjust, the lower price of equity then erodes stockholders' financial wealth, which pushes up their leverage and hence the equity premium. After the initial response, households accumulate bonds, whereby each additional unit of local debt adds further to leverage. The model eventually converges to the stationary equilibrium via a build-up of stockholder borrowing that takes several decades, which is also the horizon over which demographic change itself unfolds.

[12]The transition is evaluated at the steady-state dividend $D_t = D_0$. Table 12 and Appendix B give the price and bond-holdings paths, including the external payment.

4 Two-country model

We now extend the fixed-rate benchmark of Section 3 to a two-country model, in which the suppliers of the additional bonds are explicit. In our labeling, Home represents the U.S., while Foreign aggregates the non-U.S. advanced economies studied in Section 2. Both countries retain the household structure of Section 3: nonstockholders hold bonds, while stockholders hold Home and Foreign equity and issue debt, which nonstockholders in either country may hold. The safe rate and the division of debt between Home and Foreign stockholders, both imposed in Section 3, are now determined by world market clearing.

This allows us to ask how differential aging affects the returns required on Home and Foreign equity. When retirement-duration gaps widen more in Foreign, Foreign households develop the stronger "Mertonian" demand for bonds, and Foreign stockholders are the more reluctant to take leveraged equity positions. Home stockholders are therefore better placed, given their "relative youth", to supply the additional bonds and carry the associated equity risk. In our experiment, which combines longer lives with slower population growth, Home stockholders issue most of the additional debt, and the premium on Home equity rises by considerably more than the premium on Foreign equity, in line with the divergence documented in Section 2.1.

4.1 Demography, labor income, and traded assets

We retain the demographic and earnings structure of Section 3.1, now allowing mortality δ_i, earnings decline χ_i, and population growth n_i to differ across Home and Foreign, $i \in \{H, F\}$, so that the two countries can age differently, and hence demand bonds with different intensity. Population growth enters the age distribution and the dilution of wealth by newborns as in Section 3.6.1. Wages remain locally riskless, but their present value now moves with the equilibrium safe rate.

Each country is endowed with an equity tree whose aggregate dividend grows with its population, so that the tree remains proportional to the size of its economy and the dividend per person, $D_{i,t}$, is constant; $P_{i,t}$ denotes its price per person. The wage per person, W_i, is also constant, while χ_i governs only the timing of earnings over the life cycle. We normalize output per person to one in each country,

$$y_{i,t} = W_{i,t} + D_{i,t} = 1, \tag{20}$$

and write Y_H and Y_F for aggregate output in Home and Foreign at the initial date, with

world output $Y = Y_H + Y_F$.

Households trade the two trees and a safe bond in zero net supply. The safe rate r_t, fixed in Section 3, is now determined by world bond-market clearing. Write $\text{ERP}_{j,t} \equiv \mu_{R,j,t} - r_t$ for the premium on tree j. The conditional return volatilities, $\sigma_{R,H}$ and $\sigma_{R,F}$, are held fixed across equilibria, with correlation ϱ_R and covariance $\sigma_{R,HF} = \varrho_R \sigma_{R,H} \sigma_{R,F}$.

4.2 Households, human wealth, and portfolios

We retain the equity-participation structure of Section 3: in each country i, a share $\pi_{S,i}$ of households are stockholders and the rest are nonstockholders. Household subscripts S and N identify stockholders and nonstockholders, followed by country and, where relevant, time indices. All sector wealth, bond holdings, debt, and consumption quantities below are measured per country resident, using the country's entire population.

In a stationary equilibrium, the human wealth of each household type is

$$\mathcal{H}_{S,i,t} = \frac{\pi_{S,i} W_{i,t}}{r_t + \chi_i + \delta_i}, \qquad \mathcal{H}_{N,i,t} = \frac{(1 - \pi_{S,i}) W_{i,t}}{r_t + \chi_i + \delta_i}.$$

This is the capitalization formula (2), now evaluated at the equilibrium safe rate, so human wealth behaves like a bond whose duration is that of expected earnings, $1/(r_t + \chi_i + \delta_i)$: just as bond prices rise when interest rates fall, so does the value of future wages.

Let $\mathcal{B}_{N,i,t}$ denote country-i nonstockholder bond holdings, so that their total wealth is $\mathcal{T}_{N,i,t} = \mathcal{B}_{N,i,t} + \mathcal{H}_{N,i,t}$. They consume the fraction $m_{N,i}(r_t)$ of their total wealth, with m_N as in equation (9) evaluated at the equilibrium safe rate. Aggregating the household budget as before, and allowing for the dilution of wealth per person by newborns, gives

$$\dot{\mathcal{B}}_{N,i,t} = (r_t - n_i)\mathcal{B}_{N,i,t} + (1 - \pi_{S,i}) W_{i,t} - C_{N,i,t}.$$

In a stationary equilibrium, setting this drift to zero yields

$$\mathcal{B}^*_{N,i,t} = \mathcal{H}_{N,i,t} \frac{r_t + \gamma_{N,i}\chi_i - \rho_{N,i}}{\gamma_{N,i}(\delta_i + n_i) + \rho_{N,i} - r_t}. \tag{21}$$

The numerator and denominator are positive in the equilibria we consider. Lower mortality raises desired nonstockholder bond holdings through the same mechanism as in Section 3.2, and lower population growth raises them by reducing dilution, as in Section 3.6.1. What is new is that the safe rate now adjusts. In the two-country setting, the safe rate falls as world bond demand rises. A lower return on bonds makes saving in them less attractive, which partly offsets the increase in desired bond holdings.

Country-i stockholders hold both equities and have a bond position $\mathcal{B}_{S,i,t} \leq 0$: they may borrow from nonstockholders in either country. Let $\mathcal{E}_{ij,t}$ be the value of equity j held by country-i stockholders. Their balance sheet extends equation (5):

$$\mathcal{F}_{S,i,t} = \mathcal{E}_{iH,t} + \mathcal{E}_{iF,t} + \mathcal{B}_{S,i,t}, \qquad \mathcal{T}_{S,i,t} = \mathcal{F}_{S,i,t} + \mathcal{H}_{S,i,t}. \tag{22}$$

Stockholders have the CRRA preferences of Section 3.2, with common curvature γ_S and discount rate $\rho_{S,i}$. The two risky shares are $\theta_{S,i,H,t} = \mathcal{E}_{iH,t}/\mathcal{T}_{S,i,t}$ and $\theta_{S,i,F,t} = \mathcal{E}_{iF,t}/\mathcal{T}_{S,i,t}$, where i identifies the investor's country and the next country index identifies the issuer. In a stationary equilibrium, stockholders consume the fraction $m_{S,i,t}$ of total wealth, $C_{S,i,t} = m_{S,i,t}\mathcal{T}_{S,i,t}$.

Expressed per country resident, the stockholder budget includes dilution of financial wealth by population growth:

$$\dot{\mathcal{F}}_{S,i,t} = (r_t - n_i)\mathcal{F}_{S,i,t} + \mathcal{E}_{iH,t}\mathrm{ERP}_{H,t} + \mathcal{E}_{iF,t}\mathrm{ERP}_{F,t} + \pi_{S,i}W_{i,t} - C_{S,i,t}.$$

In a stationary equilibrium, financial wealth has zero drift. Together with portfolio choice, this condition determines each country's stockholder bond position through equation (22). This replaces the issuance rule of Section 3.2: how much debt Home and Foreign stockholders issue is now an equilibrium outcome rather than an imposed share ω.

4.3 Issuer balance sheets and leverage wedges

Stockholders in each country can hold both countries' trees, financing these equity positions with their own financial wealth and with debt. Since debt finances stockholders' entire equity portfolio, we measure the leverage of country-i stockholders over their holdings of both trees,

$$\mathcal{L}_{S,i,t} = \frac{\mathcal{E}_{iH,t} + \mathcal{E}_{iF,t}}{\mathcal{F}_{S,i,t}} = 1 - \frac{\mathcal{B}_{S,i,t}}{\mathcal{F}_{S,i,t}}, \tag{23}$$

and assume that the wedge on country-i equity rises with this leverage, with slope ψ_i:

$$\tau_{i,t} = \psi_i(\mathcal{L}_{S,i,t} - 1) = -\psi_i \frac{\mathcal{B}_{S,i,t}}{\mathcal{F}_{S,i,t}}, \qquad i \in \{H, F\}. \tag{24}$$

The wedge is thus proportional to country-i stockholders' debt per unit of financial wealth. As before, the charges are rebated, so they affect incentives without absorbing resources. When Home stockholders borrow more relative to their financial wealth, the premium on Home equity therefore rises.

This assumption is a reduced-form way of capturing limits to international risk sharing, whereby domestic risk-bearing capacity matters most at the margin when it comes to pricing domestic equity, even though stockholders in both countries hold both trees. In practice, this could reflect limited cross-border participation and information advantages (Van Nieuwerburgh and Veldkamp, 2009), institutional mandates, or the intermediary frictions discussed in Section 3.2. We do not model these frictions explicitly.

4.4 International market clearing

World asset markets must clear. We aggregate holdings measured per country resident using the fixed initial output shares Y_H/Y and Y_F/Y, which also equal the initial population shares. Holdings of each tree across both countries must equal its market value:

$$\begin{aligned} \frac{Y_H}{Y}\mathcal{E}_{HH,t} + \frac{Y_F}{Y}\mathcal{E}_{FH,t} &= \frac{Y_H}{Y}P_{H,t}, \\ \frac{Y_H}{Y}\mathcal{E}_{HF,t} + \frac{Y_F}{Y}\mathcal{E}_{FF,t} &= \frac{Y_F}{Y}P_{F,t}. \end{aligned} \tag{25}$$

Nonstockholder bond holdings are matched by stockholder borrowing, so bond positions sum to zero across the two countries:

$$\frac{Y_H}{Y}\left(\mathcal{B}_{N,H,t} + \mathcal{B}_{S,H,t}\right) + \frac{Y_F}{Y}\left(\mathcal{B}_{N,F,t} + \mathcal{B}_{S,F,t}\right) = 0. \tag{26}$$

The safe rate adjusts until the bonds that nonstockholders in both countries wish to hold equal the debt that stockholders in both countries are willing to issue. The relative age of the two countries determines how the debt is divided between Home and Foreign stockholders.

A country's net external bond position is $\mathcal{B}_{N,i,t}+\mathcal{B}_{S,i,t}$: domestically held bonds enter the nonstockholder and stockholder positions with opposite signs and cancel, so a positive position indicates net lending abroad and a negative one net borrowing. Home's net foreign assets add Foreign equity held at Home and subtract Home equity held abroad, the latter scaled by Y_F/Y_H to express it per Home resident:

$$\mathrm{NFA}_{H,t} = \mathcal{B}_{N,H,t} + \mathcal{B}_{S,H,t} + \mathcal{E}_{HF,t} - \frac{Y_F}{Y_H}\mathcal{E}_{FH,t}. \tag{27}$$

Home can thus be a net debtor in bonds while holding a positive net position in equity, as a "world venture capitalist" would (Gourinchas and Rey, 2007).

4.5 Valuation and risk premia

Stockholders in both countries have the same risk aversion and trade at the same prices, so they choose the same risky shares, $\theta_{S,H,j,t} = \theta_{S,F,j,t} \equiv \theta_{S,j,t}$, $j \in \{H, F\}$. Each country's stockholders therefore own every tree in proportion to their share of world stockholder wealth, and equity-market clearing implies that the risky share of each tree equals its market value relative to world stockholder wealth, $\theta_{S,j,t} = (Y_j/Y)P_{j,t}/\mathcal{T}_{S,W,t}$, where $\mathcal{T}_{S,W,t} = \sum_i (Y_i/Y)\mathcal{T}_{S,i,t}$. The portfolio conditions then give the two market-pricing equations:

$$\begin{aligned} \mathrm{ERP}_{H,t} &= \gamma_S\left(\sigma^2_{R,H}\theta_{S,H,t} + \sigma_{R,HF}\theta_{S,F,t}\right) + \tau_{H,t}, \\ \mathrm{ERP}_{F,t} &= \gamma_S\left(\sigma_{R,HF}\theta_{S,H,t} + \sigma^2_{R,F}\theta_{S,F,t}\right) + \tau_{F,t}. \end{aligned} \tag{28}$$

Each premium has two parts: conventional compensation for portfolio risk, which depends on the variances and covariance of the two returns and on the risky shares stockholders hold, and the leverage wedge of the issuing country.

These two parts are shared differently across countries. Because stockholders everywhere hold the same portfolio, conventional risk is borne by world stockholder wealth as a whole: if Home stockholders become more leveraged, the conventional component rises in both premia. The leverage wedge does not spread in this way. Higher Home leverage raises $\tau_{H,t}$ but leaves $\tau_{F,t}$ unchanged, so if Home stockholders supply most of the additional bonds, the Home premium rises by more than the Foreign one. This is how differential aging can generate the divergence in risk premia documented in Section 2.1.

In a stationary equilibrium, each tree is valued by the Gordon growth formula, capitalizing its dividend per person at the required return net of the growth of the issuing population:

$$P_{j,t} = \frac{D_{j,t}}{r_t + \mathrm{ERP}_{j,t} - n_j}, \qquad j \in \{H, F\}. \tag{29}$$

Slower population growth therefore lowers the price of a tree due to dividends growing more slowly in such an economy. A higher premium lowers the price as well, and because stockholders' debt is unchanged, the lower price cuts their financial wealth and pushes their leverage up further.

5 Quantitative analysis

We now calibrate the two-country model and ask how the demographic changes observed since 1980 affect the world safe rate and the premia on Home and Foreign equity. We solve three stationary equilibria: one under the initial demographic parameters, one after

longevity increases, and one after population growth also slows. We refer to initial values as $\underline{x}$, use x^L to denote longevity-only values, and refer to final values as $\overline{x}$. In each equilibrium, financial wealth per person has zero drift for both household types, and the safe rate, equity premia, portfolios, and issuer wedges are jointly determined.

5.1 Calibration and targets

We calibrate Home to the U.S. and Foreign to the other seventeen economies in Section 2. Their 2023 PPP-GDP weights imply initial output shares of 43 percent for Home and 57 percent for Foreign, which remain fixed throughout the experiment. As in the fixed-rate benchmark, the model is annual. Initial population growth is 1.0 percent per year at Home and 0.6 percent in Foreign, roughly matching population growth around 1980 in the two regions. Initial mortality and earnings-decline rates, 1.689 and 3.393 percent at Home and 1.597 and 3.446 percent in Foreign, are based on the OECD data of Section 2.2.

We target an initial equity premium of 4.0 percent at Home and 3.0 percent in Foreign, rather than the stylized 5 percent of Section 3, and a world safe rate of 2.7 percent, based on the data of Section 2.1. Equity-return volatility, from the same data, is 13.7 percent at Home and 12.0 percent in Foreign, and we set the correlation between the two returns to zero.

To discipline risky-asset supply, we set market capitalization relative to local output to 1.90 at Home and 1.30 in Foreign, reflecting the larger size of the U.S. equity market. We also set Home nonstockholder bond holdings to 60 percent of output, Home's net external bond position to -45 percent, and Home NFA to -40 percent. These values are meant to capture the U.S. position as a net debtor in bonds with a positive net equity position; we do not take them as precise estimates for any particular year. Together they imply that Home holds net foreign equity of 5 percent of output. Foreign's balance sheet then follows from market clearing.

Stock-market participation is 50 percent at Home and 30 percent in Foreign, consistent with the U.S. and non-U.S. participation rates in Chien and Naknoi (2015). Stockholders in both countries have curvature $\gamma_S = 1.5$, while nonstockholders are more risk averse, with $\gamma_{N,i} = 4$, a standard value of risk aversion in the literature.

Table 5: Baseline calibration and targets

Input or target	Home	Foreign
Output share, Y_i/Y	43.09%	56.91%
Equity-market value / own output, $\underline{P}_i/\underline{y}_i$	1.90	1.30
Initial equity premium, $\underline{\text{ERP}}_i$	4.00%	3.00%
Initial safe rate, $\underline{r}$	2.70% (common)	
Initial population growth, $\underline{n}_i$	1.00%	0.60%
Mortality, $\underline{\delta}_i$	1.69%	1.60%
Earnings decline, $\underline{\chi}_i$	3.39%	3.45%
Stockholder participation, $\pi_{S,i}$	50%	30%
Stockholder curvature, γ_S	1.50	1.50
Nonstockholder curvature, $\gamma_{N,i}$	4.00	4.00
Equity-return volatility, $\sigma_{R,i}$	13.70%	12.00%
Nonstockholder bond holdings / own output, $\underline{\mathcal{B}}_{N,i}/\underline{y}_i$	0.60	0.93
Net external bond position / own output, $(\underline{\mathcal{B}}_{N,i} + \underline{\mathcal{B}}_{S,i})/\underline{y}_i$	-0.45	0.34
NFA / own output, $\underline{\text{NFA}}_i/\underline{y}_i$	-0.40	0.30

Table 5 summarizes the calibration. Each initial balance sheet, together with the part of its premium not accounted for by risk compensation, identifies the issuer slopes $\psi_H = 0.0306$ and $\psi_F = 0.0308$. The remaining household and market conditions determine Foreign nonstockholder bond holdings and the household discount rates.[13] Appendix D gives the full system and the resulting parameters, which we hold fixed throughout the demographic experiment.

5.2 Baseline equilibrium

The initial column of Table 6 reports the baseline equilibrium. Home stockholders owe debt of 105.00 percent of output against financial wealth of 90.00 percent, giving leverage of 2.17, compared with 1.87 for Foreign stockholders. Foreign nonstockholders hold bonds worth 92.97 percent of output, well above the 60.00 percent held at Home, and part of this demand is met by Home stockholders. The Home country is therefore calibrated at the start of the experiment to be a net issuer of bonds to the rest of the world.

Stockholders in both countries hold the same portfolio shares, so each group owns a fraction of both trees equal to its share of world stockholder wealth. Home stockholders

[13]The implied discount rates ρ are too high when interpreted literally: about 7.6 percent for stockholders and 14.0 to 14.2 percent for nonstockholders. We use them, however, as effective saving parameters of the retirement-saving block, rather than as estimates of impatience. In particular, our model has no unfunded, pay-as-you-go style pension income, which on its own would imply a counterfactually high demand for private savings. Higher discount rates correct for this omission by lowering saving demand.

therefore own 53.92 percent of both the Home and the Foreign equity market. The model abstracts from home bias, so these cross-border holdings are considerably larger than in the data.

5.3 The impact of demographic changes

We apply the demographic changes observed since 1980 in two steps. First, we raise expected years after retirement by 1.30 years at Home and 4.77 years in Foreign, matching the evidence in Section 2.2. As in the longevity experiment of Section 3.5, we lower mortality and raise the rate of earnings decline one-for-one, so that the additional years are spent entirely in retirement.[14] The retirement-duration gap therefore widens almost four times as much in Foreign as at Home. Second, we also lower population growth, from 1.0 to 0.8 percent at Home and from 0.6 to 0.1 percent in Foreign, again in line with the changes since 1980 in the economies described in Section 2.

Table 6 reports the main result. The Home equity premium rises from 4.00 to 4.96 percent after the longevity change and to 6.51 percent once population growth also slows, a combined increase of 250.50 basis points. The Foreign premium rises by only 49.09 basis points, while the world safe rate falls by 71.44 basis points.[15] In the model, demographic change thus lowers the safe rate everywhere while raising the equity premium far more in the country that has aged less, which mirrors the divergence documented in Section 2.1.

[14] Foreign mortality falls from 1.597 to 1.484 percent and its rate of earnings decline rises from 3.446 to 3.559 percent; at Home, mortality falls from 1.689 to 1.653 percent and earnings decline rises from 3.393 to 3.429 percent.

[15] This is lower than implied by Rachel (2025), who puts the impact of demographics on the equilibrium safe rate at −275 basis points; our quantification is more in line with Auclert et al. (2025), who arrive at −110 basis points. Beaudry et al. (2025) show that an OLG-style setup with retirement forces at play leaves room for *monetary policy* to contribute to secular trends in safe rates. Relatedly, Hyland (2026) shows that secular increases in macroeconomic risk can raise risk premia while simultaneously lowering the neutral safe rate, providing another channel through which safe rates may decline independently of demographic forces.

Table 6: Longevity and slower population growth: stationary equilibria

Moment	Initial	Longevity	Final
Home equity premium, ERP_H (%)	4.00	4.96	6.51
Foreign equity premium, ERP_F (%)	3.00	3.17	3.49
World safe rate, r (%)	2.70	2.34	1.99
Home nonstockholder bond holdings, $\mathcal{B}_{N,H}/y_H$ (%)	60.00	56.41	50.29
Foreign nonstockholder bond holdings, $\mathcal{B}_{N,F}/y_F$ (%)	92.97	101.85	98.88
Home stockholder bond position, $\mathcal{B}_{S,H}/y_H$ (%)	-105.00	-112.60	-108.75
Foreign stockholder bond position, $\mathcal{B}_{S,F}/y_F$ (%)	-58.89	-59.30	-54.61
Home stockholder financial wealth, $\mathcal{F}_{S,H}/y_H$ (%)	90.00	75.11	53.64
Foreign stockholder financial wealth, $\mathcal{F}_{S,F}/y_F$ (%)	67.32	63.81	52.37
Home stockholder financial leverage, $\mathcal{L}_{S,H}$	2.17	2.50	3.03
Foreign stockholder financial leverage, $\mathcal{L}_{S,F}$	1.87	1.93	2.04

Notes: Stocks are per country resident and relative to own output. Negative stockholder bond positions denote borrowing. The full experiment adds the population slowdown to the longevity change. Financial wealth excludes human wealth. Output per person is unchanged in both countries. The world goods-market residual derived in Appendix D is 0.07 percent of world output in the first two columns and 0.11 percent in the third.

Longer retirements must be financed by additional saving, and this demand is stronger in Foreign, where expected years after retirement have risen by more. After the longevity change, Foreign nonstockholder bond holdings rise by 8.87 percentage points of Foreign output. The fall in the safe rate reduces Home nonstockholder bond holdings, partly offsetting this increase; this general-equilibrium offset is absent from the fixed-rate benchmark. On net, world nonstockholder bond holdings rise by 3.51 percentage points of world output. Both stockholder sectors borrow more, with Home stockholders accounting for 93 percent of the increase in borrowing. Home stockholders take on most of the new debt because their retirement-duration gap widens by less: they continue to receive safe labor income for a longer fraction of their expected lifetimes, which leaves them *relatively* better placed to carry the extra debt. Because Home stockholders take on most of the new debt, it is mainly the Home leverage wedge that rises, while conventional risk compensation is shared across both markets.

Slower population growth then reduces the dilution of accumulated wealth by new entrants, as in Section 3.6.1. In general equilibrium, however, its effects differ from the fixed-rate benchmark. The safe rate falls by a further 35.05 basis points, and at this lower rate nonstockholder bond holdings fall back, to 50.29 percent of output at Home and 98.88 percent in Foreign, so that world nonstockholder bond holdings end 0.82 percentage points of world output below their initial level. Relative to the longevity-only equilibrium, stockholder bond positions in both countries move back toward zero. The

premium nevertheless rises further, because stockholders' financial wealth falls even faster than their debt. A lower safe rate reduces the return stockholders earn on their wealth, so they accumulate less of it, and slower dividend growth lowers equity prices (Section 4.5), with higher premia deepening the fall. Over the two steps, Home stockholders' leverage rises from 2.17 to 3.03, and required returns must rise to make them willing to hold the resulting equity positions.

Foreign stockholders account for the rest of the additional debt in the longevity-only step. Over the full experiment, their financial wealth falls by more than their debt, so their leverage also rises, from 1.87 to 2.04. The Foreign premium therefore rises as well, but by much less.

Table 7 reports the premium changes for each step. Because return volatilities are held fixed (Section 4.1), the volatility channel that raised the premium in Section 3.5 is absent here, so these results likely understate the effect of demographic change on equity premia.

Table 7: Decomposition of Equity Risk Premium

Demographic change	Home	Foreign
Longevity	+96.44	+17.17
Population slowdown after longevity	+154.07	+31.92
Combined	+250.50	+49.09

Notes: Entries are changes in equity premia, in basis points. The population-slowdown row reports the additional change after longevity has increased. The combined row compares the initial allocation with the allocation after both demographic changes.

With dividends per person fixed, the higher required return on Home equity and the slower growth of its dividend base lower its price by 25.88 percent. Foreign equity rises in value by 3.92 percent after the longevity change, because the decline in the safe rate exceeds the increase in its premium, but ends 5.14 percent below its initial value once population growth slows.

Home's net external bond position becomes more negative by 13.47 percentage points of output, while its net foreign equity rises by 16.57 points, more than offsetting the additional borrowing, so NFA improves from −40.00 to −36.89 percent of output. Home thus borrows more in bonds while investing more in foreign equity, deepening the "world venture capitalist" pattern of Section 4.4. Greater aging abroad, combined with slower population growth, therefore raises the U.S. equity premium by far more than the Foreign premium while leaving the U.S. net foreign asset position little changed.

6 Conclusion

We have argued that demographic aging can simultaneously lower safe rates and raise the compensation required to bear equity risk. When individuals spend a greater fraction of their lives in retirement, their relatively safe labor income runs out earlier relative to the horizon over which they must finance consumption. To finance their longer retirement, households increase their demand for safe bonds (Merton, 1971). To meet that demand, stockholders issue safe debt, which raises the leverage on their balance sheets, and they demand a higher risk premium as compensation. Slower population growth works through a similar channel, since it pushes up a country's average age.

We study how this life-cycle mechanism operates in an open economy. We document that the rest of the world has aged more than the U.S.: its residents now spend a larger share of their lives in retirement. Demand for safe assets has therefore risen most abroad, while the relatively younger U.S. is better placed to supply them. U.S. stockholders issue most of the additional safe debt, and since the leverage wedge stays with the issuer, the U.S. equity premium rises by far more than the foreign one. Differential aging can thus connect global imbalances, with the U.S. acting as the world's venture capitalist, to the international divergence in risk premia documented in the data.

In our quantitative model, applying the demographic changes observed since 1980 lowers the world safe rate by 71 basis points and raises the U.S. equity premium by 251 basis points, against 49 basis points abroad, while leaving the U.S. net foreign asset position little changed. Demographics, a slow-moving and directly observable force, can therefore account for both the global fall in safe rates and the larger rise in the U.S. equity premium.

A Fixed-rate benchmark: Derivations

Here we derive the household saving and pricing decisions behind Section 3 and check how the results depend on the calibration and on household preferences. As in Section 3, the local economy stands for the non-U.S. part of our sample and the safe rate is fixed at r^*. Bonds supplied from abroad follow a simple issuance rule, and we do not model the decisions of whoever issues them. The state of the economy is $(D, \mathcal{B}_N)$, where D is the dividend and $\mathcal{B}_N$ denotes local nonstockholders' bond holdings. The local stockholder bond position is $\mathcal{B}_S(\mathcal{B}_N; \omega)$, defined below; debt outstanding is $-\mathcal{B}_S$. Thus $\mathcal{B}_N = -\mathcal{B}_S$ when all bonds are supplied locally, $\omega = 0$. With external issuance, $\mathcal{B}_N$ also includes bonds supplied by the rest of the world, denoted $\mathcal{B}_{\text{ROW}}$, so $\mathcal{B}_N + \mathcal{B}_S = \mathcal{B}_{\text{ROW}}$. These financial positions exclude human wealth; nonstockholders' total safe wealth is $\mathcal{T}_N = \mathcal{B}_N + \mathcal{H}_N$.

A.1 Longevity and human wealth

Households die with constant intensity δ, newborns replace those who die, and the stationary density of age $a \geq 0$ is $f(a) = \delta e^{-\delta a}$. With aggregate wage bill W, the wage profile is

$$w(a; \delta, W) = W \frac{\chi + \delta}{\delta} e^{-\chi a}.$$

Integrating over the age distribution recovers the aggregate wage bill W:

$$\int_0^\infty w(a; \delta, W) f(a)\, da = W(\chi + \delta) \int_0^\infty e^{-(\chi+\delta)a}\, da = W. \tag{30}$$

Expected remaining life is $1/\delta$, whereas the survival-adjusted duration of earnings is $1/(\chi + \delta)$. Their difference is the retirement-duration gap in the main text.

At the fixed safe rate, one unit of the remaining aggregate wage flow has the present-value multiplier

$$A^{\text{HW}}(\delta, \chi) = \int_0^\infty e^{-(r^*+\chi+\delta)u}\, du = \frac{1}{r^* + \chi + \delta}. \tag{31}$$

Aggregate human wealth is therefore $\mathcal{H}(\delta, \chi, W) = W A^{\text{HW}}(\delta, \chi)$. Because type is independent of age and earnings,

$$\mathcal{H}_S = \pi_S \mathcal{H}, \qquad \mathcal{H}_N = (1 - \pi_S)\mathcal{H}, \qquad W_S = \pi_S W, \qquad W_N = (1 - \pi_S)W. \tag{32}$$

To model a longer retirement, we lower mortality while keeping the duration of earnings unchanged. Underlines denote the initial regime and overlines the final, lower-mortality regime; they do not denote numerical bounds. We hold the aggregate wage bill

at $\underline{W}$ and raise the rate at which earnings decline:

$$\overline{W} = \underline{W}, \qquad \overline{\chi} = \underline{\chi} + \underline{\delta} - \overline{\delta}. \tag{33}$$

This adjustment keeps $\overline{\chi}+\overline{\delta} = \underline{\chi}+\underline{\delta}$, so human wealth remains unchanged for the economy as a whole and for each household type: $\mathcal{H}$, $\mathcal{H}_S$, and $\mathcal{H}_N$. We choose $\overline{\delta} = (\underline{\delta}^{-1} + 4)^{-1}$. Mortality therefore declines from 1.689 to 1.582 percent, and χ rises from 3.393 to 3.500 percent, increasing the retirement-duration gap by four years. The participation shares, preferences, and leverage-wedge slope remain fixed.

Subtracting the initial stationary nonstockholder budget from the post-longevity budget gives

$$\overline{\mathcal{B}}_N - \underline{\mathcal{B}}_N = \frac{(\underline{\delta} - \overline{\delta})(\underline{\mathcal{B}}_N + \mathcal{H}_N)}{\overline{\delta} + (\rho_N - r^*)/\gamma_N}. \tag{34}$$

Lower mortality reduces consumption out of a given wealth stock because households must spread their resources over a longer remaining lifetime. With current labor income unchanged, saving rises. Desired nonstockholder bond holdings increase by 19.67 percentage points of initial output to 164.7 percent. This saving response follows from the household budget and is independent of the boundary conditions used to solve for equity prices. With $\omega = 0.70$, the increase in local issuance is 5.90 percentage points of initial output; the remaining 13.77 percentage points are supplied externally.

A.2 Bond demand and local debt issuance

Nonstockholders have CRRA utility with curvature γ_N and pure discount rate ρ_N. They hold bonds through actuarially fair annuity accounts, so their individual annuitized return is $r^*+\delta$, and aggregate consumption is $C_N = [\delta+(\rho_N+(\gamma_N-1)r^*)/\gamma_N](\mathcal{B}_N+\mathcal{H}_N)$. Aggregating across surviving households, deaths, and newborns gives

$$\dot{\mathcal{B}}_N = \mu_{\mathcal{B}_N}(\mathcal{B}_N;\delta) \equiv r^*\mathcal{B}_N + W_N - \left[\delta + \frac{\rho_N + (\gamma_N - 1)r^*}{\gamma_N}\right](\mathcal{B}_N + \mathcal{H}_N). \tag{35}$$

Aggregate nonstockholder bond holdings earn r^*, although surviving households receive $r^* + \delta$. Annuity credits redistribute the wealth of households who die to survivors and therefore cancel in the aggregate budget.

At the initial target $\underline{\mathcal{B}}_N = -\underline{\mathcal{B}}_S$, zero drift identifies the nonstockholder discount rate as

$$\begin{aligned}\rho_N &= \gamma_N \left[\frac{-r^* \underline{\mathcal{B}}_S + \underline{W}_N}{-\underline{\mathcal{B}}_S + \underline{\mathcal{H}}_N} - \underline{\delta} \right] - (\gamma_N - 1) r^* \\ &= \frac{\underline{\mathcal{H}}_N (r^* + \gamma_N \underline{\chi}) - \underline{\mathcal{B}}_S (r^* - \gamma_N \underline{\delta})}{-\underline{\mathcal{B}}_S + \underline{\mathcal{H}}_N}.\end{aligned} \tag{36}$$

The second equality uses $\underline{W}_N = (r^* + \underline{\chi} + \underline{\delta})\underline{\mathcal{H}}_N$. We hold this discount rate fixed when mortality changes. Setting the drift in equation (35) to zero gives the stationary level of nonstockholder bond holdings:

$$\begin{aligned}\mathcal{B}_N^*(\delta) &= \frac{\gamma_N W_N - [\gamma_N \delta + \rho_N + (\gamma_N - 1) r^*] \mathcal{H}_N}{\gamma_N \delta + \rho_N - r^*} \\ &= \mathcal{H}_N \frac{r^* + \gamma_N \chi(\delta) - \rho_N}{\gamma_N \delta + \rho_N - r^*}.\end{aligned} \tag{37}$$

The stationary stock is positive and stable when $\gamma_N \delta + \rho_N - r^* > 0$ and $r^* + \gamma_N \chi - \rho_N > 0$. Holding ρ_N, $\mathcal{H}_N$, and W_N fixed, with $d\chi/d\delta = -1$, gives

$$\frac{d\mathcal{B}_N^*}{d\delta} = -\frac{\gamma_N [\mathcal{B}_N^*(\delta) + \mathcal{H}_N]}{\gamma_N \delta + \rho_N - r^*} < 0. \tag{38}$$

Initially, all bonds held by local nonstockholders are supplied by local stockholders: $\underline{\mathcal{B}}_N = -\underline{\mathcal{B}}_S = \mathcal{B}_N^*(\underline{\delta})$ and $\underline{\mathcal{B}}_{\text{ROW}} = 0$. As desired nonstockholder bond holdings change, we allocate the additional issuance between local stockholders and the rest of the world according to

$$\mathcal{B}_S(\mathcal{B}_N; \omega) = \underline{\mathcal{B}}_S - (1 - \omega)(\mathcal{B}_N - \underline{\mathcal{B}}_N), \qquad \mathcal{B}_{\text{ROW}}(\mathcal{B}_N; \omega) = \omega(\mathcal{B}_N - \underline{\mathcal{B}}_N), \qquad \mathcal{B}_N + \mathcal{B}_S = \mathcal{B}_{\text{ROW}}. \tag{39}$$

All additional bonds are supplied locally at $\omega = 0$ and externally at $\omega = 1$. The rule specifies who meets the extra demand for bonds at the fixed world safe rate.

The balance sheets of the two household types are therefore

$$\begin{aligned}\mathcal{F}_S(D, \mathcal{B}_N) &= P(D, \mathcal{B}_N) + \mathcal{B}_S(\mathcal{B}_N; \omega), \quad \mathcal{T}_S(D, \mathcal{B}_N) = \mathcal{F}_S(D, \mathcal{B}_N) + \mathcal{H}_S, \\ \mathcal{F}_N(\mathcal{B}_N) &= \mathcal{B}_N, \qquad\qquad\qquad\qquad \mathcal{T}_N(\mathcal{B}_N) = \mathcal{B}_N + \mathcal{H}_N.\end{aligned} \tag{40}$$

Local stockholders owe $-\mathcal{B}_S$, while local nonstockholders hold bonds worth $\mathcal{B}_N$. Their bond positions sum to zero at $\omega = 0$; with external issuance, the rest of the world pays part of nonstockholders' safe income.

For any smooth function $g(D, \mathcal{B}_N)$, the physical generator is

$$\mathcal{A}g = \mu_{\mathcal{B}_N}(\mathcal{B}_N; \delta) g_{\mathcal{B}_N} + \frac{1}{2}\sigma_D^2 D^2 g_{DD}. \tag{41}$$

The dividend has zero drift. Both $\mathcal{B}_{\text{ROW}}$ and $\mathcal{B}_S$ are determined by $\mathcal{B}_N$, so neither requires an additional state variable.

A.3 Stockholder pricing under log utility

We start with log utility, $\gamma_S = 1$. Here, consumption is a constant fraction of total wealth and there is no intertemporal-hedging term. Appendix A.6 covers the general CRRA case used in the calibration. Stockholders maximize

$$\mathbb{E}_t \int_0^\infty e^{-(\rho_S+\delta)u} \log C_{S,t+u}\, du.$$

Their financial leverage and tree exposure relative to total wealth are

$$\mathcal{L}_S = \frac{P}{P + \mathcal{B}_S}, \qquad \theta_S = \frac{P}{P + \mathcal{B}_S + \mathcal{H}_S}. \tag{42}$$

The log consumption rule is

$$C_S = (\rho_S + \delta)\mathcal{T}_S. \tag{43}$$

The leverage penalty is quadratic and fully rebated:

$$\Phi_S = \frac{\psi_S}{2}(\mathcal{L}_S - 1)^2, \qquad \tau_S = \frac{\partial \Phi_S}{\partial \mathcal{L}_S} = \psi_S(\mathcal{L}_S - 1). \tag{44}$$

As in the main text, the charge $\tau_S \mathcal{E}_S$ is rebated in full, $\alpha_S \mathcal{T}_S = \tau_S P$, so it uses no resources but raises the return a leveraged position must earn.

Let $u(D, \mathcal{B}_N) = \log P(D, \mathcal{B}_N)$. Itô's lemma gives the tree-return volatility

$$\sigma_R = \sigma_D D u_D = \sigma_D \frac{D P_D}{P}. \tag{45}$$

Under log utility, the stockholder price of aggregate risk is

$$\lambda_S = \theta_S \sigma_R. \tag{46}$$

Combining the tree return with the portfolio first-order condition gives a single equation

for the price:

$$0 = \frac{D}{P} + \mathcal{A}u + \frac{1}{2}\sigma_D^2 D^2 u_D^2 - r^* - \psi_S(\mathcal{L}_S - 1) - \theta_S \sigma_R^2. \tag{47}$$

The corresponding equity premium is

$$\mathrm{ERP}_{\log} \equiv \mu_R - r^* = \psi_S(\mathcal{L}_S - 1) + \theta_S \sigma_R^2. \tag{48}$$

The external payment and household decisions. Consider an atomistic stockholder with financial wealth f_h, gross human wealth h_h (the present value of contractual wages, with $dh_h = [(r^* + \delta)h_h - w_h]dt$), total resources $\mathcal{T}_h^{\mathrm{ind}} = f_h + h_h$, and risky position e_h. Taking ξ_t, τ_S, and α_S as given, the household pays $\xi_t \mathcal{T}_h^{\mathrm{ind}}$ to the rest of the world, so its financial budget is $df_h = [(r^* + \delta)f_h + e_h(\mathrm{ERP} - \tau_S) + (\alpha_S - \xi_t)\mathcal{T}_h^{\mathrm{ind}} + w_h - c_h]dt + e_h \sigma_R dZ$. Adding the value of future wages to financial wealth gives the law of motion for total resources:

$$d\mathcal{T}_h^{\mathrm{ind}} = \Big[(r^* + \delta + \alpha_S - \xi_t)\mathcal{T}_h^{\mathrm{ind}} + e_h(\mathrm{ERP} - \tau_S) - c_h\Big]dt + e_h \sigma_R \, dZ. \tag{49}$$

With $V_h^{\mathrm{ind}}(\mathcal{T}_h^{\mathrm{ind}}, D, \mathcal{B}_N) = \log \mathcal{T}_h^{\mathrm{ind}}/(\rho_S + \delta) + K(D, \mathcal{B}_N)$, the first-order conditions are $c_h = (\rho_S + \delta)\mathcal{T}_h^{\mathrm{ind}}$ and $\mathrm{ERP} - \tau_S = (e_h/\mathcal{T}_h^{\mathrm{ind}})\sigma_R^2$, and ξ_t appears in neither. The payment shows up only in K, through a term $-\xi_t/(\rho_S + \delta)$ in its linear equation. Under log utility, then, the payment changes the household's value but leaves its consumption and risky portfolio shares as they were. Aggregating over stockholders, the pricing equation (47) and premium (48) are the same at a given state with or without the payment. The result relies on log utility and on the payment being proportional to total resources; welfare is affected in any case.

The balancing rate follows from the aggregate stockholder balance sheet $\mathcal{F}_S = P + \mathcal{B}_S$. Its drift is $\mathcal{A}P + \dot{\mathcal{B}}_S$, whereas the aggregate budget gives $r^* \mathcal{F}_S + P\,\mathrm{ERP} + W_S - C_S - \mathcal{X}$ with $P\,\mathrm{ERP} = D + \mathcal{A}P - r^* P$. Equating the two yields $C_S + \mathcal{X} = D + W_S + r^* \mathcal{B}_S - \dot{\mathcal{B}}_S$. Substituting $C_S = m_S \mathcal{T}_S$, $\mathcal{X} = \xi \mathcal{T}_S$, and the prescribed path $\dot{\mathcal{B}}_{S,t} = -(1 - \omega)\dot{\mathcal{B}}_{N,t}$ gives the transfer rate

$$\xi_t = \frac{D_t + W_{S,t} + r^* \mathcal{B}_{S,t} + (1 - \omega)\dot{\mathcal{B}}_{N,t}}{\mathcal{T}_{S,t}} - m_S(D_t, \mathcal{B}_{N,t}), \tag{50}$$

where $W_{S,t} = \pi_S W_t$ and, at a given state, $\dot{\mathcal{B}}_{N,t} = \mu_{\mathcal{B}_N}$. The issuance rule determines this rate, which varies with the state and the demographic regime; we do not calibrate it. Because $\mathcal{E}_S = P$, the diffusion of the balance sheet, $P\sigma_R$, equals that of the portfolio, $\mathcal{E}_S \sigma_R$. Without the payment, the household budget would be off by exactly $\mathcal{X}$.

Adding the nonstockholder budget gives the national resource identity $C_{S,t} + C_{N,t} + \mathcal{X}_t = W_t + D_t + r^* \mathcal{B}_{\mathrm{ROW},t} - \dot{\mathcal{B}}_{\mathrm{ROW},t}$; when all bonds are supplied locally ($\omega = 0$), $C_{S,t} + C_{N,t} + \mathcal{X}_t = W_t + D_t$.

At $\omega = 1$, all additional bonds come from abroad and the local stockholder bond position stays at $\underline{\mathcal{B}}_S$. Equation (47) then has a solution that does not depend on $\mathcal{B}_N$, since $\mathcal{B}_N$ appears only in $\mathcal{A}u$ and $u_{\mathcal{B}_N} = 0$ removes the bond-holdings drift. In the longevity experiment, the price, leverage, price-dividend elasticity, return volatility, and log-utility ERP are therefore all unchanged; only the transfer adjusts, because lower mortality changes stockholder consumption. Two things deliver this, log utility and the issuance rule. Under general CRRA preferences, mortality can also affect prices through consumption and hedging demand.

A.4 Local issuance and the equity premium

Longer retirement raises desired nonstockholder bond holdings. Its effect on local stockholders depends on how much of that demand they meet. Set $z_\delta = -\delta$, so an increase in z_δ is an increase in longevity. From equation (38),

$$\mathcal{B}^*_{N,z_\delta} = \frac{\gamma_N(\mathcal{B}^*_N + \mathcal{H}_N)}{\gamma_N\delta + \rho_N - r^*} > 0, \qquad \mathcal{B}_{S,z_\delta} = -(1-\omega)\mathcal{B}^*_{N,z_\delta}. \tag{51}$$

At fixed P and fixed human wealth,

$$\left.\frac{\partial\theta_S}{\partial\mathcal{B}_S}\right|_P = -\frac{P}{\mathcal{T}_S^2} < 0, \qquad \left.\frac{\partial\mathcal{L}_S}{\partial\mathcal{B}_S}\right|_P = -\frac{P}{\mathcal{F}_S^2} < 0. \tag{52}$$

At a given tree price, additional debt reduces stockholders' net wealth while leaving their risky holdings unchanged, so leverage and risky exposure relative to total wealth both rise. We write $P_B = \partial P/\partial\mathcal{B}_S$ for the derivative of the price with respect to the local stockholder bond position, with dividends, demographic parameters, and ω held fixed. This differs from the state derivative $P_{\mathcal{B}_N}$ with respect to nonstockholder bond holdings: $P_{\mathcal{B}_N} = -(1-\omega)P_B$ for $\omega < 1$. Allowing the tree price to adjust gives

$$\begin{aligned}\frac{d\mathcal{L}_S}{d\mathcal{B}_S} &= \frac{\mathcal{B}_S P_B - P}{(P+\mathcal{B}_S)^2},\\ \frac{d\theta_S}{d\mathcal{B}_S} &= \frac{(\mathcal{H}_S+\mathcal{B}_S)P_B - P}{(P+\mathcal{B}_S+\mathcal{H}_S)^2}.\end{aligned} \tag{53}$$

With additional borrowing, the leverage wedge rises if $\mathcal{B}_S P_B/P < 1$, while risky exposure rises if $(\mathcal{H}_S+\mathcal{B}_S)P_B - P < 0$. Quantitatively, we find that the leverage condition holds. At the initial state, the lower tree price partly offsets the effect of the additional debt on risky exposure, and over the full longevity experiment, once prices and household decisions have adjusted, risky exposure rises only slightly.

The third channel operates through the price-dividend elasticity. Since

$$\sigma_R = \sigma_D \frac{DP_D}{P}, \qquad \frac{d\sigma_R}{d\mathcal{B}_S} = \sigma_D \frac{d}{d\mathcal{B}_S}\left(\frac{DP_D}{P}\right), \tag{54}$$

local debt raises return volatility when it makes the price more sensitive to a dividend shock in percentage terms. Whether it does so at a given state depends on the pricing solution there.

For log utility, holding price and volatility fixed gives the direct effect of longevity on the premium:

$$\mathrm{ERP}_{\log,z_\delta}\big|_{P,\sigma_R} = (1-\omega)\mathcal{B}^*_{N,z_\delta}\left[\psi_S \frac{P}{\mathcal{F}_S^2} + \sigma_R^2 \frac{P}{\mathcal{T}_S^2}\right] > 0 \quad \text{for } \omega < 1. \tag{55}$$

The effect is positive whenever local stockholders supply some of the additional bonds, although the full equilibrium response also reflects the adjustment of prices, risky exposure, and return volatility.

Combining the leverage, allocation, and volatility channels gives

$$\frac{d\,\mathrm{ERP}_{\log}}{d\mathcal{B}_S} = \underbrace{\frac{d\tau_S}{d\mathcal{B}_S}}_{\text{leverage-wedge channel}} + \underbrace{\sigma_R^2 \frac{d\theta_S}{d\mathcal{B}_S}}_{\text{asset-allocation channel}} + \underbrace{2\theta_S\sigma_R \frac{d\sigma_R}{d\mathcal{B}_S}}_{\text{volatility channel}}. \tag{56}$$

Multiplying this expression by $d\mathcal{B}^*_S/d\delta$ gives $\mathrm{ERP}^{\mathrm{debt}}_\delta$, the effect of mortality operating through local debt (Section 3.3). Because $z_\delta = -\delta$, $\mathcal{B}_{S,z_\delta} = -d\mathcal{B}^*_S/d\delta$, so the corresponding effect of increased longevity is $-\mathrm{ERP}^{\mathrm{debt}}_\delta$. This term captures the change in issuance and its effect on prices; the remaining effects of mortality enter the full equilibrium response separately.

To distinguish the direct debt effect from revaluation, we differentiate equation (48) along stationary states:

$$\begin{aligned} \mathrm{ERP}_{\log,z_\delta} &= A_B \mathcal{B}_{S,z_\delta} + A_P P_{z_\delta} + A_\sigma \sigma_{R,z_\delta}, \\ A_B &= -\psi_S \frac{P}{\mathcal{F}_S^2} - \sigma_R^2 \frac{P}{\mathcal{T}_S^2}, \\ A_P &= \psi_S \frac{\mathcal{B}_S}{\mathcal{F}_S^2} + \sigma_R^2 \frac{\mathcal{H}_S + \mathcal{B}_S}{\mathcal{T}_S^2}, \\ A_\sigma &= 2\theta_S\sigma_R. \end{aligned} \tag{57}$$

Equation (55) gives the first term, which holds price and volatility fixed. The other terms

capture changes in the tree price and return volatility.

Return volatility is dividend volatility times the price-dividend elasticity, as in equation (45). Along stationary states,

$$\frac{d\sigma_R}{dz_\delta} = \sigma_D D_0 \left(u_{D,z_\delta} + u_{D\mathcal{B}_N} \mathcal{B}^*_{N,z_\delta} \right). \tag{58}$$

In our quantitative experiment, longevity raises the price-dividend elasticity and hence return volatility. The pricing equation does not impose this sign in general.

For two log-utility equilibria with the same ψ_S, the change in the premium is

$$\Delta \, \mathrm{ERP}_{\log} = \psi_S \Delta \mathcal{L}_S + \Delta(\theta_S \sigma_R^2). \tag{59}$$

Using the exact symmetric-product identity $\Delta(xy) = y^{\mathrm{mid}} \, \Delta x + x^{\mathrm{mid}} \, \Delta y$, where $x^{\mathrm{mid}} = (\underline{x} + \overline{x})/2$ denotes the arithmetic average of the two endpoints being compared, gives

$$\Delta \, \mathrm{ERP}_{\log} = \underbrace{\psi_S \Delta \mathcal{L}_S}_{\text{leverage-wedge contribution}} + \underbrace{(\sigma_R^2)^{\mathrm{mid}} \, \Delta \theta_S}_{\text{asset-allocation contribution}} + \underbrace{\theta_S^{\mathrm{mid}} \, \Delta(\sigma_R^2)}_{\text{volatility contribution}} . \tag{60}$$

Here $(\sigma_R^2)^{\mathrm{mid}}$ is the average of the two endpoint variances, rather than the square of average volatility. Its CRRA counterpart adds terms for curvature and hedging (Appendix A.6). At a stockholder share of 30%, the leverage wedge accounts for 42.4 basis points of the 50.4-basis-point increase. The asset-allocation contribution is 0.1 basis points, the volatility contribution is 8.6 basis points, and intertemporal hedging contributes -0.7 basis points. The allocation contribution is small since the lower tree price largely offsets the direct effect of additional debt on θ_S, which equation (52) isolates by holding the price fixed.

A.5 Calibration and identification

We set the safe rate to 2.7 percent, the stockholder share to 30%, stockholder curvature to $\gamma_S = 1.5$, initial stockholder debt to 145% of output, dividend volatility to 12.0%, and $\rho_S = 4\%$. With $\underline{\mathcal{B}}_N = -\underline{\mathcal{B}}_S$ as the target, (36) gives $\rho_N = 12.23\%$, and given this initial balance sheet, $\psi_S = 0.0666$ delivers the initial equity premium of 5 percent. This parameter governs how much more return is required as leverage rises; risk aversion is set separately, and because the leverage charge is fully rebated, aggregate resources are unaffected.

In the longevity experiment, desired nonstockholder bond holdings rise to 164.7 percent of initial output and, with $\omega = 0.70$, local stockholder debt rises to 150.9 percent.

For the available five-country non-U.S. aggregate, annual dividend-growth volatility is 11.6 percent, which the benchmark value $\sigma_D = 12.0\%$ rounds up; equal weighting or later samples give values of roughly 13 to 15 percent. With the wedge recalibrated at the unrounded 11.6-percent estimate and at 14 percent, the longevity responses are 55.4 and 32.9 basis points, respectively. Lowering σ_D to 10 percent, with the external issuance share and pricing boundaries unchanged, gives a response of 83.2 basis points to the full four-year experiment. With lower dividend volatility, conventional risk compensation explains less of the initial premium, so ψ_S must be larger to match it, and the steeper wedge can make the premium much more sensitive to additional debt.

Our targets identify ρ_N and ψ_S, but not ρ_S. Requiring nonstockholder financial wealth to be stationary at the initial stockholder-debt target gives ρ_N, and the initial premium gives ψ_S. No pricing or goods-market restriction separately identifies ρ_S: under log utility it governs consumption out of wealth but, as long as admissibility constraints do not bind, drops out of the pricing equation. We use 4 percent in the benchmark and 16 percent as a check.

With CRRA preferences, ρ_S affects prices through continuation values, so we solve the model again for each value. A higher ρ_S raises stockholder consumption and lowers the external payment needed to balance the budget. At 16 percent the payment turns into an inward transfer of 50.9 percent of output.

Stock market participation changes household balance sheets, and with them the parameters that match the initial targets. If ρ_N is recalibrated to preserve $\mathcal{B}_N^*(\underline{\delta}) = -\underline{\mathcal{B}}_S$, then

$$-\left.\frac{d\mathcal{B}_N^*}{d\delta}\right|_{\underline{\delta},\,\underline{\mathcal{B}}_S \text{ targeted}} = \frac{(-\underline{\mathcal{B}}_S + \mathcal{H}_N)^2}{\mathcal{H}_N(\underline{\chi} + \underline{\delta})}. \tag{61}$$

The response therefore depends on more than the nonstockholder share $1 - \pi_S$. Participation also affects the wedge slope needed to hit the initial premium. Holding the initial valuation objects fixed, including the continuation-value derivative, and writing $\mathrm{ERP}^{\text{target}}$ for the common premium target, the required slope is

$$\psi_S^{\text{cal}}(\pi_S) = \frac{\mathrm{ERP}^{\text{target}} - \gamma_S \dfrac{P}{P + \mathcal{B}_S + \pi_S \mathcal{H}} \sigma_R^2 - (\gamma_S - 1)\sigma_D D v_D \sigma_R}{\mathcal{L}_S - 1}. \tag{62}$$

When $\mathcal{L}_S > 1$, a larger stockholder share lowers conventional risk compensation at these fixed valuation objects, so the wedge must be steeper to deliver the same premium.

In the participation rows of Table 8, ρ_N is reset so that initial nonstockholder bond holdings stay on target, and ψ_S so that the initial premium stays at 5 percent. Moving

from a 45-percent stockholder share to the benchmark 30% raises the response from 47.8 to 50.4 basis points.

Table 8: Participation and discount-rate robustness

Specification	π_S	ρ_S	ρ_N	ψ_S	$\underline{\text{ERP}}$	$\overline{\text{ERP}}$ / ΔERP	$\mathcal{X}/Y$ (%)	Sign
Maintained benchmark	30%	4.00%	12.23%	0.0666	5.00%	5.50% / 50.42 bp	19.81/22.46	outward
Previous participation	45%	4.00%	11.40%	0.0748	5.00%	5.48% / 47.83 bp	23.71/26.45	outward
Equal discount rates	30%	12.23%	12.23%	0.0666	5.00%	5.50% / 50.59 bp	-28.69/-23.41	inward
Inherited ρ_S	30%	16.00%	12.23%	0.0666	5.00%	5.50% / 50.64 bp	-50.89/-44.40	inward

Notes: Equal-discount and 16-percent-discount rows: benchmark ψ_S held fixed, prices and consumption policies re-solved, so the initial premium can change. Last two columns: external transfer as a percent of output in the initial and post-longevity equilibria.

Table 9: Balance-sheet mechanics across participation calibrations

						Decomposition of Equity Risk Premium			
	$\mathcal{B}_N/\underline{Y}$ (%)	$\mathcal{B}_S/\underline{Y}$ (%)	$\mathcal{L}_S$	θ_S (%)	σ_R (%)	Wedge	Allocation	Volatility	Hedging
π_S = 30%	145.00/164.67	-145.00/-150.90	1.43/1.49	82.07/82.11	13.20/13.46	42.43	0.09	8.57	-0.67
π_S = 45%	145.00/162.20	-145.00/-150.16	1.42/1.48	67.83/67.19	13.37/13.65	42.47	-1.74	7.68	-0.58

Notes: Each participation calibration matches the initial nonstockholder bond-holdings and premium targets. All four contributions use the CRRA endpoint decomposition.

In the discount-rate rows, at the fixed wedge coefficient, moving from ρ_S = 4% to either $\rho_S = \rho_N$ or 16 percent changes prices and the longevity response only slightly, while stockholder consumption remains positive.

Table 10 shows that longer retirement raises the equity premium at initial ERP targets of 4, 4.5, and 5 percent.

Table 10: Sensitivity to the initial equity-premium target

					Decomposition of Equity Risk Premium			
ERP target	ψ_S	$\underline{\text{ERP}}$	$\overline{\text{ERP}}$	ΔERP	Leverage	Allocation	Volatility	Hedging
4.00%	0.0538	4.00%	4.24%	24.25	19.95	0.88	3.63	-0.21
4.50%	0.0609	4.50%	4.85%	35.08	29.30	0.58	5.59	-0.39
5.00%	0.0666	5.00%	5.50%	50.42	42.43	0.09	8.57	-0.67

Notes: Each row recalibrates ψ_S to its initial premium target and then holds it fixed in the longevity experiment. ERP endpoints are reported in percent, and the total change and its four channel contributions in basis points.

Pricing domain and numerical solution. Throughout, stationary outcomes are evaluated at zero drift in nonstockholder bond holdings. We solve the price function on $D/D_0 \in [0.87, 2.20]$ with unit price elasticity at both dividend boundaries, and report prices and returns at the steady-state dividend D_0.

As longevity increases, we follow the solution that starts from the calibrated initial steady state. We report results for $\omega \in [0.40, 1]$, the range over which we have checked the CRRA results directly.

Table 11: Four-year post-retirement longevity increase: decomposition of the equity risk premium

ω	ΔERP (bp)	Wedge	Allocation	Volatility	Hedging
0.40	126.16	105.79	-0.53	22.76	-1.86
0.70	50.42	42.43	0.09	8.57	-0.67
0.80	31.80	26.77	0.11	5.32	-0.41
1.00	0.01	0.01	-0.00	-0.00	0.01

Notes: Contributions are in basis points. Each row starts from the same initial financial calibration and applies the same four-year increase in the retirement-duration gap, with human wealth held fixed; only ω differs. The four contributions add up to the change in the premium. Appendix A.6 reports the response without a leverage wedge.

A.6 General CRRA preferences

A.6.1 Nonstockholder saving under CRRA preferences

For a CRRA nonstockholder with coefficient $\gamma_N > 0$ and discount rate ρ_N, the ratio of consumption to total safe wealth is

$$\frac{C_N}{\mathcal{B}_N + \mathcal{H}_N} = \frac{\rho_N + \gamma_N\delta + (\gamma_N - 1)r^*}{\gamma_N} = \delta + \frac{\rho_N + (\gamma_N - 1)r^*}{\gamma_N}. \tag{63}$$

In the longevity experiment, we hold W_N fixed and adjust earnings timing to keep $\mathcal{H}_N$ fixed as mortality falls. The stationary nonstockholder bond-holdings target and its mortality derivative are then

$$\begin{aligned} \mathcal{B}^*_{N,\mathrm{CRRA}}(\delta) &= \mathcal{H}_N \frac{r^* + \gamma_N\chi(\delta) - \rho_N}{\gamma_N\delta + \rho_N - r^*}, \\ \frac{d\mathcal{B}^*_{N,\mathrm{CRRA}}}{d\delta} &= -\frac{\gamma_N[\mathcal{B}^*_{N,\mathrm{CRRA}}(\delta) + \mathcal{H}_N]}{\gamma_N\delta + \rho_N - r^*}. \end{aligned} \tag{64}$$

Lemma (Equivalent aggregate saving under CRRA and log utility)**.** *Fix r^*. If a CRRA pair satisfies $[\rho_N + (\gamma_N - 1)r^*]/\gamma_N = \rho_N^{\log}$, then its consumption propensity, aggregate nonstockholder bond-holdings drift, stationary target under earnings-timing compensation, mortality derivative,*

and reduced transition coincide with those of a log nonstockholder with discount rate $\rho_N^{\log}$, for every δ. The two need not give the same welfare.

Proof. With $[\rho_N + (\gamma_N - 1)r^*]/\gamma_N = \rho_N^{\log}$, equation (63) gives a ratio of consumption to total safe wealth of $\delta + \rho_N^{\log}$, the log value. Hence the consumption rule and the drift (35) are identical for every $(\mathcal{B}_N, \delta)$. The stationary target, its derivative, and the transition are all derived from this linear law. □

At the benchmark balance sheet, $\gamma_N = 4$ and $\rho_N = 12.23\%$ match the same initial nonstockholder bond-holdings target as the log-utility case. By the lemma, aggregate bond demand and its response to a longer retirement are then the same as in the log case at the fixed safe rate.

A.6.2 CRRA stockholders

We now derive stockholder pricing for the $\gamma_S \neq 1$ case introduced in Section 3.1. Demographics, nonstockholder saving, and the issuance rule are unchanged. We write the unnormalized CRRA value function as

$$V_S(\mathcal{T}_S, D, \mathcal{B}_N) = \frac{[\mathcal{T}_S G(D, \mathcal{B}_N)]^{1-\gamma_S}}{1-\gamma_S}. \tag{65}$$

The consumption first-order condition is

$$m_S = G^{1-1/\gamma_S}, \qquad C_S = m_S \mathcal{T}_S. \tag{66}$$

With this normalization, the consumption condition has no additional factor involving $\rho_S + \delta$. Let $u = \log P$, $v = \log G$, and $\varrho_S = \rho_S + \delta$. Itô's lemma gives

$$\sigma_R = \sigma_D D u_D, \qquad \sigma_{C,S} = \theta_S \sigma_R + \frac{\gamma_S - 1}{\gamma_S} \sigma_D D v_D. \tag{67}$$

The compensation stockholders require per unit of aggregate risk is

$$\lambda_S = \gamma_S \theta_S \sigma_R + (\gamma_S - 1)\sigma_D D v_D. \tag{68}$$

The coupled stationary equations for u and v are

$$0 = \frac{D}{P} + \mathcal{A}u + \frac{1}{2}\sigma_D^2 D^2 u_D^2 - r^* - \tau_S - \lambda_S \sigma_R \tag{69}$$

and

$$0 = \frac{m_S - \varrho_S}{1-\gamma_S} + \mathcal{A}v + \frac{1}{2}(1-\gamma_S)\sigma_D^2 D^2 v_D^2 + r^* + \delta + \tau_S\theta_S - \xi - m_S + \frac{\gamma_S}{2}\theta_S^2\sigma_R^2. \tag{70}$$

Before applying (66), the first term in the continuation equation is $\{(m_S/G)^{1-\gamma_S} - \varrho_S\}/(1-\gamma_S)$. The first-order condition implies $(m_S/G)^{1-\gamma_S} = m_S$, giving (70).

The external transfer rate ξ is given by (50), using the state-dependent consumption propensity $m_S = G^{1-1/\gamma_S}$. The proportional payment reduces total-wealth drift by ξ, which explains its negative sign in the continuation equation. Since households treat the rate as given when they choose consumption and portfolios, it is absent from their first-order conditions. We solve jointly for the price, continuation value, consumption propensity, and transfer rate.

The CRRA equity premium is

$$\text{ERP} = \psi_S(\mathcal{L}_S - 1) + \gamma_S\theta_S\sigma_R^2 + (\gamma_S - 1)\sigma_D D v_D \sigma_R. \tag{71}$$

The last term reflects the covariance of returns with changes in future investment opportunities and vanishes at $\gamma_S = 1$. We solve the log-utility case separately because the representation in (70) is singular at that limit.

Proposition (Direct longevity effect under CRRA)**.** *Suppose* $r^* + \gamma_N\chi - \rho_N > 0$, $\gamma_N\delta + \rho_N - r^* > 0$, $\psi_S \geq 0$, *and* $\sigma_R > 0$. *Let* $0 < \pi_S < 1$, $P > 0$, $\mathcal{F}_S = P + \mathcal{B}_S > 0$, *and* $\mathcal{T}_S = P + \mathcal{B}_S + \pi_S\mathcal{H} > 0$. *Under earnings-timing compensation, holding* P, σ_R, *and* v_D *fixed, the direct mortality effect is*

$$\left.\frac{\partial\,\text{ERP}}{\partial\delta}\right|_{P,\sigma_R,v_D} = -(1-\omega)\frac{\gamma_N[\mathcal{B}^*_{N,\text{CRRA}} + (1-\pi_S)\mathcal{H}]}{\gamma_N\delta + \rho_N - r^*} \times \left[\psi_S\frac{P}{(P+\mathcal{B}_S)^2} + \gamma_S\sigma_R^2\frac{P}{(P+\mathcal{B}_S+\pi_S\mathcal{H})^2}\right] \leq 0. \tag{72}$$

The inequality is strict for $\omega < 1$ *and is an equality at* $\omega = 1$. *Thus lower mortality raises the direct balance-sheet component of the ERP whenever non-U.S. stockholders supply some of the additional bonds. Their additional debt raises leverage and risky exposure, so they require more compensation to hold the tree at the fixed price and volatility.*

Proof. Substitute $\mathcal{H}_N = (1-\pi_S)\mathcal{H}$ into (64), and use $d\mathcal{B}^*_S/d\delta = -(1-\omega)d\mathcal{B}^*_{N,\text{CRRA}}/d\delta$. At fixed P,

$$\frac{\partial\mathcal{L}_S}{\partial\mathcal{B}_S} = -\frac{P}{(P+\mathcal{B}_S)^2}, \qquad \frac{\partial\theta_S}{\partial\mathcal{B}_S} = -\frac{P}{(P+\mathcal{B}_S+\pi_S\mathcal{H})^2}.$$

Differentiate (71). Holding P, σ_R, and v_D fixed, the intertemporal-hedging term does not

depend on $\mathcal{B}_S$ directly. Combining the expressions gives (72). □

The proposition holds model parameters fixed. Along stationary equilibria,

$$\begin{aligned}
\mathrm{ERP}_{z_\delta} &= A_B \mathcal{B}_{S,z_\delta} + A_P P_{z_\delta} + A_\sigma \sigma_{R,z_\delta} + A_v v_{D,z_\delta}, \\
A_B &= -\psi_S \frac{P}{\mathcal{F}_S^2} - \gamma_S \sigma_R^2 \frac{P}{\mathcal{T}_S^2}, \\
A_P &= \psi_S \frac{\mathcal{B}_S}{\mathcal{F}_S^2} + \gamma_S \sigma_R^2 \frac{\mathcal{H}_S + \mathcal{B}_S}{\mathcal{T}_S^2}, \\
A_\sigma &= 2\gamma_S \theta_S \sigma_R + (\gamma_S - 1)\sigma_D D v_D, \qquad A_v = (\gamma_S - 1)\sigma_D D \sigma_R.
\end{aligned} \tag{73}$$

For two CRRA equilibria at the same steady-state dividend D_0, the direct-risk component has the exact decomposition

$$\Delta(\gamma_S \theta_S \sigma_R^2) = \gamma_S (\sigma_R^2)^{\mathrm{mid}} \, \Delta\theta_S + \gamma_S \theta_S^{\mathrm{mid}} \, \Delta(\sigma_R^2), \tag{74}$$

while the intertemporal-hedging component satisfies

$$\Delta[(\gamma_S - 1)\sigma_D D v_D \sigma_R] = (\gamma_S - 1)\sigma_D D \left(\sigma_R^{\mathrm{mid}} \Delta v_D + v_D^{\mathrm{mid}} \Delta \sigma_R \right). \tag{75}$$

We assign the first term in the last parenthesis to intertemporal hedging: it captures the change in the hedging loading at average return volatility. The second term goes into the ordinary volatility contribution.

Equations (71)–(75) extend the balance-sheet mechanism to general CRRA preferences. Our calibration and robustness exercises use $\gamma_S = 1.5$ and $\gamma_N = 4$, at which the longevity experiment raises the equity premium by 50.4 basis points.

Most of the equity premium response comes through the leverage wedge. If we set $\psi_S = 0$, the initial equity premium is only 1.89%, and longevity raises it by just 1.4 basis points. The benchmark response is therefore large mainly because required returns rise with leverage as stockholders take on the extra debt.

B Transition dynamics in the fixed-rate benchmark

The main text compares stationary equilibria, which combine two responses that happen at different speeds: asset prices move as soon as the decline in mortality is announced, while nonstockholders accumulate the additional bonds needed for a longer retirement only gradually. To trace these responses, we use the main text's permanent longevity increase, again adjusting earnings decline so that human wealth is unchanged. Local non-U.S. stockholders issue the share $1 - \omega$ of additional bonds, with $\omega = 0.70$. The financial parameters (including the 30% participation share) keep the values calibrated in Section 3.4.

B.1 The accumulation of nonstockholder bond holdings

A longer retirement, with nonstockholder human wealth $\mathcal{H}_N$ held fixed, raises the stock of bonds that nonstockholders want to accumulate. After mortality falls to $\overline{\delta}$, aggregate nonstockholder bond holdings follow

$$\dot{\mathcal{B}}_{N,t} = -\kappa_B(\mathcal{B}_{N,t} - \overline{\mathcal{B}}^*_N), \qquad \kappa_B = \overline{\delta} + \frac{\rho_N - r^*}{\gamma_N} > 0, \tag{76}$$

where their new long-run level is

$$\overline{\mathcal{B}}^*_N = \mathcal{H}_N \frac{r^* + \gamma_N \overline{\chi} - \rho_N}{\gamma_N \overline{\delta} + \rho_N - r^*}, \qquad \overline{\chi} = \underline{\chi} + \underline{\delta} - \overline{\delta}. \tag{77}$$

The solution is

$$\mathcal{B}_{N,t} = \overline{\mathcal{B}}^*_N + (\underline{\mathcal{B}}_N - \overline{\mathcal{B}}^*_N)e^{-\kappa_B t}. \tag{78}$$

Nonstockholders build their additional bond holdings through saving, so these holdings cannot jump when mortality changes. The speed of adjustment follows from the household budget constraint and CRRA consumption rule, without an additional adjustment friction. Throughout the transition, with $\omega = 0.70$, the local stockholder bond position and externally supplied bonds track nonstockholder holdings: $\mathcal{B}_{S,t} = \underline{\mathcal{B}}_S - (1 - \omega)(\mathcal{B}_{N,t} - \underline{\mathcal{B}}_N)$ and $\mathcal{B}_{\text{ROW},t} = \omega(\mathcal{B}_{N,t} - \underline{\mathcal{B}}_N)$.

The implied half-life is about 17.5 years, so household balance sheets adjust slowly even though the demographic change is in place from date zero.

B.2 Impact repricing and subsequent accumulation

The tree price responds immediately to the change in mortality and the anticipated accumulation of stockholder debt. At the announcement, nonstockholder bond holdings, local debt, and current dividends are predetermined. We solve jointly for the price and consumption propensity along the deterministic nonstockholder bond-holdings path, using their new stationary solutions as terminal conditions. The time-dependent CRRA system adds u_t and v_t to equations (69) and (70), respectively, and replaces $\mathcal{A}$ with the dividend generator. These time derivatives already account for movement along $\mathcal{B}_{N,t}$. At each date, the transfer rate follows rule (50), using the actual stockholder bond-position drift $\dot{\mathcal{B}}_{S,t} = -(1-\omega)\dot{\mathcal{B}}_{N,t}$. Because local debt is predetermined, stockholder financial wealth, $P_t + \mathcal{B}_{S,t}$, jumps with the tree price on impact. The equity premium along the transition satisfies

$$\mathrm{ERP}_t = \psi_S(\mathcal{L}_{S,t} - 1) + \gamma_S \theta_{S,t} \sigma_{R,t}^2 + (\gamma_S - 1)\sigma_D D_t v_{D,t} \sigma_{R,t}. \tag{79}$$

On impact, the lower tree price cuts stockholders' financial wealth and so raises their leverage. Later, as nonstockholders accumulate bonds and stockholders issue the matching local debt, the wealth left to bear the tree's risk shrinks further.

Table 12: Transition following the longevity increase

	Initial	Impact	Year 10	Long run
Nonstockholder bond holdings / initial output (%)	145.00	145.00	151.44	164.67
Local stockholder bond position, $\mathcal{B}_S/\underline{Y}$ (%)	-145.00	-145.00	-146.93	-150.90
Financial leverage	1.43	1.45	1.46	1.49
Equity risk premium (%)	5.00	5.13	5.25	5.50
External payment / output (%)	19.81	22.00	22.14	22.46

Notes: Mortality falls permanently by 0.107 percentage point and χ rises by the same amount, so that human wealth is unchanged; wages are also unchanged. The retirement-duration gap widens by four years, and $\omega = 0.70$. "Impact" refers to the moment of the announcement, before nonstockholder bond holdings or local debt have changed. The transfer is divided by same-period output.

On impact, the equity premium rises by 13.2 basis points (Table 12). This is about 26 percent of the long-run increase of 50.4 basis points. The remaining 37.2 basis points come gradually, as nonstockholders accumulate bonds and stockholders issue the matching debt, until the economy reaches the new stationary equilibrium.

C Population growth and cohort composition

Slower population growth makes a population older by reducing the share of newborn households, even when individual life expectancy is unchanged. We combine this source of aging with the longevity experiment, as described in Section 3.6.1. We first increase longevity at a population-growth rate of 0.50 percent, adjusting earnings decline to keep human wealth fixed. We then lower population growth to 0.00 percent, holding mortality and earnings decline at their post-longevity values. To derive the balance-sheet effects, consider a fixed demographic regime with mortality rate δ and birth rate per person b. Net population growth is

$$n = b - \delta, \qquad \dot{N}_t = nN_t.$$

With constant mortality and population growth, the stable age distribution is

$$f_n(a) = (\delta + n)e^{-(\delta+n)a}.$$

Mean age is $1/(\delta + n)$ and an individual's expected remaining lifetime is $1/\delta$, so slower population growth makes the population older on average without giving any household a longer expected remaining life. A fall in mortality, as in the longevity experiment, raises both.

Earnings decline with age at rate χ. To hold the per-capita wage bill W fixed as the age distribution changes, we scale the earnings profile according to

$$w(a; n) = W\frac{\delta + n + \chi}{\delta + n}e^{-\chi a}.$$

Newborn households enter with no financial assets, so their arrival dilutes bond holdings per person. We measure nonstockholder bond holdings per member of the total population, denoted $\mathcal{B}_{N,t}$, and obtain

$$\dot{\mathcal{B}}_{N,t} = (r^* - n)\mathcal{B}_{N,t} + W_N - C_{N,t}.$$

Human wealth is $\mathcal{H}_N = W_N/(r^* + \delta + \chi)$. Under the CRRA preferences used in the benchmark, stationary nonstockholder bond holdings are

$$\mathcal{B}^*_N(\delta, n) = \mathcal{H}_N\frac{r^* + \gamma_N\chi - \rho_N}{\gamma_N(\delta + n) + \rho_N - r^*}, \qquad \frac{\partial\mathcal{B}^*_N}{\partial n} < 0.$$

Slower population growth reduces this dilution and raises nonstockholder bond holdings per person. The share of these additional bonds that local non-U.S. stockholders sup-

ply raises their debt. Its effect on leverage and required returns also depends on how population growth affects the value of the tree and its dividends.

Tree normalization and the external payment. Let N denote population, Q the value of the single aggregate tree, and D^{agg} its aggregate dividend. The corresponding values per person are $P = Q/N$ and $D = D^{\text{agg}}/N$. We use the same population denominator for household wealth, debt, consumption, and transfers. Mortality credits and individual consumption propensities depend on δ, rather than $\delta+n$. We hold the initial debt-issuance anchor fixed in per-capita units, so $\dot{\mathcal{B}}_S = -(1-\omega)\mu_{\mathcal{B}_N}$ and $\dot{\mathcal{B}}_{\text{ROW}} = \omega\mu_{\mathcal{B}_N}$. Even when per-capita debt is constant, aggregate net issuance per person is $-n\mathcal{B}_S$, because total debt must grow with the population.

We retain the benchmark aggregate dividend process, $dD^{\text{agg}}/D^{\text{agg}} = \sigma_D dZ$. Per-capita dividends consequently satisfy $dD/D = -n\,dt + \sigma_D dZ$. There is a single aggregate ownership claim, and newborn households receive no freely issued equity. The return on this claim satisfies

$$\frac{dQ + D^{\text{agg}}\,dt}{Q} = \frac{dP}{P} + \left(n + \frac{D}{P}\right)dt, \qquad \mu_R = \frac{D}{P} + n + \frac{\mathcal{A}_n P}{P}. \tag{80}$$

Consequently the per-capita stockholder budget is

$$d\mathcal{F}_S = \Big[(r^* - n)\mathcal{F}_S + P\,\text{ERP} + W_S - C_S - \xi\mathcal{T}_S\Big]dt + P\sigma_R dZ. \tag{81}$$

Combining this with $\mathcal{F}_S = P + \mathcal{B}_S$ yields the cash-flow formula

$$C_S + \mathcal{X} = D + W_S + (r^* - n)\mathcal{B}_S + (1-\omega)\mu_{\mathcal{B}_N}, \tag{82}$$

$$\xi = \frac{D + W_S + (r^* - n)\mathcal{B}_S + (1-\omega)\mu_{\mathcal{B}_N}}{\mathcal{T}_S} - m_S, \qquad \mathcal{X} = \xi\mathcal{T}_S, \tag{83}$$

$$C_S + C_N + \mathcal{X} = W + D + (r^* - n)\mathcal{B}_{\text{ROW}} - \omega\mu_{\mathcal{B}_N}. \tag{84}$$

Population growth enters both the return on the aggregate tree and the stockholder budget through the $-n\mathcal{F}_S$ dilution term. Combining these effects gives the $-n\mathcal{B}_S$ issuance term in the cash-flow formula; a $-nP$ term would omit the population correction to the tree return.

We evaluate prices with nonstockholder bond holdings at their zero-drift value. Let $z_D = \log(D/D_0)$, $u = \log P$, and $g_D = -n$, as implied by the aggregate dividend process.

For log-utility stockholders, the pricing equation becomes

$$0 = De^{-u} + n + g_D u_{z_D} + \tfrac{1}{2}\sigma_D^2(u_{z_D z_D} - u_{z_D} + u_{z_D}^2) - r^* - \tau_S - \theta_S \sigma_D^2 u_{z_D}^2. \tag{85}$$

We use the benchmark unit-elasticity dividend boundaries. In the CRRA system, population growth adds $g_D \partial_{z_D}$ to the generator and $+n$ to the price equation. The individual continuation equation contains $-\xi$, with no additional mortality credit or impatience term involving n: population growth changes cohort weights, rather than individual survival probabilities.

A change in n alters bond holdings through dilution, whereas the longevity experiment changes mortality and adjusts χ to keep human wealth fixed. We use the aggregate dividend process above and the external payment in equation (83) throughout the comparison.

C.1 Joint experiment and stationary implications

We calibrate the initial allocation $(\underline{\delta}, \underline{\chi}, \underline{n})$ with positive population growth, $\underline{n} = 0.005$, and the same nonstockholder bond-holdings target as in the benchmark, $\underline{\mathcal{B}}_N/\underline{Y} = 1.45$, where $\underline{Y}$ is the fixed initial output per person. Underlines denote the initial allocation, a superscript L the longevity-only allocation, and overlines the final allocation after both demographic changes. The condition that initial nonstockholder bond holdings have zero drift identifies the nonstockholder discount rate:

$$\rho_N = \gamma_N \left[\frac{(r^* - \underline{n})\underline{\mathcal{B}}_N + W_N}{\underline{\mathcal{B}}_N + \mathcal{H}_N} - \underline{\delta} \right] - (\gamma_N - 1) r^*. \tag{86}$$

This gives $\rho_N = 11.83517$ percent per year. We then match the initial 5-percent equity premium, including $\underline{n}$ in the pricing equation, which gives $\psi_S = 0.06619937$. Because initial population growth is positive, both values differ from the zero-growth benchmark; they stay fixed for the rest of the experiment. The longevity increase adds four years to expected life while holding $\delta + \chi$ fixed, so human wealth is unchanged:

$$\delta^L = (\underline{\delta}^{-1} + 4)^{-1}, \qquad \chi^L = \underline{\chi} + \underline{\delta} - \delta^L, \qquad n^L = \underline{n}.$$

Starting from this allocation, the joint experiment sets

$$(\overline{\delta}, \overline{\chi}, \overline{n}) = (\delta^L, \chi^L, 0).$$

Population growth falls by 0.5 percentage point to 0.00 percent per year. Relative to the longevity allocation at $\underline{n}$, this lowers the birth rate from $b^L = \delta^L + \underline{n}$ to $\overline{b} = \delta^L + \overline{n}$, with mortality unchanged. Consequently, individual mortality credits remain δ^L, and nonstockholders' consumption propensity remains $\delta^L + [\rho_N + (\gamma_N - 1)r^*]/\gamma_N$. Stockholders' consumption propensity, by contrast, moves with asset prices. Preferences, financial parameters, the per-capita wage bill, and human wealth are the same in all three allocations.

To isolate the additional saving generated by lower population growth, write $\mathcal{B}_N^L = \mathcal{B}_N^*(\delta^L, \underline{n})$ and $\kappa_B^L = \delta^L + (\rho_N - r^*)/\gamma_N > 0$. With the numerator of stationary bond demand unchanged, the reduction in dilution gives

$$\overline{\mathcal{B}}_N = \mathcal{B}_N^L \frac{\kappa_B^L + \underline{n}}{\kappa_B^L + \overline{n}}, \qquad \overline{\mathcal{B}}_N - \mathcal{B}_N^L = \frac{(\underline{n} - \overline{n})\mathcal{B}_N^L}{\kappa_B^L + \overline{n}} > 0, \tag{87}$$

where $\kappa_B^L + \overline{n} > 0$. Both demographic changes increase nonstockholder bond holdings relative to the same initial per-capita anchor, $\underline{\mathcal{B}}_N = -\underline{\mathcal{B}}_S$. At both the longevity-only and final allocations, the rule remains

$$\mathcal{B}_S = \underline{\mathcal{B}}_S - (1 - \omega)(\mathcal{B}_N - \underline{\mathcal{B}}_N), \qquad \mathcal{B}_{\text{ROW}} = \omega(\mathcal{B}_N - \underline{\mathcal{B}}_N). \tag{88}$$

Thus $\overline{\mathcal{B}}_S - \mathcal{B}_S^L = -(1 - \omega)(\overline{\mathcal{B}}_N - \mathcal{B}_N^L)$.

In this calibration, lower population growth reinforces the effect of longer retirement: nonstockholder bond holdings and local stockholder debt rise, increasing the risk borne by stockholders. Table 13 reports the three allocations, solved on the benchmark dividend interval $D/D_0 \in [0.87, 2.20]$ with unit-elasticity boundaries.

Table 13: Longevity increase followed by lower population growth

Object	Initial	Longevity	Final
Equity risk premium (percent)	5.00	5.47	6.16
Nonstockholder bond holdings / initial output (percent)	145.00	162.86	183.93
Local stockholder bond position, $\mathcal{B}_S/\underline{Y}$ (percent)	-145.00	-150.36	-156.68
Equity value / initial output (percent)	478.93	454.43	427.78
Stockholder financial wealth / initial output (percent)	333.93	304.07	271.10
Financial leverage	1.43	1.49	1.58
Risky allocation (percent)	81.94	81.93	82.00
Equity-return volatility (percent)	13.14	13.37	13.82

Notes: The longevity column increases the retirement-duration gap by four years at 0.50-percent population growth. Mortality falls from 1.69 to 1.58 percent and earnings decline rises from 3.39 to 3.50 percent per year. The final column additionally lowers population growth to 0.00 percent, keeping mortality and earnings decline at their post-longevity values. The safe rate remains 2.70 percent. We hold fixed the per-capita wage bill and human wealth, financial parameters, initial issuance anchor, and $\omega = 0.70$. The aggregate dividend process is unchanged, so per-capita dividend drift is $-n$. Stocks and flows are measured per person, and stocks are scaled by initial per-capita output. Prices and returns are evaluated at the steady-state dividend D_0, with nonstockholder bond holdings at their zero-drift value.

Relative to the longevity allocation, we find that reduced dilution raises nonstockholder bond holdings by 21.06 percentage points of initial output and local stockholder debt by 6.32 points. At the same time, the equity price falls by 5.86 percent and stockholder financial wealth by 10.84 percent. Stockholders must therefore finance the tree with more debt and less financial wealth: leverage rises from 1.49 to 1.58. The premium required to bear this risk increases by a further 69.4 basis points, from 5.47 to 6.16 percent. Relative to the initial allocation, the combined nonstockholder bond-holdings increase is 38.93 percentage points of initial output and the combined premium increase is 116.3 basis points.

Sources of the premium increase. We separate the effects of leverage, risky allocation, return volatility, and intertemporal hedging using the symmetric-product decomposition. For any two of these CRRA allocations,

$$\Delta\text{ERP} = \psi_S \Delta\mathcal{L}_S + \gamma_S(\sigma_R^2)^{\text{mid}}\,\Delta\theta_S + \gamma_S\theta_S^{\text{mid}}\,\Delta\sigma_R^2 + (\gamma_S - 1)\sigma_D D_0(\sigma_R^{\text{mid}}\Delta v_D + v_D^{\text{mid}}\Delta\sigma_R), \quad (89)$$

where the superscript mid denotes arithmetic averages of the endpoints of the particular comparison and ψ_S remains fixed. In particular, $(\sigma_R^2)^{\text{mid}}$ averages endpoint variances. Higher leverage accounts for most of the premium increase following lower population growth, contributing 55.2 basis points. Return volatility also raises the premium, while the risky-allocation contribution is small and positive. Intertemporal hedging partly offsets these effects. This 69.4-basis-point increase includes the adjustment of prices and balance sheets from their post-longevity values. Panel B of Table 4 reports the decomposition for each comparison, with the Δv_D term assigned to hedging and the $\Delta\sigma_R$ term to volatility, as in Appendix A.6. Total premium changes add up across the two steps; the individual contributions need not, since each comparison averages over its own endpoints.

Lower population growth in isolation. We also consider lower population growth on its own, cutting n from $\underline{n} = 0.005$ to zero while mortality and earnings decline stay at their initial values, with the same initial calibration, issuance anchor, and $\omega = 0.70$. This raises the premium by 41.50 basis points, against 69.4 basis points when the same fall in population growth follows the longevity increase. The gap of 27.91 basis points is the interaction between the two demographic changes.

Table 14: Separate and combined effects of the demographic changes

Variable and unit	Longevity only ($\underline{x} \to x^L$)	Population only ($\underline{x} \to x^G$)	Both together ($\underline{x} \to \overline{x}$)
Equity risk premium, basis points	+46.89	+41.50	+116.29
Financial leverage, ratio points	+0.06	+0.05	+0.14
Local stockholder debt, $-\mathcal{B}_S$, percent change	+3.70	+3.78	+8.05
Stockholder financial wealth, percent change	-8.94	-6.77	-18.81
Equity price, percent change	-5.11	-3.58	-10.68
Nonstockholder bond holdings / initial output, percentage points	+17.86	+18.25	+38.93
Risky allocation, percentage points	-0.01	+0.25	+0.06
Equity-return volatility, percentage points	+0.23	+0.27	+0.69

Notes: $\underline{x}$, x^G, x^L, and $\overline{x}$ are the values of a variable x at the initial, population-only, longevity-only, and final allocations. All columns are changes from $\underline{x}$; the combined column comes from a joint solution. Stock/output changes use initial per-capita output as the denominator; percent changes are relative to initial levels. The safe rate is fixed.

External supply. In Table 15, 75 percent of the additional bonds come from abroad ($\omega = 0.75$) rather than 70 percent. As a result, both demographic changes raise the

premium by less than in the benchmark. Figure 3 in the main text varies ω for longevity alone, starting from zero population growth.

Table 15: Equity-premium decomposition under alternative external supply (basis points)

ω	Longevity	Population after longevity	Combined
0.70	46.89	69.40	116.29
0.75	38.01	50.46	88.48

D Two-country model: stationary derivations

We derive the household wealth equations, issuer leverage wedges, and market-clearing conditions used in Sections 4 and 5. We then show how the calibration identifies the parameters and how demographic changes affect each premium. We evaluate all expressions in stationary equilibria and suppress time subscripts. As in Section 4.1, Y_H and Y_F denote fixed aggregate output at the initial date, with $Y = Y_H + Y_F$. Their shares Y_H/Y and Y_F/Y weight per-person quantities in world sums. Lowercase $y_i = 1$ denotes output per person; all other stocks and flows are also per country resident unless stated otherwise. Initial, longevity-only, and final values use the marks $\underline{x}$, x^L, and $\overline{x}$, respectively, as in Section 5.

D.1 Human wealth

For household type $k \in \{S, N\}$, let $\pi_{S,i}$ denote the stockholder population share and $\pi_{N,i} = 1 - \pi_{S,i}$ the nonstockholder share. The wage flow of type k per country resident is $\pi_{k,i} W_i$. Human wealth is the present value of this earnings stream. In a stationary equilibrium, earnings decline at rate χ_i and cease at death, which occurs at rate δ_i. Discounting at the safe rate r gives

$$\begin{aligned} \mathcal{H}_{k,i} &= \pi_{k,i} W_i \int_0^\infty e^{-(r+\chi_i+\delta_i)u}\, du \\ &= \frac{\pi_{k,i} W_i}{r + \chi_i + \delta_i}, \end{aligned} \tag{90}$$

which gives the human-wealth expressions in Section 4.2.

D.2 Nonstockholder consumption and bond holdings

Nonstockholders save in actuarially fair annuities to finance consumption over their remaining lives. With CRRA utility and a constant safe rate, homogeneity of the value function gives the consumption–wealth ratio

$$m_{N,i} = \frac{\rho_{N,i} + \gamma_{N,i}\delta_i + (\gamma_{N,i} - 1)r}{\gamma_{N,i}} = \delta_i + q_i(r), \tag{91}$$

where $q_i(r) \equiv [\rho_{N,i} + (\gamma_{N,i} - 1)r]/\gamma_{N,i}$. This gives the nonstockholder consumption rule of Section 4.2. At the aggregate level, annuity credits to survivors offset the financial wealth of households who die. Newborns enter without financial wealth, so population growth dilutes financial wealth per person at rate n_i. Nonstockholder bond holdings per country

resident therefore evolve according to

$$\dot{\mathcal{B}}_{N,i} = (r - n_i)\mathcal{B}_{N,i} + (1 - \pi_{S,i})W_i - (\delta_i + q_i)(\mathcal{B}_{N,i} + \mathcal{H}_{N,i}). \tag{92}$$

Using the relation between wages and human wealth,

$$(1 - \pi_{S,i})W_i = (r + \chi_i + \delta_i)\mathcal{H}_{N,i} \tag{93}$$

and setting the drift to zero gives

$$\begin{aligned} 0 &= (r - n_i - \delta_i - q_i)\mathcal{B}_{N,i} + (r + \chi_i - q_i)\mathcal{H}_{N,i}, \\ \mathcal{B}^*_{N,i} &= \mathcal{H}_{N,i}\frac{r + \chi_i - q_i}{\delta_i + n_i + q_i - r}. \end{aligned} \tag{94}$$

This establishes equation (21).

In the initial equilibrium, the nonstockholder bond-holdings target $s^{\text{target}}_{N,i} = \underline{\mathcal{B}}_{N,i}/\underline{y}_i$ implies $\underline{\mathcal{B}}_{N,i} = s^{\text{target}}_{N,i}\underline{y}_i$. Solving the zero-drift condition for the effective discount term gives

$$\underline{q}_i = \frac{(\underline{r} - \underline{n}_i)\underline{\mathcal{B}}_{N,i} + (1 - \pi_{S,i})W_i}{\underline{\mathcal{B}}_{N,i} + \underline{\mathcal{H}}_{N,i}} - \underline{\delta}_i. \tag{95}$$

The primitive discount rate is then

$$\rho_{N,i} = \gamma_{N,i}\underline{q}_i - (\gamma_{N,i} - 1)\underline{r}. \tag{96}$$

Holding $\rho_{N,i}$ and $\gamma_{N,i}$ fixed,

$$\begin{aligned} q_i(r) - q_i(\underline{r}) &= \frac{\gamma_{N,i} - 1}{\gamma_{N,i}}(r - \underline{r}), \\ \frac{d[r - q_i(r)]}{dr} &= \frac{1}{\gamma_{N,i}}. \end{aligned} \tag{97}$$

The safe rate affects the return on saving and can also change the effective discount term. These expressions describe the resulting saving incentive, as discussed in Section 4.2.

D.3 Stockholder portfolios

For a stockholder in country i, let $\theta_{S,i,H}$ and $\theta_{S,i,F}$ be Home- and Foreign-equity exposure per unit of total wealth. In our stationary portfolio specification, the intertemporal hedging term of Appendix A.6 is absent and portfolio choice is myopic: stockholders trade off

expected excess returns against risk and the issuer leverage wedges. Dropping terms independent of portfolio choice, the objective is

$$\begin{aligned}&\theta_{S,i,H}\mathrm{ERP}_H + \theta_{S,i,F}\mathrm{ERP}_F \\ &\quad - \frac{\gamma_S}{2}\Big[\sigma^2_{R,H}(\theta_{S,i,H})^2 + 2\sigma_{R,HF}\theta_{S,i,H}\theta_{S,i,F} + \sigma^2_{R,F}(\theta_{S,i,F})^2\Big] \\ &\quad - \theta_{S,i,H}\tau_H - \theta_{S,i,F}\tau_F.\end{aligned} \tag{98}$$

The portfolio wedges are rebated to stockholders. Let

$$\alpha_{S,i} = \theta_{S,i,H}\tau_H + \theta_{S,i,F}\tau_F \tag{99}$$

be the equilibrium rebate per unit of stockholder total wealth, which each household takes as given along with τ_H and τ_F. Summed over the sector, the rebate $\alpha_{S,i}\mathcal{T}_{S,i}$ equals the charge on its risky positions. The wedges therefore change portfolio choice at the margin but use up no resources. Differentiating the objective gives

$$\begin{aligned}0 &= \mathrm{ERP}_H - \gamma_S\Big(\sigma^2_{R,H}\theta_{S,i,H} + \sigma_{R,HF}\theta_{S,i,F}\Big) - \tau_H, \\ 0 &= \mathrm{ERP}_F - \gamma_S\Big(\sigma_{R,HF}\theta_{S,i,H} + \sigma^2_{R,F}\theta_{S,i,F}\Big) - \tau_F.\end{aligned} \tag{100}$$

Both groups of stockholders face the same wedge on each country's equity, regardless of where they reside. When $\sigma^2_{R,H}\sigma^2_{R,F} - \sigma^2_{R,HF} > 0$, solving these two conditions gives

$$\begin{aligned}\theta_{S,i,H} &= \frac{\sigma^2_{R,F}(\mathrm{ERP}_H - \tau_H) - \sigma_{R,HF}(\mathrm{ERP}_F - \tau_F)}{\gamma_S(\sigma^2_{R,H}\sigma^2_{R,F} - \sigma^2_{R,HF})}, \\ \theta_{S,i,F} &= \frac{\sigma^2_{R,H}(\mathrm{ERP}_F - \tau_F) - \sigma_{R,HF}(\mathrm{ERP}_H - \tau_H)}{\gamma_S(\sigma^2_{R,H}\sigma^2_{R,F} - \sigma^2_{R,HF})}, \qquad i \in \{H, F\}.\end{aligned} \tag{101}$$

Since stockholders also have the same risk aversion in both countries, their portfolio shares coincide: $\theta_{S,i,H} = \theta_{S,H}$ and $\theta_{S,i,F} = \theta_{S,F}$ for $i \in \{H, F\}$. Substituting these shares into equation (100) gives the market-pricing equations (28).

D.4 Stockholder financial wealth

Stockholders consume $C_{S,i} = m_{S,i}\mathcal{T}_{S,i}$, where

$$\begin{aligned}m_{S,i} = \delta_i + \frac{1}{\gamma_S}\Big\{\rho_{S,i} + (\gamma_S - 1)\Big[r + \theta_{S,i,H}\mathrm{ERP}_H + \theta_{S,i,F}\mathrm{ERP}_F \\ - \frac{\gamma_S}{2}\Big(\sigma^2_{R,H}(\theta_{S,i,H})^2 + 2\sigma_{R,HF}\theta_{S,i,H}\theta_{S,i,F} + \sigma^2_{R,F}(\theta_{S,i,F})^2\Big)\Big]\Big\}.\end{aligned} \tag{102}$$

Stockholders finance consumption from earnings and returns on their equity and bond positions. Their aggregate budget per person is

$$\dot{\mathcal{F}}_{S,i} = (r - n_i)\mathcal{F}_{S,i} + \mathcal{E}_{iH}\text{ERP}_H + \mathcal{E}_{iF}\text{ERP}_F + \pi_{S,i}W_i - C_{S,i}. \tag{103}$$

We write equity holdings as $\mathcal{E}_{iH} = \mathcal{T}_{S,i}\theta_{S,i,H}$ and $\mathcal{E}_{iF} = \mathcal{T}_{S,i}\theta_{S,i,F}$, total wealth as $\mathcal{T}_{S,i} = \mathcal{F}_{S,i} + \mathcal{H}_{S,i}$, and consumption as $C_{S,i} = m_{S,i}\mathcal{T}_{S,i}$, with $m_{S,i}$ given by equation (102). Substituting these expressions into the budget and setting the drift to zero gives

$$0 = (r - n_i)\mathcal{F}_{S,i} + (\theta_{S,i,H}\text{ERP}_H + \theta_{S,i,F}\text{ERP}_F)(\mathcal{F}_{S,i} + \mathcal{H}_{S,i}) + \pi_{S,i}W_i - m_{S,i}(\mathcal{F}_{S,i} + \mathcal{H}_{S,i}). \tag{104}$$

Using $\pi_{S,i}W_i = (r + \chi_i + \delta_i)\mathcal{H}_{S,i}$, we collect the terms in financial and human wealth:

$$0 = -[m_{S,i} + n_i - r - \theta_{S,i,H}\text{ERP}_H - \theta_{S,i,F}\text{ERP}_F]\mathcal{F}_{S,i} + [r + \chi_i + \delta_i - m_{S,i} + \theta_{S,i,H}\text{ERP}_H + \theta_{S,i,F}\text{ERP}_F]\mathcal{H}_{S,i}. \tag{105}$$

Solving for $\mathcal{F}_{S,i}$ yields

$$\mathcal{F}^*_{S,i} = \mathcal{H}_{S,i}\frac{r + \chi_i + \delta_i - m_{S,i} + \theta_{S,i,H}\text{ERP}_H + \theta_{S,i,F}\text{ERP}_F}{m_{S,i} + n_i - r - \theta_{S,i,H}\text{ERP}_H - \theta_{S,i,F}\text{ERP}_F}. \tag{106}$$

With $\gamma_S = 1$, $m_{S,i} = \rho_{S,i} + \delta_i$. In our calibration, financial wealth is small relative to human wealth and responds strongly to changes in the denominator. A lower safe rate reduces the return on wealth by more than it reduces $m_{S,i}$ when $\gamma_S > 1$, lowering stockholder financial wealth through the channel described in Section 5.3. Direct equity positions follow from $\mathcal{E}_{iH} = \mathcal{T}_{S,i}\theta_{S,i,H}$ and $\mathcal{E}_{iF} = \mathcal{T}_{S,i}\theta_{S,i,F}$. The stockholder bond position then follows from equation (22).

D.5 Stockholder bond positions and issuer leverage

The stockholder bond position $\mathcal{B}_{S,i}$ is negative when stockholders borrow. Financial wealth is the value of equity holdings plus this bond position:

$$\mathcal{F}_{S,i} = \mathcal{E}_{iH} + \mathcal{E}_{iF} + \mathcal{B}_{S,i}. \tag{107}$$

We consider equilibria with $\mathcal{B}_{S,i} \leq 0$ and $\mathcal{F}_{S,i} > 0$. Dividing by financial wealth and rearranging gives

$$\frac{\mathcal{E}_{iH} + \mathcal{E}_{iF}}{\mathcal{F}_{S,i}} = 1 - \frac{\mathcal{B}_{S,i}}{\mathcal{F}_{S,i}} \equiv \mathcal{L}_{S,i}. \tag{108}$$

Taking a differential gives

$$d\mathcal{L}_{S,i} = -\frac{d\mathcal{B}_{S,i}}{\mathcal{F}_{S,i}} + \frac{\mathcal{B}_{S,i}}{(\mathcal{F}_{S,i})^2}\, d\mathcal{F}_{S,i}, \tag{109}$$

and the issuer wedge changes according to

$$d\tau_i = \psi_i\, d\mathcal{L}_{S,i}. \tag{110}$$

Leverage rises when borrowing, measured by $-\mathcal{B}_{S,i}$, increases relative to stockholder financial wealth. Higher leverage then raises the wedge and the return required to hold that issuer's equity. Both countries have nearly the same cost of leverage in our calibration, so differences in the wedge part of the premium response largely reflect changes in their balance sheets.

D.6 Tree prices and market clearing

Under our stationary valuation assumption, a tree with dividend D_j and price P_j per person has expected total return $D_j/P_j + n_j$, because its aggregate dividend grows with the issuing population. Its expected excess return is ERP_j, so

$$\frac{D_j}{P_j} + n_j = r + \mathrm{ERP}_j, \tag{111}$$

which gives equation (29). There is one unit of each tree per resident of the issuing country, giving the equity-clearing condition in equation (25). Summing the safe positions of the four household sectors, weighted by initial output shares, gives world bond clearing in equation (26).

Country i's net external bond position is $\mathcal{B}_{N,i} + \mathcal{B}_{S,i}$. Home's net foreign assets per resident then equal its net external bond position plus foreign equity held at Home, less Home equity held abroad:

$$\mathrm{NFA}_H = \mathcal{B}_{N,H} + \mathcal{B}_{S,H} + \mathcal{E}_{HF} - \frac{Y_F}{Y_H}\mathcal{E}_{FH}. \tag{112}$$

World bond clearing and the two equity-market conditions imply $\frac{Y_H}{Y}\mathrm{NFA}_H + \frac{Y_F}{Y}\mathrm{NFA}_F = 0$.

Summing the four household zero-drift conditions, weighted by the initial output

shares, gives

$$
\begin{aligned}
0 = \sum_i \frac{Y_i}{Y}\Big[&(r - n_i)(\mathcal{B}_{N,i} + \mathcal{B}_{S,i}) \\
&+ (r - n_i + \mathrm{ERP}_H)\mathcal{E}_{iH} + (r - n_i + \mathrm{ERP}_F)\mathcal{E}_{iF} \\
&+ W_i - C_{S,i} - C_{N,i}\Big].
\end{aligned} \tag{113}
$$

Using bond clearing, equity clearing, and $P_j(r + \mathrm{ERP}_j - n_j) = D_j$, the asset-income terms reduce to $\sum_j \frac{Y_j}{Y} D_j - \sum_i \frac{Y_i}{Y} n_i \mathrm{NFA}_i$. Hence

$$
\sum_i \frac{Y_i}{Y}(C_{S,i} + C_{N,i}) = \sum_i \frac{Y_i}{Y} y_i - \sum_i \frac{Y_i}{Y} n_i \mathrm{NFA}_i. \tag{114}
$$

This identity underlies the goods-market residual discussed in Section 5. Goods markets clear exactly when the countries have equal population growth rates or zero net foreign assets. Otherwise, the final term measures the gap in world goods-market clearing for these stationary comparisons, reported in Section 5.3.

D.7 Calibration

We target the initial safe rate, both equity premia, and both market-capitalization ratios. With output per person normalized to one, the market-value target $\underline{P}_i/\underline{y}_i$ and the valuation equation (29) determine the dividend and wage per person:

$$
D_i = \underline{P}_i\,(\underline{r} + \underline{\mathrm{ERP}}_i - \underline{n}_i), \qquad W_i = 1 - D_i. \tag{115}
$$

The fixed output shares are Y_H/Y for Home and $Y_F/Y = 1 - Y_H/Y$ for Foreign. These wage and dividend flows per person remain fixed after the demographic change.

Home's net external bond, NFA, and nonstockholder bond-holdings targets determine its initial stockholder balance sheet. The bond target is $\underline{\mathcal{B}}_{N,H} + \underline{\mathcal{B}}_{S,H} = -0.45\underline{y}_H$. Nonstockholder bond holdings of $0.60\underline{y}_H$ therefore imply $\underline{\mathcal{B}}_{S,H} = -1.05\underline{y}_H$. The initial equity portfolio of Home stockholders satisfies

$$
\begin{aligned}
\underline{\mathcal{E}}_{HH} + \underline{\mathcal{E}}_{HF} &= \underline{P}_H + \underline{\mathrm{NFA}}_H - \left(\underline{\mathcal{B}}_{N,H} + \underline{\mathcal{B}}_{S,H}\right), \\
\underline{\mathcal{F}}_{S,H} &= \underline{\mathcal{E}}_{HH} + \underline{\mathcal{E}}_{HF} + \underline{\mathcal{B}}_{S,H} = \underline{P}_H + \underline{\mathrm{NFA}}_H - \underline{\mathcal{B}}_{N,H}.
\end{aligned} \tag{116}
$$

These targets give $\underline{\mathcal{F}}_{S,H}/\underline{y}_H = 0.90$. Initial Home leverage is $\underline{\mathcal{L}}_{S,H} = 1 - (-1.05)/0.90 = 2.17$.

Because both stockholder groups hold the same portfolio shares, Home's share of

world equity equals its share of world stockholder total wealth. World stockholder total wealth per world resident is therefore

$$\underline{\mathcal{T}}_{S,W} = \underline{\mathcal{T}}_{S,H}\,\frac{\Upsilon_H \underline{P}_H + \Upsilon_F \underline{P}_F}{\Upsilon\left(\underline{\mathcal{E}}_{HH} + \underline{\mathcal{E}}_{HF}\right)}, \qquad \underline{\mathcal{T}}_{S,H} = \underline{\mathcal{F}}_{S,H} + \underline{\mathcal{H}}_{S,H}. \tag{117}$$

Foreign stockholder total wealth follows from $\underline{\mathcal{T}}_{S,F} = (\Upsilon \underline{\mathcal{T}}_{S,W} - \Upsilon_H \underline{\mathcal{T}}_{S,H})/\Upsilon_F$. Subtracting human wealth gives financial wealth, $\underline{\mathcal{F}}_{S,F} = \underline{\mathcal{T}}_{S,F} - \underline{\mathcal{H}}_{S,F}$. The common portfolio shares follow from Section 4.5, giving equity holdings $\underline{\mathcal{E}}_{ij} = \underline{\mathcal{T}}_{S,i}\underline{\theta}_{S,j}$. We then obtain stockholder bond positions from equation (22). World bond clearing determines Foreign nonstockholder bond holdings:

$$\underline{\mathcal{B}}_{N,F} = -\frac{\Upsilon_H \underline{\mathcal{B}}_{S,H} + \Upsilon_F \underline{\mathcal{B}}_{S,F} + \Upsilon_H \underline{\mathcal{B}}_{N,H}}{\Upsilon_F}. \tag{118}$$

At these targets, both stockholder groups have negative bond positions, positive financial wealth, and positive holdings of both trees.

We identify each issuer slope from the part of its initial premium attributable to the leverage wedge:

$$\begin{aligned} \psi_H &= \left[\underline{\mathrm{ERP}}_H - \gamma_S(\sigma^2_{R,H}\underline{\theta}_{S,H} + \sigma_{R,HF}\underline{\theta}_{S,F})\right]\frac{\underline{\mathcal{F}}_{S,H}}{-\underline{\mathcal{B}}_{S,H}}, \\ \psi_F &= \left[\underline{\mathrm{ERP}}_F - \gamma_S(\sigma_{R,HF}\underline{\theta}_{S,H} + \sigma^2_{R,F}\underline{\theta}_{S,F})\right]\frac{\underline{\mathcal{F}}_{S,F}}{-\underline{\mathcal{B}}_{S,F}}. \end{aligned} \tag{119}$$

The targets imply $\psi_H = 0.0306$ and $\psi_F = 0.0308$.

Finally, the initial stockholder budgets identify the discount rates. The consumption–wealth ratio required for stationary financial wealth is

$$\underline{m}_{S,i} = \frac{(\underline{r} - \underline{n}_i)\underline{\mathcal{F}}_{S,i} + \underline{\mathcal{E}}_{iH}\underline{\mathrm{ERP}}_H + \underline{\mathcal{E}}_{iF}\underline{\mathrm{ERP}}_F + \pi_{S,i}W_i}{\underline{\mathcal{T}}_{S,i}}, \tag{120}$$

and inverting equation (102) gives

$$\begin{aligned} \rho_{S,i} = \gamma_S(\underline{m}_{S,i} - \underline{\delta}_i) - (\gamma_S - 1)\Big[&\underline{r} + \underline{\theta}_{S,H}\underline{\mathrm{ERP}}_H + \underline{\theta}_{S,F}\underline{\mathrm{ERP}}_F \\ &- \frac{\gamma_S}{2}\left(\sigma^2_{R,H}(\underline{\theta}_{S,H})^2 + 2\sigma_{R,HF}\underline{\theta}_{S,H}\underline{\theta}_{S,F} + \sigma^2_{R,F}(\underline{\theta}_{S,F})^2\right)\Big]. \end{aligned} \tag{121}$$

Equations (95) and (96) determine the nonstockholder discount rates. Table 16 reports these parameters. We hold all calibrated coefficients fixed throughout the demographic experiment.

Table 16: Calibrated parameters in the stationary two-country model

Derived parameter	Home	Foreign
Wage per person	0.89	0.93
Dividend per person	0.11	0.07
Stockholder discount rate (%)	7.62	7.61
Nonstockholder discount coefficient (%)	13.97	14.24
Initial issuer wedge (%)	3.56	2.70
Slope ψ_i	0.0306	0.0308

D.8 Longevity and slower population growth

Our longevity experiment lowers mortality in country i so that expected remaining life increases by ℓ_i years, with $\ell_H = 1.30$ and $\ell_F = 4.77$. We raise the rate of earnings decline by the same amount as mortality falls, so that the additional years of life are spent in retirement:

$$\delta_i^L = \left(\frac{1}{\underline{\delta}_i} + \ell_i\right)^{-1}, \qquad \chi_i^L = \underline{\chi}_i + \underline{\delta}_i - \delta_i^L. \tag{122}$$

The sum $\chi_i + \delta_i$ is unchanged, so the survival-adjusted duration of earnings remains $1/(\underline{\chi}_i + \underline{\delta}_i)$. The retirement-duration gap therefore increases by exactly ℓ_i years. Population growth is unchanged in the longevity-only step, $n_i^L = \underline{n}_i$. In the second step it falls to $\overline{n}_i$, while mortality and earnings decline remain at their longevity-only values: $\overline{\delta}_i = \delta_i^L$ and $\overline{\chi}_i = \chi_i^L$. Wage bills and dividend flows per person stay fixed in both countries.

At a given safe rate, fixing the duration of earnings would keep human wealth constant. Here, however, the safe rate is an equilibrium outcome, and its change between the initial and final equilibria revalues the earnings stream according to

$$\frac{\overline{\mathcal{H}}_{k,i}}{\underline{\mathcal{H}}_{k,i}} = \frac{\underline{r} + \underline{\chi}_i + \underline{\delta}_i}{\overline{r} + \underline{\chi}_i + \underline{\delta}_i}, \qquad k \in \{S, N\}. \tag{123}$$

In our quantitative experiment, the decline in the safe rate raises Foreign human wealth by 4.93 percent after the longevity change and by 10.16 percent over both steps.

Under the age–earnings normalization in Appendix C, entry wages are proportional to $(\chi_i + \delta_i + n_i)/(\delta_i + n_i)$. In Foreign they rise by 5.42 and 26.41 percent after the first and second steps, respectively, while average wages per person remain fixed. Earnings per person and their survival-adjusted duration are thus the same in every equilibrium, whereas their distribution across cohorts and their equilibrium present value are free to change. We report all stocks per country resident, in units of own output, which does not

change across equilibria.

D.9 Decomposing the change in risk premia

Each premium moves through the issuer's leverage wedge and through the allocation of risk across stockholder portfolios. Differencing the market-pricing equations between any two stationary equilibria gives

$$\begin{aligned}\Delta \mathrm{ERP}_H &= \Delta\tau_H + \gamma_S\Big(\sigma^2_{R,H}\Delta\theta_{S,H} + \sigma_{R,HF}\Delta\theta_{S,F}\Big),\\ \Delta \mathrm{ERP}_F &= \Delta\tau_F + \gamma_S\Big(\sigma_{R,HF}\Delta\theta_{S,H} + \sigma^2_{R,F}\Delta\theta_{S,F}\Big).\end{aligned} \tag{124}$$

The first term is the leverage channel. The other terms reflect changes in aggregate risky allocation, weighted by stockholder risk aversion and the relevant return variance or covariance; these moments are held fixed, so there is no contribution from changes in them. Because the decomposition follows from market clearing, its contributions sum exactly to the change in each premium. Table 7 gives the total premium changes for each step and for the two steps combined.

D.10 Numerical solution

We solve for five unknowns: the safe rate, both tree prices, and financial wealth in each stockholder sector. Two market-pricing conditions, two stationary stockholder budgets, and world bond clearing determine them. The common portfolio shares impose equity clearing, and nonstockholder bond holdings follow from the stationary saving rule. We vary the demographic parameters gradually to connect the initial solution to the longevity-only equilibrium and then to the equilibrium with slower population growth, holding financial parameters and resources per person fixed.

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