LUKASZ RACHEL
University College London

What Next for r^*? A Capital Market Equilibrium Perspective on the Natural Rate of Interest

ABSTRACT The natural rate of interest (r^*) is a central benchmark for monetary and fiscal policy, shaping decisions by firms and households across the economy. In advanced economies, r^* declined steadily for half a century, but the recent sharp increases in market-based real rates have raised the prospect of a turnaround. This paper revisits the long-run decline in real rates through a structural model in which r^* equilibrates the supply and demand in the capital market. I show that advanced economies have undergone profound shifts in both capital demand and—especially—capital supply, driving a fall in r^* of about 5 percentage points and nearly doubling the wealth-to-GDP ratio since 1970, despite weak investment and low saving. To trace the dynamics, I construct a limited foresight transition in which agents notice and understand the shocks hitting the economy only as they arrive. I argue this is a more plausible alternative to the usual perfect foresight assumption. The model's business-as-usual scenario computed this way implies r^* of around 0–1.2 percent today and points to a small gentle decline over the years to come. But r^* could instead rise, due to new forces such as artificial intelligence, deglobalization, or a persistent fall in the safety premium following the recent inflation episode. The model is capable of generating a sharp turnaround in the path for the natural rate, but for r^* to return to pre-2008 levels, several upside risks to r^* likely need to crystallize all at once.

Conflict of Interest Disclosure: The Brookings Institution is committed to quality, independence, and impact. Brookings is supported by a diverse array of funders. In line with the Brookings values and policies, each Brookings publication represents the sole views of its author(s).

Brookings Papers on Economic Activity, Fall 2025: 131–187 © 2026 The Brookings Institution.

How high will the costs of financing government debt be over the long term? What will mortgages cost in the future, and how will this affect house prices? What is the opportunity cost of capital investment? How will asset valuations evolve?

None of these questions—critical to the decision-making of central bankers, finance ministers, households, firms, and financial market participants—can be answered without forming a view on the natural rate of interest, or r^*. Up until recently, interest rates have been trending down for three decades, and a large literature has studied the causes and consequences of this decline, ascribing much of it to the fall in the natural rate. Over the same period, the value of accumulated wealth in relation to income has nearly doubled, despite subdued saving and investment flows.

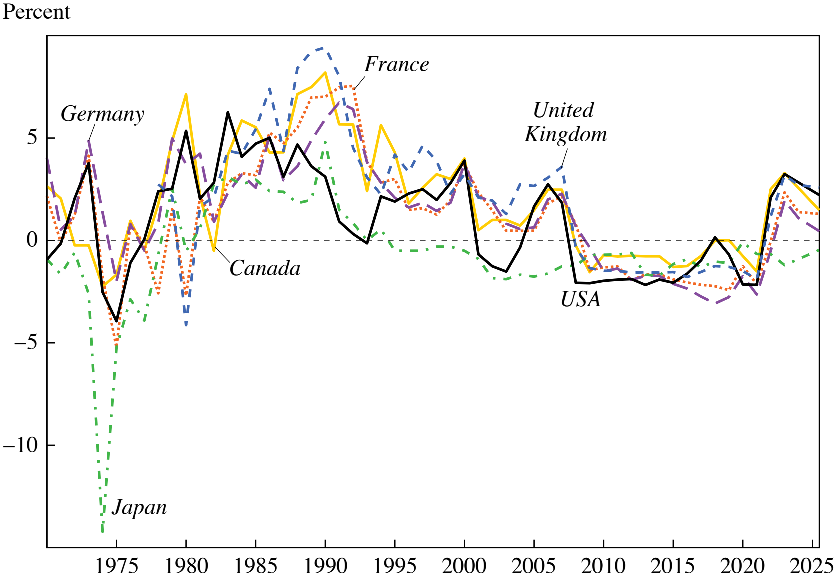
Recently, this long-running trend came to a sharp end: Since the post-COVID inflation, long-term real interest rates in financial markets have risen sharply, often by as much as the short-term policy rates (figure 1), suggesting that the markets price in the possibility that higher interest rates will be the new normal. This paper constructs a framework for understanding the joint dynamics of r^* and the wealth-to-GDP ratio in the advanced economy (AE) bloc centered on capital market equilibrium, and assesses the possibility that the era of low and falling r^*—which Summers (2015) describes as secular stagnation—has come to an end.

At the core of the analysis is a general equilibrium model of a macroeconomy, which is able to capture many of the most important trends relevant for saving and investment decisions discussed in the literature. These forces include: the changing outlook for future living standards, population and demographic dynamics, shifts in market power and risk premia, technological shifts in capital depreciation rates and capital intensity of production, changes in government fiscal and social policies, and fluctuations in foreign demand for AE assets. The goal of studying these phenomena jointly is to establish a unified and quantitatively plausible narrative to the absolute and relative influences over the past, and the likely decisive drivers in the future. The advantage of doing so through the lens of the capital market equilibrium is that this imposes additional discipline: The narrative must reconcile not only the decline in r^* but also the doubling of the wealth-to-GDP ratio over the same period as well as subdued net saving rates and net investment-to-GDP ratios.[1]

1. There are several concepts for the natural rate, and it is useful to be clear up front about the ones that are studied here. The various r^*'s differ in the horizon in question (short-term/business cycle versus medium-run versus long-run/steady state), risk characteristics

Figure 1. Real Interest Rates and Wealth-to-Income Ratios in Selected AEs

Panel A: Policy rates



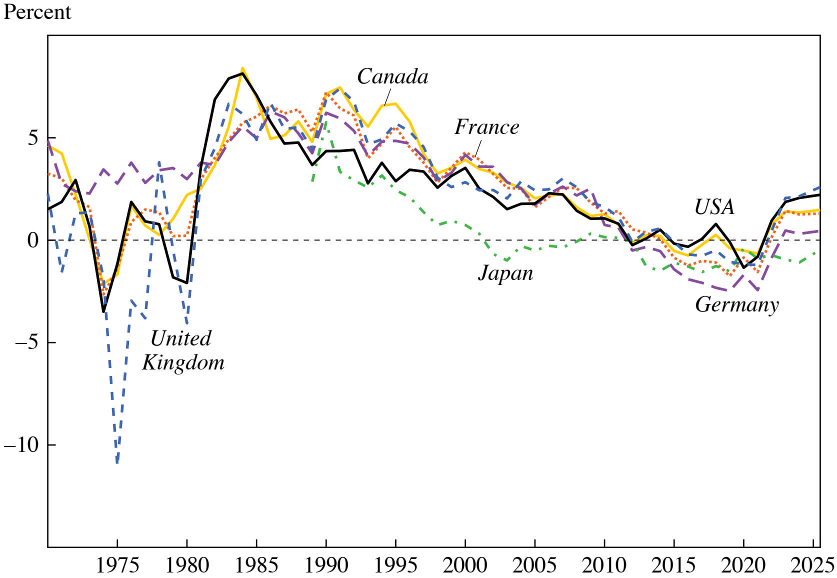
(*continued on next page*)

I proceed in four steps: First, within the general equilibrium model I write down, I characterize the steady-state equilibrium in the capital market as the intersection of the long-run capital demand and supply curves. Second, I show how these curves looked around 1970 in the industrialized economies, how they have changed, and why. Having described the corresponding steady states, I compute the full transition path between them, pinning down the level of r^* today as well as the future path in the business-as-usual scenario, and decomposing the dynamics into the various exogenous

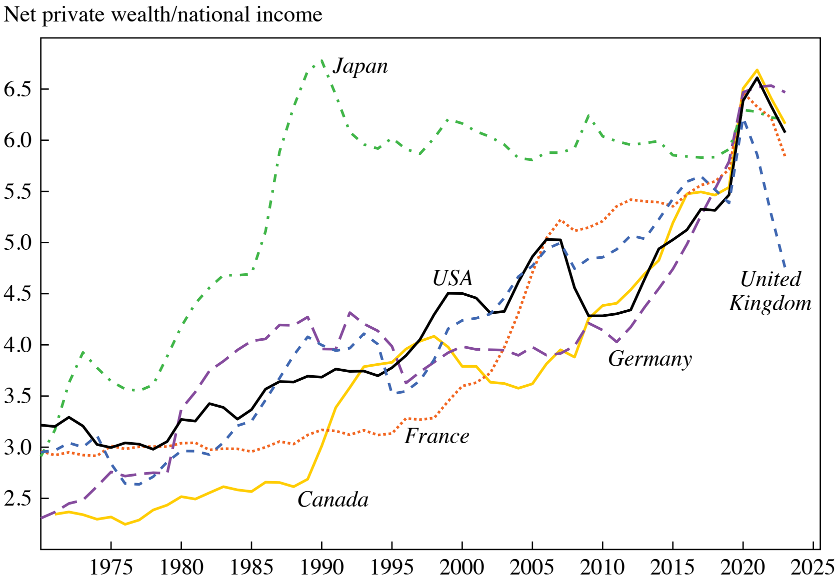
(safe versus risky versus effective, or weighted), or geography (global, regional, or country-level). In this paper, r^* stands for the medium-to-long-term safe real rate of interest, which is quantified for the AE bloc. This is the equilibrium interest rate that, on the one hand, abstracts from nominal rigidities (and so is applicable at frequencies lower than a business cycle) but, on the other hand, moves in response to real, or structural, changes to the economic environment. Once all structural changes work their way through the economy, r^* settles at its steady-state value. Below I also characterize the risky natural rate of interest and the weighted combination of the two returns.

Figure 1. Real Interest Rates and Wealth-to-Income Ratios in Selected AEs (*Continued*)

Panel B: Ten-year government yields



Panel C: Wealth-to-income ratios in AEs



Source: World Inequality Database and International Monetary Fund (IMF) World Economic Outlook.

Note: Real interest rates in panels A and B are constructed as follows: From 1991 onward, real rates are the corresponding nominal rates minus the five-year-ahead IMF World Economic Outlook inflation forecast. Prior to 1991, actual inflation outturns are used. Panel C shows the ratio of net private wealth to national income from the World Inequality Database.

drivers. Finally, motivated by the recent market moves, I quantify the impact of six common upside risk narratives popular among the commentators—deglobalization, remilitarization, artificial intelligence (AI), intangibles, debt-fueled rise in social security, and persistent inflation risk—to see whether any or all of them together can plausibly generate a sharp turnaround in the natural rate.

The capital demand–capital supply framework provides a very useful way of understanding the economics, and quantitative effects, of the structural shifts that took place in the industrialized world over the past fifty years, and as such lets us go beyond the purely numerical results in the literature.[2] Specifically, I explain why some of the forces move only one of the schedules, while others shift both, and why some of the drivers shift the schedules only horizontally, while others move them vertically too. Conceptually, the framework is useful for reconciling the flow-based (saving/investment) intuitions with the stocks-based (wealth/capital) approach, as elegantly shown by Auclert, Malmberg, Martenet, and Rognlie (2025). Moreover, because I use quantified, model-based schedules and not just a stylized representation, I am able to take account of the nonlinearities (which are behind the sometimes mysterious but quantitatively significant interaction effects between the various forces). Furthermore, I show that the elasticities of the capital demand and supply schedules are time-varying and respond to the structural shifts, providing a cautionary tale for approaches that rely on fixed slope estimates to calculate the equilibrium impact of exogenous shifts.

I find that the structural changes have led to large shifts in the two schedules, and especially in the capital supply schedule $S(r)$.[3] As a result, the model-implied steady-state safe r^* has fallen from about 5 percent in the 1970 steady state to essentially 0 percent in the new long-run steady state. The model generates a large increase in the steady-state wealth, from three to more than six times the annual GDP, while at the same time predicting lower steady-state net investment and saving rates.

2. The capital demand schedule $D(r)$ tells us the aggregate capital absorption by firms and government at any interest rate r in the long run. The capital supply schedule $S(r)$ instead answers the following question: What would the value of aggregate wealth accumulated by households (relative to income) in the long run be if the interest rate was equal to r?

3. I also find that the capital demand schedule has steepened, and the capital supply schedule has flattened. However, measured at the respective steady states, both schedules are more elastic (flatter) at the long-run (2050) steady state as compared to the 1970 steady state.

In order to give a steer on r^* at any given point in time (not least to answer the question: What is r^* right now?), research on r^* must go beyond steady-state analysis and consider the transition between steady states. This is because the forces shifting the equilibrium arrive gradually and unexpectedly, and the adjustment of the economy is not instantaneous (and may be nonmonotonic). The literature that computes transitions usually relies on perfect foresight. But this assumes that agents perfectly foresee the entire path of future shocks—for example, agents anticipate and react to a growth slowdown long before it occurs. A common result is a smooth and monotonic path for r^* that might not be entirely plausible. A contribution of this paper is to compute transitional dynamics under the more realistic assumption that agents have limited foresight and are surprised by new shocks that arrive over time.[4] I show that computing the transition this way makes a (quantitatively significant) difference to the estimate of r^*: Specifically, r^* declines faster than under perfect foresight.

In what I call the business-as-usual scenario (i.e., without taking into account any of the recently debated forces that could drive a turnaround), safe real r^* in 2025 in AEs stands at around 0.6 percent. Caution is warranted: The point estimate is highly uncertain and sensitive to the precise calibration. Reflecting these sensitivities, it might be more helpful and robust to think of the model as predicting a range for current r^*, between 0 percent and 1.2 percent (and even around this range there is a lot of uncertainty).

A decomposition of the dynamics of r^* along the transition shows, unsurprisingly, the important role played by the growth slowdown and demographics. More novel, the framework illustrates the importance of the rise in markups, which temporarily depresses r^* before pushing it up, and of the rising risk premia, which push down on safe r^* close to one to one. I also provide a decomposition of the rise in the wealth-to-GDP ratio, where the longer expected retirement and slower growth emerge as dominant (while the rise in the risk premium plays essentially no role).

A reasonably robust prediction of the model is that r^* has fallen by less than the government bond yields in the period immediately before the COVID-19 pandemic. Viewed through that lens, some (perhaps a half) of the recent spike in yields can be seen as a correction. Nonetheless, the

4. Technically speaking, along the limited foresight transition path, the agents in the economy experience a sequence of MIT shocks. In other words, they make expectational errors.

current long-term real yields stand above the baseline r^* estimate, suggesting that r^* may be higher than the business-as-usual scenario considered thus far.

In the final part of the paper, I take seriously the possibility that seems to be reflected in the bond markets, namely, that some new shifts in the environment have acted to raise the natural rate sharply higher. Rather than providing a definite view of the magnitudes of risks and their probabilities (a task beyond the scope of this paper!), the idea behind this exercise is to provide a mapping between quantitative assumptions underlying these scenarios and the impact on r^*. Such mapping might help policymakers and practitioners form their own view of the central case for r^* and the risks around it.

I find that AI and inflation risk scenarios are most powerful quantitatively, each raising r^* by about 1 percentage point. In addition, the heightened inflation risk raises the safe rate very quickly, while the effects of an AI-driven growth boom build up over several years.

Several other scenarios can prevent the gentle decline in real rates predicted in the business-as-usual scenario. At the same time, for real rates to go back to pre–global financial crisis (GFC) levels, several of the scenarios would need to materialize all at once (or individual shifts would need to be even more powerful than assumed here).

LITERATURE AND CONTRIBUTION My paper relates to several strands of the literature on the determinants of the natural rate of interest. One approach, following Laubach and Williams (2003) and Holston, Laubach, and Williams (2017), is semistructural: r^* is inferred from a representative-agent Euler equation through empirical filtering methods. The logic behind these estimates is that, if the observed interest rate has declined but inflation remains stable, it must be that the natural rate has fallen. These exercises point to long-run shifts in trend growth and the residual component z_t capturing other forces as the main driver of r^*. This approach is very distinct from the one pursued in this paper, although one common challenge is how to pin down the level of r^*. Holston, Laubach, and Williams (2017) pin down the level by equating it to their prior estimate of trend growth at the start of the sample.[5] I follow a calibration strategy where I target the wealth-to-GDP ratio in the 1970s steady state. Both approaches

5. Specifically, Holston, Laubach, and Williams (2017) initialize the random walk component z_t at zero; see footnote 6 in their paper.

yield broadly consistent answers, suggesting r^* of around 4–5 percent at that time.

A second strand of the literature, much closer to this paper, embeds richer household heterogeneity and demographic structure to study the determinants of the natural rate. Several papers use rich overlapping generation models to study the shifting age composition and its impact on r^* (Carvalho, Ferrero, and Nechio 2016; Gagnon, Johannsen, and Lopez-Salido 2021; Lisack, Sajedi, and Thwaites 2017; Auclert, Malmberg, Martenet, and Rognlie 2025). This paper follows the tradition of using a tractable overlapping generations (OLG) setup pioneered by Blanchard (1985) and Gertler (1999) and used recently in Rachel and Summers (2019a). It is closest to the papers that consider many of the drivers of r^* jointly to assess the relative quantitative importance of each factor as well as their ability to jointly account for the decline (Eggertsson, Mehrotra, and Robbins 2019; Peruffo and Platzer 2024; Rachel and Summers 2019b). The present paper incorporates a comprehensive set of factors relevant for r^*. However, one trend that is not modeled here is the rise in inequality, which may have led to a decline in r^* in the region of 1 percentage point over the past thirty years (Straub 2019; Peruffo and Platzer 2024; Auclert, Malmberg, Rognlie, and Straub 2025).

Several papers have used an explicit capital equilibrium representation to study r^*, although details vary. Rachel and Smith (2015) use a flow-based desired saving–desired investment setting to consider how the shifts in both curves imply a fall in r^* and a broadly constant gross investment and saving ratios. Moll, Rachel, and Restrepo (2022) develop a general equilibrium model where capital demand and capital supply have a closed-form representation; they use it to study the implications of equilibrium movements in returns (driven, in this case, by automation) for inequality. Auclert, Malmberg, Martenet, and Rognlie (2025) use the estimates of the elasticities of the steady-state demand and supply schedules and apply a sufficient statistics approach to infer the impact of the demographic shifts.

A contribution that is closest to mine is the contemporaneous paper of Auclert, Malmberg, Rognlie, and Straub (2025). Just as I do here, that paper uses a long-run equilibrium framework to study multiple drivers of the capital market equilibrium, including demographics, labor share, productivity growth, social security, and markups, and what they imply for wealth-to-GDP ratio and returns. The precise focus of the two papers is different, however; while Auclert, Malmberg, Rognlie, and Straub (2025) focus on the relative importance of asset demand and asset supply shifts and on fiscal sustainability questions, my main goal is to study the dynamics of r^*. The two papers are highly complementary. Auclert, Malmberg, Rognlie, and Straub (2025) use a sufficient statistics approach, utilizing the estimates of (semi-)elasticities of the asset demand and asset supply schedules to decipher the impact of the structural shifts in both curves on the wealth-to-GDP ratio and the steady-state natural rate. I follow a different route, namely, computing the schedules and their shifts directly using a general equilibrium model. This allows me to present the full set of shifts of these curves and highlight the importance of interactions between various forces given the inherent nonlinearity of the framework. In addition, I show that not only the curves shift but also their slopes change as a result of the shocks I consider. Another area of complementarity is that Auclert, Malmberg, Rognlie, and Straub (2025) use a model with a more detailed life cycle structure able to match the age-wealth profiles, while the present paper simplifies the demographic structure and utilizes the resulting tractability to study nonlinearities and compute the realistic, limited foresight transition path between steady states. Finally, Auclert, Malmberg, Rognlie, and Straub (2025) focus on the United States, while I collect data and calibrate my model to the AE bloc.

While the two papers use the same representation of the long-run equilibrium—the crossing point between two schedules—they follow different conventions in how they label these schedules. Auclert, Malmberg, Rognlie, and Straub (2025) label the upward-sloping schedule "asset demand" and the downward-sloping schedule "asset supply." This tradition follows the literature that began with Caballero (2006) and includes the important contributions of Caballero, Farhi, and Gourinchas (2008, 2017). In this tradition, the word *asset* is used from the perspective of households' balance sheets. These assets are supplied by firms (e.g., in the form of claims to future profits such as stocks) or governments (in the form of government bonds). In this paper I instead refer to the upward-sloping curve as "capital supply" and to the downward-sloping curve as "capital demand." This naming convention goes back to the neoclassical growth model, in which the equation $MPK = r + \delta$ is the downward-sloping capital demand schedule, and in which infinite lives result in an infinitely elastic capital supply. This convention is also tied to Aiyagari's (1994) heterogeneous agents tradition. Of course, both conventions are equally valid.

An important literature that this paper builds on examines global developments in r^* and the convergence of interest rates across countries (e.g., Del Negro and others 2019). Another related literature distinguishes between multiple natural rates depending on risk premia (Del Negro and others 2017; Farhi and Gourio 2018) or the macro-level financial stability implications (Akinci and others 2023). The distinction between safe, risky, and effective rates is important for interpreting the widening spread between government yields and average returns on capital (Rachel and Smith 2015; Reis 2021, 2022; Moll, Rachel, and Restrepo 2022) and motivates the inclusion of the risk premium as one of the driving forces in this paper.

Finally, by considering the upside risk scenarios beyond the business-as-usual projection, this paper connects to the recent literature that studies the potential game changers for r^*, which have become a focal point in the last few years since the pandemic. Obstfeld (2025) is a timely survey, and important examples include Ambrosino, Chan, and Tenreyro (2026) and Mehrotra and Waugh (2025) who study the impact of trade fragmentation and trade wars on r^*, and Mehrotra (2025) who considers the impact of transition to net zero carbon emissions.

ROAD MAP The rest of the paper proceeds as follows. Section I gives an overview of the model, with further details provided in the online appendix. Section II develops the capital demand-supply representation of the steady-state equilibrium and quantifies this framework for the 1970 steady state. Section III describes the calibration of the exogenous shifts, and section IV quantifies the impact of these shifts on the long-run schedules and thus characterizes the new long-run steady state in the business-as-usual scenario. Section V studies the transition between the two steady states. Section VI decomposes movements in r^* and the wealth-to-GDP ratio into the exogenous drivers in the business-as-usual scenario. Section VII presents the six risk scenarios and studies their quantitative impact on r^*. Section VIII concludes.

I. Model

I.A. High-Level Overview

The model of this paper builds closely on the important contribution of Gertler (1999), who in turn builds on Blanchard (1985) to construct a tractable model of the life cycle. This framework assumes only two stages of life, work and retirement, with a constant probability of becoming a retiree. The model remains highly tractable, permitting detailed analysis of the dynamics and nonlinearities, while at the same time capturing the essence of the incentives to save and dissave over a lifetime.

Importantly, Ricardian equivalence does not hold in this model—finite planning horizons induce households to discount the future at a higher rate than the government, which in turn means that tax-and-transfer policy, including redistribution across generations through the issuance of government debt, affects demand and hence the natural rate of interest.

Furthermore, the model offers a general equilibrium framework to study the macroeconomic impact of other important government policies, such as social security.

To account for the increase in the spread between government bond yields and risky returns (Moll, Rachel, and Restrepo 2022; Reis 2021), I assume that households' decisions are based on the weighted rate of return that combines the two rates, with an exogenous, time-varying premium between the return on government bonds and the risky return.[6] Following much of the literature, I refer to the rate on government securities as the *safe* rate of return, even if the actual returns on government bond portfolios are affected by a range of risks other than the credit risk.

I.B. Demographics and Preferences

There are two stages of life, work and retirement, with exogenous transition probabilities. That is, each worker (denoted with superscript w) faces a given probability of retirement $1 - \omega$, and, once a retiree (superscript r), a given probability of death $1 - \gamma$. Population grows at a gross rate $1 + n$.

Despite this parsimonious structure (which will pay off in terms of the model's tractability), the model can represent the demographic structure of an economy reasonably well. One can readily see that the expected durations of working life and retirement are given by $\frac{1}{1-\omega}$ and $\frac{1}{1-\gamma}$, and thus life expectancy (assuming individuals start working at age 20) is $20 + \frac{1}{1-\omega} + \frac{1}{1-\gamma}$. In a stationary equilibrium, the old-age dependency ratio—the number of retirees divided by the number of workers—is given by:[7]

$$\psi = \frac{1-\omega}{1-\gamma+n}. \tag{1}$$

6. I do not model the portfolio choice problem or the underlying risk or liquidity explicitly. See Reis (2021) or Angeletos and Panousi (2011) for examples of how to endogenize the risk premium. Auclert, Malmberg, Rognlie, and Straub (2025) provide an elegant microfoundation for the assumptions imposed here.

7. To see what this demographic structure implies for old-age dependency ratio, let N_t^r represent the number of retirees at time t. Under the demographic structure assumed here, we have $N_{t+1}^r = (1-\omega)\, N_t + \gamma N_t^r$ where N_t is the number of workers. Rearranging gives $\left(1+n\right)\frac{N_{t+1}^r}{N_{t+1}} = \left(1-\omega\right) + \gamma\frac{N_t^r}{N_t}$. Letting $\psi_t := \frac{N_t^r}{N_t}$ denote the old-age dependency ratio and imposing stationarity implies equation (1).

Thus, the dependency ratio is high when individuals retire relatively early in life, when retirement lasts long, and when population growth is low.

There is no aggregate risk; the only sources of uncertainty facing an individual are the risk of retirement while a worker (associated with a loss of labor income) and the risk of death while a retiree. Left unchecked, these sources of risk would affect agents' behavior. This would make aggregation problematic, and more importantly, it would be unrealistic: The timing of retirement is, for the most part, known. To neutralize this unrealistic feature, I assume that there are perfect annuity markets for the retirees (removing the influence of the risk of death on their behavior), and that workers' preferences have a certainty equivalence property (such that the risk of retirement does not affect workers' behavior in equilibrium).[8]

Specifically, I assume that agents have recursive Epstein-Zin preferences defined as follows (Epstein and Zin 1991):

$$V_t^z = \left[\left(C_t \right)^{\rho} + \beta^z \mathbb{E}_t \left\{ V_{t+1} \mid z \right\}^{\rho} \right]^{\frac{1}{\rho}}, \tag{2}$$

where C_t denotes consumption, V_t^z and β^z stand for agent's $z \in \{w, r\}$ value function and the discount factor, respectively, and $\sigma = \frac{1}{1-\rho}$ is the intertemporal elasticity of substitution.

Both retirees and workers make consumption-saving decisions to maximize their expected lifetime utility. I now outline the problems of the two types of agents.

I.C. Households

RETIREES Retirees consume out of savings and social security payments. Each period, some retirees die. I make the assumption—standard in the literature—that those who survive receive the proportional share of the proceeds (Blanchard 1985). This means that the effective gross return faced by individual retirees is $\frac{R_t}{\gamma}$, higher than the ongoing gross interest rate R_t.[9]

8. In particular, workers are assumed to have recursive Epstein-Zin preferences (Epstein and Zin 1991) that generate certainty-equivalent decision rules in the presence of income risk.

9. For retirees as a group, wealth accumulates at the interest rate R_t, as the higher individual return cancels out with some retirees dying.

Because the probability of death is independent of age and the government does not discriminate across retirees in its social security transfer policy, each retiree (irrespective of age) solves an identical problem, which is:

$$V_t^r = \max_{C_t^r}\left[\left(C_t^r\right)^{\rho} + \beta\gamma\mathbb{E}_t\left\{V_{t+1}^r\right\}^{\rho}\right]^{\frac{1}{\rho}},$$

subject to the flow budget constraint $A_{t+1}^r = \left(\frac{R_t}{\gamma}\right)A_t^r - C_t^r + E_t^r$, where A_t^r stands for retiree's assets, C_t^r is their consumption expenditure, and E_t^r is the social security payment.

WORKERS Individuals are born workers and have no financial assets at the start of life. They consume out of asset wealth and their labor income net of taxes. Because of the demographic structure (in particular the assumption that the probability of retirement is independent of age), the worker's problem is effectively the same no matter the age.[10] Each worker solves:

$$V_t^w = \max_{C_t^w}\left\{\left(C_t^w\right)^{\rho} + \beta\left[\omega V_{t+1}^w + \left(1-\omega\right)V_{t+1}^r\right]^{\rho}\right\}^{\frac{1}{\rho}},$$

subject to $A_{t+1}^w = R_t A_t^w + W_t - \tilde{T}_t - C_t^w$, where $\tilde{T}$ represents lump-sum tax/transfer.[11]

CONSUMPTION OF WORKERS AND RETIREES The key advantage of the tractable Blanchard-Yaari-Gertler setup employed here is that, for every

10. Clearly, this is an unrealistic assumption. But, as explained above, the effect of this assumption on workers' behavior is naturalized through the structure of preferences that exhibit a certainty equivalence property. The role of this assumption is thus only to simplify the model and achieve aggregation.

11. There are two key channels through which life cycle considerations affect workers' behavior. First, a worker takes into account the fact that with probability $1 - \omega$ they become a retiree. This means that, relative to the representative agent case, they discount the future stream of wages by more: Effectively, this is the *saving for retirement* effect. Mechanically, a larger discount rate reduces the value of human wealth in the consumption function, thus leading to lower consumption and higher saving. Second, a worker discounts the future stream of wealth more because they anticipate that inevitably there will come a time when they become a retiree, facing the sad truth that their life is finite. With finite life, wealth can be smoothed out across fewer periods, so its marginal utility value is lower. This effect shows up as a higher effective discount rate applied to future wealth.

household, individual consumption is a linear function of individual wealth (see online appendix for the derivation). In other words, within each of the two groups, individuals have identical marginal propensities to consume. This feature makes the model highly tractable, since it allows for a straightforward aggregation. For example, adding up individual retirees' consumptions, I obtain the aggregate consumption function of the retirees. With slight abuse of notation—denoting now by C_t^r, A_t^r, and so on, the aggregate variables—the aggregate consumption of all retirees and all workers in the economy is:

$$(3) \qquad C_t^r = \epsilon_t \pi_t \left(R_t A_t^r + S_t \right) \quad C_t^w = \pi_t \left(R_t A_t^w + H_t + S_t^w \right).$$

The term $\epsilon_t \pi_t$ is the marginal propensity to consume (MPC) of a retiree (the law of motion for this MPC is derived in the online appendix; see equation 19). Retiree consumption is simply the MPC multiplied by their wealth, which is composed of their financial wealth $R_t A_t^r$ and their social security wealth S_t.[12]

Analogously, workers' consumption is a linear function of their financial, human, and social security wealth.[13] Following Gertler (1999), I denote the MPC of workers with π_t, meaning that ϵ_t is the ratio of retiree-to-worker MPC. It is intuitive that $\epsilon > 1$—retirees spend down their wealth faster than workers, who are busy saving for retirement.

12. The latter is given by the discounted sum of social security payments: $S_t = \sum_{v=0}^{\infty} \frac{E_{t+v}}{\prod_{z=1}^{v} \left(1+n\right) R_{t+z} / \gamma}$. The aggregate pension payments are discounted with a gross interest rate adjusted upward on account of population growth (the same aggregate flow of social security payments is split more broadly) and on account of the likelihood of death.

13. The workers' human wealth is given by $H_t = \sum_{v=0}^{\infty} \frac{N_{t+v} W_{t+v} - \tilde{T}_{t+v}}{\prod_{z=1}^{v} \left(1+n\right) R_{t+z} \Omega_{t+z} / \omega}$. Human wealth is a discounted sum of the economy-wide net-of-tax wage bill. The discount rate applied to the aggregate wage bill is the product of the gross real interest rate, the gross population growth rate (for the same reason as discussed above), the inverse of the probability of retirement, and a factor $\Omega > 1$, which makes for a heavier discounting of the future as funds received in retirement are less valued than money received earlier. In total, therefore, there are three distinct factors in the life cycle setting, which raise the discount rate on future labor income (relative to the infinite horizon case). They are: (1) finite expected time spent working (reflected by the presence of ω in the discount rate), (2) greater discounting of the future owing to expected finiteness of life (reflected by the presence of Ω), and (3) growth of the labor force (reflected by the presence of $1 + n$).

AGGREGATE CONSUMPTION AND THE SHARE OF WEALTH HELD BY RETIREES
Denoting by λ the share of financial assets held by retirees, one can add the two aggregate consumptions above to get aggregate consumption:

$$C_t = C_t^w + C_t^r = \pi_t\left\{\left(1-\lambda_t\right)R_tA_t + H_t + S_t^w + \epsilon_t\left(\lambda_tR_tA_t + S_t^r\right)\right\}.$$

Because the MPC of retirees is higher than the MPC of workers ($\epsilon > 1$), higher λ raises aggregate consumption. So transferring resources across the demographic groups changes overall demand.

I.D. Production Side

Production is undertaken by firms using capital and labor. Aggregate output is given by the Cobb-Douglas production function:

$$Y_t = K_t^{\alpha}\left(X_tN_t\right)^{1-\alpha}, \tag{4}$$

where N_t denotes the number of workers and X_t is labor-augmenting total factor productivity (TFP). This specification can be viewed as a reduced form of task-based production frameworks used in the study of automation (Acemoglu and Autor 2011; Acemoglu and Restrepo 2018), in which α captures the fraction of tasks performed by capital.[14] There is exogenous technological progress at net rate x and population growth at net rate n, so that $X_{t+1} = (1 + x)X_t$ and $N_{t+1} = (1 + n)N_t$.

Firms in this economy have market power, and the aggregate gross markup is $\varphi \geq 1$.[15] This means that the wage W_t and the rental rate r_t^r are equated to markdown $1/\varphi$ times the after-tax marginal products of the factors: $W_t = \left(1-\tau_l\right)\frac{1-\alpha}{\varphi}\frac{Y_t}{N_t}$ and $r_t^r + \left(1-\tau_k\right)\delta = \left(1-\tau_k\right)\frac{\alpha}{\varphi}\frac{Y_t}{K_t}$. Note that I assume tax expensing of capital depreciation. Profits are taxed at the same rate as capital income, and after-tax profits are given by $\left(1-\tau_k\right)\left(1-\frac{1}{\varphi}\right)Y_t$.

I.E. Government

The government consumes $G_t + M_t$ each period (where G is civilian government consumption and M is military spending) and pays retirees a

14. In task-based models, the Cobb-Douglas form typically includes a productivity shifter that depends on parameters such as α. Here that shifter is absorbed into X_t.

15. This can be micro-founded by the standard Dixit-Stiglitz CES demand system.

total of E_t in social security and health care benefits.[16] To finance its expenditures, the government levies proportional taxes on labor at rate τ_l and on capital and profit income at rate τ_k, as well as engaging in a lump sum tax/transfer $\tilde{T}_t$ on the workers. It can also issue one-period government bonds B_{t+1}, which pay out safe gross return R_t^f. The government flow budget constraint is:

$$B_{t+1}+\tilde{T}_t+\frac{1}{\varphi}\Big(\big(1-\alpha\big)\tau_l+\big(\alpha+\varphi-1\big)\tau_k\Big)Y_t=R_t^f B_t+G_t+M_t+E_t.$$

Defining total tax collected $T_t := \tilde{T}_t+\frac{1}{\varphi}\Big(\big(1-\alpha\big)\tau_l+\big(\alpha+\varphi-1\big)\tau_k\Big)Y_t$, rewriting in terms of the households' rate of return R_t and iterating forward gives the intertemporal budget constraint of the government:

$$R_t B_t=\sum\nolimits_{v=0}^{\infty}\frac{T_{t+v}}{\prod_{z=1}^{v}R_{t+z}}-\sum\nolimits_{v=0}^{\infty}\frac{G_{t+v}+M_{t+v}}{\prod_{z=1}^{v}R_{t+z}}-\sum\nolimits_{v=0}^{\infty}\frac{E_{t+v}}{\prod_{z=1}^{v}R_{t+z}}$$
$$+\sum\nolimits_{v=0}^{\infty}\frac{\big(R_{t+v}-R_{t+v}^f\big)B_{t+v}}{\prod_{z=1}^{v}R_{t+z}}.$$

The sum of the first three terms on the right is the present value of the primary surplus. The final term is the present value of the implicit government revenues that arise from paying R_t^f on its debt, which is below the marginal return in the private economy R_t, known as a bubble premium or a convenience yield (Reis 2021; Brunnermeier, Merkel, and Sannikov 2024). I discuss the different returns and the relationship between them in detail below.

Government policy is exogenous. In particular, it is characterized by four ratios—$\bar{g}_t$, $\bar{m}_t$, $\bar{b}_t$, and $\bar{e}_t$—of government consumption (of the two kinds), debt and social security spending, all in relation to GDP, respectively:

$$G_t=\bar{g}_t Y_t$$
$$M_t=\bar{m}_t Y_t$$
$$B_t=\bar{b}_t Y_t$$
$$E_t=\bar{e}_t Y_t.$$

16. I split out the military spending since later in the paper I analyze the rearmament scenario and its impact on the natural rate.

Given the paths of G_t, M_t, E_t, and B_t, the spread between the risk-free and the market rate, and the proportional tax rates τ_l and τ_k, lump-sum taxes adjust to satisfy the intertemporal budget constraint.

I.F. Resource Constraint and International Lending and Borrowing

The economy-wide resource constraint is:

$$K_{t+1} = Y_t - C_t - G_t - M_t + \left(1 - \delta\right)K_t - NX_t, \quad (5)$$

where net exports satisfy $NX_t = NFA_{t+1} - R_t^f \cdot NFA_t$ and NFA_t is the (exogenously given) net foreign asset position of the economy. Treating the net foreign asset position as exogenous allows us to account for the impact of outside forces—such as the increase in the desire to save in safe Western assets by the Asian economies and oil producers since the late 1990s—on the natural rate in AEs. To reflect the preference for safety, I use the safe return R_t^f in equation (5).

I.G. Assets and Returns

In the description of the households' problem, I focus on the intertemporal consumption-saving decision in an environment where households have access to a saving vehicle (assets A_t) that returns the gross interest rate R_t. Within their total asset portfolio, households hold both risk-free and risky assets. For simplicity, I do not model the portfolio choice explicitly here. Instead, I assume that households (implicitly) dislike risk (and/or like liquidity) and that this results in a risk premium between the returns on the two assets:

$$R_t^r = R_t^f + \varsigma, \quad (6)$$

where ς is the exogenous risk premium and R_t^r is the gross risky rate of return.[17] Furthermore, I assume that the gross effective return faced by households is given by the weighted average of the safe and risky return:

$$R_t = safe \cdot R_t^f + \left(1 - safe\right)R_t^r,$$

where the weight $safe \in [0, 1]$ corresponds to an average share of households' portfolios held in safe assets.

In this economy, the safe assets consist of government bonds, while the risky assets comprise capital K_t (thus the rental rate is equal to the risky

17. See Auclert, Malmberg, Rognlie, and Straub (2025) for a microfoundation consistent with this setup.

rate) and the aggregate value of the claim to pure profits Π_t, which evolves according to:

$$\Pi_t = \left(1 - \tau_k\right)\left(1 - \frac{1}{\varphi}\right)Y_t + \frac{\Pi_{t+1}}{R_t^r}.$$

EQUILIBRIUM IN THE CAPITAL MARKET The equilibrium condition that carries much of the economics of the model in this paper is the capital market equilibrium, where the funds accumulated by households are equal to the use of funds by firms and the government:

$$(7) \qquad \underbrace{A_t^w + A_t^r - NFA_t}_{\substack{\text{Supply of capital:} \\ \text{households and foreigners}}} = \underbrace{K_t + B_t + \Pi_t}_{\substack{\text{Use of capital:} \\ \text{firms and government}}}.$$

The supply of funds (or capital) in this economy results from household saving: the stock of savings accumulated by households—workers and retirees—in the domestic economy, netting out the stock of savings that households invest abroad (the negative of the net international investment position, NFA_t). This capital is invested in—absorbed or used by—firms (in physical capital and equity value) and by the government (in debt).

II. Steady-State Equilibrium

In this section I introduce the steady-state capital market equilibrium framework to study movements in r^* and in the wealth-to-GDP ratio and then apply it to the AE bloc of the 1970s.

On the balanced growth path, output and other aggregate variables grow at the rate $(1 + x)(1 + n) \approx 1 + x + n$. To obtain stationarity of the system, I hence normalize all growing variables by output and refer to the balanced growth path as the steady state.

II.A. Steady-State Capital Demand

In steady state, the components of capital demand are given by:

$$(8) \qquad k = \frac{\left(1 - \tau_k\right)\frac{\alpha}{\varphi}}{r + \varsigma + \left(1 - \tau_k\right)\delta}$$

$$(9) \qquad b = \bar{b}$$

$$(10) \qquad \Pi = \frac{\left(1-\tau_k\right)\left(1-\frac{1}{\varphi}\right)}{1-\frac{1+x+n}{1+r+\varsigma}},$$

where r is the net risk-free rate (so that $r := R_t^f - 1$). I define the (steady-state) capital demand schedule as a function of the safe real interest rate, and this can be expressed in closed form as follows:

$$(11) \quad D\left(r\right) := k\left(r\right) + \bar{b} + \Pi\left(r\right) = \frac{\left(1-\tau_k\right)\frac{\alpha}{\varphi}}{r+\varsigma+\left(1-\tau_k\right)\delta} + \bar{b} + \frac{\left(1-\tau_k\right)\left(1-\frac{1}{\varphi}\right)}{1-\frac{1+x+n}{1+r+\varsigma}}.$$

The capital demand schedule is downward sloping and asymptotes to infinity—absorption of saving becomes large and ultimately diverges—when $r = \max\left(-\left(1-\tau_k\right)\delta - \varsigma, x+n-\varsigma\right)$. In the former case, firms demand an infinite quantity of capital in the long run; in the latter, the present value of the profit flow becomes infinite and so absorbs any quantity of saving in the economy.

II.B. Steady-State Capital Supply

Unfortunately, no simple expression for the steady-state capital supply schedule is attainable. Nonetheless, the capital supply schedule can be computed numerically in a few simple steps: First, transform the model economy into a small open economy model, with exogenous returns but an endogenous residual net foreign asset position (over and above the exogenous NFA_t). It is straightforward to show that the steady-state residual net foreign asset position, denoted by f, satisfies:

$$\begin{aligned}(12) \quad \left(x+n+\delta\right)k = 1 - \pi & \left\{ \begin{array}{c} \left(1-\lambda\right)\left(1+r+\left(1-safe\right)\varsigma\right)\left(k+\bar{b}+\Pi+\bar{nfa}+f\right) \\ +h+s^w+\epsilon\left[\begin{array}{c}\lambda\left(1+r+\left(1-safe\right)\varsigma\right) \\ \left(k+\bar{b}+\Pi+\bar{nfa}+f\right)+s\end{array}\right] \end{array}\right\} \\ & -\bar{g}-\bar{m}-\left[\left(1+x+n\right)-\left(1+r+\left(1-safe\right)\varsigma\right)\right]f \\ & -\left[\left(1+x+n\right)-\left(1+r\right)\right]\bar{nfa},\end{aligned}$$

which is simply the stationary resource constraint in a small open economy version of the model. Clearly, it is straightforward to compute f for any r, yielding a schedule $f(r)$. Then capital supply is simply:

$$S(r) = D(r) + f(r). \tag{13}$$

The steady-state safe interest rate, r^*, is the interest rate at which $f(r^*) = 0$ and thus:

$$S(r^*) = D(r^*). \tag{14}$$

II.C. The 1970s Steady State

I apply the model to the AE bloc, consisting of the United States, Canada, Western European economies, Japan, and other Organisation for Economic Co-operation and Development (OECD) members. The approach of treating these economies as a bloc reflects a high degree of integration on the one hand, and experience of common driving trends on the other. I leave the important question of cross-country heterogeneity and country-specific r^* for future work.

The analysis begins in the 1970 steady state.[18] To compute the steady state, the model must be parametrized. I assume that a single time period in the model corresponds to one year. I further assume that the AE bloc is characterized by three time-invariant parameters: the discount factor $\beta = 0.99$, the intertemporal elasticity of substitution $\sigma = 0.5$, and the share of safe assets $safe = 0.11$.[19] I calibrate the remaining parameters of the model (the

18. To be precise, it is unlikely that an economy is *ever* precisely in steady state—the multitude of shocks that hit the economy move the time t equilibrium away from the steady state (which in itself is time-varying), and even when the shocks abate, convergence to the steady state can be slow and is only asymptotic. Thus, assuming the economy is in steady state is an approximation. Nonetheless, of the postwar history of AEs, the early 1970s seems to be a reasonable candidate for the period when the economy was near its steady state: It is a period after the immediate post–World War II decades of reconstruction and restructuring, and before the oil shocks of the 1970s.

19. The value for the elasticity parameter σ aligns with benchmark values in the literature and is consistent with the mean estimate reported in the influential meta-study of Havranek and others (2015). Parameter *safe* reflects the average share of government bonds in total financial wealth over time, and is the same as the calibration used by Auclert, Malmberg, Rognlie, and Straub (2025). The calibration of β targets the wealth-to-GDP ratio of 3.2 in the 1970 steady state, which is consistent with the World Inequality Database data on AEs' wealth-to-GDP ratios and the US data obtained from the Bureau of Economic Analysis and the Federal Reserve Board via FRED (series GDPC1, TNWBSHNO, and GDP; https://fred.stlouisfed.org/graph/?g=Egr). The discount factor of 0.99 is a little higher than commonly

Table 1. 1970s Steady State: Parameter Values

Variable	*Symbol*	*Value*
Government debt/GDP	$\bar{b}$	0.28
Civilian government spending/GDP	$\bar{g}$	0.15
Military spending/GDP	$\bar{m}$	0.05
Social security/GDP	$\bar{e}$	0.04
Capital tax (percent)	τ_k	36
Labor tax (percent)	τ_l	21
Productivity growth (percent per year)	x	2.80
Population growth (percent per year)	n	1.12
Expected length of working life (years)	$\frac{1}{1-\omega}$	46
Old-age dependency ratio	$\frac{1-\omega}{1-\gamma+n}$	0.18
Depreciation rate	δ	0.03
Capital intensity of production	α	0.32
Gross markup	φ	1.08
Risk premium (percentage points)	ς	3.00
Global savings glut	$\bar{nfa}$	0

Source: Author's calculations.

policy variables, the demographics, and other exogenous forces) using the corresponding data from 1970, reported in table 1. I present the relevant details in the next section.

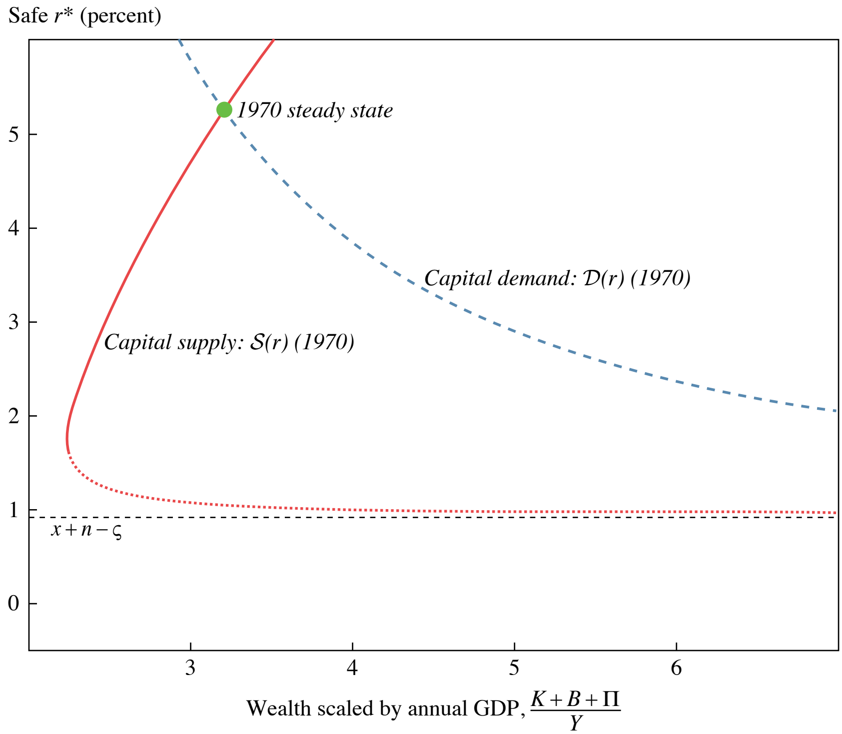
Given these parameter values, figure 2 plots the capital demand schedule $D(r)$ and the capital supply schedule $S(r)$, along with their intersection at the steady-state equilibrium. The horizontal axis reports the ratio of financial wealth to GDP, while the vertical axis shows the safe real interest rate.

The steady-state capital demand schedule is downward sloping and convex, consistent with the closed-form expression in equation (11) and familiar from canonical macro models, not least the neoclassical growth model (NGM).

By contrast, the capital supply schedule is quite different from its perfectly elastic NGM counterpart. In fact, it is *C*-shaped: It is upward sloping, except when the safe rate is close to the asymptote $x + n - \varsigma$. The upward-sloping part is the relevant one here: The steady-state equilibrium always

used discount factors. But note that the model abstracts from idiosyncratic risk, a key feature of the Bewley-Huggett-Aiyagari incomplete markets framework. Standard calibrations of such models suggest that idiosyncratic risk lowers equilibrium real interest rates by 1–2 percentage points. One way to interpret my choice of β is as an upward adjustment relative to the "true" underlying discount factor, which captures the effect of idiosyncratic uncertainty on real rates.

Figure 2. The 1970 Steady State: Capital Demand and Capital Supply Representation



Source: Author's calculations.

Note: The downward sloping schedule is the capital demand, in equation (11). The *C*-shaped schedule is capital supply, in equation (13). The dotted part of the $S(r)$ schedule arises due to the valuation effect but is not relevant for the analysis. See the discussion in footnote 20. Both schedules asymptote to the dashed line at $x + n - \varsigma$.

occurs on the upward-sloping section.[20] To make the interpretation of the figures cleaner, in what follows I truncate the capital supply schedule's downward-sloping part.

The calibrated model implies that in the 1970 steady state, the natural real rate is 5.3 percent (and the wealth-to-GDP ratio, which I target in the calibration of β, is 320 percent). In this steady state, interest rates are

20. Nonetheless, it is interesting to spell out why the capital supply schedule takes this shape. Two forces account for this pattern. At higher interest rates, the standard mechanism dominates: A higher return to saving encourages greater accumulation, so steady-state capital rises with r. At lower rates, however, this effect is outweighed by a "valuation effect."

Table 2. 1970s Steady State: Endogenous Outcomes

Variable	*Symbol*	*Value*
Safe r^* (percent)	r^*	5.3
Risky r^* (percent)	r^r	8.3
Capital-output ratio	k	1.8
Value of pure profit flow/GDP	Π	1.1
Wealth/GDP	$k + \Pi + \bar{b}$	3.2
Share of wealth held by retirees	λ	0.17
Social security wealth of workers/GDP	s^w	0.48
Social security wealth of retirees/GDP	s	0.28
Human wealth/GDP	h	4.14
MPC out of wealth—workers (percent)	π	7.3
MPC out of wealth—retirees (percent)	$\epsilon\pi$	14.7

Source: Author's calculations.

high because the future is bright. High growth expectations reduce households' desire to save and boost firms' desire to invest (trend GDP growth is nearly 4 percent, as productivity is expected to increase by 2.8 percent per year and population growth is 1.1 percent). Moreover, the population is young, with only 18 percent of the people in retirement. A worker in the 1970s is expected to spend only around five to nine years in retirement, limiting the desire to save for old age. The high interest rates translate into contained asset prices, limiting the value of the wealth-to-GDP ratio. Other endogenous variables are reported in table 2.

To characterize the slope of the two schedules, I calculate the respective semi-elasticities and evaluate them in the steady state:

$$\varepsilon^S = \frac{1}{A_{SS}} \frac{dS(r)}{dr}\bigg|_{r_{SS}} \overset{1970}{=} 12.2, \quad \varepsilon^D = \frac{1}{A_{SS}} \frac{dD(r)}{dr}\bigg|_{r_{SS}} \overset{1970}{=} -13.1.$$

Thus, the model predicts that in the 1970 steady state, the two schedules have nearly identical slopes (in absolute value). Of course, the slopes are useful as they are locally informative of the long-run equilibrium impact of shifts of these curves on interest rates and on wealth (Auclert, Malmberg,

Postponed consumption itself becomes an asset whose steady-state value rises as the interest rate falls. This effect is especially strong when interest rates approach $x + n - \varsigma$: Here, the net present value of the pure profit flow is very large, so even modest postponement of consumption maps into a large steady-state stock of funds. Importantly, this C-shaped supply curve does not imply multiple steady states.

Rognlie, and Straub 2025). Let κ^S and κ^D denote the proportional horizontal shifts in the respective curves:

$$\kappa^{S\, or\, D} := \frac{\Delta A}{A_{SS}}.$$

The impact of those shifts is given by:

$$dr = \frac{\kappa^S - \kappa^D}{\varepsilon^D - \varepsilon^S}, \tag{15}$$

$$\frac{dA}{A} = \frac{\varepsilon^D \kappa^S - \varepsilon^S \kappa^D}{\varepsilon^D - \varepsilon^S}. \tag{16}$$

For example, an increase of the government debt-to-GDP ratio of 50 percentage points—roughly the increase I have observed in the data—shifts the capital demand schedule to the right, with $\kappa^D = \frac{50}{320} \approx 0.16$. The semi-elasticity approach predicts that such a shift results in $dr \approx \frac{-0.16}{-13.1-12.2} = 0.63$ of a percentage point rise in the natural interest rate and $\frac{dA}{A} \approx \frac{-12.2 \bullet 0.16}{-13.1-12.2} =$ 7.7 percent, that is, an increase in wealth-to-GDP ratio of 7.7 percent • 320 = 25 percentage points. That is, there is about 50 percent long-run crowding out of private wealth.[21] As I show below, the equilibrium effect of the rise in debt will be different, however (the interest rate increases by more, with greater crowding out), as the capital supply schedule also shifts (leftward) due to the associated general equilibrium forces.

While this semi-elasticity approach is useful for local changes of a single driving force, it might be insufficient to understand the impact of large shifts in the environment, especially when many of the exogenous drivers change substantially all at the same time. Next, I use the framework provided by the model to study how changes in the economic environment shift the demand for capital and the supply of capital, and thus ultimately how they affect the steady-state interest rate and wealth-to-GDP ratio, taking full account of nonlinearities and interactions.

21. Indeed, note that with $-\varepsilon^D \approx \varepsilon^S$ as is the case here, we have $\frac{dA}{A} \approx \frac{1}{2}\left(\kappa^S + \kappa^D\right)$.

III. The Shifts

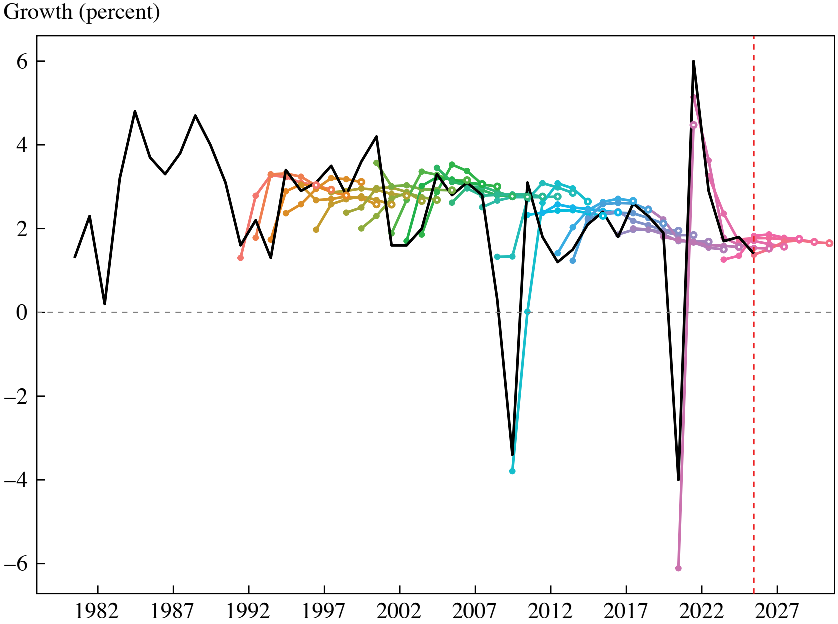
I now turn to the task of quantifying the changes in the exogenous drivers, listed in table 1, which characterize the process of structural socioeconomic change over the past five decades.

EXPECTED GROWTH OF PER CAPITA INCOME x_t Growth expectations profoundly shape both the capital demand and capital supply. Since households want to smooth consumption, expectations about the future are an important factor in determining their intertemporal saving decisions. Furthermore, future demand determines the demand for capital investment, as well as the present value of firm profits (since, when the economy grows faster, so do the profits).

On the balanced growth path, the per capita consumption growth is equal to the per capita output growth, which in turn equals x. Thus we can calibrate the time path $\{x_t\}$ by directly examining how the expectations for the growth rate of per capita output have evolved. The natural place to start is the forecast produced by the International Monetary Fund (IMF) in its World Economic Outlook publications. The vintages of historic forecasts are available starting in the 1990s. Figure 3 shows the real-time five-year-ahead forecast for aggregate GDP growth for the aggregate of AEs. The dots denote the final, fifth year of the forecast. The figure shows that long-term GDP growth expectations for the AE bloc have trended downward over time, from about 3 percent per year in the early 1990s to around 1.6 percent in the latest forecast. The decline in the per capita growth expectations is less pronounced, however, since some of this decline is due to the decline in the growth of the labor force. According to the United Nations (UN) World Population Prospects, population growth in high-income economies declined from about 0.8 percent in the 1970s to around 0.2 percent per year currently and is expected to decline to around zero by the mid-2040s. Thus, per capita growth expectations have declined by about 1 percentage point since the 1990s, from 2.3 percent to 1.3 percent.

Going farther back in time, the growth scenario prepared by the OECD in the mid-1970s and reviewed again in 1979 provides a useful perspective. In 1976 the OECD projected labor productivity to increase by 4 percent over the next five years in AEs, representing a strong pickup in expectations relative to the early 1970s (OECD 1976). However, the economies grew significantly slower, and in 1979, the likely outcome was judged to be around 1.5 percentage points below the original forecast, at around 2.5 percent (OECD 1979). This downgrade in expectations appears to have been persistent, reflecting the broad slowdown in productivity growth around that time.

Figure 3. IMF World Economic Outlook AEs' GDP Growth Projections and Outturns



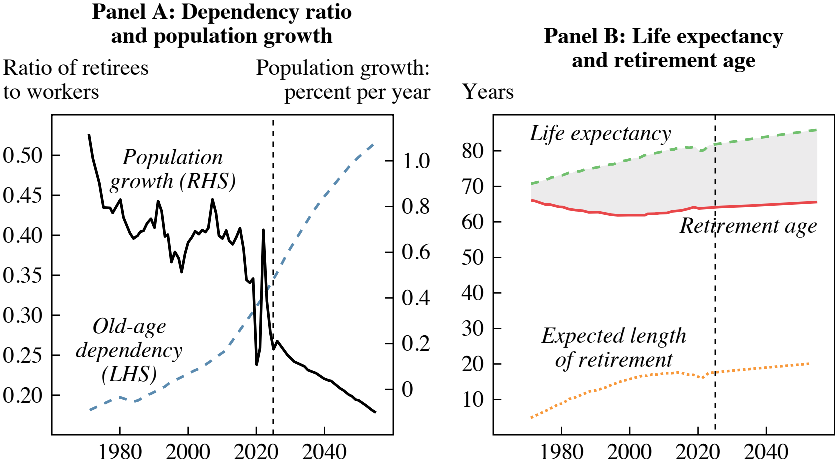
Source: Author's calculations based on data from the IMF World Economic Outlook.

Note: The black solid line is the annual growth of GDP across the AEs, as defined by the IMF. The remaining lines show the successive World Economic Outlook forecasts, with the dots denoting the final, fifth year of the forecast. In my calibration, I adjust these long-term expectations with population growth expectations and match the resulting series to productivity growth x_t.

DEMOGRAPHICS: POPULATION GROWTH n_t, LENGTH OF WORKING LIFE $1/(1 - \omega_t)$, AND LENGTH OF RETIREMENT $1/(1 - \gamma_t)$ Figure 4 illustrates the scale of the demographic transition underway in AEs. Panel A highlights the steady decline in population growth, projected to turn negative around 2050, alongside the sharp rise in the old-age dependency ratio, which has nearly doubled over the past half century and is expected to climb further. Panel B shows life expectancy continuing to rise, while the effective retirement age has remained broadly stable. As a result, the expected length of retirement has expanded dramatically—roughly quadrupling over the past century, from five to nearly twenty years.

These demographic shifts have far-reaching macroeconomic consequences. Slower population growth reduces the incentives to invest and sets the pace of aggregate output growth given productivity trends. It also shapes expectations about per capita social security benefits. A rising dependency ratio implies greater political and economic weight of retirees,

Figure 4. Demographic Transition in AEs



Source: Author's calculations based on data from the UN World Population Prospects 2024.

while longer retirement horizons strengthen incentives for households to accumulate savings.

To calibrate the time path $\{n_t\}$, I use population data and projections from the UN World Population Prospects (the medium variant). The calibration of $\{\omega_t\}$ matches the evolution of the effective retirement age data from the OECD.[22] Then, given $\{n_t\}$ and $\{\omega_t\}$, the time path for $\{\gamma_t\}$ is consistent with the old-age dependency ratio in the UN projections.[23]

CAPITAL INTENSITY OF PRODUCTION α_t The literature on task-based production models shows that the share of tasks carried out by capital is encapsulated in parameter α (Acemoglu and Autor 2011; Acemoglu and Restrepo 2018). Automation raises α and shifts out the demand for capital (Moll, Rachel, and Restrepo 2022). But it also affects how the economic pie is shared between workers and capital owners, and hence has an impact on the value of human wealth of workers in the economy, with the associated effects on saving behavior and hence capital supply.

I back out $\{\alpha_t\}$ from the Penn World Table (PWT) 10.01 labor share (Feenstra, Inklaar, and Timmer 2015), recognizing that the labor share measured in the data corresponds to the fraction $\frac{1-\alpha}{\varphi}$ in the model.

22. I assume that working life starts at age 20.
23. Matching life expectancy delivers a similar profile for γ_t.

DEPRECIATION δ_t The depreciation rate of capital affects directly the demand for capital. I calibrate $\{\delta_t\}$ directly to the depreciation series in PWT. Depreciation increases over time as the composition of capital stock shifts away from heavy machinery and toward information and communications technology and intangible capital.

GROSS MARKUP φ_t Changes in gross markups could be driven by shifts in concentration and market power, which in turn could be driven by technological or regulatory changes. Or they could reflect the greater importance of intangibles, research and development, and fixed costs. An increase in gross markup raises the ex post profit share in the economy and increases the equity value of firms, shifting out the capital demand schedule. Saving accumulation by households can also be affected as changes in gross markups alter the profile for wages and for returns.

I calibrate $\{\varphi_t\}$ directly to the estimates of gross markup available in the literature. Specifically, I base the calibration on the markup estimates from Cabaco and Ravn (2025). Their estimates are for the United States only.[24] On this measure, the gross markup falls in the 1970s, from around 1.1 to 1.075, and then increases steadily to 1.25 currently. Since these estimates reflect the United States, I adjust this trajectory downward slightly and impose less of an increase, given the evidence that markups in other AEs are lower and have increased by less than in the United States (De Loecker and Eeckhout 2021; Díez, Leigh, and Tambunlertchai 2018).

RISK PREMIUM ς_t Recall that ς_t is the spread between the safe and the risky rates of return, where the safe assets are government bonds and the risky assets are firm capital and equity (capitalizing the value of pure profits). Shifts in this spread affect both capital demand and capital supply curves vertically (since I specified these schedules in terms of the risk-free rate).

Following Moll, Rachel, and Restrepo (2022) and Reis (2022), I assume that the spread has increased over time, from 3 percentage points in the early part of the sample to 4.5 percentage points in the recent years.

GOVERNMENT DEBT $\bar{b}_t$ Government debt absorbs household saving, and so is a direct source of capital demand in the economy. Its changing level also has some general equilibrium effects on capital supply through endogenously changing taxes.

24. It is worth highlighting the two differences between this measure and that of De Loecker, Eeckhout, and Unger (2020). First, this estimate uses translog production functions; second, the aggregation is done using harmonic means.

Government debt has been on an upward trajectory across most of the AEs. For the AE bloc as a whole, government indebtedness increased from 28 percent of GDP in 1970 to 82 percent in the most recent data from the IMF World Economic Outlook. The baseline forecast (e.g., consistent with the latest IMF projections) is that the government debt-to-GDP ratio will continue to rise, albeit much more steadily than over the past decade, reaching about 90 percent of GDP in 2050.

GOVERNMENT CIVILIAN CONSUMPTION $\bar{g}_t$ AND MILITARY SPENDING $\bar{m}_t$ Direct use of resources by the government affects the economy through the resource constraint, and the need to finance such expenditures through taxation. Here I split the civilian government spending and the military spending, to highlight the trends in the latter (and later to analyze the scenario in which the military spending rises over the forecast horizon explicitly).

I use national accounts to measure general government final consumption expenditure net of defense and social transfers in kind.[25] Defense spending is taken from the Stockholm International Peace Research Institute (SIPRI) Military Expenditure Database.

SOCIAL SECURITY $\bar{e}_t$ Social security provides a source of income in retirement and, as such, alleviates the need to save for retirement. I measure old-age pensions and related cash benefits using data from the OECD Social Expenditure Database as a share of GDP.

TAX RATES $\tau_{l,t}$ AND $\tau_{k,t}$ Rates at which capital and profits are taxed will affect the value of these assets and the desirability to save.[26] Effective tax rates on labor and capital come from Bachas and others (2024), who provide a new comprehensive data set on effective tax rates across the world.

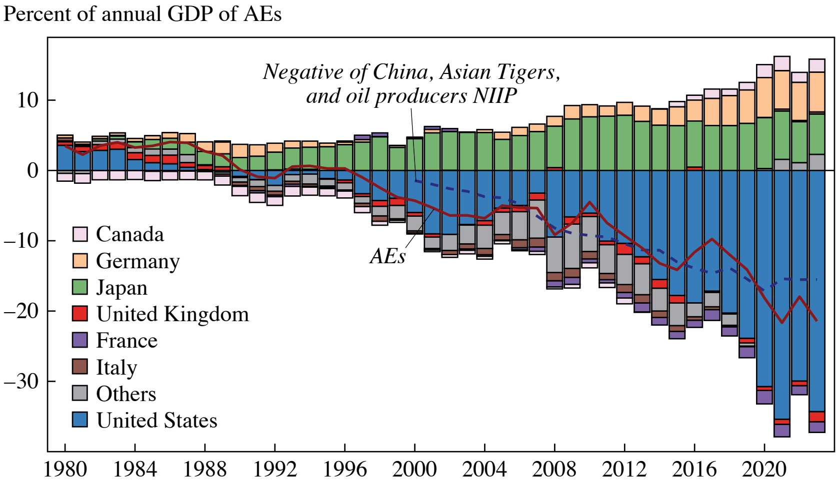
FOREIGN SAVING $\bar{nfa}_t$ Bernanke (2005) famously points out that the increased desire to save by some of the developing economies has acted as an additional source of capital supply in AEs, pushing real interest rates down. Indeed, saving by some of the Asian economies and oil-producing countries has increased sharply in the aftermath of the Asian financial crisis. This increase matches in magnitude the net international investment position of the AE bloc (figure 5).

Given the external nature of the increase in the desire to save by this group of economies, I calibrate the exogenous increase in the $\bar{nfa}$ as a share

25. World Bank, "General Government Final Consumption Expenditure (% of GDP)," https://data.worldbank.org/indicator/NE.CON.GOVT.ZS.

26. With inelastic labor supply in my model, labor taxes do not play much of a role in driving interest rates.

Figure 5. The Decomposition of the Net International Investment Position (NIIP) of AEs and the Surplus of the Selected Economies



Source: External Wealth of Nations Database (Lane and Milesi-Ferretti 2018, version 2024).
Note: All lines and bars are normalized by annual GDP of AEs.

of AEs' aggregate GDP, increasing steadily from zero in the late 1990s to around 15 percent of GDP recently.

IV. The 2050 Steady State

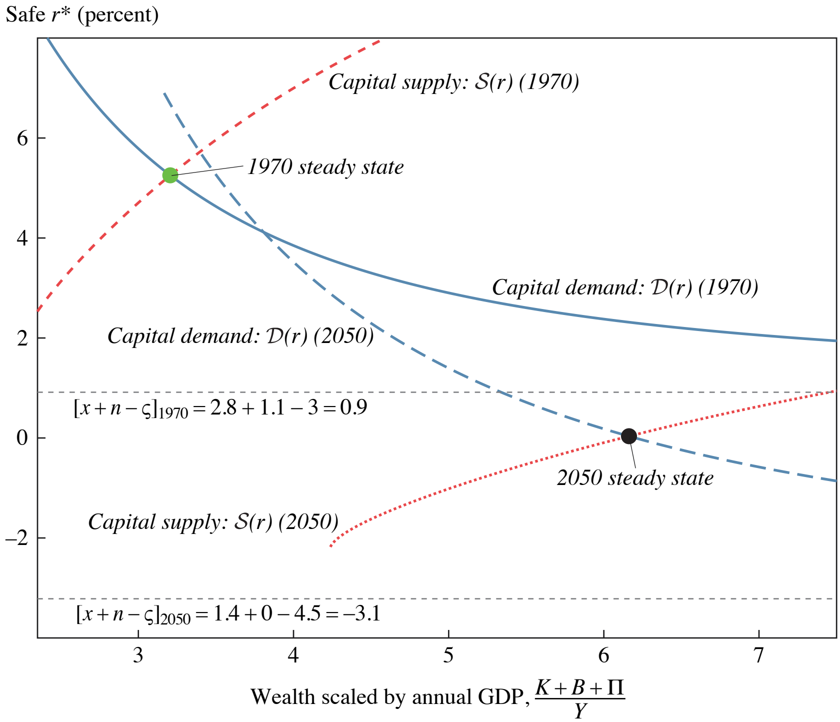
I now feed in all the changes in the environment outlined above, and compute the long-run steady state. For convenience, I refer to this as a 2050 steady state, since the transition toward the long run is largely complete by then.

Figure 6 provides the key result of the paper. It shows that the AE bloc has experienced large shifts in both capital demand and (especially) in capital supply, and that these shifts have driven a large decline in the safe natural rate of interest of over 5 percentage points, to essentially 0 percent in real terms, and a large increase in the wealth-to-output ratio, to more than six. Table 3 compares the key endogenous variables across the two steady states.

Recomputing the elasticities of the two schedules, I obtain:

$$\varepsilon^S = \frac{1}{A_{SS}} \frac{dS(r)}{dr}\bigg|_{r_{SS}} \overset{2050}{=} 20.8, \quad \varepsilon^D = \frac{1}{A_{SS}} \frac{dD(r)}{dr}\bigg|_{r_{SS}} \overset{2050}{=} -18.6.$$

Figure 6. 1970 and 2050 Steady States: Capital Demand and Capital Supply Representation



Source: Author's calculations.

Note: The figure shows the shifts of the steady-state schedules in the capital market equilibrium in the business-as-usual scenario (i.e., between the 1970 and 2050 steady states). See main text for details.

Table 3. The 1970 and 2050 Steady States: Endogenous Outcomes

Variable	*Symbol*	*1970*	*2050*
Safe r^* (percent)	r^*	5.3	0.0
Risky r^* (percent)	r^r	8.3	4.5
Physical capital-output ratio	k	1.8	2.6
Value of pure profit flow/GDP	Π	1.1	2.7
Wealth/GDP	$k + \Pi + \bar{b}$	3.2	6.2
Share of wealth held by retirees	λ	0.17	0.35
Social security wealth of workers/GDP	s^w	0.48	0.92
Social security wealth of retirees/GDP	s	0.28	1.13
Human wealth/GDP	h	4.1	6.1
MPC out of wealth—workers (percent)	π	7.3	4.1
MPC out of wealth—retirees (percent)	$\epsilon\pi$	14.7	6.6

Source: Author's calculations.

Thus, both schedules are significantly flatter at the new steady state, compared to the 1970 steady state. The figure shows that the capital demand schedule has become steeper overall; however, because of its convex shape and the rise in wealth-to-GDP ratio, the schedule around the new steady-state equilibrium is flatter than in the 1970 steady state.

The capital supply schedule has shifted down and to the right. In the new steady state, it is now upward sloping at much lower real rates; it is also significantly more elastic around the steady-state equilibrium.

What accounts for these large shifts in the steady-state capital demand and capital supply schedules? The figure already gives us a hint, since it shows that the horizontal asymptote given by $x + n - \varsigma$ shifted downward as productivity growth has halved, population stopped growing, and the risk premia have increased (and are assumed to remain elevated). Thus, these three factors are likely quantitatively important. I explore all the driving forces next.

IV.A. Decomposition of Capital Demand

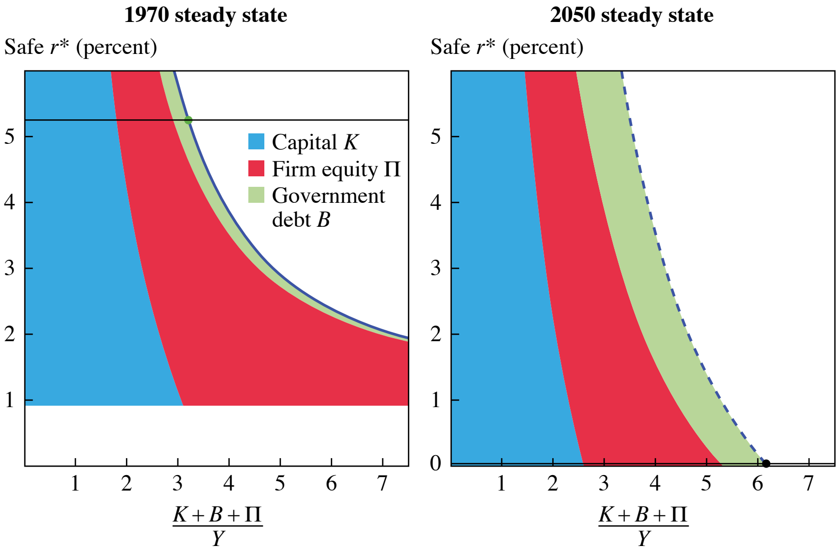
I first compute an accounting decomposition of the capital demand curve into physical capital, the value of pure profits, and outstanding government debt. Figure 7 shows this decomposition for both steady states.

This decomposition reveals an interesting yet subtle feature of macroeconomic adjustment that has occurred in the developed world over the past fifty years (and that is still underway). While the wealth-to-GDP ratio (the sum of three components, $k + \Pi + \bar{b}$) has increased over time both in the model and in the data, the demand curve for physical capital and the schedule representing the value of firm profits both shifted in. The only component of demand for funds that unambiguously expanded is government borrowing. However, even though the capital absorption coming from the firm side of the economy is lower in the long-run steady state compared to the 1970s for every interest rate, the steady-state capital stock and firm equity have increased (precisely because interest rates declined).

IV.B. Capital Demand and Supply Shifts, Force by Force

The shifts depicted in figure 6 show the joint effect of all the forces simultaneously. To learn more about the economic effects of individual drivers, figure 8 shows how the schedules would have shifted if only a single force was operational from 1970 onward (keeping the actual size of the shift fixed). The short-dashed and solid lines represent the schedules in the initial steady state and are identical across panels. The other two lines show the respective shifts of capital demand and supply as a result of any single force.

Figure 7. Decomposition of the Capital Demand Curve in the 1970 and 2050 Steady States

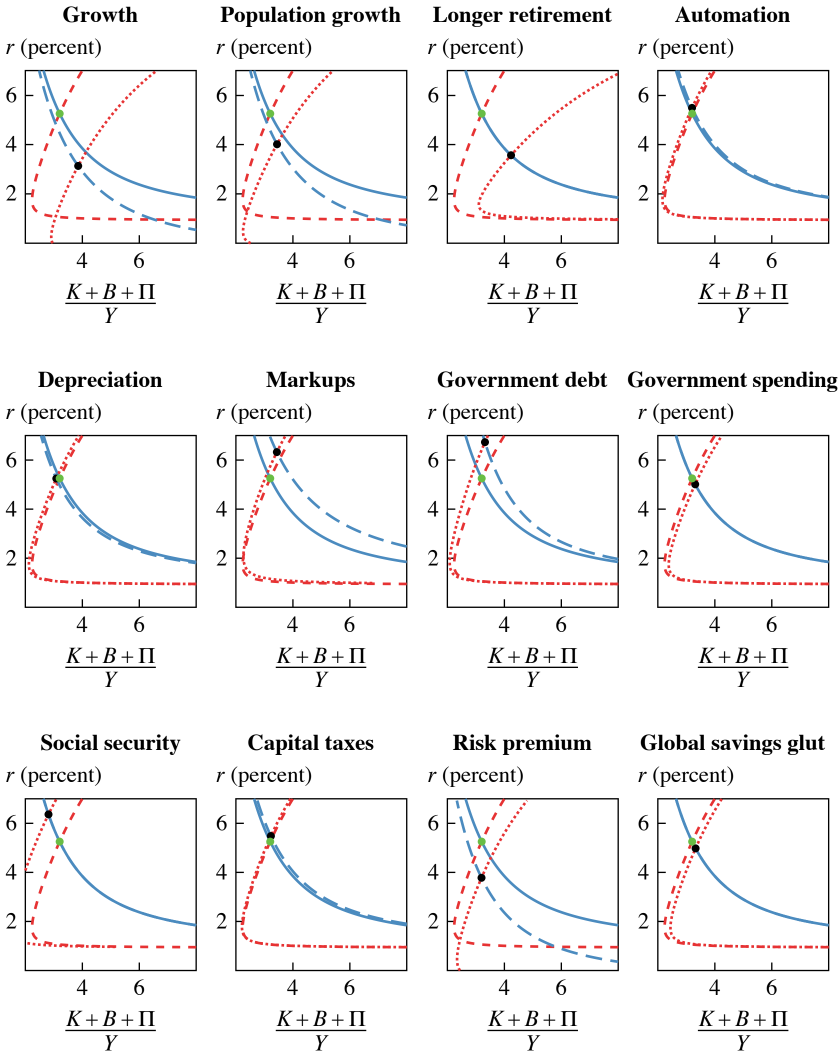


Source: Author's calculations.
Note: Both panels decompose the capital demand curve $D(r)$ horizontally into components, according to equation (11). The horizontal lines with dots denote the respective steady states.

The figure presents a fascinating insight into how the long-run capital market equilibrium is affected by the various drivers I have considered. Noticeably, most of the forces shift both capital demand and capital supply. The four exceptions to this are: (1) increasing duration of retirement due to higher life expectancy, (2) rise in social security spending, (3) the bloating of the global saving glut, and (4) the increase in the depreciation rate. The first three shift only capital supply, while the last one only moves capital demand.

Three of the drivers shift the schedules vertically. Quite intuitively, these are the forces that determine the effective discount rate that is applied to future payoffs: TFP growth x, population growth n, and risk premium ς. In effect, these shifters move the horizontal asymptote for both schedules. Clearly, given these changes in the shape of the curves and the inherent nonlinearities, the sum of the impacts of individual shifters is different from the joint effect—in other words, interaction effects between the forces are important. This will be shown momentarily in the decomposition of r^* dynamics.

Figure 8. The Capital Market Equilibrium Shifts in Response to Individual Exogenous Drivers



Source: Author's calculations.

Note: The short-dashed and solid curves show the 1970 steady state and are identical across panels. The other two curves show the positions of the long-run capital demand and capital supply under the assumption that only the specific force shifts.

IV.C. Desired Saving and Desired Investment

The steady state can also be thought of as an intersection of the desired saving and desired investment schedules—that is, in the space of flows rather than stocks. For example, this is the approach taken by Rachel and Smith (2015). To go from the capital market equilibrium characterized above to the saving-and-investment equilibrium, note that net investment and saving satisfy:

$$\text{(17)} \qquad \frac{I_t}{Y_t} = \frac{K_{t+1} - K_t + \Pi_{t+1} - \Pi_t + B_{t+1} - B_t}{Y_t} \qquad \frac{S_t}{Y_t} = \frac{A_{t+1} - A_t}{Y_t}.$$

Since on the balanced growth path, capital and wealth grow at the same rate as output (namely, $g := x + n$), I obtain the following formulas for the desired investment and desired saving schedules:

$$\text{(18)} \qquad \frac{Inv}{Y}(r) = gD(r) \qquad \frac{Sav}{Y}(r) = gS(r).$$

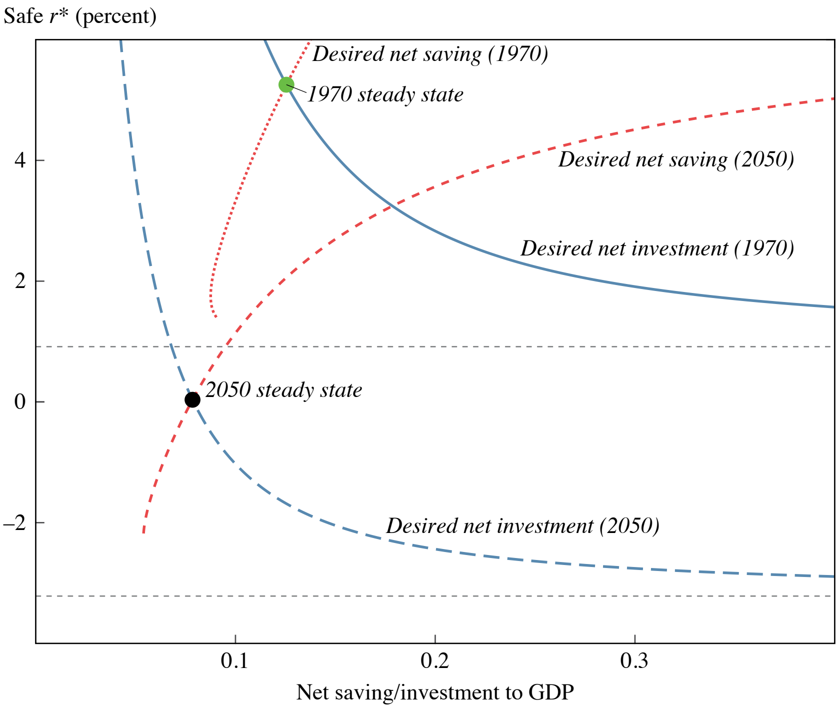
Figure 9 shows the desired saving–desired investment representation of the equilibrium. It makes the point that even though wealth in the new steady state is much higher than in 1970, the net investment and net saving flows consistent with the long-run steady state are actually lower. The significant decline in growth means that saving and investment flows sufficient to keep asset ratios steady are much lower.

V. Transitional Dynamics

The steady state analysis can tell us a lot about where the economy started and where it is headed. But it does not tell us what the natural real rate is today, has been, or will be at any given point in time. To address this question, I turn to transitional dynamics and ask: What path connects the 1970 steady state to the long-run (2050) steady state, and where along that path are we in 2025?

When analyzing transitional dynamics, researchers must confront the question of how to model expectations. The literature (e.g., Rachel and Summers 2019a) typically assumes perfect foresight: At the point of departure from the initial steady state, agents anticipate the entire sequence of current and future shocks. This assumption makes more sense in certain contexts, for example, when the exogenous drivers that are being studied are predictable: The demographic processes are slow-moving, and dependable

Figure 9. Desired Saving–Desired Investment (Flows) Representation of the Steady-State Equilibrium



Source: Author's calculations.

Note: This figure is the flow equivalent of figure 6. It depicts the desired saving and the desired investment schedule defined in equation (18).

demographic projections are widely available. But the perfect foresight assumption is less appealing when forces at play are difficult to predict. For example, it is highly unlikely that those alive in the 1970s anticipated the decline in labor share of income in the 1990s, the rise in markups in the 2000s, or the decline in expected future growth post-GFC. Transition dynamics based on the perfect foresight assumption might provide a misleading steer on the dynamics of the natural rate and the wealth-to-GDP ratio.

V.A. Imperfect Forecasts and Surprises

To tackle this issue, I compute transitional dynamics with a limited degree of foresight. This requires making assumptions about what the agents in the economy expect at each point in time.

To keep the analysis manageable, I first assume that agents can perfectly foresee shifts in some of the drivers, namely, government spending, capital taxes, military spending, and the lengths of working life and retirement. Some of these are genuinely predictable (demographics), while others are quantitatively minor for the results (e.g., government spending; see the previous section).[27]

The other eight exogenous drivers are imperfectly foreseen. To pin down the expectations, for some of them I rely on direct measures, for example, historical IMF forecasts can be informative about expectations of future productivity growth x, population dynamics n, and debt-to-GDP ratio $\bar{b}$. For others, I make narrative-style assumptions that broadly reflect the limited ability of the agents to anticipate the structural shifts. In that spirit, I assume that agents learned about the rise in the foreign demand for safe assets $\bar{nfa}$ gradually, only as this demand materialized following the Asian financial crisis, or that shifts in the risk premia ς occurred around the 1990s recession, the burst of the dot-com bubble, and the GFC. Similarly, I assume that the realization of the initially falling then rising markups φ came gradually, with a big shift in the perception of the markups that occurred in the recovery from the GFC when corporate profits recovered more strongly than the rest of the economy. Finally, I assume expectations about capital intensity α and depreciation rate δ change only around the same time as the shifts actually happen (i.e., I assume limited anticipation of these shocks). Even though by their nature my assumptions are imprecise, they are likely more realistic than the perfect foresight assumption they replace.

I also assume that expectation revisions occur at discrete, infrequent dates rather than continuously. This "episodic" updating—consistent with limited or costly attention and with market narratives that ebb and flow—induces jumps in expectations and makes it more likely that the limited foresight transition departs materially from the perfect foresight benchmark.[28]

A detailed account of all of the assumptions about the historical expectations is in the online appendix.

27. I also assume there are investment adjustment costs, with the cost parameter calibrated to the value typically used in the literature. This makes very little quantitative difference to the results.

28. Nonetheless, for three of the drivers (α, δ, and $\bar{nfa}$) where the timing of these changes to expectations is particularly uncertain, I assume that expectations themselves evolve continuously.

V.B. The Natural Rate Along the Transition Path

The resulting transition path is shown in figure 10. The solid lines are the limited foresight paths; for comparison, the dashed lines show the perfect foresight transition. Panel A shows the equilibrium safe and risky rates; panel B shows the corresponding paths of the wealth-to-GDP ratio and its components.

Historically, the model predicts an increase in safe r^* in the early 1980s and a large subsequent decline. Safe r^* is estimated to be 0.6 percent in 2025 (in the limited foresight transition). Overall, the transition toward the long-run steady state that is currently underway is to a large extent complete, although the natural rate is expected to decline further toward zero (by around half a percentage point) in the decades to come.

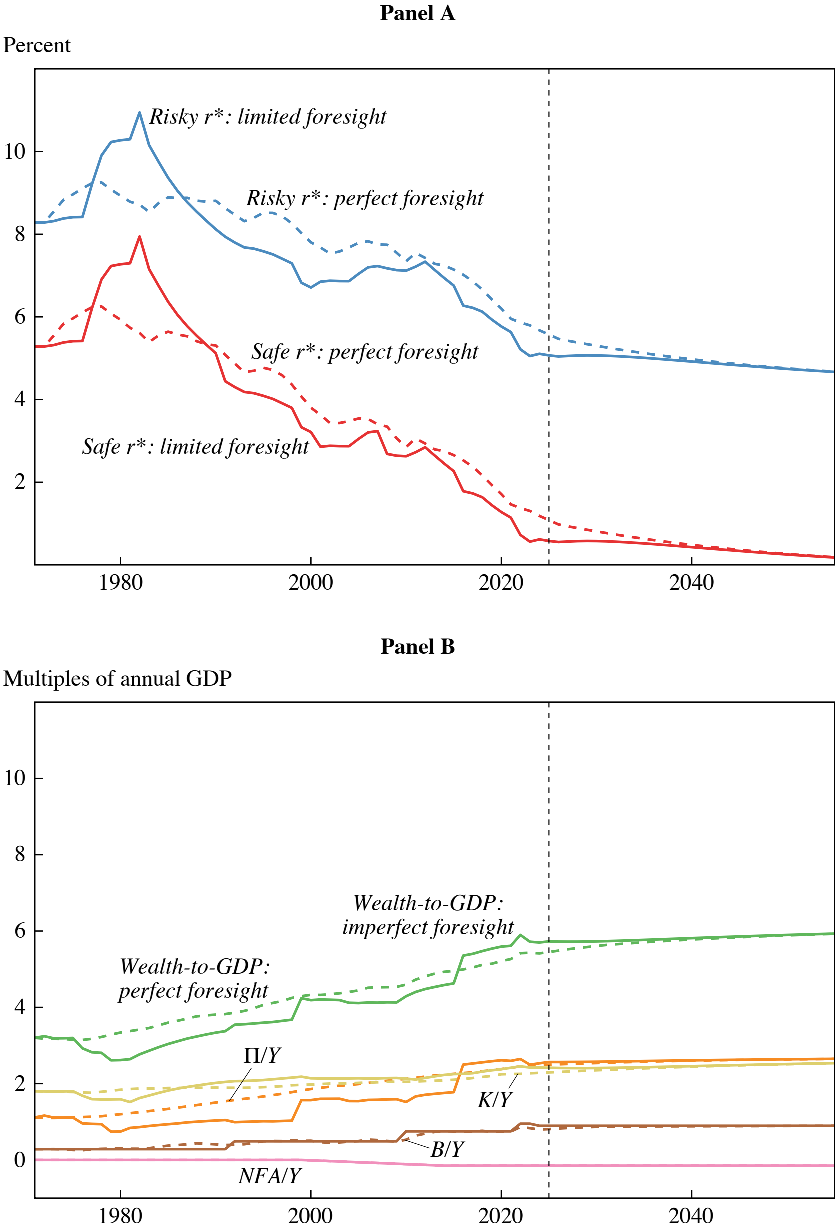
The differences between the perfect and limited foresight paths for r^* are substantial. Most notably, there is a large divergence in the 1980s, driven by large swings in growth expectations. In the last twenty-five years, the model predicts that the limited foresight r^* is consistently below its perfect foresight counterpart. This is a surprising prediction, given that the natural rate was on a downward trend over this period, and so one might expect the perfect foresight path to be running ahead of the limited foresight path in predicting the decline. This difference is also present today: The perfect foresight r^*, which stands at 1.2 percent, is 0.6 percentage points higher than the limited foresight r^*. Figure 11 decomposes the difference between the safe r^* in the limited and perfect foresight transitions, respectively, and shows that the gap is largely accounted for by shocks to markups. This is because a surprise shock to markups has a short-run effect that is of opposite sign to the long-run effect (see the online appendix for a more detailed discussion).

A useful way to visualize the transition path is to return to the capital market equilibrium and plot the transition alongside the steady-state shift (figure 12). The lines showing the perfect and limited foresight transition paths are marked with the stars denoting year 2025. The figure shows that the transition seemed to have followed the capital demand schedule. This is consistent with the capital supply shifts being dominant.

V.C. Transition Paths Versus Sequence of Steady States

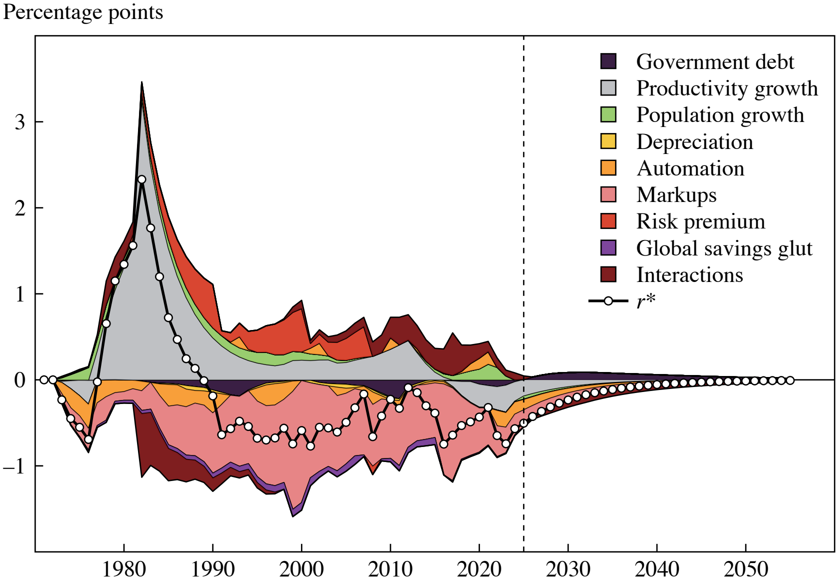
An alternative method of computing a time path for the natural rate is to ignore the transitional dynamics completely and instead compute the sequence of steady states consistent with the value of the exogenous drivers at each t. This approach is followed, for example, in Auclert, Malmberg, Rognlie, and Straub (2025). A natural question that arises is: How much difference do transitional dynamics make?

Figure 10. Model-Implied Estimate of r^* and Wealth Along the Transition Path



Source: Author's calculations.
Note: Panel A shows the model-implied natural rates in both the baseline limited foresight transition, as well as the perfect foresight transition in the dashed lines. Panel B shows the equivalent paths of the wealth-to-GDP ratio and its components.

Figure 11. Decomposition of the Difference Between Safe r^* in the Limited and Perfect Foresight Transitions



Source: Author's calculations.

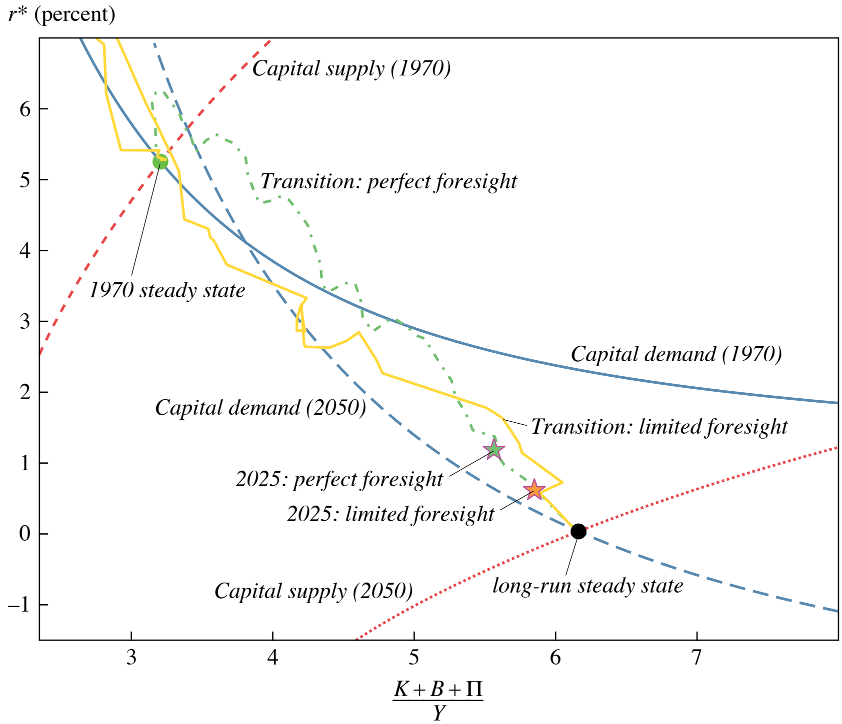
Note: The figure decomposes the difference between the limited and perfect foresight safe r^*—the two "Safe r^*" lines in panel A of figure 10—into the underlying exogenous forces. Only the forces that are imperfectly foreseen are shown (contributions of all others are zero by construction).

To explore this, figure 13 plots the perfect and limited foresight transition paths for safe r^*, alongside the sequence of steady-state r^*. The latter implicitly assumes that the economy transitions to a new steady state instantaneously each period. The differences between the time paths are even larger in this case, with r^* estimates that differ by over a percentage point in most periods. The approaches provide a qualitatively different steer in terms of the levels and the direction of r^* change in the 1980s, the mid-2000s, and much of the 2010s. The steady-state sequence also suggests that r^* is higher today, at 1.5 percent per annum. These large differences highlight the importance of taking transitional dynamics and paths for expectations into account when estimating the natural rate.

V.D. A Word of Caution and Comparison to Data

The preceding analysis illustrates that the estimate of r^* at any given time is sensitive to specific assumptions about the transitional dynamics.

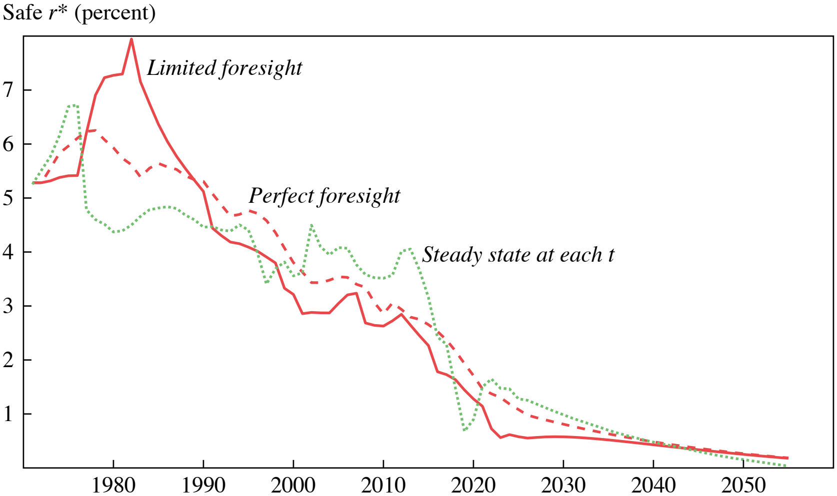
Figure 12. ***r**** **and Wealth Along the Transition Path**



Source: Author's calculations.
Note: This figure overlays the transition paths on the steady-state equilibrium representation familiar from previous figures.

This, of course, is also true for other aspects of the calibration, and so caution is warranted when interpreting any point estimates coming out of the model's simulations. To illustrate, figure 14 shows the path of r^* coming out of the (limited foresight) transition under three different calibrations of the pure discount factor β: the baseline $\beta = 0.99$, as well as $\beta = \{0.98, 1\}$. Either of these alternative calibrations meets the broad targets in terms of the 1970 level of the wealth-to-GDP ratio (of around three times of GDP). This exercise shows that plausible alternative calibrations can change the level of r, and the level and sensitivity of wealth to the exogenous drivers. One must exercise caution in order not to overinterpret the point estimates as being precise or definitive. Plenty of uncertainty surrounds these model predictions.

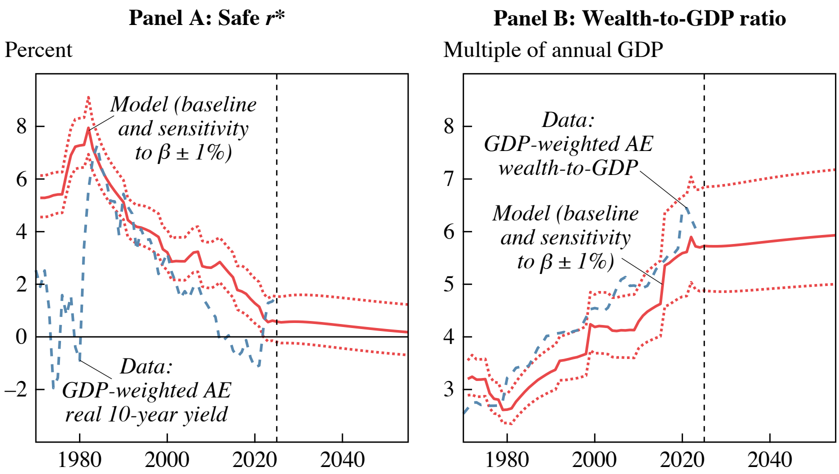
Figure 13. Estimates of Safe r^* Along the Transition Path and the Sequence of Steady States



Source: Author's calculations.

Note: The solid and dashed lines are the same as in panel A of figure 10. The dotted line shows the sequence of steady-state r^*.

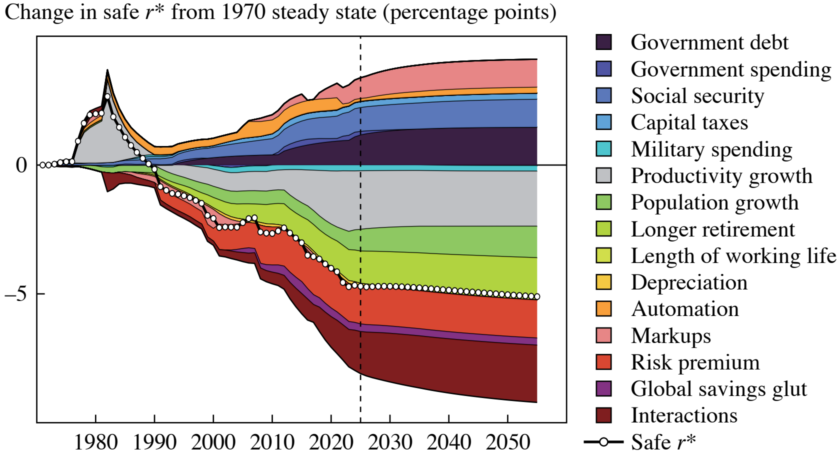
Figure 14. Model Predictions Versus the Data on Long-Term Real Yield and Wealth-to-GDP Ratio



Source: Author's calculations.

Note: The "Model" lines in both panels show the baseline business-as-usual transition for safe r^* (panel A) and wealth-to-GDP ratio (panel B). The dotted lines show the equivalent paths when the discount factor β is assumed to be higher or lower, illustrating the sensitivity of the results. The "Data" lines show data on ten-year government bond yield (real rate constructed in the same way as in the introduction) and wealth-to-GDP ratio across AEs.

Figure 15. Decomposition of the Decline in the Safe r^* in AEs



Source: Author's calculations.

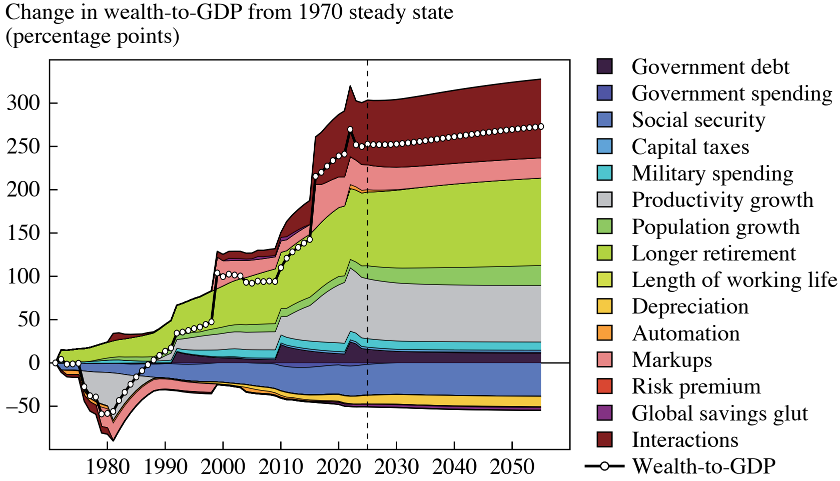
Note: The figure shows the model-based decomposition of the drivers of the decline in the safe real rate of interest along the limited foresight transition.

This uncertainty notwithstanding, figure 14 also illustrates how the estimates of r^* and wealth-to-GDP ratio from the model line up against the data on real ten-year bond yields and the estimate of the wealth-to-GDP ratio. The findings are interesting. Panel B shows that the rise in wealth-to-GDP ratio is broadly in line with the data. Focusing on panel A, back in the 1970s and 1980s, the realized real rates (which back then were measured using inflation outturns) were well below the estimate of the natural rate. This might help explain why inflation was high and volatile back then. Real rates caught up with the natural rate in the second half of the 1980s and both began going down. Market rates fell faster more recently, especially in the run-up to the pandemic. Thus, part of the recent spike in real rates can be interpreted as a correction. Nonetheless, market-based real rates, at around 2 percent, are somewhat higher than the central estimate from the model.

VI. What Caused the Decline in the Natural Rate?

Figure 15 presents the decomposition of the safe r^* along the transition path. The pickup in r^* in the late 1970s was driven largely by high growth expectations. But these expectations did not last, and by the late 1980s, they started to contribute to the decline in r^*. Other forces that were important early on included the demographic factors and the transitional effect

Figure 16. Decomposition of the Rise in Wealth-to-GDP Ratio in AEs



Source: Author's calculations.
Note: The figure shows the model-based decomposition of the drivers of the rise in the wealth-to-GDP ratio.

of markups, which were offset to some extent by public sector forces, not least the climb in social security spending and increased demand for capital due to automation.

More recently, the 2010s saw a slow recovery from the GFC, and long-term growth expectations were eventually revised as well, dragging down r^*. The continued increases in pension benefits offset some, but not all, of the impact of rising life expectancy and slowing population growth. Rising spread between the risky rate and the safe rate lowered the latter consistently through the episode. On the other hand, the government debt ratio continued to increase, pushing r^* higher, particularly so in the aftermath of the GFC. The long-run effect of the rise in markups started to be visible around 2007, with the contribution turning from negative to positive around that time. It has since become quantitatively large, supporting r^* by about half a percentage point from about 2020 onward. Last but not least, the decomposition reveals large and growing interactions between the forces, which can be understood bearing in mind how the various forces—particularly growth and the risk premia—change the shape of the long-run capital demand and supply schedules.

Figure 16 shows the decomposition of the changes in wealth-to-GDP ratio implied by the model. Here, the rise in life expectancy (and the associated rise in the length of retirement) emerges as the main driver. This is because this force shifts capital supply but does not move capital demand, resulting in large effects on wealth accumulation. In contrast, the decline in population growth shifts both schedules, resulting in large effects on r^* but small effects on wealth accumulation.

VII. What Next for r^*? Beyond the Business-as-Usual Path

The baseline simulation represents a business-as-usual path for r^*. It incorporates only the forces emphasized in the pre-pandemic literature—before COVID-19, the war in Ukraine and heightened geopolitical tensions, and the emergence of generative AI. In this scenario, r^* remains broadly stable, with only a gentle downward drift over the coming decades. This stands in stark contrast to recent market developments: Long-term government yields in some countries have risen back to levels last seen before the GFC, marking a decisive break from the half century trend of declining real rates.

The final part of the paper therefore asks: Within the framework developed here, what assumptions would one need to make in order to rationalize such a turning point in the natural rate? And are any of the forces discussed by commentators and priced by market participants quantitatively strong enough to generate the observed upward shift in expectations for r^*?

VII.A. Sensitivities

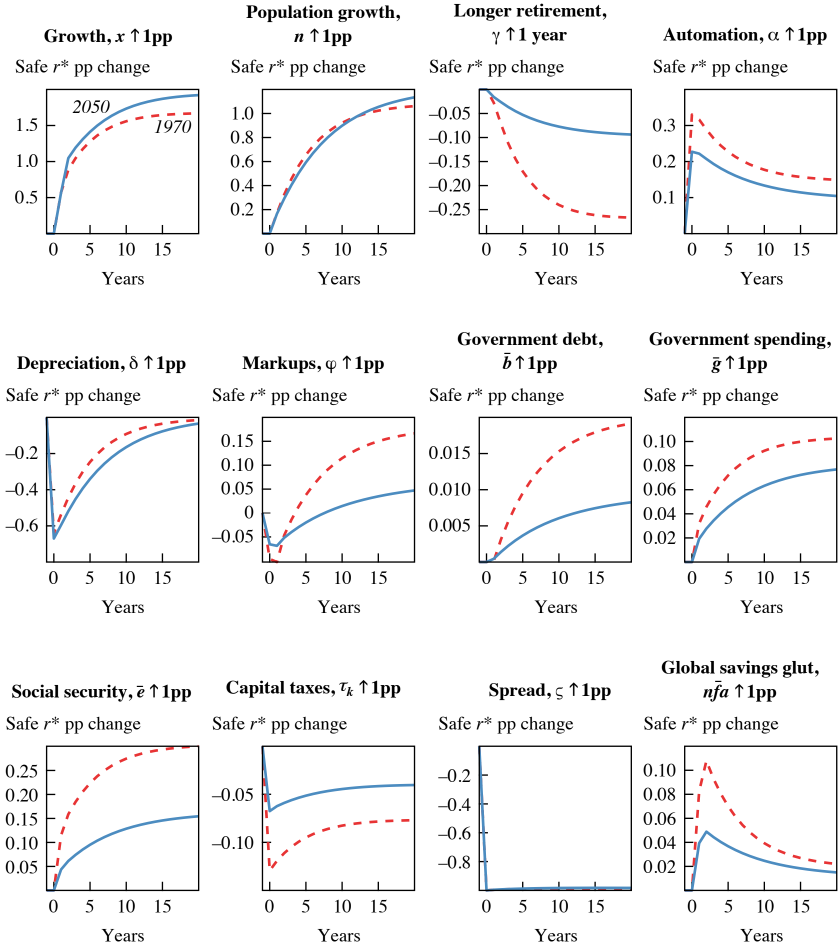
A useful tool for building a coherent view of r^* is a set of model-based sensitivities: responses of r^* to a range of exogenous drivers. Figure 17 illustrates the response of safe r^* to a range of shocks, with the size of the shock indicated above each panel. Each panel contains two impulse responses, corresponding to the circumstances when the shock hits: either the 1970 or the 2050 steady state. The differences between these two impulse response functions within each panel show how, according to the model, the sensitivity of r^* has changed over time. For example, r^* is now less sensitive to shocks to government debt or social security, but it remains as sensitive as in the past to changes in growth rates. This provides a useful set of multipliers, which I combine in a scenario analysis in the next section.

VII.B. Six Scenarios

I consider six scenarios:

- Scenario 1: deglobalization
- Scenario 2: remilitarization
- Scenario 3: AI

Figure 17. Sensitivity of Safe r^* to Various Exogenous Drivers: 1970 and 2050



Source: Author's calculations.

- Scenario 4: rise in intangibles
- Scenario 5: debt-funded social security
- Scenario 6: inflation risk

In designing the scenarios, my aim is to highlight material risks to the baseline, or business-as-usual projection for the natural rate that I discussed above. I therefore consider quantitatively meaningful departures from the baseline assumptions. While plausible, these scenarios are best viewed as upside risks for r^* rather than as predictions. I discuss each in turn.

SCENARIO 1: DEGLOBALIZATION ($\bar{nfa}$, x, AND ς) With the tariff wave under the Trump administration and rising geopolitical tensions, there is broad concern that globalization may go into reverse.[29] In this scenario, surplus economies (China, other Asian exporters, and oil producers) reduce their holdings of Western assets: Their net foreign asset position falls by 10 percentage points, from 15 percent to 5 percent of AEs' annual GDP. Furthermore, I assume reshoring improves resilience, lowering the risk premium by a quarter percentage point (from 4.5 to 4.25 percentage points) but at the cost of loss in efficiency: TFP growth is 0.1 percentage points lower. The net effect on r^* is in principle ambiguous—slower growth pushes down, while narrower spreads and a partial reverse of the "global savings glut" push the natural rate up.

SCENARIO 2: REMILITARIZATION ($\bar{m}$ AND $\bar{b}$) Russia's invasion of Ukraine ended the "peace dividend" era and raised defense needs in Western democracies. I assume the military spending share rises from 2.4 percent (baseline) to 3.8 percent of GDP, with no offset elsewhere in government consumption. One-third of the increase is debt-financed, lifting the debt-to-GDP ratio by 14 percentage points by 2050.

SCENARIO 3: AI (x, φ, AND α) AI is a major technological force with uncertain macro impacts. One way to view the AI revolution is to perceive it through the accumulation of both tangible and intangible capital, chiefly by superstar firms in the economy (Autor and others 2020). The large capital investments coupled with novel technological capabilities might result in faster productivity growth. Beyond efficiency gains, AI may increase market concentration (data-driven scale economies) and, akin to automation, shift the income distribution away from labor. In this scenario I assume TFP growth is boosted by 0.75 percentage points over the next decade and by 0.25 percentage points thereafter—large but in the middle of the pack of current guesstimates (see Filippucci, Gal, and Schief 2024, fig. 1). I also assume gross markups rise by 2 percentage points and the labor share declines gradually by up to 1.1 percentage points, as AI favors large firms with access to large amounts of data and generates a boom in capital demand as it takes over an increasing share of tasks.

SCENARIO 4: RISE IN INTANGIBLES (φ, x, AND δ) One of the most important and hotly debated trends of the ones I discussed is the rise of markups. Several

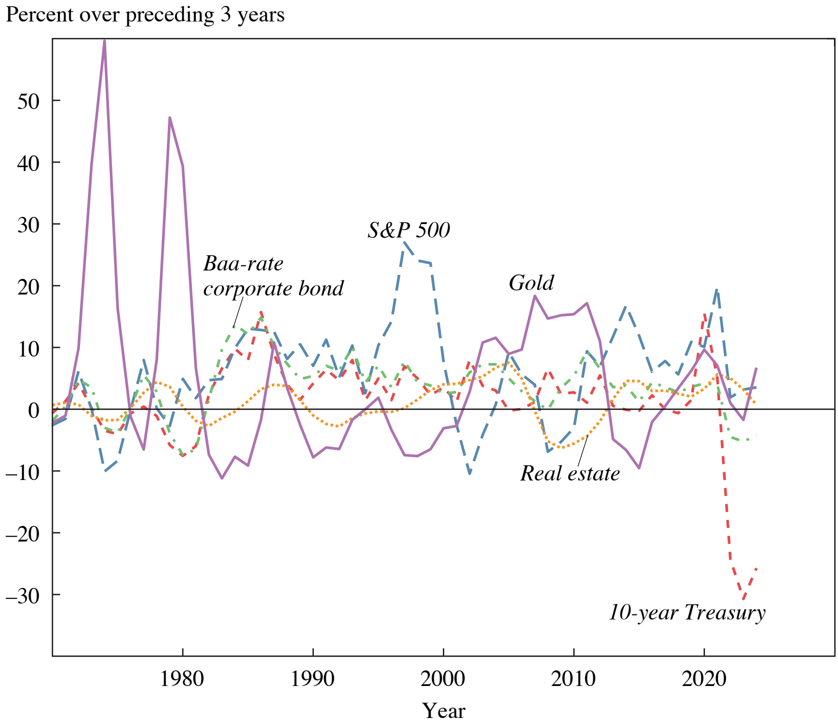
29. The processes of globalization and trade integration are complex; the model captures them only at a high level of abstraction. For a more thorough assessment, see Ambrosino, Chan, and Tenreyro (2026) and Mehrotra and Waugh (2025).

interpretations of what underlies this trend have been discussed in the literature: One possibility is that the increase in markups reflects the rise in market power and the associated increase in rents (Barkai 2020; Gutiérrez and Philippon 2018), perhaps in part driven by less effective antitrust policy. Another view is that the rise in markups reflects the rise of intangible inputs, which either have an important fixed cost component (De Ridder 2024) that is covered, ex post, with a markup, or they represent payments to the unmeasured capital stock (Crouzet and Eberly 2023). The latter interpretation can also explain some of the observed weakness in measured or true productivity (Crouzet and Eberly 2021; Crouzet and others 2025). In this scenario, which builds on Crouzet and others (2025), I assume that a continued rise in intangibles leads to a further rise in concentration and hence in markups (by an additional 1 percentage point), together with a gradual increase in the depreciation rate (by 1.5 percentage points), and a 0.1 percentage point slowdown in productivity growth (which reflects the dominant role for diminished entry incentives that the research has identified).

SCENARIO 5: DEBT-FUNDED SOCIAL SECURITY ($\bar{e}$ AND $\bar{b}$) As the share of (soon-to-be) retirees rises, their political influence likely grows. Here, social security outlays continue to increase—reaching 13 percent of GDP in the 2050s rather than stabilizing below 8 percent as in the baseline—and are financed by debt issuance (a transfer from the young and unborn to the old). The debt-to-GDP ratio climbs to over 170 percent in this scenario, much greater than the 156 percent projected by the Congressional Budget Office (2025) for the United States (and note this is for all AEs taken together).

SCENARIO 6: INFLATION RISK (ς) Post-COVID inflation has eroded the real value of nominal claims—most visibly the "safe" stock of government debt—while the sharp rise in policy rates and the yield curve has generated sizable capital losses on bond portfolios. Put differently, the safe assets are safe from credit risk (assuming that national treasuries of the developed countries will never default on their debts) but not immune from other risks, such as the inflation risk. For instance, in the United States, holders of the nominal ten-year Treasury bonds experienced roughly 25–30 percent real losses over the past three years, a stark departure from the low but steady real realized returns of the preceding four decades (figure 18). A natural hypothesis is that a persistent increase in compensation for inflation risk has raised government yields and compressed the safety premium. If this persists, the spread between so-called safe and risky assets might narrow persistently. In this scenario I therefore exogenously reduce the safe-risky

Figure 18. Realized Real Return on US Assets over the Preceding Three-Year Period



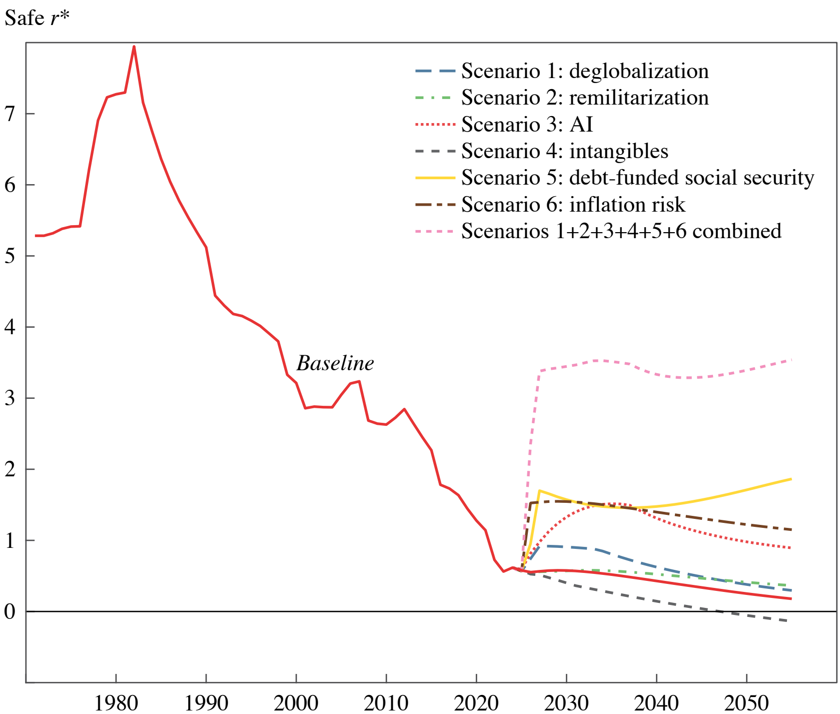
Source: Computed based on the returns database of Damodaran (2024).

spread by 1 percentage point—from 4.5 to 3.5 percentage points (recall that in the 1970s–1980s benchmark the spread is 3 percentage points, so the spread remains higher than this starting level, but significantly lower than in the recent decades).

VII.C. Turning Point for r?*

Figure 19 shows, in the separate lines, the paths for safe r^* under each of the six scenarios described above, as well as a path that combines all of the scenarios. All scenarios result in higher r^*, except scenario 4, where the growth slowdown driven by the rise of intangibles dominates the rise in markups and the natural rate is lower than baseline as a result. Quantitatively, the remilitarization scenario is not very important: It builds up slowly and the magnitude of the effect is limited.

Figure 19. Upside Risk Scenarios



Source: Author's calculations.
Note: The figure shows simulations based on surprise increases in exogenous factors described in the main text. The combined scenario is calculated as the sum of the marginal effects of each of the six scenarios considered.

Other scenarios matter more: In particular, both AI and the inflation risk scenarios raise the safe natural rate by over a percentage point. The decline in the risk premium due to a persistent perception that *safe* assets have become riskier generates a sharp jump in r^*, not dissimilar to the one I observed in the financial markets in recent years.

Nonetheless, the modeled scenarios can only generate a pickup in the natural rate to the levels last seen in the pre-GFC period when they are considered jointly (or if some of the individual scenarios play out more strongly, of course). It is in the combined (all) scenario that the natural rate returns to the levels last seen prior to the GFC. So while the model with imperfect foresight is capable of generating a sharp turnaround in rates (it does so in the 1980s), and while the narratives discussed among economists and market participants can generate a large swing in natural rates, one needs to believe a confluence of risk scenarios hitting the economy all at once to generate a return to a natural rate of 3 percent or more. And of course, besides the upside scenarios considered here, there are also risks pertinent to the downside.[30]

One important lesson that comes out of the scenario analysis is the quantitative importance of the evolution of the risk premium for safe r^*. Since the pass-through from shocks to the spread to movements in the safe rate is close to one-to-one in this model, whether the spread remains elevated, shrinks, or increases has a profound impact on the safe natural rate relevant for central banks and finance ministries. The flip side of this is that, in this simple model, changes in the spread have little bearing on the risky r^*. Given the importance of the spread for the determination of the natural rates, a more in-depth modeling of the drivers of this spread, for example, as in the models of Angeletos and Panousi (2011) and Reis (2021), is warranted.

VIII. Conclusions

The natural real interest rate is unobserved but central to economic policy and long-horizon private decisions. The recent departure from the three-decade downward drift in government bond yields calls for a reassessment of the determinants of r^*.

This paper develops and quantifies a capital market equilibrium framework to study the joint evolution of r^* and wealth across AEs. An important finding is that the AE bloc has undergone substantial shifts in both capital demand and—especially—capital supply. These shifts help explain the long-run decline in the natural rate and the sharp increase in the wealth-to-GDP ratio, broadly consistent with empirical trends.

In the new steady state, capital demand and supply are more elastic. Despite the near doubling of the wealth-to-GDP ratio, equilibrium saving and investment flows remain modest, driven by the decline in population and productivity growth. Thus, the model can reconcile the two seemingly puzzling trends in the data: a large rise in wealth-to-GDP ratio and subdued saving and investment flows.

The business-as-usual scenario—based on drivers identified prior to the recent economic and geopolitical shocks—implies that r^* will remain low. It is somewhat higher than market-implied real rates in the pre-pandemic

30. For example, the uncertainty associated with the technological revolution powered by AI could translate to greater precautionary saving and lower neutral rates.

years (0–1.2 percent rather than negative values), but still far below historical averages. This highlights that, according to the model, the big forces that drove the continued decline of r^* over the preceding decades are still present, and there is little sign of a rapid unwind.

Model-based sensitivities and the scenario analysis provide a way to quantify alternative views and risks to the level of r^*. The three most powerful scenarios of the ones I considered are the AI scenario, the inflation risk scenario, and the fiscal scenario. Beyond the direct quantification, this analysis contains several themes.

The AI scenario shows that in a macroeconomic model such as the one developed here, changes in growth expectations are an important driver of the neutral rate. This is true across a range of scenarios that one might consider (e.g., impact via growth is also the key for thinking about trade policy and globalization).

The safety premium plays an important role in anchoring long-term safe rates, because the changes in the safety premium translate into changes in safe rates, close to one-to-one (they induce vertical shifts in both capital demand and capital supply schedules). The rise in the safety premium plays a critical role in driving the safe r^* downward, as safe rates of return decline by more than the returns to a broader class of assets. The present model offers little in terms of deeper explanations for what could stand behind these changes, beyond highlighting its importance in driving r^*.

The rising debt levels have historically provided a quantitatively important offset to the forces pulling r^* down. Going forward, they could become dominant, given the seemingly explosive debt dynamics in countries such as the United States. At the same time, the model predicts that the sensitivity of r^* to government debt today is significantly lower than in the past.

This paper points to several directions for future work. Future research should investigate risk premia in greater detail, including idiosyncratic risks to physical and intangible capital, shifts in preferences toward risk, and the evolving supply of safe assets. Quantifying the productivity and welfare gains from AI and other technologies will also be crucial for forecasting r^*.[31]

Finally, this analysis has focused on the AE bloc. While the resulting r^* serves as a useful benchmark for an integrated area, country-specific natural rates may diverge from the bloc rate under incomplete financial

31. For example, Rachel (2024) studies leisure-enhancing technologies—technologies that are monetized indirectly through the sale of consumers' time, attention, and data—and considers the implications for growth and for the natural rate.

integration. Extending the framework to incorporate country-level drivers of r^*, together with measures of cross-border financial linkages, is a promising avenue for future work.

ACKNOWLEDGMENTS I am immensely grateful to Antoine Ding, who provided outstanding research assistance. I thank the editors, Janice Eberly and Jón Steinsson, and my discussants, Adrien Auclert and Marco Del Negro, for extremely helpful and detailed comments and suggestions. I am also grateful to Ben Moll and Morten Ravn, and for the participants at the 2025 Federal Reserve Bank of New York research symposium on r^* where I presented some of the early ideas contained in this paper.

References

Acemoglu, Daron, and David Autor. 2011. "Skills, Tasks and Technologies: Implications for Employment and Earnings." In *Handbook of Labor Economics*, vol. 4: 1043–171. Amsterdam: North-Holland.

Acemoglu, Daron, and Pascual Restrepo. 2018. "The Race Between Man and Machine: Implications of Technology for Growth, Factor Shares, and Employment." *American Economic Review* 108, no. 6: 1488–542.

Aiyagari, S. Rao. 1994. "Uninsured Idiosyncratic Risk and Aggregate Saving." *Quarterly Journal of Economics* 109, no. 3: 659–84.

Akinci, Ozge, Gianluca Benigno, Marco Del Negro, and Albert Queralto. 2023. "The Financial (In)Stability Real Interest Rate, r^{**}." Staff Report 946. New York: Federal Reserve Bank of New York.

Ambrosino, Ludovica, Jenny Chan, and Silvana Tenreyro. 2026. "Trade Fragmentation, Inflationary Pressures and Monetary Policy." *Journal of International Economics*, Forthcoming in Press: 104219.

Angeletos, George-Marios, and Vasia Panousi. 2011. "Financial Integration, Entrepreneurial Risk and Global Dynamics." *Journal of Economic Theory* 146, no. 3: 863–96.

Auclert, Adrien, Hannes Malmberg, Frédéric Martenet, and Matthew Rognlie. 2025. "Demographics, Wealth, and Global Imbalances in the Twenty-First Century." Working Paper 29161. Cambridge, Mass.: National Bureau of Economic Research.

Auclert, Adrien, Hannes Malmberg, Matthew Rognlie, and Ludwig Straub. 2025. "The Race Between Asset Supply and Asset Demand." Paper presented at the 2025 Jackson Hole Economic Policy Symposium on Labor Markets in Transition—Demographics, Productivity and Macroeconomic Policy, Federal Reserve Bank of Kansas City, Jackson Hole, Wyo., August 21–23.

Autor, David, David Dorn, Lawrence F. Katz, Christina Patterson, and John Van Reenen. 2020. "The Fall of the Labor Share and the Rise of Superstar Firms." *Quarterly Journal of Economics* 135, no. 2: 645–709.

Bachas, Pierre, Matthew H. Fisher-Post, Anders Jensen, and Gabriel Zucman. 2024. "Capital Taxation, Development, and Globalization: Evidence from a Macro-Historical Database." Working Paper 29819. Cambridge, Mass.: National Bureau of Economic Research.

Barkai, Simcha. 2020. "Declining Labor and Capital Shares." *Journal of Finance* 75, no. 5: 2421–63.

Bernanke, Ben S. 2005. "The Global Saving Glut and the U.S. Current Account Deficit." Remarks delivered at the Sandridge Lecture, Virginia Association of Economists, Richmond, Va., March 10.

Blanchard, Olivier J. 1985. "Debt, Deficits, and Finite Horizons." *Journal of Political Economy* 93, no. 2: 223–47.

Brunnermeier, Markus K., Sebastian Merkel, and Yuliy Sannikov. 2024. "Safe Assets." *Journal of Political Economy* 132, no. 11: 3603–57.

Cabaco, Brian Amorim, and Morten O. Ravn. 2025. "Antitrust, Market Power, and US Macroeconomic Outcomes." Working Paper (unpublished).

Caballero, Ricardo J. 2006. "On the Macroeconomics of Asset Shortages." Working Paper 12753. Cambridge, Mass.: National Bureau of Economic Research.

Caballero, Ricardo J., Emmanuel Farhi, and Pierre-Olivier Gourinchas. 2008. "An Equilibrium Model of 'Global Imbalances' and Low Interest Rates." *American Economic Review* 98, no. 1: 358–93.

Caballero, Ricardo J., Emmanuel Farhi, and Pierre-Olivier Gourinchas. 2017. "The Safe Assets Shortage Conundrum." *Journal of Economic Perspectives* 31, no. 3: 29–46.

Carvalho, Carlos, Andrea Ferrero, and Fernanda Nechio. 2016. "Demographics and Real Interest Rates: Inspecting the Mechanism." *European Economic Review* 88: 208–26.

Congressional Budget Office. 2025. *The Long-Term Budget Outlook: 2025 to 2055*. Washington: Congressional Budget Office.

Crouzet, Nicolas, and Janice Eberly. 2021. "Intangibles, Markups, and the Measurement of Productivity Growth." *Journal of Monetary Economics* 124, suppl.: S92–S109.

Crouzet, Nicolas, and Janice Eberly. 2023. "Rents and Intangible Capital: A Q+ Framework." *Journal of Finance* 78, no. 4: 1873–916.

Crouzet, Nicolas, Janice Eberly, Andrea Eisfeldt, and Dimitris Papanikolaou. 2025. "Intangible Capital, Firm Scope, and Growth." Working Paper. Evanston, Ill.: Northwestern University Kellogg School of Management. https://www.kellogg.northwestern.edu/academics-research/research/detail/2025/intangible-capital-non-rivalry-and-growth/.

Damodaran, Aswath. 2024. "Equity Risk Premiums (ERP): Determinants, Estimation, and Implications—The 2024 Edition." Working Paper, Social Science Research Network, March 5. https://dx.doi.org/10.2139/ssrn.4751941.

Del Negro, Marco, Domenico Giannone, Marc P. Giannoni, and Andrea Tambalotti. 2017. "Safety, Liquidity, and the Natural Rate of Interest." *Brookings Papers on Economic Activity*, Spring: 235–94.

Del Negro, Marco, Domenico Giannone, Marc P. Giannoni, and Andrea Tambalotti. 2019. "Global Trends in Interest Rates." *Journal of International Economics* 118: 248–62.

De Loecker, Jan, and Jan Eeckhout. 2021. "Global Market Power." Working Paper, February 10. https://www.janeeckhout.com/wp-content/uploads/Global.pdf.

De Loecker, Jan, Jan Eeckhout, and Gabriel Unger. 2020. "The Rise of Market Power and the Macroeconomic Implications." *Quarterly Journal of Economics* 135, no. 2: 561–644.

De Ridder, Maarten. 2024. "Market Power and Innovation in the Intangible Economy." *American Economic Review* 114, no. 1: 199–251.

Díez, Federico J., Daniel Leigh, and Suchanan Tambunlertchai. 2018. "Global Market Power and Its Macroeconomic Implications." Working Paper 2018/137. Washington: International Monetary Fund.

Eggertsson, Gauti B., Neil R. Mehrotra, and Jacob A. Robbins. 2019. "A Model of Secular Stagnation: Theory and Quantitative Evaluation." *American Economic Journal: Macroeconomics* 11, no. 1: 1–48.

Epstein, Larry G., and Stanley E. Zin. 1991. "Substitution, Risk Aversion, and the Temporal Behavior of Consumption and Asset Returns: An Empirical Analysis." *Journal of Political Economy* 99, no. 2: 263–86.

Farhi, Emmanuel, and François Gourio. 2018. "Accounting for Macro-Finance Trends: Market Power, Intangibles, and Risk Premia." *Brookings Papers on Economic Activity*, Fall: 147–223.

Feenstra, Robert C., Robert Inklaar, and Marcel P. Timmer. 2015. "The Next Generation of the Penn World Table." *American Economic Review* 105, no. 10: 3150–82. www.ggdc.net/pwt.

Filippucci, Francesco, Peter Gal, and Matthias Schief. 2024. "Miracle or Myth? Assessing the Macroeconomic Productivity Gains from Artificial Intelligence." OECD Artificial Intelligence Paper 29. Paris: OECD Publishing.

Gagnon, Etienne, Benjamin K. Johannsen, and David Lopez-Salido. 2021. "Understanding the New Normal: The Role of Demographics." *IMF Economic Review* 69: 357–90.

Gertler, Mark. 1999. "Government Debt and Social Security in a Life-Cycle Economy." *Carnegie-Rochester Conference Series on Public Policy* 50: 61–110.

Gutiérrez, Germán, and Thomas Philippon. 2018. "How EU Markets Became More Competitive than US Markets: A Study of Institutional Drift." Working Paper 24700. Cambridge, Mass.: National Bureau of Economic Research.

Havranek, Tomas, Roman Horvath, Zuzana Irsova, and Marek Rusnak. 2015. "Cross-Country Heterogeneity in Intertemporal Substitution." *Journal of International Economics* 96, no. 1: 100–18.

Holston, Kathryn, Thomas Laubach, and John C. Williams. 2017. "Measuring the Natural Rate of Interest: International Trends and Determinants." *Journal of International Economics* 108, suppl. 1: S59–S75.

Lane, Philip R., and Gian Maria Milesi-Ferretti. 2018. "The External Wealth of Nations Revisited: International Financial Integration in the Aftermath of the Global Financial Crisis." *IMF Economic Review* 66: 189–222. Database available at https://www.brookings.edu/articles/the-external-wealth-of-nations-database/.

Laubach, Thomas, and John C. Williams. 2003. "Measuring the Natural Rate of Interest." *Review of Economics and Statistics* 85, no. 4: 1063–70.

Lisack, Noëmie, Rana Sajedi, and Gregory Thwaites. 2017. "Demographic Trends and the Real Interest Rate." Staff Working Paper 701. London: Bank of England.

Mehrotra, Neil R. 2025. "The Macroeconomics of Net Zero." Working Paper, January 7. https://drive.google.com/file/d/1OTP-WMrKJ69GxoEFyHDqjR51aXC5mNde/view.

Mehrotra, Neil R., and Michael E. Waugh. 2025. "Tariffs, Trade Wars, and the Natural Rate of Interest." *Quarterly Review* 45, no. 2: 2–18.

Moll, Benjamin, Lukasz Rachel, and Pascual Restrepo. 2022. "Uneven Growth: Automation's Impact on Income and Wealth Inequality." *Econometrica* 90 no. 6: 2645–83.

Obstfeld, Maurice. 2025. "Natural and Neutral Real Interest Rates: Past and Future." *IMF Economic Review* 73: 339–92.

OECD (Organisation for Economic Co-operation and Development). 1976. *OECD Economic Outlook* 1976, no. 1. Paris: OECD Publishing.

OECD. 1979. *OECD Economic Outlook* 1979, no. 1. Paris: OECD Publishing.

Peruffo, Marcel, and Josef Platzer. 2024. "Secular Drivers of the Natural Rate of Interest in the United States: A Quantitative Evaluation." Working Paper, August 26.

Rachel, Lukasz. 2024. "Leisure-Enhancing Technological Change." Working Paper, June 12. https://www.dropbox.com/scl/fi/i9gmdjqhdgp2ei5rx2s19/Leisure_web.pdf?rlkey=rerfi8ptr0i7a2zxlpgi7t2ch&raw=1.

Rachel, Lukasz, and Thomas D. Smith. 2015. "Secular Drivers of the Global Real Interest Rate." Staff Working Paper 571. London: Bank of England.

Rachel, Lukasz, and Lawrence H. Summers. 2019a. "On Falling Neutral Real Rates, Fiscal Policy, and the Risk of Secular Stagnation." *Brookings Papers on Economic Activity*, Conference Draft, Spring.

Rachel, Lukasz, and Lawrence H. Summers. 2019b. "On Secular Stagnation in the Industrialized World." *Brookings Papers on Economic Activity*, Spring: 1–54.

Reis, Ricardo. 2021. "The Constraint on Public Debt When $r < g$ But $g < m$." Working Paper 939. Basel: Bank for International Settlements.

Reis, Ricardo. 2022. "Which *r*-Star, Public Bonds or Private Investment? Measurement and Policy Implications." Working Paper, September. https://personal.lse.ac.uk/reisr/papers/99-ampf.pdf.

Straub, Ludwig. 2019. "Consumption, Savings, and the Distribution of Permanent Income." Working Paper, June 5. https://straub.scholars.harvard.edu/publications/consumption-savings-and-distribution-permanent-income.

Summers, Lawrence H. 2015. "Demand Side Secular Stagnation." *American Economic Review* 105, no. 5: 60–65.

Comments and Discussion

COMMENT BY

ADRIEN AUCLERT Monetary policymakers care about a lot of numbers, but there is one number they arguably care about more than any other, and that number is r^*. Adding r^* to their inflation target gives them the nominal interest rate they should be setting to hit that inflation target in the long run; comparing current estimates of r^* to the current real interest rate tells them how tight or loose current monetary policy is. Fiscal policymakers care a lot about r^* too, since it determines the long-run sustainability of a given fiscal trajectory and how urgent any fiscal consolidation might be.

This excellent and timely paper by Lukasz Rachel gives us historical estimates of r^* and scenarios for the future. These will be very welcome by monetary and fiscal policymakers alike. Even more importantly, in my opinion, the paper gives us a framework for thinking about the determinants of r^*, both qualitative and quantitative. The framework is of enormous value because we know from an earlier quantitative literature that forces such as productivity growth, markups, automation, population aging, inequality, government debt, taxes, and the generosity of social security should affect r^*, but it is not always easy a priori to understand which force acts in which direction, or the extent to which, say, a 1 percentage point increase in the debt-to-GDP ratio should raise r^*.

The paper is also a timely update on Rachel's earlier *BPEA* paper with Lawrence Summers. That paper argues, based on its estimates of low and declining r^* at the time, that "the industrialized world, taken as a whole, [was] currently—and for the foreseeable future [would] remain—highly

Brookings Papers on Economic Activity, Fall 2025: 188–213 © 2026 The Brookings Institution.

prone to secular stagnation" (Rachel and Summers 2019, p. 1).[1] In the intervening time from June 2019 to September 2025, long bond yields have risen by 2 percentage points in the United States,[2] leading commentators, including Summers, to argue that we have entered a "new normal" where secular stagnation is no longer a concern (Singh 2024). One of the benefits of Rachel's current paper is that it uses the very model that Summers had used to argue in favor of secular stagnation, updated with the most recent macroeconomic data, to evaluate these kinds of arguments. Ironically, Rachel does not find a strong case for rising r^*: His central scenario is a continued decline, although r^* could increase significantly if "several upside risks . . . crystallize all at once."

I think this is a fantastic paper: timely, clear, well written, with important findings. What I love the most about it is that it uses an approach that is clearly right: conceptualizing r^* as the price that equalizes asset supply and asset demand in the long run. This kind of framework allows us to use classic price theory to get at both the qualitative and the quantitative effects of various forces on r^*. It turns our attention to matching not just price (r^*) but also quantity (in this case, the wealth-to-GDP ratio); it also highlights the sufficient statistics that are relevant for making quantitative predictions. Of course, I am a little biased in saying this, since this framework is very similar to the one I used in a recent paper on this topic (Auclert, Malmberg, Rognlie, and Straub 2025). Our two papers implement this framework in very different ways, but our conclusions end up being quite similar!

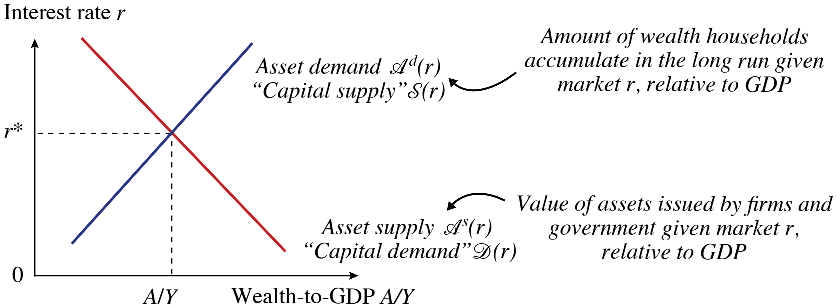
My discussion will highlight these key points of agreement, as well as some sources of disagreement, and provide some thoughts on where the literature could go forward from here.

SUPPLY AND DEMAND DETERMINANTS OF LONG-RUN r^* Many of the leading macroeconomic models of r^* feature a similar structure: In the long run, the interest rate r^* is the one that equilibrates the supply and the demand for assets. Figure 1 visualizes what this means. Given the market interest rate (r), households decide the amount of wealth they would like to accumulate in the long run, relative to GDP: I call this relationship the

1. Once r^* turns sufficiently negative, the central bank can no longer keep output at potential even by setting nominal interest rates at their effective lower bound. This situation can result in a steady state with below-potential output known as secular stagnation (see, e.g., Eggertsson, Mehrotra, and Robbins 2019).

2. Organisation for Economic Co-operation and Development, "Interest Rates: Long-Term Government Bond Yields: 10-Year: Main (Including Benchmark) for United States," series IRLTLT01USM156N, retrieved from FRED, https://fred.stlouisfed.org/series/IRLTLT01USM156N.

Figure 1. Supply and Demand Determinants of r^*



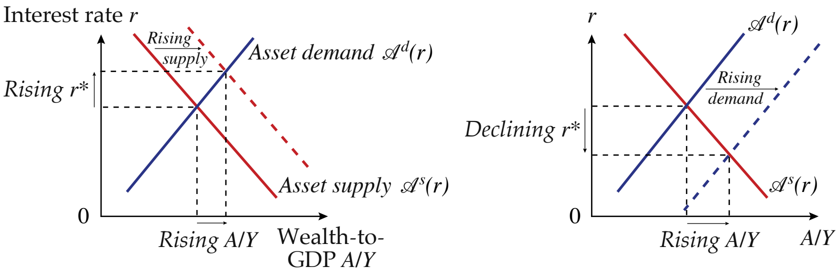
Source: Author's illustration.

asset demand curve, $\mathcal{A}^d(r)$. This curve is typically upward sloping (higher interest rates make households want to postpone consumption, which they do by accumulating wealth), but it can be downward sloping, especially at low interest rates, where the income effect (higher interest rates mean retirees can afford to save less) can dominate the substitution effect. Critically, "interesting" models of r^* have an imperfectly elastic asset demand curve. This requirement rules out the presence of any infinitely lived agent with standard macro preferences $\sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma}}{1-\sigma}$, since any such agent accumulates infinite long-run wealth as soon as the interest rate r exceeds $\frac{1}{\beta}\left(1+g\right)^{\sigma}-1$, where g is the growth rate of income, making the economy-wide asset demand curve $\mathcal{A}^d(r)$ infinitely elastic at that rate.

Similarly, given the market interest rate r, the value of assets issued by firms and the government achieves a certain level relative to GDP: I call this relationship the asset supply curve, $\mathcal{A}^s(r)$. This curve is typically downward sloping, since neoclassical firms choose to accumulate less capital when the user cost of capital is higher; and also because stock market valuations are lower when interest rates are higher, and because the government may decide to reduce its stock of government in response to rising market rates.

One semantical point of departure with Rachel's paper is that he calls "capital supply" the asset demand curve, and "capital demand" the asset supply curve. This convention makes sense in simple models, where asset supply is made up entirely of the capital stock, and the relationship between asset supply and the interest rate comes from firms' demand for capital given that interest rate; in turn, households must accumulate wealth

Figure 2. Equilibrium Effect of Asset Supply and Demand Shifts



Source: Author's illustration reproduced from Auclert, Malmberg, Rognlie, and Straub (2025).

to provide that capital, such that their asset demand is the capital supply. However, I think the convention becomes less tenable in models such as ours, where asset supply is also made up of stock market values and government bonds. So I will follow the asset demand and asset supply convention—a convention dating back at least to Caballero (2008) in the literature—rather than the author's for the rest of this discussion.[3]

The reason why this framework is such a nice way to understand the determinants of r^* is that it allows us to immediately make sense of the direction through which potentially complex forces act. For instance, higher government debt-to-GDP ratios, automation, rising capital intensity, or lower risk premia (which boost firm valuations) all increase asset supply: We should expect them to raise the long-run level of wealth-to-GDP ratio as well as long-run r^* (figure 2, left panel). By contrast, population aging or a decline in the generosity of social security (both of which make people save more), rising inequality, and an increasing foreign demand for assets all raise asset demand, so these forces raise the long-run level of wealth-to-GDP ratio but lower long-run r^* (figure 2, right panel). The effect of some forces becomes clear this way: Rising markups, for instance, have very large positive effects on valuations (rising supply), which offsets any effect from reduced capital accumulation; therefore, at least to the extent that the corresponding profits are capitalized in the stock market, markups should raise r^*. Some forces act in more complex ways, affecting both asset demand and supply. Take rising productivity growth: If cohorts perceive higher life cycle growth, they

3. Another point in favor of Rachel's convention is that capital demand is downward sloping in r, while capital supply is upward sloping in r, as in standard price theory. This is convenient, but also a little confusing, since asset prices actually move inversely to the interest rate r.

will borrow more (or save less, i.e., falling demand); at the same time, firm valuations will get a boost (rising supply). The net effect is a rise in r^*, but an ambiguous effect on the level of wealth-to-GDP ratio and so on. Virtually any force can be understood this way.

Given this framework, it is clear that any understanding of the past evolution or the future direction of r^* relies on correctly identifying the shifters of asset demand and supply. The paper proposes a fully structural approach to do this.

THIS PAPER: A STRUCTURAL APPROACH Specifically, Rachel constructs the asset supply and asset demand schedules $\mathcal{A}^s(r)$ and $\mathcal{A}^d(r)$ by fully specifying the primitives underlying both and then solving for the value of each of these schedules at each possible value of r. The model is simple enough that $\mathcal{A}^s(r)$ and $\mathcal{A}^d(r)$ have an almost closed-form solution, making this procedure numerically straightforward.

On the asset supply side, the model features standard neoclassical production, markups resulting from monopolistic competition, and government debt. This results in a simple functional form for $\mathcal{A}^s(r)$ as a function of primitives such as capital intensity α, depreciation of capital δ, markups φ, and the government debt-to-GDP ratio. Rachel proposes simple strategies to back out these primitive parameters from the data. One could quibble with the details of how this is done, but for the most part it is a fairly straightforward procedure. The only real stance to take is the level and the pace of increase of markups over time, which is subject to considerable debate in the literature; given the structure of the model, capital intensity then follows from $1 - \alpha = \varphi \times \frac{wL}{Y}$ where $\frac{wL}{Y}$ is the labor share in the data.

On the asset demand side, the model is what one could call a "double heart attack" model. As discussed above, one must step outside of the world of standard infinitely lived consumers to generate an inelastic asset demand curve. Overlapping generation models with finite lifetimes are one way to achieve this, but they can get quite complicated when modeling many periods of life, with agents solving a very different problem at each age as they go through their life cycle with evolving income prospects and mortality risk. Blanchard (1985) introduces the single heart attack model as an alternative: Agents face a constant probability of having a heart attack in a period, after which they die; a constant fraction of agents is born each period to replace the dying. This setting has tractable aggregation because agents have linear consumption rules, but it also builds in life cycle effects, with agents accumulating wealth over time as they age. However, agents have effectively only a working period of life, which doesn't allow for the possibility of a retirement phase. To remedy this and think about issues such as social security, Gertler (1999) introduces the double heart attack model: After a first heart attack, agents move to a retirement phase of life, in which they face another (possibly higher) constant probability of death. This setting remains highly tractable, with nice aggregation properties, which is why it is heavily used in the macro demographics literature to derive analytical results (see, e.g., Carvalho, Ferrero, and Nechio 2016).

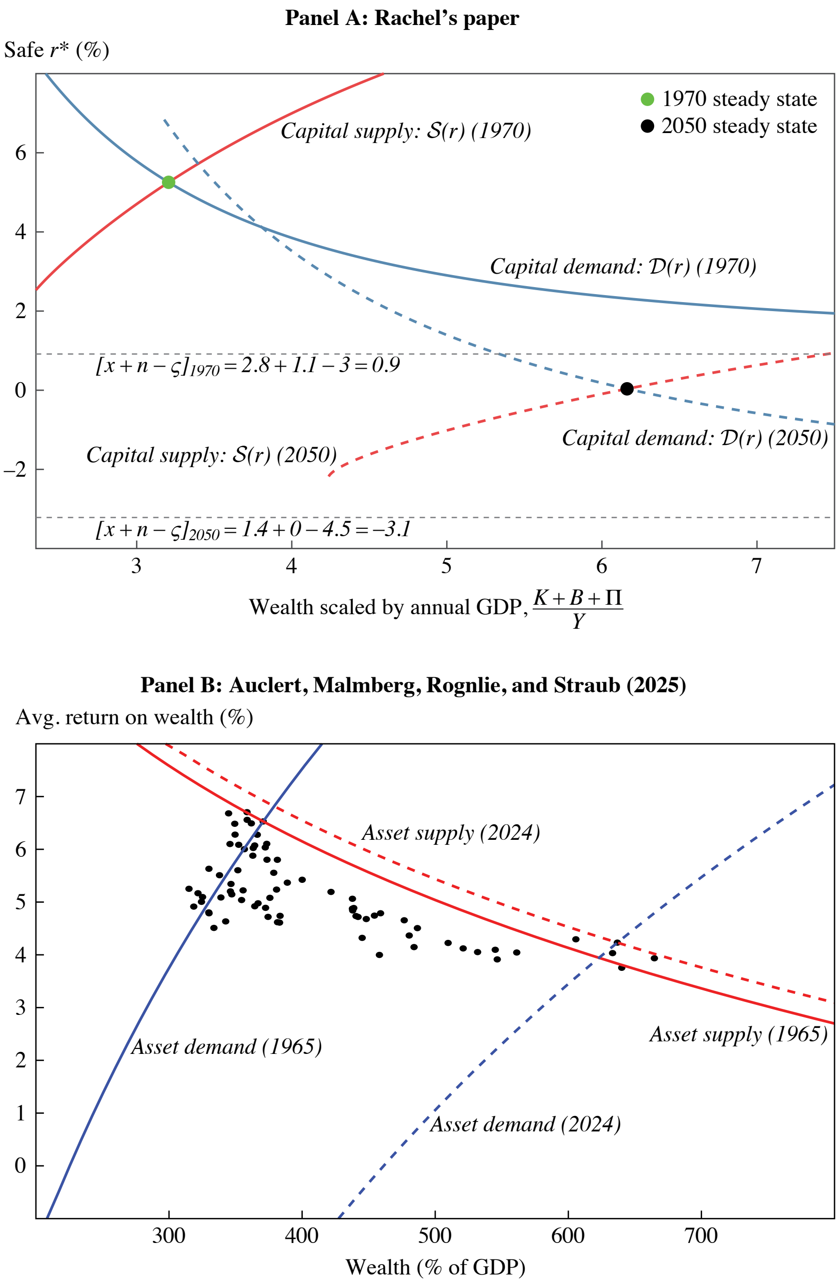
The resulting model has very few parameters, most of which (the growth rate of newborns, the length of working life, the length of retirement, the average income of workers and retirees) can be taken directly from the data. As in standard life cycle models, asset accumulation responds to cuts in social security income or to increases in the length of time in retirement; one drawback, however, is that it is not possible to separate the effect of a shift in an increase in the retirement age (a policy parameter) from an actual increase in life expectancy.

The main finding from Rachel's paper is that, between 1970 and 2050, factors that increase asset demand/capital supply at given interest rates, such as longer retirement, falling population growth, and declining income growth, are much more potent than factors that increase asset supply/capital demand, such as automation, rising government debt, and rising markups. This is nicely visualized in figure 6 of the paper, which I reproduce here as figure 3, panel A. The outcome is a decline in r^*, by about 530 basis points (from 5.3 percent in 1970 to 0 percent today). This baseline specification refutes Summers's "new normal" hypothesis: In the transition between 1970 and 2050, interest rates fall continuously, and they do not get back to their pre-2008 level in the decades to come.

The paper's figure 8 breaks down the overall shifts into contributions from each of the factors. It is clear there that longer retirement, slowing population growth, and falling growth are the three major drivers of the shift in asset demand. Since the first two are slow-moving demographic drivers that cannot be reversed, this finding implies that reversing the prediction of falling r^* would require a large increase in productivity growth, perhaps one that could result from the development of artificial intelligence.

AN ALTERNATIVE REDUCED-FORM APPROACH The structural approach followed by Rachel relies on trusting that the model provides the "true" nonlinear mapping between macroeconomic fundamentals and asset demand and supply. In practice, however, there is a lot of uncertainty about the right underlying model. The double heart attack model is convenient but also highly counterfactual at the microeconomic level, implying, for instance, the simultaneous presence of very young retirees (who had a heart attack

Figure 3. Asset Demand Wins



Source: Panel A is reproduced from Rachel's paper; panel B is based on author's calculations as described in Auclert, Malmberg, Rognlie, and Straub (2025). Dots in panel B represent data.

in their twenties) and extremely old workers (who have yet to get a heart attack at age 200). At that level, the model—just like most macro models—is therefore clearly unrealistic. Nevertheless, it may give similar predictions as a more complex model that would have more micro-level realism. How can we evaluate whether it does or not?

One way to answer this question is to take a more reduced-form approach, deriving sufficient statistics for predictions of r^* that would be valid in a class of models, including more realistic models of household behavior. Indeed, the price theory framework I spelled out above is useful not just to understand qualitative directions, but quantitative magnitudes as well, at least to a first order. To see this, write $\mathcal{A}^s(r, \eta)$ for the asset supply curve and $\mathcal{A}^d(r, \eta)$ for the asset demand curve with macro shifter η, then the relationship $\mathcal{A}^s(r, \eta) = \mathcal{A}^d(r, \eta)$ implies that the change in the level of the equilibrium interest rate dr^* and in the equilibrium log asset-to-GDP ratio $d \log \mathcal{A}$ resulting from a small change in macro fundamentals $d\eta$ is given by:

$$dr^* = \frac{\frac{\partial \log \mathcal{A}^s}{\partial \eta} d\eta - \frac{\partial \log \mathcal{A}^d}{\partial \eta} d\eta}{\epsilon^s + \epsilon^d} \tag{1}$$

$$d \log \mathcal{A} = \frac{\epsilon^d \frac{\partial \log \mathcal{A}^s}{\partial \eta} d\eta + \epsilon^s \frac{\partial \log \mathcal{A}^d}{\partial \eta} d\eta}{\epsilon^s + \epsilon^d}, \tag{2}$$

where the semi-elasticities of asset supply and demand are defined as:

$$\epsilon^s \equiv -\frac{\partial \log \mathcal{A}^s}{\partial r} \qquad \epsilon^d \equiv \frac{\partial \log \mathcal{A}^d}{\partial r},$$

with all derivatives evaluated at the original steady state. Equations (1) and (2) are helpful because they show that, to the first order, the equilibrium interest rate and quantity changes in the asset market following a change in macro fundamentals only require knowledge of the semi-elasticities of asset supply and demand ϵ^s and ϵ^d and the extent to which macro fundamentals shift the asset supply and the asset demand curves and given interest rates, $\frac{\partial \log \mathcal{A}^s}{\partial \eta} d\eta$ and $\frac{\partial \log \mathcal{A}^d}{\partial \eta} d\eta$. Similarly, by linearity of the first-order approximation, the effect of any combination of shifters $\eta_1, \eta_2, \ldots \eta_N$ is then the sum of each effect in isolation, which gives us a simple way to decompose the total effect into a sum of components. Any difference between model predictions for the given fundamental shift $d\eta$ can then be traced back to differences in the elasticities of supply and demand ϵ^s and ϵ^d or to differences in asset supply and demand shifters $\frac{\partial \log \mathcal{A}^s}{\partial \eta} d\eta$ and $\frac{\partial \log \mathcal{A}^d}{\partial \eta} d\eta$.

If we have data on the historical evolution of both r^* and $\log \mathcal{A}$, and if we know ϵ^s and ϵ^d, we can back out the shifters of asset demand and supply that rationalize this evolution. Auclert, Malmberg, Rognlie, and Straub (2025) propose a procedure to do this.[4] Using the procedure and data from that paper, I back out the 1965 and 2024 asset supply and demand curves and visualize them in figure 3, panel B. Notice the striking visual analogy between this figure and that from Rachel's paper in panel A. The slopes of asset supply and demand are similar: $\epsilon^s = 13$ and $\epsilon^d = 12$ in Rachel's paper, $\epsilon^s = 20$ and $\epsilon^d = 8$ in Auclert, Malmberg, Rognlie, and Straub (2025). In particular, the sum $\epsilon^s + \epsilon^d$ is about the same, implying that the papers will make similar predictions for interest rates given shifters even though they will have different implications for how much these shifters translate into equilibrium quantities. Both papers agree that asset demand shifts were much larger than asset supply shifts over the 1965–2024 period, which Auclert, Malmberg, Rognlie, and Straub (2025) summarize as demand won the historical race between asset demand and supply.

On the other hand, some differences appear too: Most notably, the 1970–2050 decline in the equilibrium interest rate is much more pronounced than the 1965–2024 decline in Auclert, Malmberg, Rognlie, and Straub (2025). This is partly because we treat r^* very differently—r^* is an unobservable factor in Rachel's paper while I argue we can observe it in Auclert, Malmberg, Rognlie, and Straub (2025)—but, given that we have similar elasticities, must also boil down to much larger underlying shifters of asset demand and supply.[5]

Backing out underlying drivers. Further progress with the reduced-form approach can be made by noticing that first-order shifters of asset supply and demand can sometimes be straightforward to calculate. For

4. Most models agree with the formulation of the supply side, and ϵ^s is then easy to calculate from model primitives and a few macroeconomic observables. Auclert, Malmberg, Rognlie, and Straub (2025) provide a formula for ϵ^d that holds in standard life cycle models as a function of the elasticity of intertemporal substitution in consumption and observable age profiles.

5. The difference in endpoints does not make much of a difference given that the transitions in Rachel's model see very little action between 2025 and 2050.

Table 1. Comparison of the Effects on r^* of Various Forces

*Basis point change in r**	*Rachel's paper*	*Auclert, Malmberg, Rognlie, and Straub (2025)*
Time period	*1970–2050*	*1965–2024*
Overall	−530	−247
Productivity growth	−215	−103
Demographics	−275	−110
Inequality	—	−92
Global saving glut	−25	−72
Risk premium	−160	9
Government debt	145	44
Markups	105	97
Social security and taxes	130	22
Interaction terms	−200	—

Source: Auclert, Malmberg, Rognlie, and Straub (2025) and Rachel's paper.

instance, a rise in government debt by 1 percent of GDP raises asset supply by $\frac{1}{A/Y}$ percent, where A/Y is the asset to GDP ratio: This gives us $\frac{\partial \log \mathcal{A}^s}{\partial \eta} d\eta$ for such a shift. A little more involved, but just as simple to calculate, a decline in fertility affects the age structure of the population, and its effect on asset demand can then be studied by integrating the life cycle profile of assets using the new age distribution, in a shift-share type of calculation (see my other paper, Auclert, Malmberg, Martenet, and Rognlie 2025). Auclert, Malmberg, Rognlie, and Straub (2025) provide a full set of sufficient statistics for shifters of $\frac{\partial \log \mathcal{A}^d}{\partial \eta} d\eta$ in standard life cycle models and implement them using micro data on household behavior, together with information on the evolution of inequality and demographics.

COMPARING RESULTS FROM THE TWO APPROACHES Table 1 shows the change in r^* implied by our two models and its decomposition into various forces. I backed out the numbers on the left column from figure 15 in Rachel's paper; this includes an interaction term because the model is nonlinear so that the overall isn't just the sum of the individual effects. The right column is from Auclert, Malmberg, Rognlie, and Straub (2025) over the 1970–2024 range; here the interaction term is zero by construction.

The two decompositions should, of course, not be expected to line up exactly. The time periods are slightly mismatched. Rachel's model is one of all advanced economies, while the Auclert, Malmberg, Rognlie, and Straub (2025) model is for the United States only; this matters, for instance, when evaluating the magnitude of the increase in government debt or the net foreign asset position. Nevertheless, the signs of almost all forces are aligned—a reflection of the fact that the underlying framework is essentially the same. The main notable exception is the risk premium, which lowers r^* by 160 basis points in Rachel's model and raises it by 9 basis points in the Auclert, Malmberg, Rognlie, and Straub (2025) model. This is due to a disagreement over the evolution of the risk premium itself over this time period: Rachel assumes that this risk premium rises over the period, following Moll, Rachel, and Restrepo (2022), while the data in Auclert, Malmberg, Rognlie, and Straub (2025) suggest a decline in the risk premium instead.

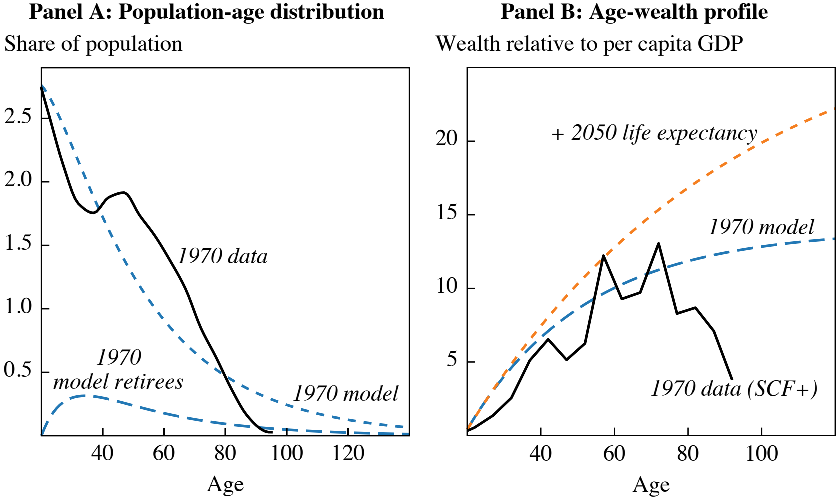
For other forces, the signs are the same, and the magnitudes tend to align as well. As I mentioned above, since the sum $\epsilon^s + \epsilon^d$ is comparable in both models, those differences can largely be traced back to differences in the magnitude of the underlying asset supply or demand shift. Sometimes, this is just due to a mere difference in scope: For instance, the increase in net foreign assets or government debt depends on whether one takes Rachel's advanced economy perspective or Auclert, Malmberg, Rognlie, and Straub's (2025) US perspective.

Rachel's paper and Auclert, Malmberg, Rognlie, and Straub (2025) have more fundamental disagreements about the effects of productivity and demographics: These have much bigger effects in Rachel's model than in the Auclert, Malmberg, Rognlie, and Straub (2025) model. For productivity, this comes from the fact that Rachel loads productivity growth on time effects: Falling productivity growth implies that incomes rise less steeply for each individual in the economy, and this results in much higher savings. In the Auclert, Malmberg, Rognlie, and Straub (2025) model, productivity growth loads on cohort effects instead: Lower productivity growth means new cohorts enter the labor market with lower earnings, but the life cycle profiles of income are unaffected. Therefore, there are no life cycle savings responses to lower productivity growth, with the only remaining effect coming from savings composition across cohorts. The bottom line is that, as pointed out by Blanchard (2023), the r^* effect of productivity growth depends a lot on whether this growth loads on time or cohort effects. Future literature should try to adjudicate this important question.

For demographics, my calculations in the next section suggest that the double heart attack model tends to overstate the savings responses to rising longevity, for reasons I will explain.

Another noteworthy factor is that interaction terms end up mattering a lot in Rachel's model, explaining almost the entire difference in aggregate predictions in the change in r^* between it and Auclert, Malmberg, Rognlie,

Figure 4. Micro Implications of the Double Heart Attack Model



Source: Author's simulations based on parameters from Rachel's paper.

and Straub (2025). There are two ways to view this result. One is that nonlinearities may matter quite a lot when thinking about these issues. The other one is that we should have less confidence about any result coming from nonlinear interactions, since they cannot be explained by taking an alternative reduced-form approach (at least to first order). By construction, this type of nonlinearity will be quite model-specific, and future work can also help determine whether the linearities robustly go in the direction of Rachel's paper.

This discussion just illustrates one way in which results from papers on *r** can be compared to each other. While the point estimates differ, my view is that there is already quite a bit of convergence, and future work can narrow that gap further.

AGGREGATE SAVINGS IMPLICATION OF THE DOUBLE HEART ATTACK MODEL One particular asset demand shifter that I suspect Rachel's model of overpredicting is that of the effect of rising mortality on life cycle saving. Figure 4 presents my simulations of the micro part of the model, using the author's parameters, for the population age distribution in panel A and the age-wealth profile in panel B. As discussed above, the model features a lot of young retirees as well as extremely old retirees and workers. However, in terms of the fit to the overall population age distribution in 1970, it does a decent job: In both the model and the data, high recent fertility means the population is disproportionately young. Aggregating across all agents, we obtain an age-wealth profile of assets, which is relatively aligned with the data from the Survey of Consumer Finances in 1970 (panel B). However, considering the 2050 steady state with much higher life expectancy implies a very large savings response in the model, with the (now more numerous) 120+ year-olds accumulating an enormous amount of assets. This effect seems implausible. If the model embedded the type of bequest forces that are generally seen as necessary to match life cycle asset profiles, these effects would be dramatically mitigated, as shown by Auclert, Malmberg, Martenet, and Rognlie (2025).

OUR FISCAL FUTURE Going forward, the model considers a number of very interesting alternative scenarios. I think most of these are plausible, but I would highlight one that seems quite optimistic. The model assumes that the level of advanced economy government debt-to-GDP ratio rises very modestly between 2024 and 2050, from 82 percent to 90 percent. Contrast this with the Congressional Budget Office projections, with US debt exploding out to the forecast horizon, with no fiscal consolidation in sight. This effect is directly related to the aging of the population: Expenditures on programs such as Medicare and Medicaid grow with the elderly population. This creates a channel through which demographic change affects not just asset demand but asset supply as well. In Auclert, Malmberg, Rognlie, and Straub (2025), I argue that this is actually the main reason to think that r^* may go up significantly in the future.

CONCLUSION I have stressed some of the benefits of the reduced-form approach over Rachel's structural approach. But the structural approach has advantages too: Notably, the tractability of the model allows the author to easily solve for transition dynamics rather than treating the system as if it were in steady state at all times, and to incorporate a more realistic treatment of expectations than the usual perfect foresight assumption. Ultimately, reduced-form and structural approaches are highly complementary and will help us refine our views of the evolution of r^* going forward, providing those all-important numbers to monetary and fiscal policymakers.

REFERENCES FOR THE AUCLERT COMMENT

Auclert, Adrien, Hannes Malmberg, Frédéric Martenet, and Matthew Rognlie. 2025. "Demographics, Wealth, and Global Imbalances in the Twenty-First Century." Working Paper 29161. Cambridge, Mass.: National Bureau of Economic Research.

Auclert, Adrien, Hannes Malmberg, Matthew Rognlie, and Ludwig Straub. 2025. "The Race Between Asset Supply and Asset Demand." Paper presented at the 2025

Economic Policy Symposium on Labor Markets in Transition—Demographics, Productivity and Macroeconomic Policy, Federal Reserve Bank of Kansas City, Jackson Hole, Wyo., August 21–23.

Blanchard, Olivier J. 1985. "Debt, Deficits, and Finite Horizons." *Journal of Political Economy* 93, no. 2: 223–47.

Blanchard, Olivier J. 2023. *Fiscal Policy Under Low Interest Rates*. Cambridge, Mass.: MIT Press.

Caballero, Ricardo J. 2008. "On the Macroeconomics of Asset Shortages." In *The Role of Money: Money and Monetary Policy in the Twenty-First Century*, edited by Andreas Beyer and Lucrezia Reichlin: 272–83. Frankfurt am Main: European Central Bank.

Carvalho, Carlos, Andrea Ferrero, and Fernanda Nechio. 2016. "Demographics and Real Interest Rates: Inspecting the Mechanism." *European Economic Review* 88: 208–26.

Eggertsson, Gauti B., Neil R. Mehrotra, and Jacob A. Robbins. 2019. "A Model of Secular Stagnation: Theory and Quantitative Evaluation." *American Economic Journal: Macroeconomics* 11, no. 1: 1–48.

Gertler, Mark. 1999. "Government Debt and Social Security in a Life-Cycle Economy." *Carnegie-Rochester Conference Series on Public Policy* 50: 61–110.

Moll, Benjamin, Lukasz Rachel, and Pascual Restrepo. 2022. "Uneven Growth: Automation's Impact on Income and Wealth Inequality." *Econometrica* 90, no. 6: 2645–83.

Rachel, Lukasz, and Lawrence H. Summers. 2019. "On Secular Stagnation in the Industrialized World." *Brookings Papers on Economic Activity*, Spring: 1–54.

Singh, Milan. 2024. "Larry Summers Isn't Worried About Secular Stagnation Anymore." *Slow Boring*, Substack, April 18. https://www.slowboring.com/p/larry-summers-isnt-worried-about.

COMMENT BY

MARCO DEL NEGRO[1] Lukasz Rachel's excellent contribution uses a model to discuss drivers of r^* across advanced economies. In my discussion, I will use international data on inflation as well as short- and long-term yields to estimate r^* for several countries and provide a measure of "global r^*" using the approach in Del Negro and others (2019). I will then interpret some of Rachel's findings in light of this evidence, and compare the outcome of his quantitative analysis to my estimates.

1. I am very grateful to Elena Elbarmi and Michael Pham for excellent research assistance, and to Maurice Obstfeld for helpful feedback. The views expressed herein are mine and not necessarily those of the Federal Reserve Bank of New York or the Federal Reserve System.

The analysis in Del Negro and others (2019) covers the G7 countries and ends in 2017. Relative to that paper, I will extend the sample in the time dimension so that I will be able to discuss what happened to r^* in the post-COVID period, and in the cross-sectional dimension, including all eighteen countries in the Jordà-Schularick-Taylor Macrohistory Database (see Jordà, Schularick, and Taylor 2017) to have broader international coverage.[2]

ESTIMATING TRENDS In order to obtain estimates of r^* I will use an econometric framework—a "trendy VAR" or, more formally, a VAR with common trends—that was developed in Del Negro and others (2017). This framework is a multivariate trend-cycle decomposition that uses a panel to extract trends that are potentially common to multiple variables. I will describe the model in broad strokes, referring the reader to Del Negro and others (2019) for a fuller description and all the details of the implementation.

The model postulates that the $n \times 1$ vector of observables y_t can be decomposed into a nonstationary component $\Lambda\overline{y}_t$ and a stationary component $\tilde{y}_t$:

$$y_t = \Lambda\overline{y}_t + \tilde{y}_t, \tag{1}$$

for $t = 1, \ldots, T$, where $\overline{y}_t$ is a $q \times 1$ vector of trends and Λ a $n \times q$ matrix describes how each observable loads on the trends. The trends $\overline{y}_t$ evolve according to a random walk:

$$\overline{y}_t = \overline{y}_{t-1} + e_t, \tag{2}$$

while the stationary components $\tilde{y}_t$—that is, the cycle—follow an unrestricted VAR:

$$\tilde{y}_t = \Phi_1\tilde{y}_{t-1} + \cdots + \Phi_p\tilde{y}_{t-p} + \varepsilon_t. \tag{3}$$

The innovations to the trend and the cycle, e_t and ε_t, are orthogonal to one another. The prior specification used for all the results below is exactly as in Del Negro and others (2019).

My observables are inflation rates $\pi_{i,t}$, and short- and long-term nominal yields on government bonds—$R_{i,t}$ and $R^L_{i,t}$, respectively—for the eighteen

2. These eighteen countries are Australia, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

countries ($i = 1, \ldots, 18$) in the database. For each country i, the corresponding rows of equation (1) are:

$$
\begin{aligned}
\pi_{i,t} &= \overline{\pi}_{i,t} + \tilde{\pi}_{i,t}, \\
R_{i,t} &= \overline{\pi}_{i,t} + \overline{r}_{i,t} + \tilde{R}_{i,t}, \qquad (4)\\
R^L_{i,t} &= \overline{\pi}_{i,t} + \overline{r}_{i,t} + \overline{ts}_{i,t} + \tilde{R}^L_{i,t}.
\end{aligned}
$$

These equations imply that each country's inflation trend $\overline{\pi}_{i,t}$ is identified off inflation rates and nominal yields, while the trend in real rates $\overline{r}_{i,t}$ is identified as the level factor moving the permanent component of both short- and long-term *real* yields. The model also allows for trends in the term spread $R^L_{i,t} - R_{i,t}$, which are called $\overline{ts}_{i,t}$.

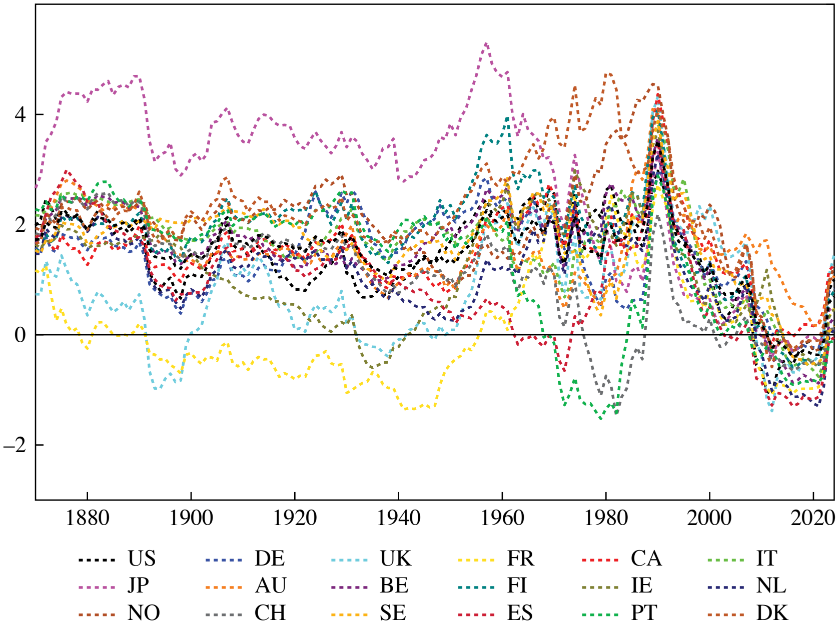
Finally, each of these trends consists of a common/global and an idiosyncratic/country-specific component, where the former moves the permanent component for the entire cross section of countries while the latter only affects trends in country i:[3]

$$
\begin{aligned}
\overline{\pi}_{i,t} &= \lambda^{\pi}_i \overline{\pi}^w_t + \overline{\pi}^i_t, \\
\overline{r}_{i,t} &= \overline{r}^w_t + \overline{r}^i_t, \qquad (5)\\
\overline{ts}_{i,t} &= \overline{ts}^w_t + \overline{ts}^i_t.
\end{aligned}
$$

Before delving into the results, a brief comment on the interpretation of $\overline{r}_{i,t}$. Obstfeld (2025) distinguishes between the neutral rate $r*$ that is relevant for monetary policymakers in the short run and the long-run equilibrium real rate $\overline{r}$, which he calls the natural rate. In the language of dynamic stochastic general equilibrium (DSGE) models, Obstfeld's neutral rate broadly coincides with the notion of short-run r^*_t—that is, the real rate in a counterfactual economy with flexible prices and wages, which moves with the cycle—while the natural rate $\overline{r}$ is the long-run version of the same object (formally, $\lim_{h \to \infty} E_t r^*_{t+h}$), which abstracts from the cycle and only reflects more long-lasting features of the economy. The $\overline{r}_{i,t}$'s estimated here squarely fall into the natural rate $\overline{r}$ camp, which is consistent with Rachel's

3. Theory-based restrictions suggest that the loading on $\overline{r}^w_t$ and $\overline{ts}^w_t$ is one for all countries, as discussed in Del Negro and others (2019). In that paper we show that these restrictions are not rejected by the data. However, no such restrictions apply to the loadings λ^{π}_i for inflation trends.

Figure 1. Global Convergence in r^*



Source: Author's calculations.
Note: The figure shows the median estimates of the real interest rate trends $\bar{r}_{i,t}$ for the eighteen countries in the sample.

paper since his estimates also abstract from cyclical fluctuations.[4] In the remainder of the discussion I will follow Rachel, as opposed to Obstfeld, and often refer to the $\bar{r}_{i,t}$ as r^*.

GLOBAL CONVERGENCE IN r^* Figure 1 plots the median estimates of $\bar{r}_{i,t}$ for the eighteen countries in my sample. The figure shows that before the 1980s the $\bar{r}_{i,t}$'s comoved, but there was a lot of dispersion across countries. After the late 1980s all of a sudden this dispersion disappeared, possibly as a result of financial market integration. In other words, after around 1990 the trends in real rates are one and the same across advanced economies. The implication of this finding, which was first documented in Del Negro and others (2019), is that both the decline in r^* from 1990 to 2019, as well

4. In Del Negro and others (2017) we show that for the United States, the DSGE-based measure of $\lim_{h\to\infty} E_t r^*_{t+h}$, which the paper approximates with a thirty-year r^* ($E_t r^*_{t+30}$), essentially coincides with the $\bar{r}_{US,t}$ estimate extracted from a trendy VAR for most of the sample.

as the post-COVID rise that is evident from the figure, are *global* phenomena. Therefore, whatever explanations for the decline (and recent rise) in r^* would also better be global. In this sense, Rachel's paper does the right thing by taking a global perspective.

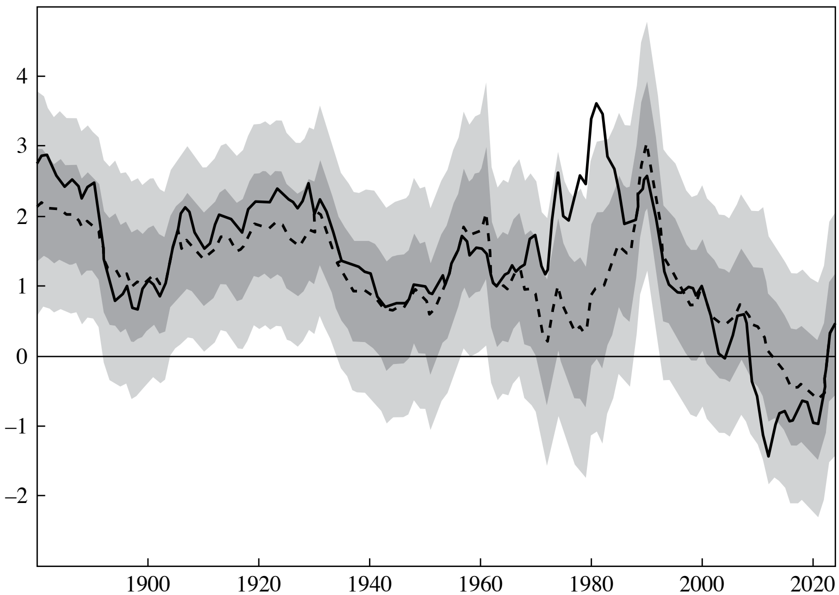
ESTIMATING GLOBAL r^* AND ITS DRIVERS As the second part of equation (5) makes clear, $\bar{r}_t^w$ is estimated as the common trend among the $\bar{r}_{i,t}$'s. Under financial markets integration, which as I have just argued is not a bad assumption since the 1990s, $\bar{r}_t^w$ can be interpreted as the trend in the world real interest rate (see the discussion in Del Negro and others 2019)—that is, global r^*. The idiosyncratic trends $\bar{r}_t^i = \bar{r}_{i,t} - \bar{r}_t^w$ can be interpreted as country-specific convenience yields $-\overline{cy}_t^i$: If $\bar{r}_t^i$ is negative, that is, $\bar{r}_{i,t} < \bar{r}_t^w$, this must be because country i government bonds have some comparative "specialness" $\overline{cy}_t^i > 0$ in terms of either safety or liquidity relative to the average government bond in the sample.[5]

Figure 2 shows that global r^* fell from about 3 percent in the early 1990s to below zero after the global financial crisis, continued declining in the 2010s, and then rose by about 1 percentage point after the COVID-19 pandemic. By and large, since the late 1980s the US r^* has been in tow of global r^*, except that it declined more in the aftermath of the financial crisis. By 2024, the end of the sample, the median posterior estimates of both $\bar{r}_t^w$ and $\bar{r}_t^{US}$ are around 0.5 percent (more precisely, $\bar{r}_{2024}^w = 0.31$ and $\bar{r}_{2024}^{US} = 0.46$). The estimate for $\bar{r}_t^w$ is in line with the number reported in Rachel's paper for the safe real r^* in 2025 in advanced economies. It is also consistent with Williams's (2025) assessment of the GDP-weighted estimates of r^* for Canada, the euro area, the United Kingdom, and the United States, although my US r^* estimate is a bit below current estimates of US r^* from Laubach and Williams (2003) and Holston, Laubach, and Williams (2017), which are about 1 percent. Having said that, the large posterior coverage intervals shown in figure 2 are there to remind us that extracting trend from cycle is a difficult task, and that one should take point estimates with more than a grain of salt. The 68 percent posterior coverage intervals for both $\bar{r}_{2024}^w$ and $\bar{r}_{2024}^{US}$ range from about −0.5 percent to above 1 percent, while the 95 percent intervals range from about −1.5 percent to above 2 percent.

While the *level* of r^* is very uncertain, the model can make statistically sharper statements about the *change* in r^* over time. To that effect, the size

5. In principle, differences in trends of real rates across countries could also reflect trends in real exchange rate changes. Del Negro and others (2019) discuss the fact that low-frequency movements in real exchange rate changes are very hard to detect.

Figure 2. The Decline, and Recent Rise, in Global r^*



Source: Author's calculations.

Note: The dashed line shows the posterior median of $\bar{r}_t^w$ and the shaded areas show the 68 and 95 percent posterior coverage intervals. The solid line shows the posterior median of $\bar{r}_{US,t}$.

of the pre-COVID decline in global r^* according to my estimates is in the ballpark of what is reported in Rachel's paper. The first row of table 1 reports the decline in $\bar{r}_t^w$ and $\bar{r}_t^{US}$ from 1990 to 2019. The median estimate of the decline is about 3.5 percentage points for both the global and US r^*'s, and the 95 percent posterior coverage intervals approximately include both Rachel's estimate of the decline at the upper end, as well as Auclert and others' (2025) estimate at the lower end. Although its exact magnitude is uncertain, from a statistical point of view there is no question that a decline has taken place: The posterior probability that $\bar{r}_{2019}^w - \bar{r}_{1990}^w$ and $\bar{r}_{2019}^{US} - \bar{r}_{1990}^{US}$ are less than zero is greater than 97.5 percent.

The first row of table 1, as well as figure 2, also point to a non-negligible and statistically significant rise in $\bar{r}_t^w$ and $\bar{r}_t^{US}$ in the post-COVID period between 2019 and 2024: about 0.8 percentage points for global r^* and a little more than 1 percentage point for the US r^*. To the extent that you believe these estimates, they beg the question of why r^* has risen in the

Table 1. Global r^*, the US r^*, and Their Drivers

	$\bar{r}^w$		$\bar{r}^{US}$	
	1990–2019	*2019–2024*	*1990–2019*	*2019–2024*
Baseline model				
$\bar{r}$	−3.52***	0.79***	−3.27***	1.11***
	(−4.94, −2.09)	(0.07, 1.49)	(−5.13, −1.36)	(0.18, 2.06)
Convenience yield model				
$\bar{r}$	−3.83***	1.01***	−3.11***	1.14***
	(−5.41, −2.27)	(0.30, 1.70)	(−4.45, −1.75)	(0.42, 1.86)
$-\overline{cy}$	−1.58***	0.35	−0.85**	0.49*
	(−2.64, −0.50)	(−0.17, 0.86)	(−1.57, −0.11)	(−0.05, 1.03)
$\bar{m}$	−2.36***	0.65**	−2.26***	0.65**
	(−3.55, −0.98)	(0.08, 1.22)	(−3.55, −0.98)	(0.08, 1.22)

Source: Author's calculations.

Note: For each trend, the table reports the posterior median, with the 95 percent posterior coverage interval in parentheses. Statistical significance is indicated with *, **, and ***, if the posterior probability that the change in the trend is below (for the 1990–2019 period) or above (for the 2019–2024 period) zero is greater than 90, 95, or 97.5 percent, respectively.

recent period.[6] In light of what I have shown, the drivers of such an increase better be global. Also, they better be able to generate a sudden movement in r^*. The remainder of my discussion focuses on what these drivers may be.

In previous research (Del Negro and others 2017, 2019), my coauthors and I have argued that an increase in the *global* convenience yield—that is, the convenience for safety and liquidity that applies to all advanced economies' government bonds—is an important driver of the pre-COVID decline in r^*. We now discuss whether my estimates confirm this result and, more importantly, to what extent a decline in the convenience yield between 2019 and 2024 drove r^* up. In order to investigate the role of trends in the convenience yield $\overline{cy}_t$, I follow Del Negro and others (2019) and decompose $\bar{r}_t^w$ into a world convenience yield component and a remainder term $\bar{m}_t^w$ that captures all other factors:

$$\bar{r}_t^w = \bar{m}_t^w - \overline{cy}_t^w. \tag{6}$$

These two terms are separately identified by adding one more observable to the system (4), namely, the yield on US Baa corporate bonds following

6. On the one hand, models such as those of Laubach and Williams (2003) and Holston, Laubach, and Williams (2017) do not feature such a post-COVID rise in r^*. On the other hand, other models such as some of those featured in Baker and others (2023), as well as the data shown in Rachel's paper, suggest that such an increase has taken place.

Krishnamurthy and Vissing-Jorgensen (2012) and assuming, as in their work, that Baa corporate bonds earn no convenience yield for either safety or liquidity.[7] This implies that:

$$(7) \qquad R^{Baa}_{US,t} = \overline{\pi}^{w}_{US,t} + \overline{m}^{w}_{t} + \overline{ts}_{US,t} + \tilde{R}^{Baa}_{US,t}.$$

Taking the difference between the equation for $R^{L}_{US,t}$ and $R^{Baa}_{US,t}$, one can see that the trend in the spread between the two captures the sum of the world and the US convenience yield:

$$(8) \qquad \overline{R}^{Baa}_{US,t} - \overline{R}^{L}_{US,t} = \overline{cy}^{w}_{t} + \overline{cy}^{US}_{t}.$$

Since the second term on the right-hand side, $\overline{cy}^{US}_{t}$, is already identified as the US-specific trend in real rates (recall that $-\overline{cy}^{US}_{t} = \overline{r}^{US}_{t} = \overline{r}_{US,t} - \overline{r}^{w}_{t}$), I can use equation (8) to recover estimates of $\overline{cy}^{w}_{t}$.

The bottom panel of table 1 shows the results for this convenience yield model. The table shows that indeed an increase in the convenience yield played a significant role in driving r^* down both for the United States and the world, in line with research summarized in Caballero, Farhi, and Gourinchas (2017): The rise in $\overline{cy}^{w}_{t}$ and $\overline{cy}_{US,t}$ (which equals $\overline{cy}^{w}_{t} + \overline{cy}^{US}_{t}$) explains about one-third of the decline in $\overline{r}^{w}_{t}$ and $\overline{r}_{US,t}$, respectively. The decline in the convenience yield for government bonds also explains one-third to half of the post-COVID rise in r^*, although it is not precisely estimated. This decline in $\overline{cy}_{t}$, which in the United States is reflected in a compression of corporate spreads, reflects the fact that for a variety of reasons, possibly including the surge in government debt across advanced economies, the safety and liquidity appeal of government bonds in the United States and around the world has declined.[8] At the same time, table 1 shows that this decline in $\overline{cy}$ is clearly not the entire story: The change in the remainder $\overline{m}^{w}$ is larger and statistically more significant than the change in $\overline{cy}$.

If not the convenience yield, what factors account for the post-COVID rise in r^*, and can Rachel's model account for them? Two natural candidates for the sudden post-COVID rise in r^* across advanced economies are news about: (1) an artificial intelligence–driven forthcoming uptick in productivity growth; and (2) future surges in debt-to-GDP ratio, possibly driven by

7. This is, of course, a very strong assumption, which leads to understating $\overline{cy}^{w}_{t} + \overline{cy}^{US}_{t}$ in our estimation.

8. For the United States this finding is consistent with the evidence in Jiang, Richmond, and Zhang (2025).

a perceived unwillingness on the part of governments to raise taxes to deal with the demographics transition or by higher expected military spending. Rachel's paper is well positioned to study the effect of news about such structural developments on r^* (see section VII in the paper) and therefore whether these or other factors can provide a potential explanation for the post-COVID rise in r^*.

The results in figure 19 of the paper hint at the answer. The figure shows the effect on r^* of various scenarios, including the two I just mentioned. It shows that the only scenario that can produce a sudden change in r^* besides the convenience yield (called "inflation risk" in the paper) is the debt-funded social security scenario. In this scenario, households are promised higher social security coverage than expected under the baseline (social security outlays reach 13 percent of GDP in the 2050s rather than stabilizing below 8 percent as in the baseline), and the higher coverage is funded by debt issuance. The reason this scenario works is not so much because of the increase in debt—the effect of the rise in debt on r^* is only gradual—but because it prompts a sudden decline in desired savings by households as they realize that they need to save less for old age. It is not immediately clear how well this scenario squares with the post-COVID experience in advanced economies—if anything, a number of countries such as France are attempting to reduce social security spending, as opposed to increasing it. However, one can interpret the generous post-COVID benefits as an implicit promise by governments to bail households out in case of future needs, possibly including those related to old age. Under this interpretation, the debt-funded social security scenario can perhaps rationalize some of the post-COVID sudden rise in r^*. For other scenarios, including news about artificial intelligence, the effect on r^* is potentially large but more gradual.

To conclude, I thoroughly enjoyed reading Rachel's very timely, interesting, and comprehensive paper on the factors driving the decline, and the possible future rise, in global r^*. I found Rachel's quantitative analysis to be mostly in line with the empirical evidence generated by the global "trendy VAR" in Del Negro and others (2019). The model presented in the paper may also be able to explain some of the sudden increase in global and the US r^* that—at least according to my estimates—we have observed since COVID.

REFERENCES FOR THE DEL NEGRO COMMENT

Auclert, Adrien, Hannes Malmberg, Matthew Rognlie, and Ludwig Straub. 2025. "The Race Between Asset Supply and Asset Demand." Paper presented at the 2025 Economic Policy Symposium on Labor Markets in Transition—Demographics, Productivity and Macroeconomic Policy, Federal Reserve Bank of Kansas City, Jackson Hole, Wyo., August 21–23.

Baker, Katie, Logan Casey, Marco Del Negro, Aidan Gleich, and Ramya Nallamotu. 2023. "The Post-Pandemic *r**." *Liberty Street Economics*, August 9. https://libertystreeteconomics.newyorkfed.org/2023/08/the-post-pandemic-r/.

Caballero, Ricardo J., Emmanuel Farhi, and Pierre-Olivier Gourinchas. 2017. "The Safe Assets Shortage Conundrum." *Journal of Economic Perspectives* 31, no. 3: 29–46.

Del Negro, Marco, Domenico Giannone, Marc P. Giannoni, and Andrea Tambalotti. 2017. "Safety, Liquidity, and the Natural Rate of Interest." *Brookings Papers on Economic Activity*, Spring: 235–94.

Del Negro, Marco, Domenico Giannone, Marc P. Giannoni, and Andrea Tambalotti. 2019. "Global Trends in Interest Rates." *Journal of International Economics* 118: 248–62.

Holston, Kathryn, Thomas Laubach, and John C. Williams. 2017. "Measuring the Natural Rate of Interest: International Trends and Determinants." *Journal of International Economics* 108, suppl. 1: S59–S75.

Jiang, Zhengyang, Robert J. Richmond, and Tony Zhang. 2025. "Convenience Lost." Working Paper 33940. Cambridge, Mass.: National Bureau of Economic Research.

Jordà, Òscar, Moritz Schularick, and Alan M. Taylor. 2017. "Macrofinancial History and the New Business Cycle Facts." *NBER Macroeconomics Annual* 31: 213–63.

Krishnamurthy, Arvind, and Annette Vissing-Jorgensen. 2012. "The Aggregate Demand for Treasury Debt." *Journal of Political Economy* 120, no. 2: 233–67.

Laubach, Thomas, and John C. Williams. 2003. "Measuring the Natural Rate of Interest." *Review of Economics and Statistics* 85, no. 4: 1063–70.

Obstfeld, Maurice. 2025. "Natural and Neutral Real Interest Rates: Past and Future." *IMF Economic Review* 73: 339–92.

Williams, John C. 2025. "All the Stars We Cannot See." Remarks at the Banco de México Centennial Conference, Mexico City, August 25.

GENERAL DISCUSSION David Romer drew attention to the role of uncertainty around not just individual parameters but also general modeling and calibration choices, pointing to the discrepancies between the author's r^* estimates and those presented by the discussant Adrien Auclert. He posited that such variation is representative of what a broader set of researchers might find, which suggests that true uncertainty about r^* is very large. Romer suggested that this uncertainty may not matter much to monetary policy but is likely very relevant to fiscal policy.

Tarek Hassan commented that economic theory dictates that the risk-free rate is a function of intertemporal substitution and aggregate risk. He asked whether the author's framework could be leveraged to measure the extent to which each of these matters. He thought that predicting the risk is likely to be more difficult.

Neil Mehrotra asked what the sensitivity of r^* is to debt-to-GDP ratio in the author's model, highlighting the importance of this for the analyses conducted by the Congressional Budget Office. He further noted that this type of model often implies there is a large capacity for increasing the debt-to-GDP ratio with relatively limited effect on interest rates. He wondered how one should approach fiscal sustainability in these models.

In regard to duration in the author's model, Jonathan Pingle noted that the debt-to-GDP ratio is negatively correlated with estimates of r^* in the time series. However, the opposite can be true in term premium farther out the curve: One can observe that the supply of debt is positively correlated with term premium. He suggested that if long-term government debt pushes term premium up, in equilibrium this may imply a lower short-term policy rate, for the same setting of financial conditions.

Gabriel Chodorow-Reich brought up productivity as a driver of the author's results. He explained that in the neoclassical framework, productivity is linked to interest rates through the Euler equation, where an intertemporal elasticity of substitution of 0.5 would yield a relatively large sensitivity to productivity. He wondered what the corresponding parameter would look like in the author's framework and suggested the author take a look at this as a source of uncertainty. In addition, Chodorow-Reich inquired about the relevance and validity of the author's assumption that people have perfect foresight over time spent in retirement and how that would interact with the "double heart attack" model discussed in Auclert's presentation: As life expectancy and time in retirement increase, savings go up, leading to downward pressure on r^*; but what happens if one changes this assumption?

Lawrence Schmidt highlighted that, considering the Euler equation, in a model with incomplete markets, change in the amount of idiosyncratic risk people face will have a large effect on r^*—all kinds of risk that occur along the way, not just late in life, to people's key assets and human capital. Schmidt asked how this could be mapped into the author's framework.

Jón Steinsson was surprised to see high estimates of r^* in the early 1980s in the paper. He noted that Thomas Laubach and John Williams also estimated high values for r^* in the early 1980s and said that he had hoped to see a different result in this paper, but this was not the case.[1] He commented

1. Thomas Laubach and John C. Williams, "Measuring the Natural Rate of Interest," *Review of Economics and Statistics* 85, no. 4 (2003): 1063–70.

that he thought the high r^* in the early 1980s was a strange result because one view of the world during that time was that interest rates were high as a result of extremely tight monetary policy under the Volcker Fed. But, taking the author's results at face value, monetary policy was not tight in the 1980s—rather, the interest rates were equal to r^*. Steinsson asked how these two views could be reconciled.

Justin Wolfers questioned the viability of including 2020–2021 in the sample, viewing those years as outliers. By the same logic, relying on 2022–2023 estimates to draw conclusions on the post-2020 period may be too thin. Following up to Wolfers's comment, Gerald Cohen asked what has changed since 2019 when the author coauthored another *BPEA* paper with Lawrence Summers on this topic: an inflation shock, change in debt dynamics, or change in parameters that led the author to place more weight on certain aspects?[2]

Considering the change in the world interest rate over a century, Minchul Yum wondered if change in capital mobility across countries should also be taken into account.

Looking at the wealth-to-GDP ratio in the author's model, Janice Eberly cautioned that the present value of equity plays an important role, which could be driven by the present value of rents or by the present value of expected research and development (R&D) payoffs—both referred to as intangibles. One's view of the future economic outcomes would differ markedly depending on which force dominates. Eberly emphasized that the author's assumption about this parameter would have a significant effect on the implications of the analysis.

Regarding the sensitivity of the results to fiscal risk, Lukasz Rachel responded that the baseline assumptions on the fiscal side in his business-as-usual projections are fairly benign and that the scenario of higher debt to higher social security spending would be closer to the central case and upside risks could be analyzed relative to that.

To Mehrotra's question about the sensitivity of r^* to debt-to-GDP ratio, Rachel explained that this relationship has changed drastically between two steady states: Previously, a 1 percentage point change in debt-to-GDP ratio would induce a 2–2.5 basis point change in r^*. The reason, he said, is that the capital supply schedule is half as steep, so any shift in capital demand as a result of increase in debt yields a smaller increase in r^*; hence, thinking about what the capital market equilibrium is helps us think through

2. Lukasz Rachel and Lawrence H. Summers, "On Secular Stagnation in the Industrialized World," *Brookings Papers on Economic Activity*, Spring (2019): 1–54.

that. However, Rachel acknowledged, the convenience yield in his model is treated in a rather basic way, and a natural extension to this issue is to consider convenience yield as endogenous to level of debt. In a scenario where debt grows rapidly, he noted, convenience yield would fall as a result.

In response to comments on uncertainty, Rachel recognized that there is a great amount of uncertainty in his estimates, but based on his experience working with this type of model, uncertainty is probably greater on specific levels of $r*$ than on sensitivities that can be checked against empirical evidence more easily. Using the capital market equilibrium is helpful in this regard because one would end up tracking two measures: $r*$ and the wealth-to-GDP ratio, which provides the model with another dimension to match against existing evidence.

On channels that are not considered in his framework, particularly incomplete markets and idiosyncratic risk, Rachel pointed out that these were taken into account in the calibration of the model, loosely speaking, but only in so far as there are no changes in the market incompleteness over time. Rachel shared that, for his paper with Summers mentioned above, they did an exercise with a separate model to calibrate increase in idiosyncratic risk and back out the impact on $r*$. Building a bigger compound model like this, he said, would result in some loss of tractability and ability to perform things like transitions.

Regarding what has changed since 2019, Rachel responded that not much has changed in terms of the model—interest rates have been declining for decades and will likely continue to do so slightly over the coming years—thus the "business-as-usual" scenario as presented by the paper. It's the sensitivity and scenario analysis in the paper that's supposed to answer this question, he argued: For example, in the case of artificial intelligence (AI), the model is here to produce sensitivity of $r*$ to specific AI impacts on economic growth, capital intensity of production, or automation, rather than pinpointing what has happened.

Appendix

A Solution to retirees' and workers' problems

Retirees. The first-order conditions of the retiree's problem yield the Euler Equation:

$$C_{t+1}^{rjk} = (R_{t+1}\beta)^{\sigma} C_t^{rjk}$$

Denoting by $\epsilon_t \pi_t$ the retiree's marginal propensity to consume out of wealth[32], we can write down retiree's consumption function as:

$$C_t^{rjk} = \epsilon_t \pi_t (R_t/\gamma) A_t^{rjk}$$

Plugging this expression into the Euler Equation yields the expression for the evolution of the retiree's MPC:

$$\epsilon_t \pi_t = 1 - (R_{t+1}^{\sigma-1}\beta^{\sigma}\gamma)\frac{\epsilon_t \pi_t}{\epsilon_{t+1}\pi_{t+1}}. \tag{19}$$

Workers. The Euler Equation from the worker's problem is:

$$\omega C_{t+1}^{rjk} + (1-\omega)\Lambda_{t+1} C_{t+1}^{rj(t+1)} = (R_{t+1}\Omega_{t+1}\beta)^{\sigma} C_t^{wj}$$

where Λ is the marginal rate of substitution across consumption while being a worker and a retiree, and Ω is a weighing factor which captures the fact that workers discount future more: $\Omega_{t+1} = \omega + (1-\omega)\epsilon_{t+1}^{\frac{1}{1-\sigma}}$.[33]

Denoting the MPC of the worker by π, and conjecturing that the consumption function takes the form:

$$C_t^{wj} = \pi_t (R_t A_t^{wj} + H_t^j + S_t^j)$$

(where H stands for human wealth and S is social security wealth, given respectively by $H_t^j = \sum_{\nu=0}^{\infty} \frac{W_{t+\upsilon} - T_{t+\nu}}{\prod_{z=1}^{\upsilon} R_{t+z}\Omega_{t+z}/\omega}$ and $S_t^j = \sum_{\nu=0}^{\infty} \frac{E_{t+\nu}^j}{\prod_{z=1}^{\upsilon} R_{t+z}\Omega_{t+z}/\omega}$), we obtain the time path of worker's

[32] Reasons for this notation will become clear momentarily.

[33] For the complete derivation of worker's Euler Equation, see the Appendix of Gertler (1999).

MPC :

$$\pi_t = 1 - (R_{t+1}\Omega_{t+1})^{\sigma-1}\beta^{\sigma}\frac{\pi_t}{\pi_{t+1}}.$$

Social security wealth of the workers is:

$$S_t^w = \sum_{\nu=0}^{\infty} \frac{(1-\omega)\omega^{\nu} N_t \left(\frac{\epsilon_{t+\nu+1}\frac{S_{t+\nu+1}}{\psi N_{t+\nu+1}}}{R_{t+\nu}\Omega_{t+\nu}}\right)}{\prod_{z=1}^{\nu} R_{t+z}\Omega_{t+z}}.$$

The numerator of the sum on the right hand side is a time-$t+\nu$ capitalized value of the social security payments to all the individuals who were in the workforce at t and retire at $t+\nu+1$. The total social security wealth is just the infinite sum of the discounted value of these capitalized payments.

The evolution of total wealth of retirees is the sum of return on their wealth from last period plus what the newly retired bring in:

$$\lambda_{t+1}A_{t+1} = \lambda_t R_t A_t - C_t^r + (1-\omega)[(1-\lambda_t)R_t A_t + W_t - C_t^w]$$

From this, we get the explicit expression for the evolution of the retiree share:

$$\lambda_{t+1} = \omega(1-\epsilon_t\pi_t)\lambda_t R_t \frac{A_t}{A_{t+1}} + (1-\omega).$$

B A model with hand-to-mouth households

The model in the main text of the paper assumes that all households behave in a forward-looking fashion: workers save for retirement, and retirees manage their savings in such a way as to achieve a smooth consumption profile over their expected retirement. In reality, however, a substantial fraction of households hold little wealth (see, e.g., Aguiar et al. (2025) and references therein). If a significant fraction of households behave in a hand-to-mouth (HtM) way, this raises the concern that some of the shifts—not least the rise in longevity—have smaller effects on behavior and thus on the equilibrium real interest rate.

To respond to these concerns, this appendix introduces HtM households into the model and explores the consequences for capital market equilibrium and the natural rate of interest.

Aguiar et al. (2025) estimate that around 23% of households in the United States are hand-to-mouth due to low levels of wealth.[34] In the context of the model of this paper, these

[34] They estimate that a further 17.3% of households are wealthy hand-to-mouth, meaning that they have

households consume their labor income when they are workers and rely on social security payments to fund consumption in retirement.

Figure 21 shows the capital market equilibrium (the 1970 steady state) in the baseline model (described in the main text) and in the alternative model with 23% of households living hand-to-mouth. In the HtM model, the capital supply curve is both shifted inward and is steeper due to the reduced responsiveness of savings to changes in the real interest rate. To reach the same steady-state level of capital, the economy requires a much higher return to induce the non-HtM households to supply sufficient capital.

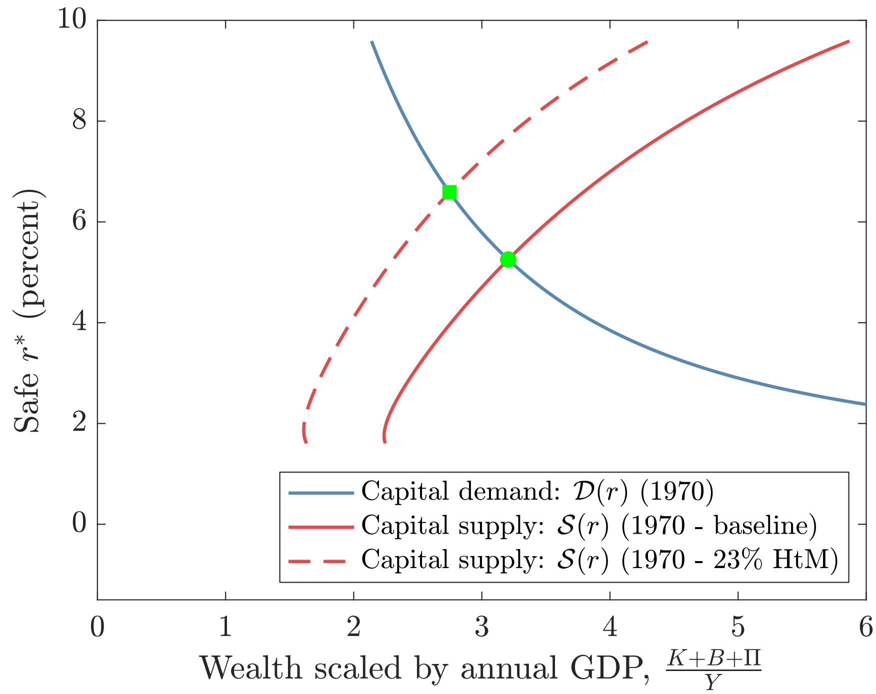


Figure 21: Capital market equilibrium with 23% HtM vs. baseline.

This has two important implications. First, the equilibrium interest rate is significantly higher when HtM households are present. Second, the economy operates along a steeper part of the capital demand curve, meaning any given shift in capital supply (e.g., due to demographics) induces a larger change in the equilibrium interest rate. It is that second implication that has important consequences for the sensitivity of the neutral rate to shifts in capital supply, e.g. those driven by the demographic factors.

low liquid wealth. Since these wealthy HtM households still accumulate assets over the life cycle, I restrict attention to the no-wealth HtM in the analysis here.

Impact of demographics. Figure 22 presents the shifts in capital market equilibrium due to individual driving factors —such as the rise in longevity—in the model with HtM households. This figure can be directly compared to Figure 8 which is the equivalent figure in the baseline. Even though the shift in capital supply due to demographics is smaller in the HtM case (consistent with the intuition that HtM households' behavior is unaffected by changes in life expectancy), the effect on the equilibrium real interest rate r^* is of comparable magnitude. This occurs because a given shift in capital supply results in a greater change in r^*, because of the greater slope of the capital demand schedule in the initial equilibrium. Thus, the partial equilibrium intuition that more hand to mouth agents translates into a smaller effects of demographic factors on the real rate of interest does is incomplete and can lead to misleading conclusions in general equilibrium.

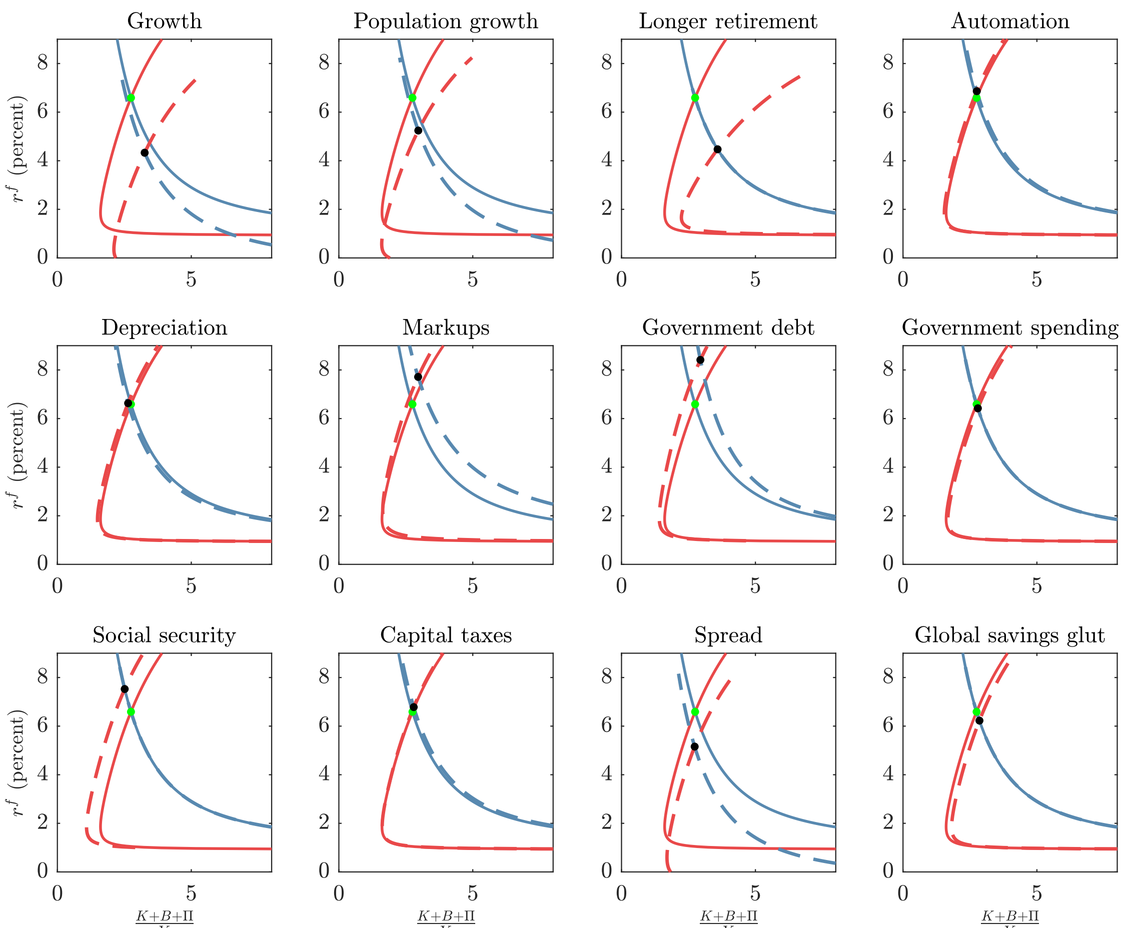


Figure 22: Effect of demographic shocks on capital market equilibrium (23% HtM).

Recalibration of the HtM model The model with HtM households predicts higher interest rates, and so a natural question to ask is what the model's predictions would be if it was recalibrated to be consistent with wealth-to-GDP ratio in the 1970s. To address this, I recalibrate the discount factor β to match this moment (and by the same token match the baseline model's real interest rate in 1970).

Since the baseline model has a relatively high discount factor ($\beta = 0.99$ at annual frequency), bringing down the interest rate in the HtM model requires raising patience to a high level, specifically $\beta = 1.0065$. This is feasible due to the finite life structure of the model.

However, with such high patience, the response of savings to changes in longevity becomes large, and the recalibrated model predicts even larger effects of demographic change on r^* than the baseline—*despite* the presence of HtM households.

As a result, r^* in the recalibrated HtM model declines by more than in the baseline, as shown in Figure 23.[35]

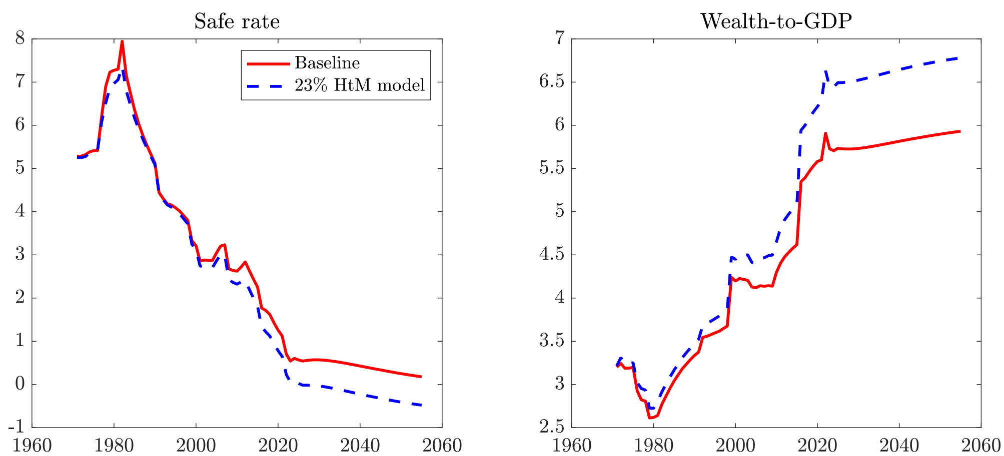


Figure 23: r^* and wealth-to-GDP in the recalibrated HtM model.

[35] An alternative approach to recalibration is to increase the intertemporal elasticity of substitution (IES) rather than raise β. This approach also allows the HtM model to match the empirical interest rate in 1970 while keeping patience close to the baseline level. The predicted fall in r^* is very similar to that in the baseline model in this case.

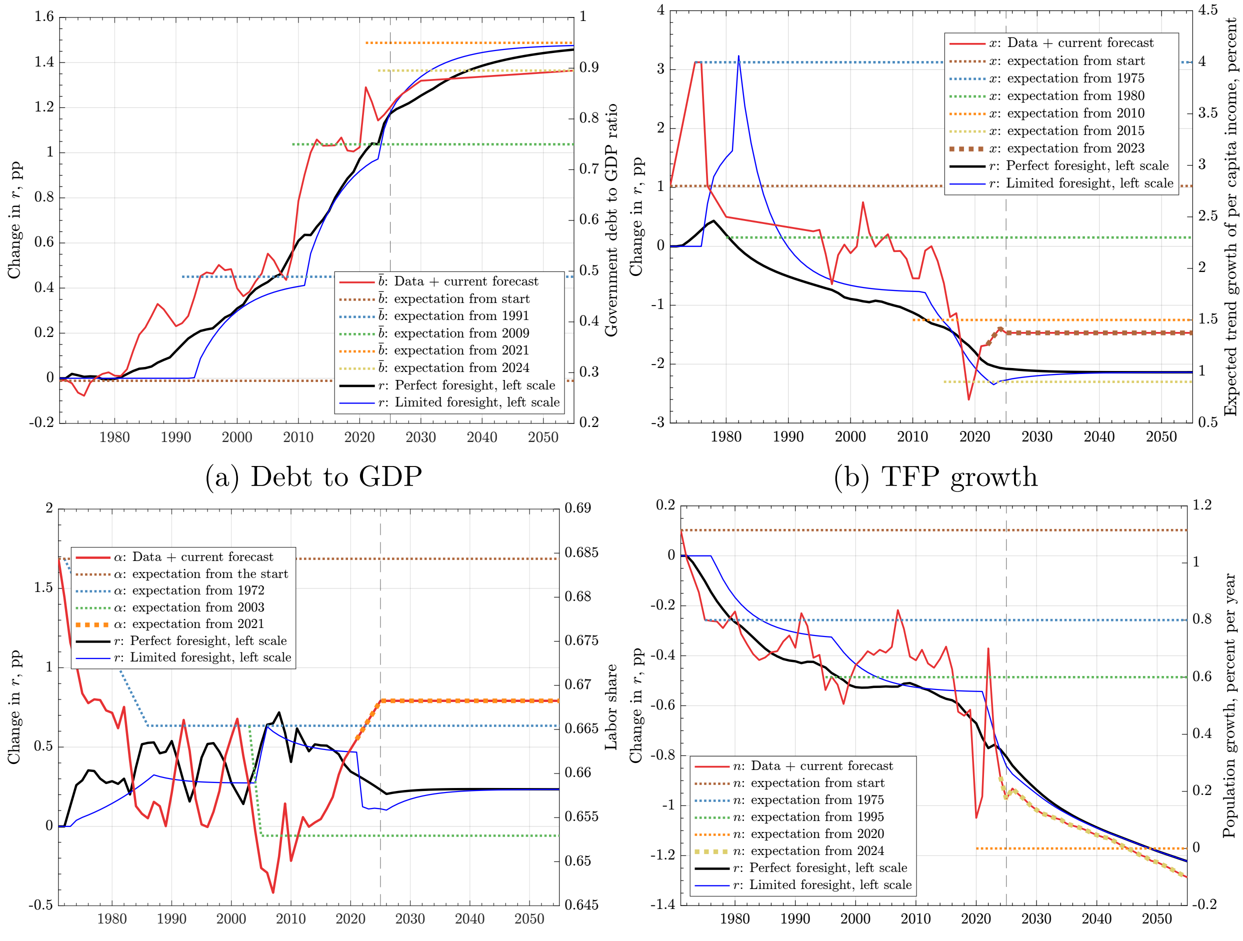
C Details about the imperfect transition path assumptions

This appendix presents the specifics and the results of the limited foresight exercise. Figures 24 and 25 plot, in solid red, the realized data for each shifter; dotted lines show the expectations formed at different dates. To illustrate, the first panel traces advanced-economy government debt, which rose from about 28% to 82% of GDP and is expected to increase further. The dotted curve labeled "expectations from start" depicts what agents in the 1970 steady state anticipated: a roughly constant debt ratio near 30%. That view held until the early 1980s, when debt began to climb. Initially, this was thought to be temporary (anticipated fiscal consolidation), but after a decade of persistence, expectations for the debt-to-GDP ratio were revised up toward 50%. Subsequent surprises included the jump in debt after the global financial crisis (expectations updated in 2009) and during the COVID period, followed by recent downside surprises as post-pandemic inflation eroded debt ratios. Deficits nevertheless remained elevated, with looser fiscal stances (e.g., suspension of Germany's debt brake and major U.S. fiscal packages), reflected in the most recent expectations.

In each panel, the two lines on the left scale show the transition of the safe natural real rate r^* under perfect foresight (solid black) and under limited foresight using the evolving expectations just described (solid blue). In general, the r^* profiles under limited forecast are less smooth. This is intuitive: agents are surprised over time; not anticipating the shocks means they are able to smooth through them less. But ultimately both the perfect and limited forecast lines converge to the same endpoint because expectations are assumed to align over the forecast horizon.

Within each panel, comparing the solid black and blue lines—the perfect- and limited-foresight paths for the natural rate—shows how much relaxing perfect foresight matters for each trend. For some drivers the gap is small: changes in population growth, labor share, depreciation, and net foreign assets move r^* similarly whether anticipated or not.

For other drivers, imperfect foresight is pivotal—most notably for markups. An unexpected rise in markups lowers r^* in the short run before pushing it above baseline in the long run. The short-run decline reflects weaker capital demand with a predetermined capital stock, which forces the rental rate down; over time firms shed capital and r^* rises. In capital market equilibrium, the valuation effect from higher firm equity offsets (and ultimately dominates) the contraction in capital demand. Because markups fell in the 1970s before rising from the 1980s onward, the perfect-foresight path implies a persistent upward push on r^*.



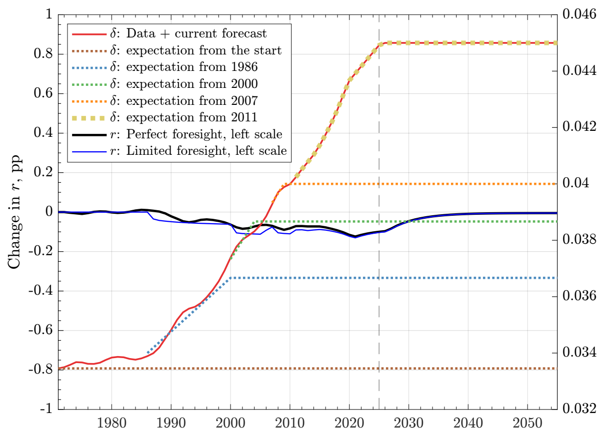
(a) Debt to GDP

(b) TFP growth

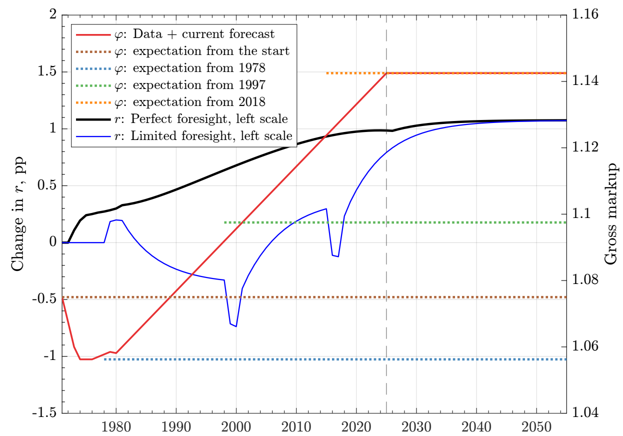
(c) Labor share

(d) Population growth

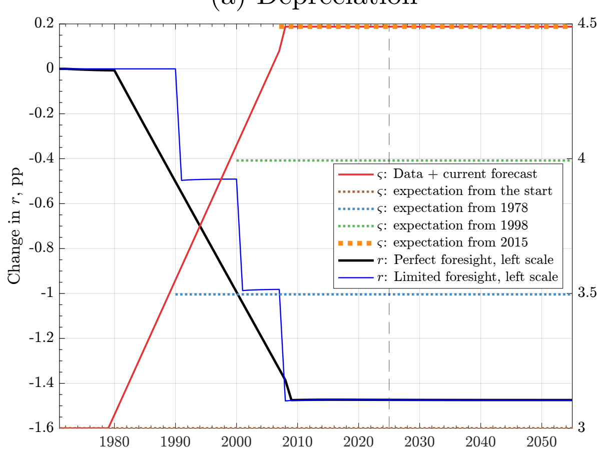
Figure 24: Limited foresight: assumptions on the evolution of expectations and the results in terms of r^* dynamics



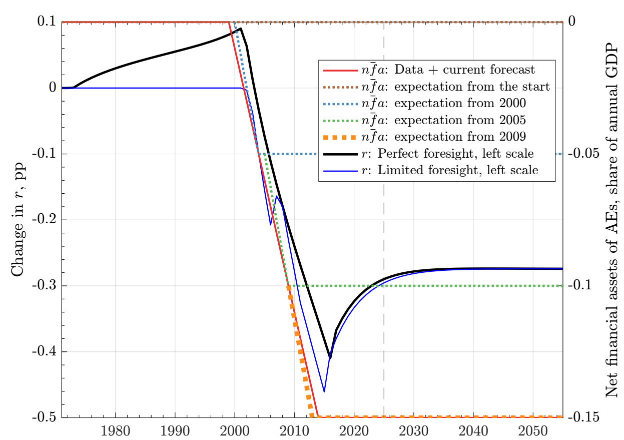
(a) Depreciation



(b) Markups



(c) Risk premium



(d) Net foreign assets

Figure 25: Limited foresight: assumptions on the evolution of expectations and the results in terms of r^* dynamics

Under limited foresight, by contrast, markups depressed r^* for much of the period and only recently become a force raising it as expectations converge to their long-run level.

Imperfect foresight also reshapes the timing of the growth slowdown's impact. Under perfect foresight, the post-GFC decline in trend growth is anticipated well in advance, dragging on r^* before the crisis. With limited foresight, elevated mid-1970s expectations lift r^*, early-1980s revisions pull it down, the Great Moderation stabilizes it, and then the GFC prompts a renewed decline as agents internalize the persistence of weaker growth in living standards.