

Medium and Long-Run Trends in Interest Rates – Causes and Implications for Monetary Policy

Sofía Bauducco
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editors



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The sharp and synchronized post-pandemic monetary tightening lifted policy rates worldwide from historical lows, reviving a fundamental debate in macroeconomics: will real interest rates eventually return to the very low levels that prevailed before 2020, or has the global economy entered a new regime in which long-run equilibrium rates settle at higher values? This volume explores the likely evolution of medium- and long-term interest rates and their implications for monetary and fiscal policy, offering a comprehensive and nuanced view of the structural, fiscal, financial, and geopolitical forces that shape them. Despite the uncertainty regarding the future path of these rates, the analyses presented in this book clarify the mechanisms at work and the policy challenges ahead. Amid accelerating structural change and rising global risks, understanding these forces is essential for designing robust monetary and fiscal frameworks capable of sustaining macroeconomic and financial stability.

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Central Bank of Chile / Banco Central de Chile

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MEDIUM AND LONG-RUN TRENDS IN INTEREST RATES – CAUSES AND IMPLICATIONS FOR MONETARY POLICY: AN OVERVIEW

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This volume brings together a set of papers presented at the XXVII Annual Conference of the Central Bank of Chile, held in Santiago in November 2024. The conference examined one of the most consequential questions in contemporary macroeconomics: the evolution of medium- and long-run interest rates and the forces shaping their behavior. Its objective was to convene leading scholars working at the frontier of this field to assess both the historical trajectory of interest rates and the structural determinants that are likely to influence their future path.

The topic could hardly be more timely, particularly in light of the sharp and synchronized post-pandemic monetary tightening, which lifted policy rates worldwide from historically low levels. While 2025 marked the beginning of modest policy easing in several economies, policy rates remain well above their pre-pandemic levels. This has revived a fundamental debate in macroeconomics: will real interest rates eventually return to the very low levels that prevailed before

Medium and Long-Run Trends in Interest Rates – Causes and Implications for Monetary Policy, edited by Sofia Bauducco, Mariana García-Schmidt, Atif Mian, and Lucciano Villacorta, Santiago, Chile. © 2026 Central Bank of Chile.

2020, or has the global economy entered a new regime in which long-run equilibrium rates settle at higher values?

Experts disagree sharply on the future path of long-run rates. One strand of research emphasizes that the forces driving the secular decline in real rates—population aging, low productivity growth, rising inequality, elevated risk aversion, increased market concentration, and persistent global demand for safe assets—are unlikely to reverse soon. If these structural drivers continue to dominate, real interest rates may eventually resume their downward trend.

Recent developments, however, point in a different direction. Long-term real yields—particularly in the United States—have increased materially since 2020, and new estimates of the natural rate of interest suggest upward revisions in several advanced economies.¹ These developments suggest that structural conditions may have shifted, reflecting higher public debt burdens, geopolitical fragmentation, or emerging global investment needs.

Understanding this debate requires revisiting the extraordinary decline in interest rates from the early 1980s until the pandemic. Over these forty years, nominal US Treasury yields fell dramatically by more than ten percentage points at both short and long maturities. Inflation also declined over the same period, though by less, leaving real rates roughly five and four percentage points lower for two- and ten-year bonds respectively. Sovereign real rates approached zero—and occasionally turned negative—in several advanced economies. The decline extended beyond sovereign bonds to other so-called “safe” assets and beyond the United States: real long-term rates fell by several percentage points across both advanced and emerging economies.²

The sustained downward trend in risk-free rates points to a significant decline in the natural rate of interest—often referred to as R -star—the long-run equilibrium real rate consistent with stable inflation and output at potential. This secular decline coincided with a marked expansion in credit, while the marginal product of capital, returns on risky assets, and the investment rate remained relatively stable, particularly in advanced economies.³ These patterns are typically attributed to forces that lifted the overall supply of savings while redirecting those savings toward safe assets rather than productive investment.

1. See Benigno and others (2024).

2. See Obstfeld (2023).

3. See Farhi and Gourio (2025).

One prominent explanation for this long-run decline is the so-called global saving glut. Since the 1990s, several emerging economies have accumulated substantial savings driven by rapid economic growth, heightened precautionary motives, and favorable terms of trade. A significant portion of these savings flowed into safe assets issued by advanced economies. At the same time, rising wealth inequality in advanced economies contributed to a parallel increase in savings among top-income households. The “saving glut of the rich” became quantitatively comparable to the savings surpluses generated in emerging markets.⁴

Other explanations for the excess supply of savings emphasize broader structural forces. The secular stagnation hypothesis points to a long-term decline in potential growth that reduces profitable investment opportunities and channels savings toward safer assets. Demographic changes—lower population growth and rising life expectancy—have also raised the demand for savings across generations and regions. Rising risk aversion, the declining relative price of investment goods, and the growing concentration of corporate market power have all contributed to directing excess savings toward safe assets rather than productive investment.

Looking forward, several of these structural drivers may continue to exert downward pressure on equilibrium rates. Yet powerful countervailing forces are also emerging. These include the fiscal implications of large and rising public debt, the investment needs associated with the climate transition and geopolitical rearmament, demographic shifts that may eventually reduce saving propensities, and the potential productivity gains linked to advances in artificial intelligence. As these forces interact, the future path of the natural rate of interest, safe real interest rates, and the marginal product of capital remains deeply uncertain.

For policymakers, the stakes are high, and the different rates play distinct roles. For central banks, the natural rate provides a benchmark for the stance of monetary policy, yet it is inherently unobservable and harder than ever to estimate under elevated uncertainty. For fiscal authorities, the gap between the safe real rate and the growth rate determines public debt sustainability, while the level of debt in turn shapes the convenience yield on government bonds and the fiscal space available. For the broader economy, persistent wedges between safe returns and the marginal product of capital—arising from inequality,

4. See Mian and others (2020).

market power, and financial frictions—shape investment, leverage, and the distribution of wealth, reinforcing the very forces that generate those wedges.

The contributions in this volume examine the conceptual foundations, empirical behavior, and policy implications of the interest rates that anchor modern macroeconomic dynamics. The volume contains four research papers and two keynote addresses, each offering a distinct perspective on the forces driving medium- and long-run interest rates. Together, they address four broad themes: (i) the conceptual distinctions among the various interest rates relevant for macroeconomic analysis, (ii) the determinants and measurement of the natural rate of interest, (iii) the historical evolution of real interest rates and the structural shocks that have shaped them, and (iv) the emerging global forces likely to influence future savings-investment equilibria.

The volume opens with Ricardo Reis's keynote lecture, **The Four R -Stars: From Interest Rates to Inflation and Back**. Reis argues that one way to understand the future trajectory of interest rates is to focus on the natural rate of interest, R -star, which in the long run acts as a common component underlying several key interest rates in the economy.

Reis emphasizes that R -star is not a single number but a collection of four distinct equilibrium rates. He develops a framework that distinguishes among these rates and clarifies the economic mechanisms behind each, an exercise essential for both monetary and fiscal policymaking. The first rate corresponds to the return on productive capital, determined by its marginal product. The second is the expected return on safe savings, shaped by safety and liquidity premia as well as global savings flows. The third is the realized return on government bonds, reflecting the nominal yield adjusted for realized inflation. The fourth is the neutral monetary policy rate—the policy rate consistent with achieving the central bank's inflation objective.

Reis constructs a conceptual framework in which each interest rate arises from a distinct equilibrium condition: productive investment and savings, portfolio allocation between productive and safe assets, aggregate supply and realized inflation, and the conduct of monetary policy. Structural forces such as productivity growth, demographics, and inequality; financial factors including liquidity and risk premia; and policy decisions can therefore shift these equilibria independently, allowing the four rates to diverge for extended periods.

Empirically, Reis shows that the evolution of these four rates over the past three decades has differed substantially. The return on

productive capital has remained broadly stable, the expected return on safe assets has declined steadily, the realized return on government bonds fell until the mid-2010s and later rose following the inflation episode of 2021–2024, and the neutral monetary policy rate declined significantly until around 2015 before increasing modestly thereafter.

Looking ahead, Reis discusses three policy-dependent scenarios for the future evolution of interest rates. In a benevolent scenario, monetary policy recognizes a higher neutral policy rate and fiscal authorities adjust primary surpluses to maintain debt sustainability. In a forever-higher-inflation scenario, policymakers attempt to run the economy persistently hot, leading to rising inflation and declining real returns to bondholders. Finally, in a double-trap scenario, higher term premia and fiscal constraints leave both monetary and fiscal policy with limited room to stabilize the economy, thus resulting in persistent underemployment and inflation below target.

Galo Nuño's paper, **Three Theories of Natural Rate Dynamics**, challenges the conventional view that the natural rate depends solely on slow-moving structural forces such as productivity growth and demographics. Nuño argues instead that the natural rate can shift significantly in response to policy actions and shocks, primarily through their effects on precautionary saving.

The first mechanism operates through fiscal policy. Drawing on Campos and others (2024), Nuño shows that in a heterogeneous-agent New Keynesian (HANK) model, the natural rate depends positively on the long-run level of public debt. Because households face income risk and incomplete markets, the stock of government debt determines the extent to which they can self-insure against adverse income shocks. Higher public debt increases the supply of safe assets, reduces precautionary saving, and therefore raises the natural rate of interest.

The second mechanism relates to monetary policy and the zero lower bound (ZLB). Building on Fernández-Villaverde and others (2025), Nuño explains that precautionary savings motivated by the prospect of hitting the ZLB exert downward pressure on the natural rate. When households expect the economy to hit the ZLB more frequently, they save more to smooth consumption in adverse states. This creates a feedback loop: a lower natural rate raises the probability of hitting the ZLB, which induces further precautionary saving and pushes the natural rate down further.

Finally, the third mechanism focuses on persistent supply shocks and draws on Nuño and others (2024). In this framework, the economy can switch between “good” and “bad” states, for example, in response

to trade disruptions or geopolitical conflicts. When such regime shifts are possible, households accumulate additional savings during good states in order to insure themselves against the risk of transitioning to a bad state. This precautionary behavior depresses the natural rate even when the economy appears to be performing well. When the economy transitions to the adverse state, the natural rate can move sharply, reflecting the change in underlying risks and expectations.

Nuño concludes that the natural rate should not be viewed as a fixed or purely exogenous variable. It may instead respond endogenously to policy decisions and to changes in the economic environment. This perspective implies that central banks need to monitor the natural rate more actively, and to recognize that policy itself can shape its evolution.

The first two contributions focus on the conceptual interpretation of the natural rate of interest and on the mechanisms through which policy actions and shocks influence its dynamics. The next group of papers turns to how the evolution of interest rates interacts with broader macroeconomic forces, including fiscal policy, financial stability, and structural changes in the global economy. These contributions show how the behavior of interest rates—both policy rates and market rates—shapes macroeconomic outcomes and financial vulnerabilities.

The first paper in this group, **Fiscal Policy and Real Interest Rates**, by Francesco Bianchi, Renato Faccini, and Leonardo Melosi, studies how fiscal policy influences real rates in a class of general equilibrium models with partially unfunded debt. The authors distinguish between funded fiscal shocks, which are backed by future fiscal adjustments, and unfunded fiscal shocks, which are not expected to be offset by future tax increases or spending cuts.

The analysis shows that these two types of shocks have markedly different macroeconomic consequences. Funded fiscal shocks generate a modest increase in inflation and real interest rates because the central bank responds more than one-to-one to inflationary pressures. In contrast, unfunded fiscal shocks generate persistent inflation that is only partially offset by monetary policy, thus leading to a decline in real interest rates and an expansion in real activity.

To study these mechanisms quantitatively, the authors embed funded and unfunded transfer shocks into a two-agent New Keynesian (TANK) model with savers and hand-to-mouth households, nominal rigidities, and a detailed fiscal sector. They then use this framework to analyze the historical behavior of US real interest rates. Their results suggest that unfunded fiscal shocks account for a large share

of the low-frequency movements in real rates. The interaction between monetary and fiscal policy thus plays a central role in shaping long-run real rate dynamics, which implies that fiscal policy may be a key determinant of future movements.

The second paper, **Monetary Policy and Banking Stability**, by José-Luis Peydró, examines how the monetary policy cycle shapes banking-sector risk. Both prolonged periods of very low interest rates and the subsequent rapid rate hikes can jointly raise the likelihood of banking crises. Peydró characterizes this dynamic as a U-shaped path of monetary policy.

During the low-rate phase of the cycle, financial vulnerabilities tend to accumulate. Cheap credit encourages lending booms, rising asset prices, and increased risk-taking by banks. These vulnerabilities remain latent while interest rates stay low but become exposed once monetary policy begins to tighten. When interest rates rise, balance sheet fragilities become visible through higher defaults, declining asset prices, and stresses in the banking sector.

By using long-run historical data covering seventeen countries since 1870, together with detailed loan-level data from Spain, Peydró documents that banking crises are consistently preceded by such U-shaped monetary policy paths. The key mechanism is not the decline or the increase in interest rates in isolation, but the full cycle of prolonged accommodation followed by tightening. During the low-rate phase, banks expand credit supply, compress lending spreads, and extend loans to increasingly risky borrowers. When rates subsequently rise, these vulnerabilities materialize as higher defaults and weaker bank performance.

Evidence from Spanish administrative data further confirms that banks with higher risk exposure increase lending disproportionately to riskier borrowers during extended periods of monetary easing and subsequently experience larger increases in default rates once interest rates begin to rise.

Peydró concludes by emphasizing the policy implications of these findings. Monetary policy should take financial stability risks into account, and policymakers may need to tighten earlier in the cycle to prevent the buildup of vulnerabilities. Once vulnerabilities are already elevated, moderate rate increases combined with supervisory and macroprudential tools may be more effective than abrupt monetary tightening.

The third contribution, drawn from Atif Mian's keynote **Long-Run Interest Rates: Past, Present, and Future**, examines the persistent

rise in global debt alongside the sustained decline in long-run real rates since the early 1980s. Mian argues that two profound structural transformations—the sharp increase in extreme inequality and the expansion of financialization following the collapse of the Bretton Woods system—have jointly produced a macroeconomic environment of rising debt and falling rates.

At the core of Mian's narrative is the imbalance generated by extreme inequality and the heterogeneous saving behavior of households. The very rich save at disproportionately high rates, so as inequality rises, an ever-larger share of national income flows to high-saving households, thus generating excess savings. The macroeconomy must absorb these savings somewhere in equilibrium, yet they have not flowed into productive investment or corporate expansion. Instead, the financial system has reconciled the imbalance by channeling the surplus into debt. Before 2008, this took the form of household borrowing that financed consumption rather than investment. After the Global Financial Crisis, once households had reached their borrowing limits, public debt increasingly stepped in to support aggregate demand. The economy has held this together only by pushing interest rates progressively lower and by allowing debt—first private, then public—to grow continuously.

This adjustment mechanism reinforces the underlying structural problem. Lower interest rates raise asset prices, which disproportionately benefit the wealthy and amplify inequality, thus generating still more excess savings. Mian highlights the irony of this dynamic: extreme inequality produces the saving glut that pushes interest rates down and inflates asset valuations, which in turn concentrates wealth further. The process becomes increasingly fragile. Once private balance sheets saturate, governments must run deficits to sustain demand, but they too face limits: borrow too little and the economy slips into recession; borrow too much and interest rates, fiscal stress, and market instability rise. Mian calls this narrow window the fiscal “Goldilocks zone”—deficits large enough to offset depressed private demand, but not so large as to push borrowing costs into trouble.

Recent US data—large fiscal deficits, elevated debt-to-GDP ratios, and rising long-term interest rate expectations—suggest that the United States may already be approaching the limits of this narrow zone. Mian concludes that unless the structural drivers of extreme inequality are addressed, the global economy may remain trapped in a high-debt, low-rate equilibrium with limited policy space and

heightened vulnerability to fiscal and financial instability. Durable macroeconomic stability, in his view, ultimately requires addressing the root causes of the saving glut rather than relying on monetary and fiscal policy to manage its consequences.

The final paper, **The Impact of Climate Change and Geopolitical Tensions on Long-Term Interest Rates**, by Elías Albagli, Sofía Bauducco, Guillermo Carlomagno, Luis Gonzales, and Juan Marcos Wlasiuk, examines how two major global transformations—the climate transition and the resurgence of geopolitical tensions—are likely to reshape the global savings-investment balance over the coming decades.

The authors argue that, while some forces may continue to push global savings upward, the scale of the investment required to address climate change and heightened geopolitical risks is considerably larger. Achieving climate mitigation and adaptation goals will require a substantial and sustained increase in global investment. These needs are likely to be further amplified by rising defense expenditures and broader geopolitical fragmentation.

Because the investment required to meet these challenges is expected to exceed any plausible increase in global savings, the equilibrium marginal product of capital is likely to rise, exerting upward pressure on real interest rates. The authors stress, however, that the transmission from a higher cost of capital to risk-free rates and to the natural policy rate is not mechanical: it depends on risk premia, term premia, and the balance between public and private financing.

Their analysis suggests that the combined effects of climate-related investment, geopolitical fragmentation, and fiscal pressures from elevated public debt may produce a structural increase in long-term real interest rates over the coming decades—a potential reversal of the secular downward trend of the previous forty years.

Taken together, the contributions in this volume offer a comprehensive and nuanced view of the structural, fiscal, financial, and geopolitical forces shaping medium- and long-run interest rates. The future path of these rates remains uncertain, but the analyses presented here clarify the mechanisms at work and the policy challenges ahead. Amid accelerating structural change and rising global risks, understanding these forces is essential for designing robust monetary and fiscal frameworks capable of sustaining macroeconomic and financial stability.

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THE FOUR R -STARS: FROM INTEREST RATES TO INFLATION AND BACK

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Where are interest rates going? The answer to this question can be stated in terms of what R -star (or R^*) is: the long-run common component of all relevant interest rates in the economy.

By definition, we cannot directly observe this variable. It is a latent trend driving the co-movement of different variables, a model counterfactual, or a policy benchmark. Measuring it is a daunting task. And yet, economists have done it in many and intricate ways, since the stakes are high.

1. MEASURING R -STAR

1.1 Why Does It Matter?

As of the end of 2024, monetary authorities across the OECD are looking at the inflation disaster of 2021–24 through the rearview mirror and asking whether to cut policy rates any further. Their main doubt is how far away they are from the normal steady state in terms of the monetary policy stance. That is, what is R -star for the policy rate?

This article was delivered as the keynote address at the twenty-seventh annual conference of the Central Bank of Chile on 4 November 2024, and then as the keynote address of the forty-ninth *Simposio de la Asociación Española de Economía* on 17 December 2024. Anna Pilipentseva and Nicholas Tokay provided outstanding research assistance and the UK Research and Innovation grant number EP/Eo25039/1 gave financial support.

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In turn, fiscal policymakers in the G7 countries spent the first twenty years of this century running large public deficits, while paying in interest roughly a constant fraction of GDP every year. This was possible because the interest rate they paid on the public debt steadily fell and was often below the growth rate of the economy. Following the pandemic spending, public debt at the end of 2024 is even higher. Fiscal authorities are asking whether interest rates will stay low, fall further, or (God forbid!) rise, which would force tax rises or spending cuts to pay for it. What is R -star for the public debt?

Macroeconomists build their study of growth, business cycles, and much else on the neoclassical model they learned from Ramsey and Solow. At its heart, this is a model where savings equals investment to pin down the real return on investing in capital. What moves savings and investment drives economic growth and consumption. Understanding the frictionless steady-state level of the real interest rate in that model tells us what lies ahead for human welfare. At what price— R -star—will the market for savings clear?

Finally, all economists, when confronting problems that involve a trade-off between dates, need a measure of the relative price of resources today versus in the future. They need an interest rate with which to discount payoffs in a distant future into present terms. What is the right discount rate R -star to do so?

All combined, measuring R -star today (and at all times) may be hard. But it would be foolish not to try. The answers to too many important questions depend on the estimates of R -star.

1.2 The Current Approaches to Measuring It

In the literature, there are at least four approaches to measuring R -star.

The first of these focuses on extracting the long-run component of realized returns. The natural approach is to include long samples of data and to use time-series models that separate trends from cycles and that tease out common from idiosyncratic components. The confidence bands around the resulting estimates tend to be wide, which is an inevitable consequence of the data for interest rates showing jumps both up and down every week while moving smoothly and steadily when averaged over many years.¹

1. See Jordà and others (2019) or Rogoff and others (2024).

The second approach uses equilibrium models of savings and investment, with parameters that are calibrated or estimated. Within a model, researchers can define counterfactual equilibria for the interest rate, either as time approaches infinity or as multiple frictions go to zero. These estimates of R -star can change substantially with the assumptions in the model or with different definitions of the counterfactual.²

The third approach uses other variables that could indicate whether current interest rates are far from R -star. For instance, in models of monetary policy in the Wicksellian tradition (like New Keynesian models), if the policy rate is above (below) it, then inflation will fall (rise). Combining aggregate time series with models of inflation and measures of expected rates leads to estimates that are as imprecise as our forecasts of inflation and as limited as our understanding of the channels of monetary policy.³

Finally, the fourth approach draws inspiration from the study of financial markets. If the returns on any asset are equal to the common R -star plus a premium that is linked to duration, risk, or illiquidity, then being able to extract these premia would reveal the desired object. Yet, while some progress can be made down this path, the asset that has the smallest premium because it is overnight, the safest, and the most liquid is... a deposit at the central bank. Concluding that the best measure of R -star is the current policy rate is not terribly useful, especially since one of the key motivations of the exercise was to figure out where the policy rate was going.⁴

1.3 My Approach

Part of the difficulty with measuring R -star is that each of the above methods was measuring a different object. It was not just the data or the econometric technique that differed between estimates, but also the underlying economic concepts.

Thinking about each of them long enough reveals four R -stars that are related to one another but are not the same.

This provides a perspective on why it has been so hard to pin down R -star. Each econometrician is using one rifle to hunt one hare, without

2. See Goodhart and Pradhan (2020) or Rachel and Summers (2019).

3. See Holston and others (2017), Del Negro and others (2017), or Cúrdia and others (2015).

4. See Del Negro and others (2019) or Kiley (2020).

realizing that there are four hares running in the field. Even as she changes rifles with different ranges, each of them more appropriate to a different hare, she continues shooting at all four and, therefore, is hitting none.

This article tries to make progress by characterizing each of the hares separately. Namely, I conceptually distinguish between four *R*-stars, characterizing which market each clears, what fundamentals separately or jointly drive them, and how they relate to each other in general equilibrium.⁵ I present rough estimates of each of them since 1995 that strongly suggest that they have followed different trends. I lay out a model of the four equilibrium interest rates that, while not micro-founded, relies heavily on existing canonical models.⁶ I then look at the data between 2021 and 2024 through the lenses of the model, which suggests a new trend for two of the *R*-stars. For the other two, I speculate on three different scenarios matching three different choices made by fiscal and monetary policy, to highlight the challenges that may lie ahead.

2. THE TRENDS IN THE *R*-STARS BETWEEN 1995 AND 2019

This section conceptually defines the four distinct *R*-stars: (m , y , ρ , i) and measures their trends in the data.

2.1 The Expected Return on Productive Investment (m)

The key interest rate at the heart of the Ramsey-Solow model of savings and investment is the marginal product of capital. This is the expected return from investing in the private economy to produce output.⁷ I call it m .

Measuring a marginal return is hard, but measuring its average counterpart is relatively straightforward. Simply divide the payments to capital in the economy by the size of the private capital stock.

5. There are other *R*-stars that I do not discuss, such as those linked to financial instability (Akinci and others, 2020), those in different regions with imperfect capital mobility (Carvalho and others, 2025), or those associated with misallocation of capital across sectors and firms (Reis, 2013).

6. Among others, see Rachel (2023) for the model of investment, Reis (2021) for the model of unproductive and productive savings, Acharya and Dogra (2021) for the model of actual and potential output, and Galí (2008) for the model of monetary policy.

7. It is also the concept closest to that discussed by Wicksell (1936) in its classic analysis of *R*-star.

In practice, one must be careful with what to put in the numerator and in the denominator because of differing trends in relative prices, in depreciation rates, in types of capital, and many other dimensions. Yet, after going through many of them, Reis (2022b) concludes that the trends over the 1995–2019 period are similar.

Panel (a) in Figure 1 shows two straightforward measures of m for the United States. The first divides net private operating surplus from the national income and product accounts by the private capital stock from the fixed assets table and subtracts 10-year expected inflation from the mean answer in the Survey of Professional Forecasters (SPF). The second calculates a weighted-average cost of capital by combining the first measure with the yield on Baa-rated bonds and adjusting for the effective tax treatment of leverage. This is a leveraged return on private capital.

Both series reach the same conclusion: m was essentially unchanged for the 25 years displayed. This is consistent with the Ramsey-Solow theoretical prior that the American economy has been near its steady state throughout its period. The marginal product of capital does move from year to year, and studies of business cycles with a neoclassical core dissect those movements carefully. However, from the perspective of stars, or trends, the appropriate inference is of a constant R -star.

Appendix A expands on this conclusion in two directions. First, I look further back in time, for the US until the 1920s and then all the way until 1856 by shifting to UK data. Second, I broaden the scope to include the other countries in the G7, as well as Chile. While there are larger fluctuations, partly because the data is measured less precisely, it is hard to reject the hypothesis that the returns on private capital have been roughly constant. Neither the last 25 years nor the United States stand out as exceptional.

2.2 The Expected Return on Unproductive Savings (y)

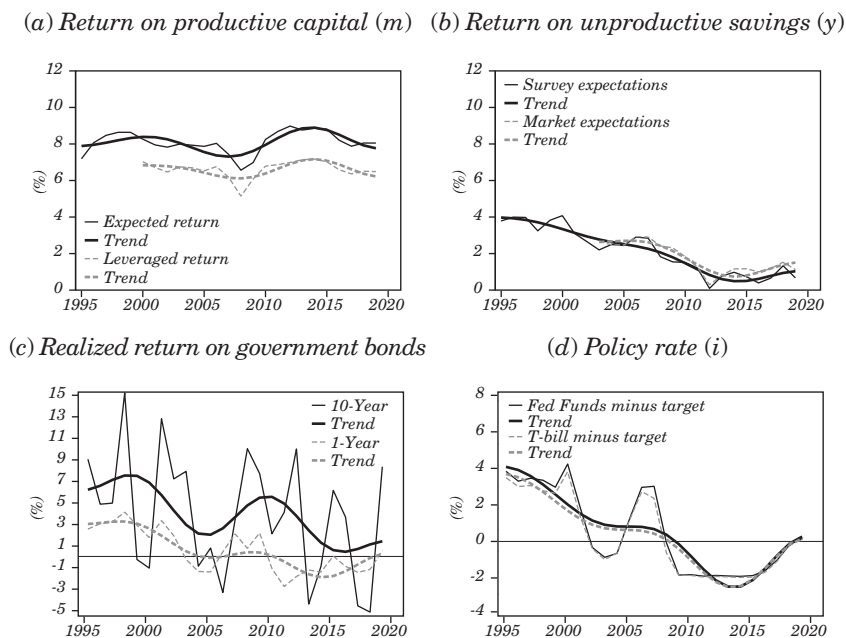
Not all savings go into the productive capital stock. Instead, many of them go to stores of value, like land or government bonds. One measure of the returns on these savings is the yield from holding a long-term government bond. As in Diamond (1965)'s classic article, saving in government bonds is a way to store resources that is an alternative to using them for production. This return is easier to measure, widely accessible to most households, and closer to being interpreted as free from risk and liquidity premia. Naturally, this is the

preferred measure for studies of R -star that take a finance approach, going back to the literature described above.

Panel (b) in Figure 1 shows two measures of this real return, y , in the US data. The first measure subtracts expected inflation (again, the mean answer across the SPF survey respondents) from the 10-year yield, while the second measures directly the yield on bonds whose returns are indexed to the rate of inflation. Appendix A plots similar measures for the G7 countries.

The data tells a consistent story across measures: y had a smooth downward trend during these 25 years, falling by between 2 and 3 percentage points. This is strikingly different from what we saw for m .

Figure 1. The Four R -Stars and their Trends



Sources: FRB Philadelphia, Bureau of Economic Analysis, FRED, Reis (2022b).

Notes: Panel (a): Expected return is the US nominal return on private capital minus the average of expected 10-year-ahead inflation in the SPF. Leveraged return is a weighted average cost of capital using Baa bonds and effective tax rates. Panel (b): “Survey expectations” subtracts from the 10-year yield on US government bonds the average expected 10-year-ahead inflation in the SPF, while “Market expectations” is the yield on a 10-year Treasury inflation-protected security. Panel (c): Holding period real return on 10-year and 1-year US government bonds. Panel (d): Federal Funds rate or 3-month government bond rate minus 2%. Trends calculated by using a Mueller-Watson filter with a 10-year window.

2.3 The Realized Return on Savings (ρ)

If y captures the expected return, then ρ captures the actual return. From the perspective of time-series approaches that measure average returns common across different assets, this is often the preferred measure. This is also the measure that enters the government budget constraint and is more relevant for fiscal authorities and for assessing the sustainability of the public debt.

Panel (c) in Figure 1 plots the holding-period return for one year on a 10-year government bond minus the realized inflation during that year. As an alternative, it also plots the return on a 1-period bond, which is just its yield minus actual inflation. The 10-year returns were significantly above the 1-year ones through the sample: this is the consequence of the fall in yields in panel (b), since these correspond to a rise in bond prices and thus successive capital gains from holding these bonds.

The trend in this figure is less visible because of the large fluctuations in realized returns. Approximately, though, it seems that between 1995 and 2015, ρ fell just as much, or maybe slightly more, than the fall in y . However, in the last five or so years of the sample, there is a clear increase in both measures of realized returns, ρ , even as expected returns, y , kept on falling.

2.4 The Monetary Policy Rate (i)

Finally, when discussing the link between interest rates, inflation, and other business-cycle variables, the typical and adequate focus is on an interest rate that is controlled by monetary policy. In the US, the natural measure of this is the overnight Federal Funds rate, although the return on a 3-month Treasury bill is just as adequate and captures both the current policy rate and what it is expected to be in the next three months. Panel (d) of Figure 1 plots both, subtracting 2 percent from either, so that they are in pseudo-real units using as reference the Federal Reserve's inflation target and so are comparable with the other panels.

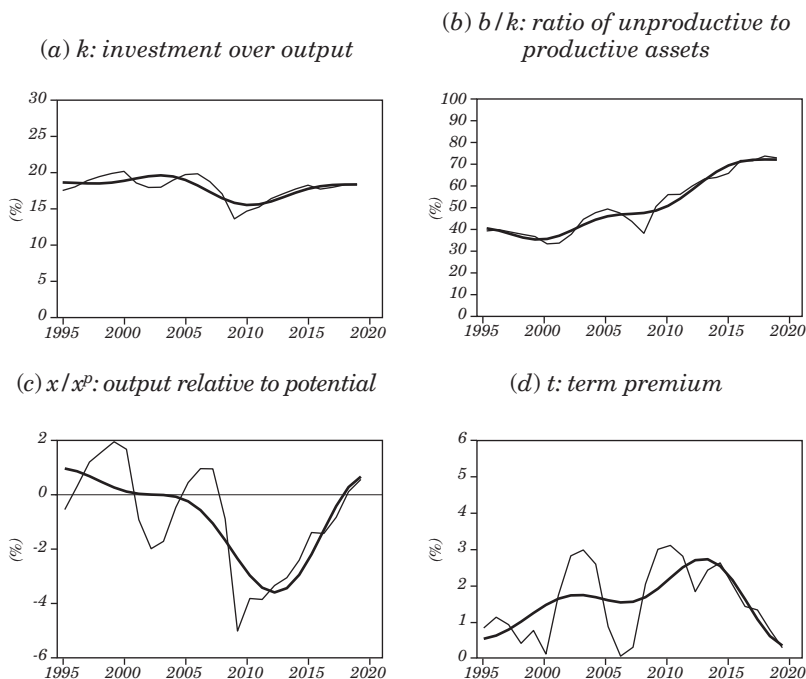
The path of the policy rate had two stages in the sample. Between 1995 and 2015, it fell decisively and more than the other rates, by approximately 6 percentage points. Between 2015 and 2019, it recovered by about 2 percentage points. This i looks quite different from either m or y .

2.5 Other Indicators

Figure 2 shows four other macrofinancial indicators. An account of the trends in R -star during this period should be able to fit these as well.

First, and since a measure of the returns on productive investment should be connected to the levels of that investment, panel (a) shows private investment as a ratio of GDP. I will refer to this in the model as k , since in a steady state, the flow of investment and the stock of capital are linked one to one. During most of this period, it was slightly below its usual value, although not much so. This constancy matches the constancy of the return on capital.

Figure 2. Other Relevant Indicators



Sources: Bureau of Economic Analysis, Congressional Budget Office, FRED.

Notes: Panel (a): Ratio of private investment to GDP. Panel (b): Ratio of government debt plus the capital stock on dwellings to the private capital stock excluding dwellings. Panel (c): GDP relative to potential GDP according to the Congressional Budget Office. Panel (d): Difference between the yield on 10-year and 1-year government securities. Trends calculated by using a Mueller-Watson filter with a 10-year window for a 1995-2019 data.

Second, panel (b) shows the ratio of the stock of unproductive investment to the productive stock. I denote this by b/k and measure it as the ratio of government bonds plus the residential capital stock to the nonresidential capital stock. This measure has a clear and significant upward slope during this period, partly driven by an increase in the stock of government bonds. Even as their yield was falling, the stock of bonds rose throughout, keeping government interest expenses roughly constant.

Third, realized returns and inflation are linked in many theories of aggregate demand to the level of unused productive capacity or slack. If output is denoted by x and potential output by x^p , the output gap is the ratio: x/x^p . Panel (c) shows that for almost a decade, between 2005 and 2015, output was below potential in the US.

Finally, panel (d) shows a measure of the link between interest rates at different maturities. This is the term premium, or the difference between the yield on 10-year and 1-year government bonds, denoted by t . It rose between 1995 and 2010 and then sharply fell for the last ten years. This is associated with unconventional monetary policies, like forward guidance and quantitative easing, which were explicitly designed to lower the term premium, in an attempt to raise inflation towards its target.

3. A FRAMEWORK FOR THE FOUR *R*-STARS

In many models, m , y , ρ , and i are either constant or move together in steady state. In the Ramsey-Solow neoclassical model, the return on private capital in the steady state is constant. In most models that build on it, the return on other forms of savings must likewise be constant, although they may differ from each other in levels to account for risk or other premia. In steady state, expected and realized returns are the same. Finally, most models of monetary policy have at their core a Fisher equation that equates the policy rate minus the inflation target with the return on capital or bonds.

Yet, in the US data of the last 25 years that we just looked at, only m is constant, and the trends in the other three do not match with each other. This section sketches a simple model where the four *R*-stars can differ. I present their steady-state relations, in some generality, but without specifying the micro-foundations or the dynamics that lead to these steady states. For readers who prefer to see the equations behind each curve, they are listed in Appendix B.

3.1 Investment and Savings

The demand for savings to invest productively is lower the higher the required return on those savings. This is so because of the usual assumption that the marginal return on capital diminishes as capital rises. There is a negative relation between k and m , plotted in panel (a) of Figure 3 and labelled as Investment.

The investment curve is steeper the faster diminishing returns set in. In the standard case of a Cobb-Douglas production function, this slope is higher the smaller the capital share of income.

The curve shifts left and downwards when the same level of private investment gives yields a lower marginal return. This could be because: (i) productivity is lower, so each unit of capital gives less output; (ii) depreciation of capital is higher; or (iii) the price of capital goods is expected to fall. Moreover, (iv) less competition, (v) more regulation, or (vi) higher income taxes, all reduce the returns on investment, and shift the relation left and down. Finally, insofar as k is total capital, then a fall in public investment is also a shift in this direction.

As for the supply of savings, in the Ramsey model, it would be a horizontal line in (k, m) space. The vertical intercept would be proportional to the subjective rate at which households discount the future minus the growth rate of the economy at this steady state. In panel (a) of Figure 3, I plot instead a Savings schedule that is upward sloping, so that the higher the investment, the higher the returns offered to savers must be. The traditional way to justify the upward slope is incomplete markets, so that capital provides a service as self-insurance. Unpacking this service and why markets fail to equalize returns leads to the next part of the model.

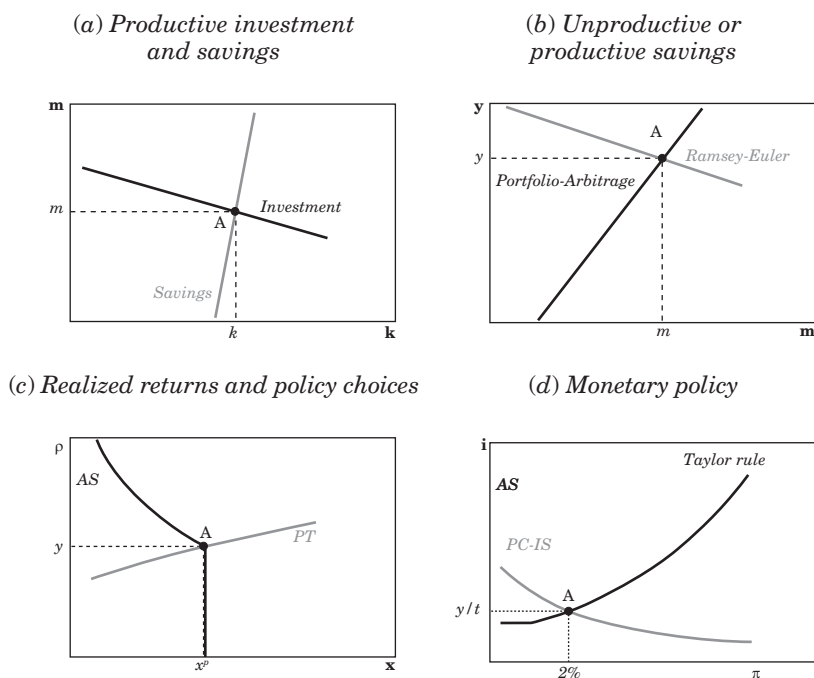
3.2 Productive and Unproductive Savings

Savers can opt between putting their resources into productive uses, like buying equity or lending to firms, or into unproductive savings, like government bonds or land. Their choices determine, in equilibrium, a relation between the returns on the two alternatives: m and y . This equilibrium depends on two conditions. The first is an arbitrage condition between the two returns that arises from the optimal portfolio choice of savers. The higher the return on productive savings, the higher the return on government bonds must be, so that savers continue to be indifferent at the margin between saving an extra unit in either of these two uses. If they only cared about the expected

financial return, this condition would be a 45° line in the (m, y) space. However, unproductive savings provide liquidity or safety services. This makes the relation always lie below the 45° line and the vertical distance to it measure what is often called the convenience yield of government bonds.

This Portfolio-Arbitrage relation is plotted in panel (b) of Figure 3. It shifts right and down when productive investments are perceived as riskier or less liquid, thus raising the premium they must pay relative to the expected return on government bonds. More broadly, it shifts right and down if the financial frictions preventing the direction of funds towards productive uses are more intense.

Figure 3. A Model of Four Returns



Source: Author's calculations.

The second relation in the figure is the familiar optimal savings conditions from the Ramsey model that comes from the Euler equation: the average return on savings is equal to the expected growth rate of consumption (scaled by intertemporal substitution) plus the subjective discount rate. Because of the incompleteness of markets, there is not a single return driving savings behaviour, but rather a weighted average of the return on the two forms of savings.

For a fixed growth rate, the average return must be constant. Therefore, the higher the return on productive capital m , the lower the return on unproductive storage y must be. The Ramsey-Euler schedule in panel (b) of Figure 3 therefore slopes down. It shifts left and down when either: (i) expected growth is lower; (ii) the discounting of the future is lower, for instance, because of an increase in longevity; or (iii) inequality is higher and the rich have a greater propensity to save so that expected aggregate consumption growth is lower.

The equilibrium for the two returns is given by point A in panel (b) of Figure 3. How that equilibrium moves with k traces out the Savings curve in panel (a) of Figure 3. When productive investment k rises, this lowers the ratio of unproductive to productive assets b/k . With a lower b/k , there is higher demand for safety and liquidity, so the Portfolio-Arbitrage curve shifts right and down. The equilibrium m rises, and so the Savings curve in panel (a) slopes up. A simple intuition is that the higher k is, the higher the return offered to savers by productive savings must be, otherwise they would rather channel their savings to government bonds.

Panel (b) of Figure 3 also unveils what is behind shifts in the Savings curve in panel (a). It will shift right and down when: (i) growth is lower, (ii) population ages, or (iii) inequality decreases, since all of these shift the Ramsey-Euler schedule left and downwards. Likewise, the Savings curve will shift left and upwards in panel (a) when financial frictions are more intense and productive investments are perceived as riskier or less liquid than storage, so the Portfolio-Arbitrage equation shifts right and downwards in panel (b).

3.3 Realized Returns and the Output Gap

Production combines capital with variable inputs, like labour. The suppliers of those inputs write contracts to supply them, taking into account an expected real reward. Those expectations have slow-moving norms for what constitutes an adequate nominal payment. If inflation is in line with this norm, then inputs are hired according to

their marginal product, given the installed capital. If so, output x is equal to potential x^p .

However, if inflation comes down below the norm, then the real compensation of the variable inputs turns out to be higher. Firms are willing to hire fewer of them, and output falls below potential. This mechanism, made famous by Friedman (1968), is elaborated and explored in many models of nominal rigidities in wages.

It leads to an AS—for Aggregate Supply—relation in panel (c) of Figure 3. When inflation is below the expected norm, realized returns are higher than expected returns ($\rho > y$), and variable input suppliers and bondholders receive more than they expected. The flip side of the coin is that firms hire fewer of them, so output is lower than potential. The relation is downward-sloping in the (x, ρ) space.

When inflation is instead higher than the norm, so returns ρ are lower, then the economy is operating at potential. All the installed capital is fully employed, and the AS relation becomes vertical. The kink point is when inflation is just equal to the norm, so that realized and expected returns are the same: $\rho = y$.

The AS curve shifts left and down if there is less capital k and so lower potential output x^p . From panel (a), this may be the result of lower productivity or higher markups, which shift the Investment curve left and down. From panel (b) instead, if the equilibrium expected return on bonds is lower, then the kink point for the AS in panel (c) is lower. These are the direct general equilibrium forces from the top panels in Figure 3 to panel (c).

The other relation in panel (c) of Figure 3 comes from the management of aggregate demand by policy, both fiscal and monetary. Given a target for output and for inflation, optimal policy will tolerate some inflation above target only if output is below potential. If the shocks hitting the economy satisfy a “divine coincidence,” then both output and inflation will be on target at all times. But, if there is an inevitable trade-off between the two—sometimes called a “supply shock”—, then output may be below (above) potential, and inflation will be above (below) target. The preferences of the policymaker determine how it sets fiscal and monetary policy to manage aggregate demand and lower (raise) inflation to raise (lower) output to trade off the dual deviations from target.

Since realized returns depend negatively on realized inflation, this PT relation, for Policy Target, is an upward-sloping relation in (x, ρ) space. It is steeper if: (i) policymakers put a higher weight on keeping output near its target, so they are willing to tolerate wider fluctuations

in p relative to deviations in x , and (ii) the Phillips curve trade-off between output and inflation is flatter, so managing aggregate demand requires a larger movement in inflation for smaller changes in output.

From general equilibrium, this PT curve shifts right and down when the expected return on bonds y falls. More interestingly, it also shifts right and down when policymakers' output target is higher relative to potential output, so they are willing to pursue high inflation and deliver low returns. The same applies if the inflation target is higher than the norm, perhaps because policymakers are willing to use unexpected inflation to lower the public debt burden. Fiscal and monetary policy can be understood as shifts in those targets, whether intentionally or because of the imprecision in controlling aggregate demand.

The natural goal of policy is to have the two schedules intersect precisely at the kink, as portrayed in panel (c) of Figure 3. At this point, realized and expected inflation are the same, and output is at potential. This is achieved if the policymakers are able to calibrate their output target precisely at potential, and their target for inflation is achieved repeatedly, so that the inflation norm for private negotiations is just equal to that target.

But, if policy repeatedly fails, say by delivering a PT curve that intersects below the kink making inflation persistently high, then the negotiation norm for nominal payments will adjust upwards. This will gradually shift the PT curve left and up. Eventually, the economy will move to a new steady state where the PT curve still intersects the AS at the same point, but behind the curves there is now a higher level of the inflation target and the inflation norm. This is the equilibrating force from the rationality of expectations. Policy can deliver some unexpected inflation for some time, but not forever, unless it is willing to keep on providing more and more stimulus and having inflation spiral upwards.

3.4 The Policy Rate and Inflation

An important component of aggregate demand management is monetary policy. In our context, it sets a key interest rate, i , that has its own R -star equilibrium. The final piece of the puzzle is how this is set and how it affects inflation π .

A lower policy rate i raises aggregate demand by lowering the returns on saving through a conventional Keynesian IS equation. This higher demand then pushes for high inflation given sticky prices

by firms, through a conventional Keynesian Phillips curve equation. In the end, a lower i comes with a higher π . This downward-sloping relation is portrayed in panel (d) of Figure 3 as the *PC-IS* relation. It is flatter the flatter the Phillips curve is and the less sensitive spending is to interest rates.

The stimulus to aggregate demand comes from the policy rate being temporarily below a natural or Wicksellian rate. This is equal to the expected rate on government bonds discounted by the term premium: y/t . Therefore, a fall in y from the top panels in the figure will shift left and down the *PC-IS* relation. In the other direction, an increase in the term premium t also shifts it left and down. Finally, this curve shifts left and down when firms' expected inflation falls relative to the inflation target.

The final component of the model is the Taylor rule. Higher inflation π makes policymakers raise the policy rate, as long as that rate is above its effective lower bound (ELB). The slope of this relation is higher the more aggressive policymakers are in controlling inflation. The curve shifts right and down when the inflation target of monetary policy is higher.

A policymaker committed to its inflation target has to target a Wicksellian or neutral rate, which works as a shifter of the Taylor rule. Only if this is set at the right level will inflation be equal to its target. That right level, in our model, corresponds to y/t , that is, the expected return on government bonds discounted by the term premium t . When the policy calibrates the Taylor rule to exactly intersect the *PC-IS* at that point, the inflation is equal to its 2-percent inflation target, as shown in the figure.

3.5 All Together

Figure 3 has the four diagrams that pin down the four *R*-stars as the variables in the vertical axis of each diagram. The figure also links them to three important macroeconomic outcomes on the horizontal axes: investment, slack, and inflation. The equilibrium is depicted by the points *A*.

Clearly, nothing imposes that all four interest rates should be the same in this steady state of an economy. There are equilibrium forces within the model that draw them close to each other as well as exogenous drivers that will tend to move them together, like adjustments of norms, expectations, and policies. But over many years, or decades, these endogenous variables can move in different

directions. Some of the forces driving them apart are structural features of the economy, like growth, demographics, productivity, competition, inequality, and the desire for safety or liquidity. Others are characteristics of contracts and expectations, like norms on compensation, expected inflation, and term premia between shorter and long-term bonds. And others depend on aggregate demand policy via the targets that it pursues for output, inflation, and policy rates. As they change, the framework in this model provides a way to analyse their consequences, as I will do next.

4. USING THE FRAMEWORK TO ACCOUNT FOR THE 1995–2019 TRENDS

Confident in a set of facts about the four R -stars and armed with a model where they are jointly determined, I now turn to matching the two.

4.1 The Movements in m and y

Rachel and Smith (2017) provide a thorough account of some of the major economic shifts in the early twenty-first century driving changes in R -star.⁸

Three of them are relevant for the Investment schedule. First, US economic growth was slightly lower than before, in terms of both productivity and population growth. Second, the price of investment relative to consumption goods had been falling for decades. Third, public investment was low relative to the past, partly because of prioritizing social spending, partly because of austerity policies following the Global Financial Crisis. Two other factors, highlighted by research since then, go in the same direction in the model. Depreciation rates have risen, partly as more of the capital stock is intangible, and markups have risen, especially in the US economy, as industries have become more concentrated.

All combined, these five changes shift the Investment curve left and down, as shown in panel (a) in Figure 4.

Were these the only changes, then we should have seen a fall in the return on capital m . Yet we know from the data that the latter was constant. Therefore, the Savings curve must have shifted left and up

8. Updated in Rachel (2023).

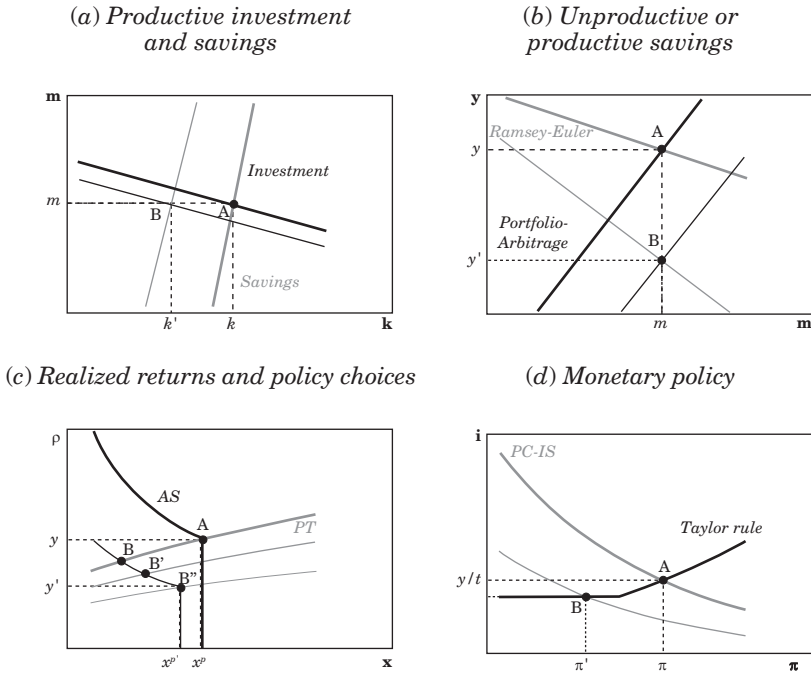
in the 1995–2019 period, so as to keep this R -star roughly unchanged in spite of the headwinds facing investment. The economy moved from point A to point B in panel (a) of the figure, which is also consistent with the depressed private investment during this period.

To understand what caused the decline in savings channelled to productive investment, we have to turn to panel (b). Going back to the literature, as distilled by Rachel and Smith (2017), the decline in the rate of growth in the economy during this period shifted the Ramsey-Euler curve left and down. In the same direction, population aging translates into people wanting to save more, or subjective patience rising in Ramsey's formula. Finally, the rise in inequality, together with a higher propensity to save by the rich, both raise the desire to save by households and so also shift the Ramsey-Euler curve left and down. By themselves, these would lower both y and m , not matching the evidence.

Yet, just as important to savings as the changes in 1995–2019 was the so-called rise in global imbalances. Countries in Southeast Asia saved large amounts in advanced economies abroad tied to the large surpluses in their trading relations. At the start of the century, a significant share of these savings was directed to build foreign reserves abroad, following the Southeast Asia Crisis of the end of the twentieth century. These savings therefore had a strong relative preference for safe and liquid stores of value that could be easily accessed and used in a new crisis. This raised the desired supply of savings in the US, especially directed to unproductive stores of value, shifting the Portfolio-Arbitrage curve right and down. At the same time, and for many years after, China grew to become one of the world's largest economies. In that process, China was also one of the largest exporters of savings as it had a persistent current account surplus. These savings did not flow freely but were subject to capital controls through which authorities dictated investments abroad. Given the information asymmetries and other financial frictions limiting the desire to directly invest in US companies, there was a strong bias by these official authorities to value the safety and liquidity of government bonds. This increased preference for unproductive stores of value shifted the Portfolio-Arbitrage curve right and down.⁹

9. See Reis (2022a).

Figure 4. Accounting for the 1995–2019 Trends in Light of the Model



Source: Author's calculations.

Two other factors following the Global Financial Crisis plausibly shifted the Portfolio-Arbitrage schedule right and down as well. First, there was a decline in the supply of private assets deemed safe, as many asset-backed securities lost their safe ratings. Second, and related, there was an increase in risk aversion by investors and an increase in regulation by authorities. Both led to a relative shift in the excess demand for safe and liquid unproductive stores of value over risky and illiquid productive investment.

All these factors combined led to the changes displayed in panel (b) of Figure 4. The equilibrium shifted from point A to point B with a decline in the yield on government bonds y , while the marginal product of capital m stayed unchanged.

Back to panel (a), this translates into the savings schedule shifting left and up, not because overall savings fell, but because the supply of

savings directed to risky and illiquid productive investment contracted. The opening of the gap between the two R -stars, m and y , that we found in the data is consistent with the large shifts in the global market for savings and investment.

4.2 How Policy Responded to the Challenge of High and Rising $m - y$

The account that I just provided for the trends in m and y has implications for the potential output in the economy. The shift in desired savings away from productive investments, together with the higher markups and depreciation rates, all resulted in a lower steady-state level of investment in panel (a) of Figure 4. In turn, the global imbalances and the stronger relative preference for safety and liquidity resulted in a fall in y in panel (b).

These macro trends translate in panel (c) into a shift left and down of the AS schedule, as the level of productive capacity falls from x^p to $x^{p'}$. Moreover, as the yield on unproductive assets falls from y to y' , the kink point in the AS is at a lower level. Point B'' in the figures is vertically below the old equilibrium point A . Both changes combined give the lighter new schedule for the AS in Figure 4.

How policy responded to these changes was different across regions and, especially, over time during this period. Arguably, during 2008–12, the combination of the Global Financial Crisis and the European sovereign debt crisis caught policymakers by surprise and constrained their ability to provide stimulus to aggregate demand right away. The PT curve stayed approximately in the same place (or only slightly shifted to the right and downwards). Therefore, the intersection with the new AS happened at its downward-sloping segment, at a point like B . Output was below its potential, and there was underemployment of variable inputs, like labour, during this period. Inflation was lower than expected and realized returns ρ exceeded yields.

The policy challenge in the years after was to shift the PT schedule through monetary and fiscal stimulus. Fiscal policy engaged in large deficit programs, while conventional monetary policy set the main policy rate as low as possible for a prolonged period of time. At the same time, as inflation stayed low, often below target (especially in the eurozone, EZ), the norms for expected nominal increases slowly fell. The associated wage restraint was widely discussed during this time. It was linked to the decline in unionization rates and to the perception that trends in offshoring meant that the bargaining power of workers had dwindled, leading to “expected deflation forces”.

In panel (c) of Figure 4, this shows up as a gradual shift of the PT curve right and down, from an initial point B to B' and eventually reaching B'' . As both norms and policy adjusted to the new lower value of R -star for government bond yields, and as the inflation target of 2 percent was reached, the economy achieved its potential level of activity.

4.3 Inflation and Unconventional Monetary Policies

In this process of adjustment to the changes in macro trends, monetary policy faced a particular challenge in regard to its R -star level for the policy rate i . All else equal, a lower y requires a proportionately lower i to deliver the inflation target. Yet, if i cannot fall because of an effective lower bound, then monetary policy will fall short in this adjustment.

In terms of the model, the fall in y leads to a shift left and down of the PC - IS curve. The new intersection, displayed in panel (d) of Figure 4, is now in the horizontal segment of the Taylor rule, at point B . The resulting inflation is below target, at π' .

This is consistent with the B equilibrium in panel (c), as an inflation below target delivers high realized returns p that come with underemployment. The lack of a decisive shift in the PT curve in panel (c) is partly explained by monetary policy being constrained at its horizontal segment by the ELB in panel (d). Conventional policy that, for instance, shifted the aggressiveness with which policy responds to inflation in the Taylor rule would not have helped. This would make the Taylor rule steeper in its upward-sloping component but would keep the horizontal component unchanged. The intersection would stay at the same point B .

How did the PT curve then shift in panel (c) to bring the economy back to capacity in point B'' ? Some of it happened through expansionary fiscal policy. Especially in the EZ, this came slowly, as there were constraints and scars left by the European sovereign debt crisis of 2010. Both in the US and the EZ, monetary policy played a role, albeit through unconventional channels. Quantitative easing and forward guidance, among other policies, were deployed with the goal of lowering the term premium t : the wedge between the (long-term) government bond yield y and the policy rate i . These policies, in the model, shift the PC - IS back right and upwards.

In an extreme case, the shift is back to the old PC - IS . This would bring the economy back to equilibrium in point A , with inflation on target π . While the horizontal intersection point is the same, this

now corresponds to a lower y' matched precisely by a lower t' . The lower R -star on government bonds comes with the same R -star for the policy rate, achieved by unconventional policies that lower the term premium between these two rates. This is approximately what happened in the US data.

In the EZ data, this process took longer. There was a mix of lower term premium achieved through unconventional policies and persistently lower conventional policy rates. This shift in conventional policy into a more “dovish” stance extended the horizontal segment of the Taylor rule and flattened it. In the end, it intersected a PC - IS that shifted right and up by the fall in the term premium, but not all the way back to its original position, at a new point. This delivered an inflation rate again close to the 2-percent target (or slightly below it), but now with a policy rate that was persistently lower.

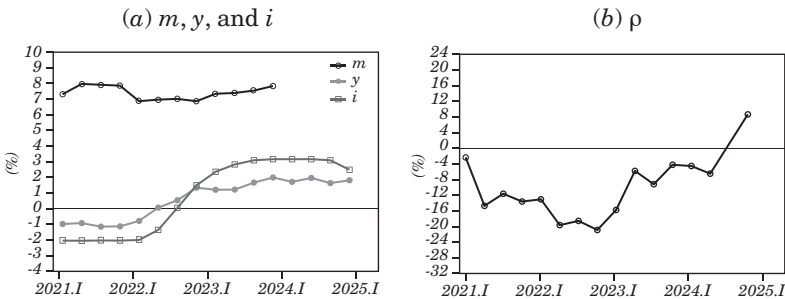
5. THE RECENT PAST: 2021–24

With a coherent account of what happened to the four R -stars in 1995–2019, I now turn to the harder challenge of interpreting recent movements in interest rates.

5.1 The Recent Data

Only three years have passed since the atypical pandemic years of 2020–21. Moreover, different advanced economies have faced different challenges and followed different policies. Therefore, inferring trends common to economies on the four R -stars come with great uncertainty.

Figure 5. The Four Returns since 2021



Sources: FRB Philadelphia, Bureau of Economic Analysis, FRED, Reis (2022).
Notes: See the notes in Figure 1. For m , this is the unleveraged return; for y , it is the market yield; for ρ , it is the annual holding return on a 10-year bond; and for i , it is the Federal funds rate.

With this caveat in mind, Figure 5 shows the measures of the four returns from the previous Figure 1 on the historical annual data, but now for US quarterly data between 2021 and 2024.

Starting with the return on productive capital m in the left panel, the data indicate that it may have slightly fallen but, roughly, it continues to be unchanged.

The yield on government bonds y , instead, has continuously and quite quickly risen since 2022. Inasmuch as the 1995–2019 period was characterized by the slow build-up of a wedge between m and y , the gap between the return on productive capital and the yield on government bonds sharply fell in 2002–23.

The policy rate i is also in the left panel. It stayed low at first. But, since 2022, it has moved up as monetary policy tightened.

The right panel shows the realized return on government bonds, ρ , using a scale blown up by a factor of four relative to the other three series. It was sharply negative for most of this period, as a result of the sharp fall in bond prices and the large surprise inflation disaster.

5.2 Interpreting the Sharp Fall in the $m - y$ Wedge

The first place to look for the reason why $m - y$ has fallen is the set of factors that had driven its rise in the decades before.

Start with the previous shift towards preferring safe, liquid, and unproductive stores of value. The large increase in US public debt during the pandemic and the sustained and expected public deficits might well have reduced the perception of safety attached to government bonds. In the same direction, their liquidity might have been questioned following the problems in the US Treasury market identified in 2020 (as well as parallelisms with the Truss event in the UK market), and the halting of bond-buying programs by the Federal Reserve.

The global imbalances that played a large role in the previous decades have also changed. The accumulation of reserves in the US by Southeast Asian countries has stagnated or reversed. Moreover, the desire by Chinese authorities to buy US government bonds has declined significantly. The fragmentation of world capital markets and geopolitical tensions may extend this for many years. All combined, the supply of savings from abroad to US markets, and especially its tilt towards unproductive stores of value, may well be persistently lower.

In the model, this change is depicted in panel (b) of Figure 6. The Portfolio-Arbitrage schedule shifted left and up. Since m has barely

changed in the data, starting from the B equilibrium point in 2019, the economy shifted to a point like C, with the yield on government bonds rising from y' to y'' .

This required either that the Ramsey-Euler schedule was very steep or that it shifted right and up during this time, as plotted in the figure. Recalling what is behind the Ramsey formula, a shift of the schedule requires a consumption spree or a savings glut. This is consistent with the post-pandemic data, at least for a few years. More persistent might be an increase in optimism about future economic growth, perhaps driven by artificial intelligence.

This leads to turning to panel (a) in Figure 6, where the shifts in equilibrium in panel (b) translate into a shift right and down of the Savings schedule. As we see in the data, this led to a small rise in private investment in the US, which may persist, although it is too early to tell. At the same time, there was a rise in public investment with a turn towards industrial policy in the “Inflation Reduction Act”. This might have led to a small shift of the Investment curve to the right and up. Either way, the return on private capital fell only slightly, from m' to m'' , as displayed in the figure.

5.3 Inflation and Realized Returns

A sharp rise in the government bond yield to y'' would alter the policy tradeoffs facing the fiscal and monetary authorities.

Turning to panel (c) in Figure 6, the AS curve would have shifted vertically up in the recent past. Eventually, the increase in investment will also shift this schedule to the right; how much of that shift has occurred does not change the arguments and challenges laid out here. With unchanged policy, the economy operates at full capacity, but inflation spikes upwards. The economy goes to point B with very negative returns for bondholders, matching the data in 2021–22.

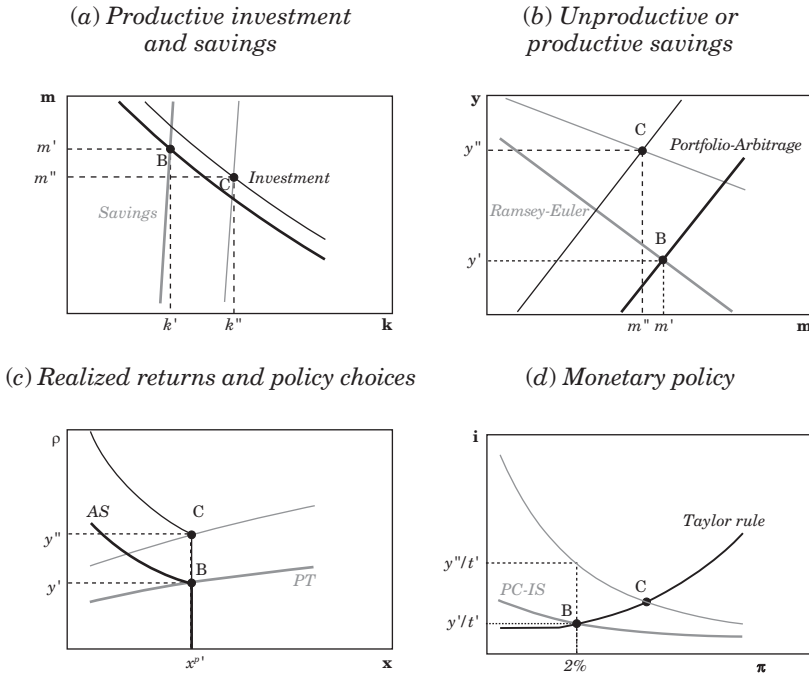
At first, aggregate demand policy might have tolerated the higher inflation and even promoted it with large fiscal stimulus programs and loose monetary policy. The losses to bondholders from “inflating the debt away” partly paid for the pandemic increase in the public debt. Moreover, calibrating the tightening of fiscal or monetary policy was challenging and subject to the risk of overdoing it, leading to underemployment right after the pandemic shock. Eventually, and only gradually, policy did tighten. This shifted the *PT* curve left and up, as shown in Figure 6. By the end of 2024, the economy was close

to point C , where inflation was almost back on target and realized returns were equal to yields.

Panel (d) in Figure 6 zooms in on the monetary policy rate. The higher y'' shifted the $PC-IS$ curve to the right and up, reversing some of its slow shift in the opposite direction during the previous 25 years. The economy moved from the previous equilibrium at point B with inflation on target to a new equilibrium at point C , with inflation at π'' well above the 2-percent target.

Keeping inflation on target would have required raising the intercept in the Taylor rule. As y''/t' is now higher, this means the neutral, or Wicksellian, rate for policy is now higher. We turn to this and other options next.

Figure 6. The Four R -Stars in 2021–24 according to the Model



Source: Author's calculations.

6. THE FUTURE

If interpreting the recent past is challenging, speculating what will happen to the *R*-stars in the future is even more so. This section offers some conjectures, without taking a stand on their relative likelihoods.

I start from the presumption that the state of affairs in the previous section is persistent. Namely, the reversal of the revealed preference for government bonds of the previous 25 years, together with some optimism surrounding future economic growth, has shifted the yield on government bonds persistently higher to y'' , even as m'' is only slightly lower than it was in 1995–2019. Therefore, the equilibrium will stay as in points *C* in the top two panels of Figure 6.

What happens to inflation and realized returns depends on how monetary and fiscal policy are set. This will affect the bottom two panels in the figure, starting from point *C*. I consider three scenarios.

6.1 Policy Scenario 1: The Benevolent Benchmark

The first scenario is where inflation stays on target and output is at capacity. Achieving this benevolent scenario requires two changes in policy relative to the past.

Starting with monetary policy, displayed in the right panel of Figure 7, policymakers would realize that, with a higher *R*-star for government bond yields, the neutral policy rate is persistently higher. The Taylor rule would shift up relative to the last 30 years, matching the shift up of the *PC-IS* because of the higher y'' . The new equilibrium would be at a point like *D*, vertically above the pre-pandemic point *B*.

This would come with persistently higher policy rates. The central bank would still raise or lower policy rates as inflation goes up and down, but around a higher average level. The need for unconventional monetary policy or the concerns with the ELB would be left in the past.

Turning to fiscal policy, with steady inflation on target, $\rho = y$. Therefore, the *R*-star on the realized real return paid on government bonds would also be forever higher. Fiscal policy would adjust to the higher interest expenses on the debt by raising primary surpluses and keeping the public debt sustainable.

The joint goal of monetary and fiscal policy in managing aggregate demand would be to ensure that the *PT* curve intersects the *AS* at the point *D*, vertically above the pre-pandemic point *B*, as shown in

Figure 7.¹⁰ With the intersection at the kink, output would be at potential. Real payments of variable inputs would be in line with norms given productivity growth and the inflation target, keeping expectations of inflation steady and anchored.

While this scenario may seem optimistic, it comes with three important policy challenges.

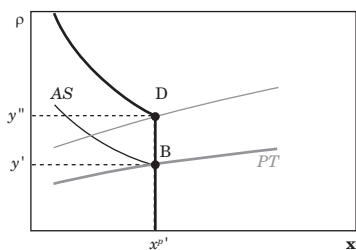
First, the movement to a lower wedge between the return on private capital and the return on government debt might well not be smooth. Calibrating policy to achieve the outcomes in Figure 7 with real-time imperfect data will be far from easy.

Second, taking as given that the $m - y$ wedge has permanently become smaller, it makes a difference what the source of that change is. On the other hand, if this happens because there is less demand for safety and liquidity, or a perception that government bonds are less likely to have these properties, then this calls for tighter monetary and fiscal policy to achieve the same growth rate or unemployment rate.

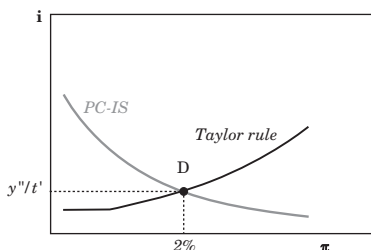
On the other hand, say the fall in the $m - y$ wedge happens because there is an increase in productivity, or a re-channelling of investment towards productive capital, which in turn may raise the productive capacity of the economy. With it come higher tax collections making it easier to pay for the higher interest. Monetary and fiscal policy can be looser relative to the previous case.

Figure 7. Benevolent Future Policy Scenarios

(a) Inflation and realized returns



(b) Inflation and policy rates



Source: Author's calculations.

10. Point *D* in Figure 7 is the same as point *C* in Figure 6.

More generally, the model makes clear that a fall in $m - y$ through a rise in y calls for shifting the PT curve left and up; while if it comes through a fall in m , then the PT has to shift right and down. Distinguishing the two is not easy and detecting separate trends in m and y in real time is near-impossible.

Third, forever-higher returns on government bonds would put pressure on the Treasury to honour its commitment to bondholders. This pressure would be bound to spill over to the policy targets. Central bank independence would likely be tested, and the inflation target reconsidered, as often happens during fiscal crises. In terms of the model, managing the debt and saving on interest expenses will call for the PT curve to move right and down. On average, this can only happen if inflation is higher.

6.2 Policy Scenario 2: Forever-Higher Inflation

The second scenario most likely arises if monetary and fiscal policy give in to the pressure from high interest payments on the public debt. Also pointing in the same direction might be a heightened fear of underemployment. The post-pandemic boom and its reduced inequality and improved well-being of the poor may have raised the appreciation for the relative benefits of “running the economy hot.”

In the model, either the desire to inflate the public debt or to run the economy hot leads to a PT shifted to the right and down. As shown in Figure 8, it would then intersect the AS at a point like D' . This way, the returns paid to bondholders would be lower at ρ'' , thus reducing the interest paid on the debt. By having the equilibrium below the kink, the economy would be running hot.

At first, these two consequences might make this a desirable scenario. But they rely on the norms for remunerating bondholders, workers, and other suppliers of variable inputs, holding steady in line with the inflation target. As realized inflation would be persistently above that and all of these economic agents earn realized returns below what they expected, those norms would change. Expected inflation would rise and nominal wages would grow faster. Policymakers can only achieve the low-returns and hot-economy situation by aiming for even higher inflation. Eventually, inflation would run out of control.

In terms of the model, as norms about inflation rise, the PT curve endogenously shifts left and upwards. The economy naturally moves towards point D . Fiscal and monetary policy would therefore be continuously loosening to bring the economy back to D' .

Keeping $\rho'' < y''$ to lower interest payments or run the economy hot can only be achieved with forever-higher inflation.

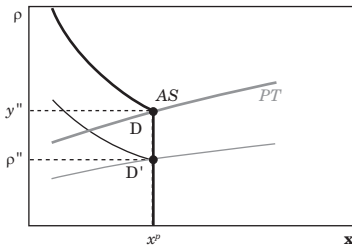
This sequence of events for monetary policy is displayed in the right-hand side plot in Figure 8. Starting from point D with inflation on target, running the economy hot and having realized returns low requires shifting the Taylor rule right and up to achieve a point D' . The inevitable result is that inflation is above target.

With time, expected inflation adjusts upwards. This shifts the $PC-IS$ right and up, and moves the economy to point D'' , with even higher inflation. This process continues with the two curves shifting right and inflation spiralling upwards. Throughout, policy rates are kept too low.

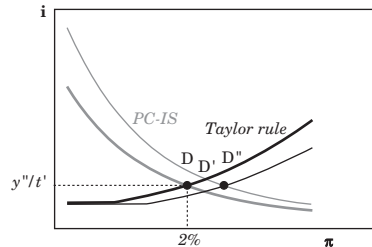
This description of events is familiar. It matches what Friedman (1968) feared would happen, and partly did happen, in the United States in the 1970s. Friedman (1968) wrote in terms of the central bank trying to target a real interest rate away from its equilibrium value. From the perspective of this article, he was talking about policy trying to peg a value for ρ below the value for y . Understanding the distinction between these two R -stars provides some perspective on his arguments.

Figure 8. Policy Scenario with High and Rising Inflation

(a) Inflation and realized returns



(b) Inflation and policy rates



Source: Author's calculations.

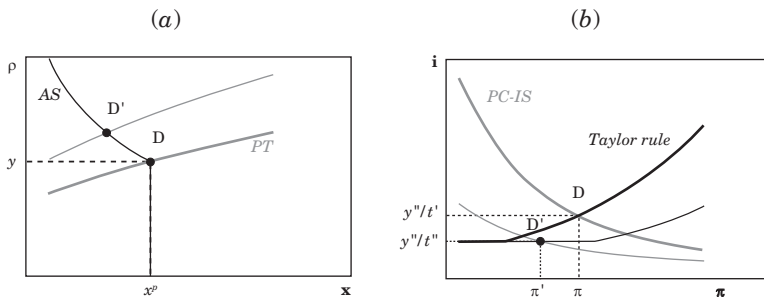
6.3 Policy Scenarios: A Double Trap

A final scenario is less familiar but also has a long intellectual tradition in the study of the Keynesian liquidity trap. It is displayed in Figure 9.¹¹

A feature of the US data in the second half of 2024 was a sharp rise in the term premium. There are a few reasons why this might have happened and might persist in the future ahead. One is a rise in expected inflation and in inflation risk premia. This might be because of forward-looking bondholders perceiving the risk of the second scenario above or backward-looking ones adjusting to the large losses they had in 2021–24. Another reason is a rise in the perception that the large public debt and political unwillingness to lower public deficits might lead to financial repression of the holders of long-term bonds, which investors are pricing in. A third, more direct factor might be the unwinding of quantitative easing or, looking ahead, the loss of effectiveness of this unconventional policy after its overuse in the previous 15 years.

In the model, if the term premium rises from t' to t'' , the *PC-IS* curve moves to the left and down as shown in the right-hand side plot of Figure 9. Just as was the case in 2010–15, monetary policy might find itself at the ELB. Even if it adjusts its inflation target, extending the horizontal segment of the Taylor rule to the right, this might not be enough. The higher yields on government bonds y'' are offset by the higher term premium t'' to leave policy rates against the ELB. The economy would find itself in a too-low inflation trap at point D' .

Figure 9. Policy Scenario with a Double Trap



Source: Author's calculations.

11. See Adrian and others (2024) for related points with a different perspective.

In turn, imagine that fiscal policy is forced into a path of austerity by the higher yields. In part, this is because of the permanently higher yield on government bonds y'' but can also come from a heightened fear of sovereign default. Either way, the stance of fiscal policy may be contractionary.

The combination of tight fiscal and monetary policy then implies that the PT curve in the left-hand side plot of Figure 9 moves left and upwards. The economy would find itself in a too-low activity trap at point D' .

In this scenario, there is a double trap. Both fiscal and monetary policy find themselves constrained—one by fiscal capacity and the other by the lower bound on policy rates. The economy operates below capacity, inflation is too low, and policy is unable to escape.

This liquidity trap occurs partly because of the sins of the past. The inflation disaster of 2021–24 would have fed into permanently higher term premium, while the erosion of the perceived safety and liquidity of government bonds would have fed into higher yields. The latter would reduce fiscal capacity, while the two combined would reduce room for monetary policy. Aggregate demand would be insufficient, and the economy would be in a persistent recession.

7. CONCLUSION

This article distinguished between four R -stars to make sense of why it has been so hard to measure this concept in the data. Both theory and the 1995–2019 experience support making this distinction. I offered a framework that explains why the four R -stars will differ given the macro trends that we observed. Each of the R -stars is important for different questions that are central to macroeconomics and finance, and the framework connected their evolution to the levels of investment, output, and inflation.

Looking at the recent 2021–24 past, there are signs in the data that the wedge between the marginal return on private investment and the yield on government bonds is closing. I laid out arguments in theory explaining why this may be a persistent trend and suggested that this will come through a fall in the safety and liquidity premium of government bonds and perhaps due to an investment boom lowering the returns on private investment. Forecasting the future is very hard, so these arguments should be interpreted as having very wide confidence bands around them. But speculating on these trends is

important because it sheds light on the challenges policymakers will face.

In particular, I laid out three possible policy scenarios in which the US and other advanced economies might find themselves. In a first benevolent scenario, monetary policy would set policy rates forever higher on average, and fiscal policy would raise primary surpluses to pay for the higher interest on the public debt. Inflation would stay on target. In a second scenario, policy would try to run the economy hot and deliver low returns to bondholders. This would lead to high and rising inflation. In a third scenario, both monetary and fiscal policy would find themselves constrained by the effective lower bound and by fiscal capacity, respectively. The economy would be stuck with stagnation, operating below capacity and with too-low inflation.

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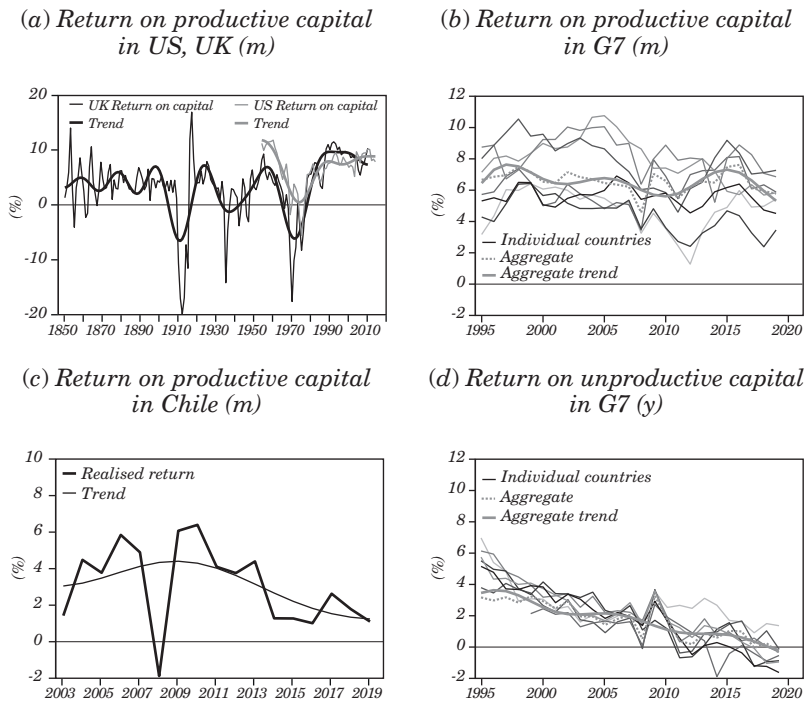
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APPENDICES

APPENDIX A: OTHER VARIABLES

Figure A1 shows three other measures of m , perhaps the hardest of the four R -stars to measure. They all tell the same story: a near constancy of the returns on private capital during this period. The figure also shows measures of y across countries, all of which share the decline in the return on unproductive savings.

Figure A1. Alternative Measurements



Source: Author's calculations.

Notes: Panel (a): Historical real returns on productive capital in the US and the UK. UK historical data is from "A Millennium of Macroeconomic Data for the UK" from the Bank of England for capital stock of nondwellings. US historical data partly comes from BEA, partly from the Jordà-Schularik-Taylor Macrohistory Database using private capital. Panel (b): Real return on productive capital in G7 countries is nominal return on private capital minus realized inflation. Panel (c): Real return on productive capital in Chile is nominal return on private capital minus inflation. Panel (d): Yield on government bonds in G7 countries minus inflation. Trends calculated by using a Mueller-Watson filter with a 20-year window for panel (a) and 10-year window for panels (b)-(d).

APPENDIX B: THE MODEL IN EQUATIONS

Since I am discussing steady states, all endogenous variables (denoted with small letters) have no time subscript. Capital letters refer to exogenous variables that may shift, while Greek letters refer to parameters. Note that all returns are in gross terms.

The Investment curve comes from the standard firm optimality condition that the payment from renting the capital stock equals the marginal product of capital:

$$m = 1 - \delta + Ak^{\theta-1},$$

where δ is the depreciation rate, and θ is the capital share parameter in a Cobb-Douglas production function. As for A , it depends positively on the level of total factor productivity and negatively on markups.

The Savings curve comes from combining the Portfolio-Arbitrage and the Ramsey-Euler relations. Turning to those, the Portfolio-Arbitrage schedule is:

$$m = yB\left(\frac{k}{b}\right)^{\gamma},$$

Starting from the frictionless framework where $m = y$, there is a convenience discount on government bonds that falls with the size of their holdings b relative to the holdings of capital k . The elasticity of the convenience yield to the supply of bonds is γ . As for B , it controls the relative safety and liquidity of government bonds: it is higher if they are perceived to satisfy the demand for those attributes more and thus can pay a lower return relative to productive capital.

The Ramsey-Euler equation is standard from any macro textbook:

$$G = \alpha m + (1 - \alpha)y \Rightarrow y = \frac{G - \alpha m}{1 - \alpha}.$$

The expected growth rate of consumption, adjusted by the inverse of the intertemporal elasticity of substitution, plus the subjective discount rate is captured by the shifter G . It is equal to the average returns from savings, which are a weighted average of the returns from savings in productive capital, and the return from savings in bonds, with the weight on the first being α . Note that there is an approximation assumed here: the weights on the two forms of savings are kept constant even as b and k change. In general, a rise in b/k would

lower α , providing a countervailing force. The force I highlight in this model is the dominant one in a micro-founded version of the model.¹²

Combining the Ramsey-Euler with the Portfolio-Arbitrage equations to replace out y gives the Savings curve:

$$m = \frac{G}{\alpha + \frac{1 - \alpha \left(\frac{K}{b}\right)^{-\gamma}}{B}}.$$

This completes the first two panels and determines the first two R -stars: m and y .

Turning to the management of aggregate demand, the AS or aggregate supply curve is:

$$\rho = y \max \left\{ 1; \left(\frac{x}{x^p} \right)^\eta \right\}.$$

Realized returns ρ are anchored by expected returns y . However, when output is below potential, then they are higher, with a slope given by η . This reflects the demand curve for variable inputs, since $\rho > y$ means that the realized returns from supplying those inputs are higher, and so the firm will want to demand less of them. The potential output depends on capital, which I write as $x^p = Dk^\theta$ —recall that θ was the capital share in the Cobb-Douglas production function—, while D is a shifter linked to productivity, markups, or regulation that lowers the output produced with a given amount of capital.

As for aggregate demand, the standard first-order condition from minimizing quadratic deviations of output and inflation from target, subject to a positively sloped frontier that trades off the two is: $\pi/\bar{\pi} = (x/\bar{x})^{-\lambda}$, where $\bar{\pi}$ is the inflation target, $\bar{x}$, is the output target and λ is the ratio of the relative weight on output in the policymakers' objective function to the slope of the trade-off between inflation and output (the slope of the Phillips curve). Now, by the definition of actual returns after realized inflation π , and expected returns according to the norm π^n , it must be that $\rho\pi = y\pi^n$.

Combining the two relations in the previous paragraph gives the PT curve:

$$\rho = yEx^\lambda \text{ where } E = \left(\frac{\pi^n}{\bar{\pi}} \right) \bar{x}^{-\lambda}.$$

12. See Reis (2021).

The *PT* schedule shifts up when the norm rises, and down when the inflation target falls or when policy starts targeting a higher level of output.

Finally, we turn to monetary policy. Recall that i stands for the nominal policy rate divided by the inflation target $\bar{\pi}$. Starting with the Taylor rule, it is:

$$i = \max\left\{\frac{1}{\bar{\pi}}, F\left(\frac{\pi}{\bar{\pi}}\right)^\phi\right\}.$$

The first term on the right-hand side captures the zero lower bound on nominal rates. The second term is a standard Taylor rule. The coefficient ϕ is the responsiveness of policy to inflation, which is typically taken to be a number above 1 to satisfy Taylor's principle.

The shifter F plays an important role in monetary policy: it is sometimes called the Wicksellian natural rate. As long as $F = y/t$, inflation will be on target $\bar{\pi}$, but understanding this result requires introducing the other equilibrium relation.

The *PC-IS* equilibrium relation starts with a Phillips curve that links unexpected inflation to deviations of output from a natural rate: $\pi/\mathcal{M} \equiv (x/x^n)^{1/\kappa_0}$. It combines this with a New Keynesian IS linking that output gap to the deviation of the real short-term rate to the natural rate of interest. Now, since $i\bar{\pi}$ is the nominal short-term rate, then $i\bar{\pi}/\pi^e$ is the real short-term rate, where π^e is expected inflation. The natural rate of interest is then y/t , the expected rate on government bonds adjusted for the term premium. Therefore, the IS is: $x/x^n = ((i\bar{\pi}/\pi^e)/(y/t))^{-\frac{1}{\kappa_1}}$.

Combining the two relations to eliminate the output gap delivers the *PC-IS*, which is:

$$i = \left(\frac{y}{t}\right) H \bar{\pi}^{-\kappa}, \text{ where } H = \left(\frac{\pi^e}{\bar{\pi}}\right) (\pi^e)^\kappa.$$

The new coefficient $\kappa = \kappa_0 \kappa_1$ is positive. It is higher, and so the *PC-IS* is steeper, if the Phillips curve is very steep (κ_0 is high) or if the sensitivity of spending to interest rates is very high (κ_1). Since both of these seem to run against the evidence, we expect the *PC-IS* to be relatively flat. As for shifts, it will shift up when the expected return y rises, when the term premium t falls, and when expected inflation π^e rises.

By combining the two curves, we can now verify that, when expectations are anchored on target $\bar{\pi} = \pi^e$, then inflation is $\pi = \bar{\pi}((y/t)/F)^{1/(\phi + \kappa)}$. Therefore, it must be that $F = y/t$ for inflation to be on target $\pi = \bar{\pi}$.

THREE THEORIES OF NATURAL RATE DYNAMICS

Galo Nuño

Banco de España

Centro de Estudios Monetarios y Financieros

Centre for Economic Policy Research

The natural rate of interest, or r^* , is generally defined as the risk-free real interest rate that would prevail in the absence of nominal rigidities and business cycle fluctuations.¹ The natural rate concept dates back at least to Wicksell (1898). This concept is important in macroeconomics for several reasons. First, it provides a benchmark for the monetary policy stance in the long run. Second, it plays an important role in asset pricing, as the long segment of the (real) yield curve is the sum of the natural rate and the term premium. Third, it matters for debt-sustainability analysis.²

The traditional view is that the natural rate primarily depends on structural factors, such as demographics and productivity growth.³ For instance, in an economy with perpetual-youth individuals, the natural rate r^* is equal to the steady-state interest rate $r^* = g^y/(\beta\eta) - 1$, where

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1. This definition roughly coincides with the natural rate definition in Obstfeld (2025), though he employs the term $\bar{r}$.

2. There are different methods for estimating the natural rates, including semi-parametric methods (Laubach and Williams, 2003; Holston and others, 2017), nonstructural time series methods (Lubik and Matthes, 2015), or methods based on extracting information on the expected long-run real interest rate from bond prices (Christensen and Rudebusch, 2019; Davis and others, 2024).

3. See, for instance, Cesa-Bianchi and others (2022), Gagnon and others (2021), or Del Negro and others (2017).

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g is total factor productivity (TFP) growth, β is the subjective discount factor, γ denotes risk aversion, and η is the survival probability.

In this paper, we challenge this view.⁴ We consider three alternative, and complementary, theories of natural rate determination. These theories link the natural rate to fiscal policy, monetary policy, and persistent supply shocks such as tariffs or wars.

First, in Section 1, we reproduce the results in Campos and others (2024), who consider a standard heterogeneous-agent New Keynesian (HANK) model with a fiscal block and an occasionally-binding zero lower bound (ZLB). The models incorporate a continuum of atomistic households subject to idiosyncratic risk that can save only by using non-state-contingent instruments. One important feature of HANK models is that the natural rate depends on the stock of public debt, as originally pointed out by Aiyagari and McGrattan (1998), and more recently by Rachel and Summers (2019) and Bayer and others (2023).⁵ The idea is straightforward: given market incompleteness, the stock of public debt determines how much households can self-insure against negative idiosyncratic shocks and, therefore, the interest rate at which the savings market clears.⁶

The link between debt and the natural rate leads to a form of monetary fiscal interaction. The economy has a unique steady state in which the treasury's debt target pins down the natural rate: the higher this target, the higher the natural rate is. Steady-state inflation deviates from the central bank's target proportionately to the difference between the natural rate and the intercept of the Taylor rule. Thus, to ensure price stability, the central bank should change the Taylor rule intercept depending on the treasury's long-run debt target. We develop an analytical expression linking deviations of long-term inflation from the central bank's inflation target to the policy

4. A recent empirical challenge comes from Rogoff and others (2024), who find that for most of history, long-term real interest rates have trended counter to growth and demographics.

5. Bayer and others (2023) and Hänsel (2024) analyze how a permanent increase in the ratio of public debt to GDP increases real public bond yields in the long run. Hagedorn (2026) shows that prices and inflation are jointly and uniquely determined by fiscal and monetary policy in a HANK model with nominal debt. Kaplan and others (2023) analyze the fiscal theory of the price level (FTPL) in the context of a heterogeneous-agent model with flexible prices. In their model, a permanently higher deficit is associated with a lower steady-state real interest rate and less real public debt, as well as a higher long-run inflation rate for a given monetary policy setting.

6. The natural rate is the real interest rate in the deterministic steady state of the model.

gap between the natural rate and the central bank's long-term rate implicit in its reaction function. We evaluate this expression using market data on long-term interest rates and inflation expectations and find significant policy gaps, especially in the post-pandemic period.⁷

There is nevertheless a situation in which the central bank in a HANK world cannot deliver on its long-run mandate even if it is willing to adapt its rule to the fiscal position. If the debt level is sufficiently low, the natural interest rate becomes negative. If the natural rate is so negative that its sum with the inflation target falls below zero, the ZLB will be binding in the long run, and inflation will be equal to the opposite of the natural rate. Thus, there is a minimum debt level that is compatible with the inflation target. For any debt target below that minimum level, the central bank fails to deliver on its mandate.⁸

Second, we follow Fernández-Villaverde and others (2025) and build a HANK model with a ZLB and aggregate demand shocks in Section 2. The model is similar to the one above, but we solve it by using global methods to capture how households' demand for savings increases with the frequency of ZLB spells. This is due to a precautionary motive: when the nominal rate is constrained by the ZLB, the central bank cannot provide an adequate degree of monetary accommodation—households then save to self-insure against aggregate risk linked to the ZLB.⁹ The increased demand for precautionary savings lowers the natural interest rate. Since the long-run nominal interest rate is simply the real interest rate plus inflation, the average nominal rate is lower, providing less room for the central bank to stabilize the economy away from the ZLB. This creates a feedback loop through which lower natural rates increase the frequency of ZLB episodes, making it more likely to reach the ZLB, thus further reducing the natural rate.

This observation has a significant implication: monetary policy is not neutral in the long run in a HANK economy, as the Fisher equation depends on the central bank's stance. More specifically, if we denote the steady-state nominal interest rate, inflation rate, and inflation target by i , π , and $\bar{\pi}$, respectively, then $i(\bar{\pi}) = r^*(\bar{\pi}) + \pi(\bar{\pi})$, such that

7. Chortareas and others (2023) estimate a time-varying Taylor rule for the United States and document how the Federal Reserve has occasionally misread the natural rate of interest. Bocola and others (2024) use high-frequency data to detect shifts in financial markets' perception of the Federal Reserve stance on inflation.

8. Mian and others (2025) show that greater deficits may reduce, rather than increase, debt when at, or near, the ZLB.

9. This mechanism is already present in representative-agent models (e.g., Adam and Billi, 2007, Nakov, 2008, and Bianchi and others, 2021).

$dr^*/d\bar{\pi} > 0$, meaning that the natural rate increases with the central bank inflation target.

Third, we analyze the representative-agent New Keynesian (RANK) model with persistent supply shocks of Nuño and others (2024) in Section 3. The novelty of that model lies in the introduction of a persistent cost-push shock in addition to the standard autoregressive shocks. The economy randomly switches between two regimes: (1) when the persistent shock does not affect the economy, and (2) when the shock increases production costs for all firms. This can be interpreted as a proxy for various types of cost-increasing shocks. For example, Afrouzi and others (2023) consider a shock similar to the one used here as a proxy for changes in labor market composition towards more regulated labor sources or a deceleration in globalization.¹⁰

There is a precautionary saving mechanism through which the persistent cost-push shock affects the natural rate. During normal times, the economy is undistorted, and consumption aligns with that of efficient allocation; thus, the output gap is zero. In contrast, during bad times, the average markup becomes suboptimal, leading to a reduction in output and consumption and, ultimately, to a negative output gap. Consequently, the economy features two distinct stochastic steady states (sss), each associated with a different regime.¹¹ The variation in consumption between the two regimes explains the dynamics of the natural interest rate.¹² In normal times, households anticipate a potential transition to a regime where their average consumption would decline, leading to a precautionary increase in the demand for savings. Given the fixed supply of savings instruments, this results in a decline in the natural rate. Conversely, when the economy transitions to the bad-times regime, consumption falls and demand for savings decreases as households anticipate higher future consumption once the regime ends, which in turn causes the natural rate to rise.

Traditional Taylor rules fail to stabilize inflation in both regimes due to shifts in the natural interest rate. Specifically, the Taylor rule sets the long-term real interest rate equal to the average natural rate across regimes, which proves too restrictive during normal times and too lax during bad times. Consequently, inflation systematically

10. This addition complicates the model solution, as it requires solving the model globally with regime switching dynamics.

11. An ss refers to the equilibrium state when shocks are zero, and the economy remains within its current regime, with agents anticipating the stochastic processes.

12. The natural interest rate is defined here as the real interest rate in each ss corresponding to the long-term real interest rate when temporary shocks dissipate.

deviates from the target, underscoring the limitations of existing policy rules that assume a constant natural rate.

What these three theories have in common is the central role played by precautionary savings motives. In the three models, either agents react to shifts in idiosyncratic or aggregate risks by changing their demand for risk-free saving instruments or the government changes the long-run supply of these instruments. As the natural rate is the inverse of the price of risk-free assets, these changes lead to different levels of the natural rate. Compared to the standard complete-markets representative-agent economy in which the demand for assets is perfectly elastic, the presence of precautionary savings gives rise to an upward-sloping demand.

These theories bear relevant implications for monetary policy design: (i) central banks should track, as best as possible, the future path of the natural rate, and avoid assuming that this is a slow-moving variable;¹³ (ii) the natural rate may jump in response to fiscal and political events; and (iii) when deciding inflation targets, central banks should take into account that the natural rate may decrease if long-term inflation is too low and therefore aim for a reasonable inflation target that guarantees that nominal rates remain well above the ZLB.

1. A FISCAL THEORY OF THE NATURAL RATE

We start with the model in Campos and others (2024), in which the natural rate depends on fiscal policy. First, we introduce their model and then we describe the implications for the natural rate.

1.1 Model

The model is a baseline discrete-time HANK model with monetary and fiscal policy. Wages are subject to nominal rigidities and hours are determined by a union on behalf of the workers. Firms produce

13. Bauer and Rudebusch (2020) show how accounting for time variation in natural rates is crucial for understanding the dynamics of the yield curve, a key object in monetary policy transmission. Alternatively, central banks may look for monetary policy rules that are robust to natural rate dynamics. Campos and others (2024), for instance, show how a monetary policy rule à la Orphanides and Williams (2002) may stabilize inflation and output gap when the natural rate evolves with long-term debt without any reference to the natural rate. Daudignon and Tristani (2026) analyze the optimal monetary policy response to stochastic changes in the natural rate in a New Keynesian model.

the final good with the labor supplied by the union. The model is closed by a monetary policy authority, which determines the nominal interest rate, and a treasury, responsible for taxation, spending, and public debt issuance.

1.1.1 Households

There is a continuum of households indexed by $i \in [0, 1]$. Households derive utility from consumption, $c_{i,t}$, and disutility from working $n_{i,t}$ hours. They can only save in a nominal public bond. Given a discount factor β , the intertemporal problem solved by each household is:

$$V(a_{i,t}, z_{i,t}) = \max_{c_{i,t}, a_{i,t+1}} u(c_{i,t}) - v(n_{i,t}) + \beta E_t [V(a_{i,t+1}, z_{i,t+1})]$$

$$s.t. \quad c_{i,t} + a_{i,t+1} = (1 + r_t)a_{i,t} + (1 - \tau) \frac{W_t}{P_t} z_{i,t} n_{i,t} + T_t,$$

$$a_{i,t+1} \geq \bar{a},$$

where $a_{i,t}$ is the household's asset position in real terms at the start of the period, $z_{i,t}$ is the idiosyncratic labor productivity, r_t denotes the ex-post real return of bonds in period t , W_t is the nominal wage, and P_t is the price level. Labor income is taxed at a constant rate τ . Households receive real net lump-sum transfers T_t from the treasury. Households cannot short bonds, i.e., $a_{i,t+1} \geq \bar{a} = 0$.

At time t , household i works $n_{i,t}$ hours. A union chooses these hours on behalf of households. Each hour provides $z_{i,t}$ units of effective labor, so that aggregate hours are $N_t = \int_0^1 z_{i,t} n_{i,t} di$. The idiosyncratic shock $z_{i,t}$ follows a first-order Markov chain with mean $E_t z_{i,t+1} = 1$. Agents take their hours $n_{i,t}$ as given. We assume a proportional allocation rule for labor hours, with $n_{i,t} = N_t$. The nominal wage W_t is determined by union bargaining as specified below.

1.1.2 Unions

The union aggregates different labor tasks provided by the households into a homogeneous labor service. The union employs all households for the same number of hours N_t and sets nominal

wages by maximizing the welfare of the average household subject to a penalty term on the deviation of nominal wages from the central bank's inflation target $\bar{\pi}$.

Solving this problem leads to a wage Phillips curve:¹⁴

$$\log\left(\frac{1 + \pi_t^w}{1 + \bar{\pi}}\right) = \kappa_w \left[-\frac{\epsilon_w - 1}{\epsilon_w} (1 - \tau) \frac{W_t}{P_t} \int u'(c_{i,t}) z_{i,t} di + v'(N_t) \right] N_t + \beta \log\left(\frac{1 + \pi_{t+1}^w}{1 + \bar{\pi}}\right), \quad (1)$$

where ϵ_w is the elasticity of substitution between different labor tasks, k_w is the slope of the Phillips curve (itself a nonlinear function of other parameters of the model), and $\pi_t^w \equiv W_t/W_{t-1} - 1$ is the nominal wage inflation rate.

1.1.3 Firms

There is a continuum of identical firms. Firms produce final goods using a constant return-to-scale technology $Y_t = \Theta N_t$, where N_t is aggregate labor and $\Theta > 0$ is a constant productivity parameter. The real wage is given by $W_t/P_t = \Theta$. From these equations, wage inflation is equal to goods inflation, $\pi_t^w = \pi_t$, where the latter is defined as $\pi_t \equiv P_t/P_{t-1} - 1$.

1.1.4 Monetary Policy

The central bank sets the nominal interest rate on nominal bonds i_t according to a standard monetary policy rule that responds to inflation, and it is subject to a ZLB:

$$\log(1 + i_t) = \max\left\{ \log(1 + \bar{r}) + \log(1 + \bar{\pi}) + \phi_\pi \log\left(\frac{1 + \pi_t}{1 + \bar{\pi}}\right), 0 \right\}, \quad (2)$$

where $\phi_\pi \geq 1$ is the slope of the Taylor rule, $\bar{\pi}$ is the inflation target, and $\bar{r}$ is the real rate intercept.

14. See Auclert and others (2018).

1.1.5 FISCAL POLICY

The treasury collects labor taxes from households and spends on real government consumption G_t and real lump-sum transfers to households T_t (a negative real transfer can be interpreted as a lump-sum tax). Also, the treasury can issue one-period nominal bonds. Government consumption does not enter households' utility (or, equivalently, it enters in a separable way from private consumption and labor supply, and we can drop the term).

Given a level of real tax collection T_t , public debt accumulates according to

$$P_t B_t = (1 + i_{t-1}) P_{t-1} B_{t-1} + P_t (G_t + T_t - T_t),$$

where B_t denotes the stock of bonds in real terms. If we define ex-post real rates as $(1 + r_t) \equiv (1 + i_{t-1}) P_{t-1} / P_t$ we can express the government's budget constraint as

$$B_t = (1 + r_t) B_{t-1} + G_t + T_t - T_t.$$

Tax collection is given by:

$$T_t = \int_0^1 \tau \frac{W_t}{P_t} z_{i,t} n_{i,t} di.$$

T_t follows an endogenous process determined by the evolution of its underlying component variables. Similarly to τ , transfers $T_t = T$ will be a constant in the baseline calibration. In comparison, government consumption, G_t , follows a fiscal rule depending on expenditure $\bar{G}$ and the debt target $\bar{B}$:

$$G_t = \bar{G} - \phi_G (B_{t-1} - \bar{B}), \quad (3)$$

where $0 < \phi_G < 1$ controls the speed of fiscal adjustment when debt is not at its target.

1.1.6 Aggregation and Market Clearing

In equilibrium, the labor, bond, and goods markets clear:

$$N_t = \int_0^1 z_{i,t} n_{i,t} di,$$

$$B_t = \int_0^1 a_{i,t+1} di,$$

$$C_t = \int_0^1 c_{i,t} di,$$

and the aggregate resource constraint holds: $G_t + C_t = Y_t$.

1.1.7 Calibration and Computational Method

The calibration is described in Appendix A.1. The model is solved only in the steady state.

1.2 The Natural Rate and the Long-Run Debt Level

We focus on the deterministic steady state (DSS) of the model. In the DSS, there are no aggregate shocks, but there are idiosyncratic shocks at the household level. First, we characterize the demand and the supply of bonds, and then we combine supply and demand with the monetary policy rule to obtain the real interest rate and the inflation rate. We denote all steady-state variables with the subindex “ss”, except for the real interest rate, for which we use the standard r^* , since in the model this variable coincides with what is usually called the long-run natural rate. In addition, we retain the t subindex for variables that relate to choices made by households because they still face idiosyncratic shocks in the DSS.

1.2.1 The Natural Rate as a Function of the Debt Level

The demand for bonds aggregates the individual savings decisions of households, which accumulate bonds to smooth their consumption across time and the world’s idiosyncratic states. We express the aggregate demand for bonds in the DSS by

$$A_{ss}(r^*) = \int_0^1 a_{i,t+1}(r^*) di,$$

where we make explicit that both the aggregate and the individual demands for bonds are a function of r^* . The solid line in Figure 1

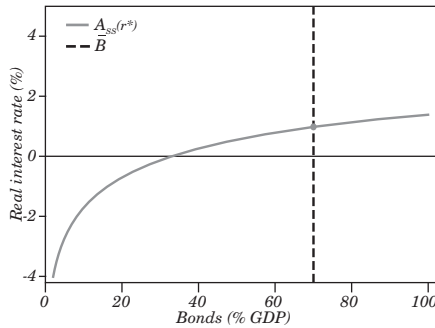
displays the demand for bonds. It is well-known, at least since Aiyagari (1994), that an economy with incomplete markets such as the one analyzed here produces an upward-looking demand curve. This is due to precautionary savings: as the volume of debt decreases, households are willing to accept debt with lower returns in order to save against potential bad realizations of idiosyncratic income risk.

The supply of bonds in the DSS is exogenous and equals $\bar{B}$. The vertical dashed line in Figure 1 displays the supply of bonds.

We combine the supply and demand of bonds and the monetary policy rule to characterize the DSS of the model. When we equate supply and demand, we find that $A_{ss}(r^*) = \bar{B}$. The vertical supply of bonds allows us to pin down the range of steady-state real interest rates that align with the steady-state debt target. Because the demand for bonds slopes upward, an increase in the steady-state debt level will result in a higher steady-state real interest rate. By inverting the function $A_{ss}(r^*)$, we can establish that the relationship $r^*(\bar{B})$ is an increasing function. In other words, the natural rate depends positively on the level of debt.

The bottom line is that, as we deviate from complete markets, the precautionary savings motive induces a demand for bonds that is not perfectly elastic, thus making the long-term real rate (also known as the natural rate) a function of the level of long-term debt.

Figure 1. Determination of the Natural Interest Rate



Source: Author's calculations.

1.3 Implications for Monetary Policy Design

1.3.1 Long-Term Inflation Rates

We approximate the monetary policy rule (2) in the DSS by $i_{ss} \approx \max\{\bar{r} + \bar{\pi} + \phi_{\pi}(\pi_{ss} - \bar{\pi}), 0\}$. This rule can be combined with the long-run Fisher equation $i_{ss} = r^* + \pi_{ss}$ to get:

$$r^* + \pi_{ss} \approx \max\{\bar{r} + \bar{\pi} + \phi_{\pi}(\pi_{ss} - \bar{\pi}), 0\}. \quad (4)$$

It is well known that equation (4) has two solutions.¹⁵ The first solution, which we term a nonbinding ZLB scenario, corresponds to the case in which $\bar{r} + \bar{\pi} + \phi_{\pi}(\pi_{ss} - \bar{\pi}) > 0$, and results in the solution $r^* + \pi_{ss} \approx \bar{r} + \bar{\pi} + \phi_{\pi}(\pi_{ss} - \bar{\pi})$, or equivalently

$$\pi_{ss} \approx \bar{\pi} + \frac{r^* - \bar{r}}{\phi_{\pi} - 1}, \quad (5)$$

which relates the deviation of long-term inflation from the inflation target $\pi_{ss} - \bar{\pi}$ to the *policy gap* $r^* - \bar{r}$ between the natural rate and the intercept in the central bank's reaction function. The second solution to equation (4) is a binding ZLB scenario, in which $\bar{r} + \bar{\pi} + \phi_{\pi}(\pi_{ss} - \bar{\pi}) \leq 0$, that the maximum of the right-hand side of the equation is zero. In this case, the nominal interest rate is zero, and $\pi_{ss} = -r^*$.

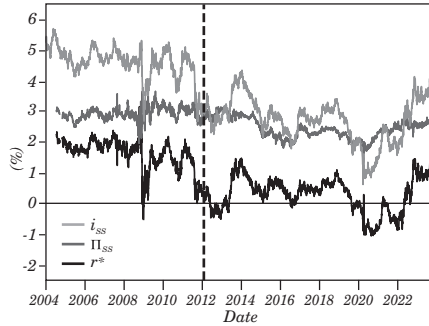
1.3.2 What Happens if the Central Bank Fails to Track the Natural Rate?

Equation (5) implies that, if the central bank wishes to ensure that long-run inflation remains at its target, $\pi_{ss} = \bar{\pi}$ the intercept $\bar{r}$ should perfectly track the natural rate r^* , ensuring that the policy gap is always zero. Otherwise, the central bank fails to deliver on its mandate.

To investigate whether this second possibility has some empirical support, Campos and others (2024) take equation (5) to the data. To this end, they collect variables that approximate the (potentially time-varying) steady-state values of real interest rates and inflation. They think of steady-state objects as random variables instead of constant parameters.¹⁶

15. See Benhabib and others (2002).

16. They collect daily data on the 5-year, 5-year (5y5y) forward nominal yield. This is a measure of the 5-year yield expected five years ahead, which is commonly used as a proxy for long-term nominal interest rates. For long-term inflation, they employ the 5y5y inflation-linked swaps (ILS). These are swap contracts that transfer inflation risk from one party to another through an exchange of fixed cash flows. The real interest rate is computed as the difference between the 5y5y nominal rate and the 5y5y ILS.

Figure 2. Long-Term Nominal and Real Rates and Inflation

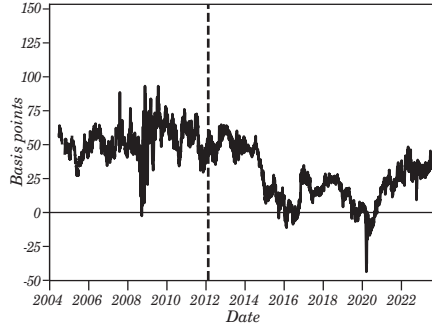
Source: Author's calculations.

Notes: i_{ss} is the 5y5y forward nominal rate obtained from the zero-coupon US yield curve. π_{ss} is the 5y5y ILS. r^* is computed as the difference $i_{ss} - \pi_{ss}$. The dashed vertical line marks the date when the 2 percent inflation target was announced (January 24, 2012).

Their results are reported in Figure 2. Three patterns are immediately apparent. First, market expectations of long-term nominal and real rates and inflation are neither constant nor evolve solely based on low-frequency secular trends; instead, they display a significant level of high- and medium-frequency volatility. Second, both nominal and real rates display greater volatility than inflation. Third, long-term inflation expectations have systematically deviated from the 2 percent target. The Federal Reserve officially adopted this value in January 2012, but it was considered the implicit target long before that date, in line with other major central banks such as the European Central Bank and the Bank of England.

Figure 3 plots the estimated policy gap $r^* - \bar{r}$ using equation (5).¹⁷ This gap was markedly different from zero before 2014. From 2015 to 2020, the gap largely closed, but it reopened after the large fiscal expansion that followed the COVID-19 pandemic. These results provide evidence supporting the idea that market participants perceive that the Federal Reserve's reaction function has not always tracked the natural rate perfectly, which explains the dynamics in long-term inflation.

17. See Campos and others (2024) for a discussion on how the slope of the Taylor rule can be estimated from market data.

Figure 3. Policy Gap $r^* - \bar{r}$ 

Source: Author's calculations.

Notes: The policy gap is based on Figure 2.

1.3.3 The Minimum Debt Level Compatible with an Inflation Target

Next, we combine the real interest rate that clears the bond market in the DSS with the Taylor rule. When the ZLB is not binding, we assume that the central bank picks this real interest rate as the intercept in the Taylor rule to ensure that inflation remains on target. That is $\bar{r} = r^*(\bar{B})$, and, hence, $\pi_{ss}(\bar{B}) = \bar{\pi}$. This can always be achieved if real interest rates are high enough. There is, however, a level of the debt target $\bar{B}^*$, defined as

$$r^*(\bar{B}^*) + \bar{\pi} = 0$$

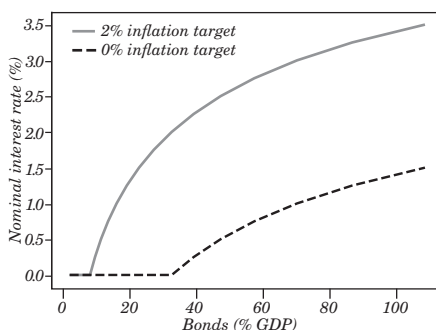
for which the nominal interest rate is zero. We illustrate this result in Figure 4. It displays the nominal interest rate for two different inflation targets—2 percent (solid) and 0 percent (dashed). The figure shows that, for an inflation target of 2 percent, the minimum debt level $\bar{B}^*$ is 8 percent of GDP. In contrast, for 0 percent, it is 33 percent.

For debt levels below $\bar{B}^*$, $\bar{B} < \bar{B}^*$ the central bank is forced to accept steady-state inflation levels above its target due to the inability of nominal rates to become negative. In this case, the ZLB is binding, $i_{ss} = 0$, and inflation is determined by $\pi_{ss} = -r^*(\bar{B})$. Campos and others (2024) call $\bar{B}^*(\bar{\pi})$ the *minimum debt level compatible with the inflation target* $\bar{\pi}$ because the central bank can deliver on its inflation target in the DSS only if $\bar{B} > \bar{B}^*$. The dashed line in Figure 5 displays a frontier $\pi(\bar{B}^*)$ for positive inflation targets. The shaded area above this frontier

contains the set of (non-negative) inflation targets that can be achieved in equilibrium for varying levels of debt. The level of debt $\bar{B}^*$ shown in this graph is the lowest level of debt compatible with an inflation objective of zero.

An alternative interpretation of the minimum debt level compatible with the inflation target is that, if public debt is too low, conventional monetary policy will not be enough to guarantee the central bank's inflation target, so other interventions will be needed.

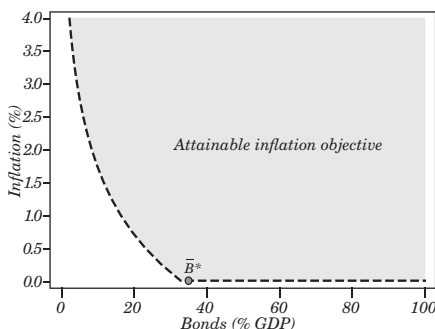
Figure 4. Steady-State Nominal Interest Rate as a Function of Long-Term Debt



Source: Author's calculations.

Notes: The dashed line shows the steady-state nominal interest rate as a function of the long-run debt level $\bar{B}$ for an inflation target of 0 percent and the solid line for 2 percent.

Figure 5. Steady-State Inflation as a Function of Long-Term Debt



Source: Author's calculations.

Notes: The shaded area shows the combinations of (non-negative) inflation objectives that can be achieved in equilibrium for a varying level of debt. The level of debt is the lowest level of debt B^* compatible with an inflation objective of zero.

2. INFLATION, THE ZLB, AND THE NATURAL RATE

Next, we challenge the view that the natural rate is independent of monetary policy. We summarize the main results in Fernández-Villaverde and others (2025).

2.1 Model

The model is a HANK model similar to the one in Section 1. Here we highlight the main differences.

2.1.1 Households

Households maximize a problem similar to that in Section 1. There are only two differences. First, households are affected by a preference shifter ξ_t , such that instantaneous utility is $\xi_t[u(c_{i,t}) - v(n_{i,t})]$. The shock evolves as an AR(1) process in logs, $\log \xi_t = \rho_\xi \log \xi_{t-1} + \zeta_t$, where $\rho_\xi \in (0, 1)$ and $\zeta_t \sim N(0, \omega_\xi)$. Second, there are no labor taxes ($\tau = 0$): all taxes are lump-sum.

2.1.2 Labor Market

The wage Phillips curve is now¹⁸

$$\log \left(\frac{1 + \pi_t^w}{1 + \bar{\pi}} \right) = \kappa_w \left[\frac{v'(N_t)}{u'(C_t)} - \frac{\epsilon_w - 1}{\epsilon_w} \frac{W_t}{P_t} \right] + \beta E_t \left[\log \left(\frac{1 + \pi_{t+1}^w}{1 + \bar{\pi}} \right) \frac{N_{t+1}}{N_t} \right]. \quad (6)$$

2.1.3 Central Bank

The central bank sets the nominal interest rate i_t according to the Taylor rule:

$$1 + i_t = \max \left\{ 1, (1 + \bar{r})(1 + \bar{\pi}) \left(\frac{1 + \pi_t}{1 + \bar{\pi}} \right)^{\phi_\pi} \left(\frac{Y_t}{\tilde{Y}} \right)^{\phi_y} \right\},$$

where $\tilde{Y}$ denotes the level of output, both in the DSS of the economy. The central bank sets i_t by reacting to deviations of inflation from its

18. See Hagedorn and others (2019).

target—the parameter φ_π determines the strength of this response—and to deviations of output from its DSS level, with the parameter φ_y pinning down the strength of this second channel, unless the ZLB constraint $i_t \geq 0$ is binding, in which case it sets $i_t = 0$.

2.1.4 Fiscal Authority

The fiscal authority levies lump-sum taxes T_t on households to finance a fixed amount of outstanding debt $\tilde{B}$, such that the government budget constraint is satisfied $T_t = r_t \tilde{B}$. Given $\tilde{B}$ and the equilibrium interest rate, the lump-sum taxes T_t are set to clear the budget constraint.

2.1.5 Calibration and Computational Method

We calibrate the model to replicate labor earnings and wealth dispersion, average marginal propensity to consume (MPC) and the frequency of ZLB occurrences observed in the US economy since 1945. The calibration is described in Appendix A.2. We solve the model nonlinearly using the neural network algorithm proposed by Fernández-Villaverde and others (2023).¹⁹

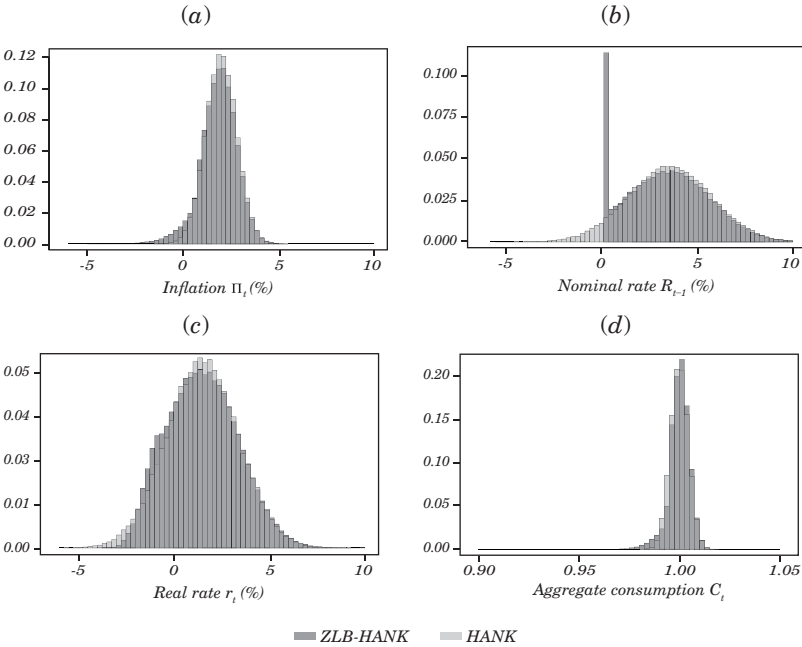
2.2 The Natural Rate and the ZLB

Ergodic distributions. Before analyzing the link between monetary policy and the natural rate, it is important to understand the implications of this nonlinearity for the model's dynamics. An intuitive way to grasp this is by comparing the ergodic distribution of the aggregate variables in the model, which we call ZLB-HANK, with those of a standard HANK economy with the same parameterization, except that the ZLB is absent from the Taylor rule followed by the central bank.

19. This allows us to compute the stochastic equilibrium dynamics of the economy instead of using standard computation methods for HANK models based on linearization. See, for example, Ahn and others (2018), and Auclert and others (2021).

Figure 6 shows the ergodic distribution of inflation, the nominal interest rate, the real interest rate, and aggregate consumption in the ZLB-HANK and HANK economies. The figure shows how the presence of the ZLB skews the dynamics of the model to the left, except for the real rate, where the left tail gets truncated. These are the cases in which the ZLB constrains the nominal interest rate, and the economy experiences a sharp drop in aggregate consumption amidst a deflationary spiral and real rates that are too high. These dynamics are absent in the HANK economy.

Figure 6. Ergodic Distributions



Source: Author's calculations.

Notes: The figure displays the ergodic distribution in the model. The figure is produced by simulating the model for a large number of periods.

2.2.1 The Natural Rate and the ZLB

Standard models typically predict that structural parameters determine the real interest rate in the DSS, meaning that monetary policy does not affect it. Although this model yields similar results in the DSS, it generates a relationship between changes in the inflation target and changes in real interest rates in the stochastic steady state.²⁰

For instance, in the DSS of the model, the inflation rate is 2 percent, which coincides with the central bank’s inflation target. However, in the ss, the level of inflation is lower (1.90 percent). This happens because households internalize the possible occurrence of sizable negative demand shocks that could push the economy to the ZLB constraint, thus triggering deflationary episodes. In the following paragraphs, we will show how this model implies that changes in the level of the central bank’s inflation target move real interest rates in the ss even if they do not do so in the DSS.

Table 1 reports the DSS and ss values for inflation, the nominal interest rate, and the real interest rate, along with the frequency of ZLB events in each model’s ergodic distribution.²¹

Table 1. Comparison of DSS and ss in ZLB-HANK, and HANK

Variable	ZLB-HANK		HANK	
	DSS	SS	DSS	SS
Inflation (%)	2.00	1.92	2.00	1.99
Nominal rate (%)	3.50	3.32	3.50	3.48
Real rate (%)	1.50	1.40	1.50	1.48
(Shadow) ZLB Frequency	-	9.62		(5.70)

Source: Author’s calculations.

20. The ss is a point at which all aggregate variables are constant, and the realization of the aggregate demand shock is zero. However, agents are aware that nonzero realizations can come in the future and continue to face idiosyncratic risk. The ss is an important concept because it often provides a better summary of the ergodic distribution of nonlinear models than the DSS.

21. For the HANK economy, we report the shadow frequency and duration of ZLB events, defined as any period where the nominal interest rate equals or falls below zero.

Both the ZLB-HANK and the HANK economies exhibit identical values for all macroeconomic variables at the DSS since the ZLB is not binding at that point. However, the ss values of the two economies diverge. Specifically, the HANK economy displays ss values for inflation, the nominal rate, and the real rate that are virtually identical to those at the DSS, differing by only 1 bp, 2 bp, and 2 bp, respectively. In contrast, introducing the ZLB into the ZLB-HANK economy reduces the ss values for inflation, the nominal rate, and the real rate by approximately 8 bps, 18 bps, and 10 bps, respectively.

How does the introduction of the ZLB explain these differences? The ZLB changes the behavior of households and firms in the ss, even if it is not binding at that point. Agents understand that a demand shock could push the economy toward the ZLB in the future and respond preemptively. After all, the ZLB-HANK economy spends 9.62 percent of quarters at the ZLB. In particular, households increase their precautionary savings to ensure a savings buffer (or reduce their borrowing) to smooth their consumption stream in recessions where the nominal rate hits zero. This effect is particularly marked for wealth-poor households, which suffer disproportionately more from ZLB episodes. Higher precautionary savings exert downward pressure on the real interest rate level, reducing the central bank's room for maneuvering the nominal rates and making the ex-post realization of ZLB events even more likely.

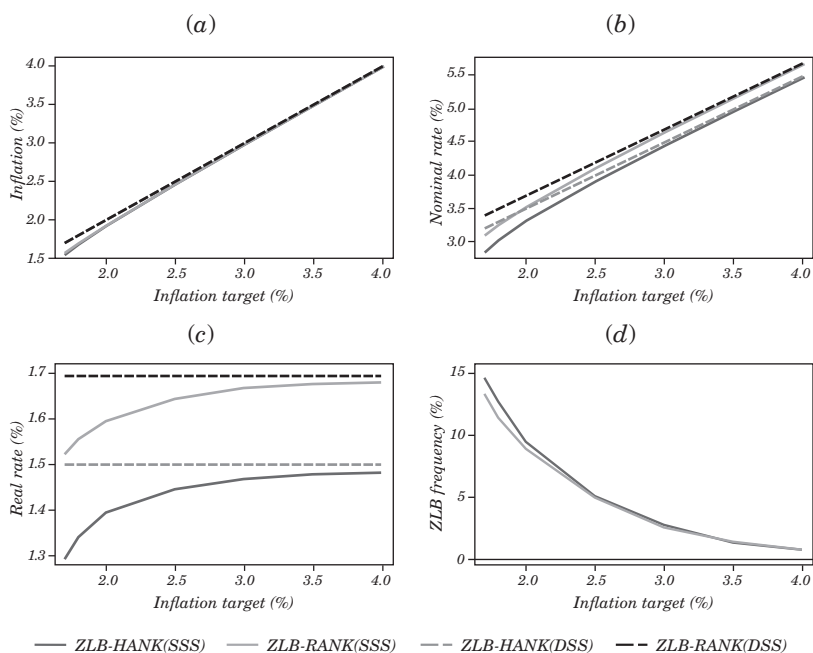
In comparison, the shadow frequency of ZLB events in the HANK economy is lower (5.70 percent of quarters) since the central bank can accommodate negative demand shocks with aggressive reductions of the nominal interest rate more effectively, and households have a smaller need for precautionary behavior.

2.3 Implications for Monetary Policy Design

We just saw how, in the ZLB-HANK economy, the presence of ZLB episodes changes the real interest rate even when we are not at the ZLB. This observation raises an intriguing possibility. Since the central bank can alter the frequency of the ZLB episodes by modifying its inflation target, it can affect the level of real interest rates through the change in the households' savings behavior. In other words, monetary policy is not neutral, even in the long run. More specifically, the model features a long-run Fisher equation, $i_{ss}(\bar{\pi}) = r^*(\bar{\pi}) + \pi_{ss}(\bar{\pi})$, in which the real rate in the ss depends on the central bank's inflation target $\bar{\pi}$. In this setting, a higher inflation target raises the ss level of the real rate, that is, $dr^*/d\bar{\pi} > 0$.

To establish this result, we compare the real interest rate levels in different model economies, which differ only in their inflation target $\bar{\pi}$. Figure 7 plots the DSS and ss levels of inflation, the real rate, the nominal rate, and the frequency of ZLB episodes for $\bar{\pi}$ between 1.7 percent and 4 percent in both the ZLB-RANK and ZLB-HANK economies. The ZLB RANK is a version of the model where we shut down idiosyncratic labor risk to obtain a representative household. The graph shows that, in both economies, the central bank successfully achieves its inflation target at the ss when $\bar{\pi}$ falls within the range of 3 to 4 percent. For those high inflation targets, the probability of experiencing a ZLB event is so low that the nonlinearity of the model is not quantitatively relevant. The economy behaves in practice as if there were no ZLB constraint, and changes in the inflation target between 3 and 4 percent do not alter the level of real interest rates.

Figure 7. DSS/SS in ZLB-RANK and ZLB-HANK as a Function of the Inflation Target



Source: Author's calculations.

However, when the inflation target falls below 3 percent, the nonlinearity caused by the ZLB kicks in, and the ss and DSS diverge substantially. First, the central bank undershoots its inflation target. When the target is 1.7 percent, the inflation rate in the ss is 1.54 percent.²² This 16 bp undershoot is associated with the fact that the economy spends 15 percent of quarters at the ZLB, compared with less than 1 percent of quarters when the inflation target is 4 percent. Importantly, in the ZLB-HANK economy, the sensitivity of the probability of reaching the ZLB to changes in the inflation target is higher than in the ZLB-RANK economy. In the latter, the proportion of quarters spent at the ZLB goes from less than 1 percent when the inflation target is 4 to 13 percent when the inflation target is 1.7 percent.

Then, as we vary the inflation target, the real interest rate in the DSS does not change (dashed lines in the bottom left-hand panel of Figure 7), since idiosyncratic labor income risk is either independent of the inflation target in the ZLB-HANK economy or nonexistent in the ZLB-RANK economy. In comparison, the real rate in the ss increases with the inflation target because we reduce the probability of hitting the ZLB (solid lines in the bottom left panel of Figure 7). Notably, the sensitivity of the real rate in the ss to changes in the inflation target is greater in the ZLB-HANK economy than in the ZLB-RANK economy (i.e., $dr^*/d\bar{\pi}$ in ZLB-HANK is greater than $dr^*/d\bar{\pi}$ in ZLB RANK). In other words, looking at the DSS could lead to the incorrect conclusion that the monetary policy stance does not affect the real interest rate level in the economy's ergodic distribution. Moreover, by analyzing the ss of an economy without heterogeneity, we could overlook the strength of the relationship between the inflation target and the real rate.

What drives the relationship between the inflation target and the real and nominal interest rates? To study this relationship, let us refer again to the Fisher equation. In the DSS of standard models, the real rate is the inverse of households' time discount parameter, whereas the level of inflation is a policy parameter. Given these two structural parameters, standard models determine the level of the nominal interest rate.

22. This undershoot is happening in the ss, where the economy is not at the ZLB. In other words, the undershoot is caused by the agents reacting to the possibility of being at the ZLB in the future, not because of the deflationary spiral triggered when the ZLB is reached.

In the ZLB-HANK economy, by contrast, we have the deflationary bias triggered by the possibility of hitting the ZLB, which lowers the real rate and pushes inflation below its target, with both forces bringing down the nominal rate. While this deflationary bias also exists in the ZLB-RANK economy, it is stronger in the ZLB-HANK case because idiosyncratic uncertainty also lowers the real rate and makes hitting the ZLB more likely.

3. PERSISTENT SUPPLY SHOCKS AND THE NATURAL RATE

Finally, we reproduce the analysis in Nuño and others (2024), in which the natural rate changes in response to persistent shocks such as tariffs or wars.

3.1 Model

3.1.1 Households

A continuum of identical households consumes goods c_t , and supply labor h_t to maximize the expected discounted utility:

$$E_0 \left[\sum_{t=0}^{\infty} \beta^t \left(\frac{c_t^{1-\gamma}}{1-\gamma} - \frac{h_t^{1+\omega}}{1+\omega} \right) \right],$$

subject to the budget constraint:

$$p_t c_t + B_t \leq p_t w_t h_t + (1 + i_{t-1}) B_{t-1} + T_t,$$

where B_t are holdings of a nominal bond which pays interest $1 + i_t$, w_t is the real wage, p_t is the price level, and T_t are the profits from monopolistic producers. We assume that the good is a basket of varieties indexed by j . Thus, the household also wants to choose the consumption of each variety $c_t(j)$ to minimize its expenditure. The outcome of the optimization problem is the optimal demand for j -th variety of good:

$$c_t(j) = \left(\frac{p_t(j)}{p_t} \right)^{-\epsilon} c_t, \quad (7)$$

where ϵ is the elasticity of substitution among varieties, $p_t(j)$ is the nominal price of the j -th variety and p_t is the nominal price index for the basket.

3.1.2 Firms

There is a continuum of monopolistic firms, each of them producing a variety j . Each firm uses labor to produce the good according to the technology $y_t(j) = A_t h_t(j)$, where A_t is the stochastic total factor productivity. There is a labor subsidy $\bar{\tau} = \frac{1}{\epsilon}$ to correct the distortions associated with monopolistic competition. Firms face temporary and persistent cost-push shocks, denoted by ξ_t and η_t , respectively. Each firm's total cost is $(1 - \bar{\tau})\eta_t w_t h_t(j)$. We define the labor wedge as

$$(1 + \tau_t) \equiv (1 - \bar{\tau})\xi_t\eta_t, \quad (8)$$

which lumps together the labor subsidy and the cost-push shocks.

Each of these firms has monopoly power over its respective variety and takes the demand for its variety, $c_t(j)$, as given. We assume price stickiness *à la* Calvo: each retailer receives a random signal to adjust their prices with a probability $1 - \theta$, allowing them to choose a new price $p_t(j)$ to maximize the stream of expected profits, that is:

$$\max_{P_t^*(j)} E_t \sum_{k=0}^{\infty} \Lambda_{t,t+k} \left[\frac{P_t^*(j)}{p_{t+k}} y_{t+k}(j) - \Psi(y_{t+k}(j)) \right],$$

subject to (7), where $\Psi(y_{t+k}(j)) \equiv (1 + \tau_{t+k})w_{t+k}(y_{t+k}(j)/A_{t+k})$ are total costs, and $\Lambda_{t,t+k} \equiv \beta^k \lambda_{t+k}/\lambda_t$ is the stochastic discount factor for payments between periods t and $t+k$. The rest of the firms maintain prices constant, that is, $p_{t+k}(j) = p_t(j)$.

We assume a symmetric equilibrium in which all firms are identical, and thus $p_t(j) = p_t$ holds. The optimal price is given by:

$$\frac{P_t^*}{p_t} = p_t^* = \mathcal{M} \frac{E_t \sum_{k=0}^{\infty} \theta^k \Lambda_{t,t+k} y_{t+k} \left(\frac{p_{t+k}}{p_t} \right)^{\epsilon} \Psi'(y_{t+k})}{E_t \sum_{k=0}^{\infty} \theta^k \Lambda_{t,t+k} y_{t+k} \left(\frac{p_{t+k}}{p_t} \right)^{\epsilon-1}}, \quad (9)$$

where $\mathcal{M} = \epsilon/(\epsilon-1)$, and where $\Psi'(y_{t+k}) = w_{t+k}(1 + \tau_{t+k})(A_{t+k})^{-1}$.

3.1.3 Central Bank

The central bank sets the nominal interest rate on bonds. Bonds are in zero net supply $B_t = 0$. The central bank follows a Taylor rule of the form:

$$i_t = \frac{1 + \bar{\pi}}{\beta} - 1 + \psi(\pi_t - \bar{\pi}), \quad (10)$$

where $\bar{\pi}$ is the inflation target and ψ is the slope of the Taylor rule as a function of inflation deviations.

3.1.4 Market Clearing Conditions

The market clearing conditions for goods are given by:

$$y_t(j) = c_t(j) + g_t,$$

where g_t is a government spending shock. By aggregating, we obtain:

$$y_t = \int y_t(j) dj = \int (c_t(j) + g_t) dj = c_t + g_t.$$

Since all firms face the same probability θ of keeping prices fixed, the law of large numbers ensures that a fraction θ of firms will keep their prices fixed, while the remaining fraction $(1 - \theta)$ will optimally reset their prices. As a result, the price level evolves according to:

$$p_t = \left\{ \theta (p_{t-1})^{1-\epsilon} + (1-\theta) (P_t^*)^{1-\epsilon} \right\}^{\frac{1}{1-\epsilon}},$$

which implies

$$1 = \theta (1 + \pi_t)^{1-\epsilon} + (1-\theta) (p_t^*)^{1-\epsilon}. \quad (11)$$

The market clearing condition for labor is given by:

$$h_t = \int h_t(j) dj = \left(\frac{y_t}{A_t} \right) \int \left(\frac{p_t(j)}{p_t} \right)^{-\epsilon} dj.$$

We define price dispersion as:

$$\Delta_t \equiv \int \left(\frac{p_t(j)}{p_t} \right)^{-\epsilon} dj = \theta(1 + \pi_t)^\epsilon \Delta_{t-1} + (1 - \theta)(p_t^*)^{-\epsilon},$$

such that the aggregate production function becomes:

$$y_t = A_t h_t \Delta_t^{-1}.$$

3.1.5 Shocks and Regimes

We define the temporary and persistent shocks. We consider TFP, government spending, and cost-push shocks, each following an AR(1) process in logs. First, we define:

$$g_t = \bar{g} \tilde{g}_t,$$

where $\bar{g}$ is a constant. Then, we have:

$$\log(A_t) = (1 - \rho^A) \left(-\frac{(\sigma^A)^2}{2} \right) + \rho^A \log(A_{t-1}) + \varepsilon_t^A,$$

$$\log(\tilde{g}_t) = (1 - \rho^g) \left(-\frac{(\sigma^g)^2}{2} \right) + \rho^g \log(\tilde{g}_{t-1}) + \varepsilon_t^g,$$

and

$$\log(\xi_t) = (1 - \rho^\tau) \left(-\frac{(\sigma^\tau)^2}{2} \right) + \rho^\tau \log(\xi_{t-1}) + \varepsilon_t^\tau,$$

where $\varepsilon_t^A \sim N(0, \sigma^A)$, $\varepsilon_t^g \sim N(0, \sigma^g)$ and $\varepsilon_t^\tau \sim N(0, \sigma^\tau)$.

We assume that the persistent cost-push shock, η_t , evolves according to a two-state Markov chain. We consider two regimes. In regime 1 “good times”, the value of η_t is 1. In regime 2 “bad times”, its value is $\bar{\eta} > 1$. This implies that the shock is only active during bad times. The transition probabilities are p_{12} from regime 1 to 2:

$$p_{12} = P(\eta_t = \bar{\eta} \mid \eta_{t-1} = 1), \quad (12)$$

and p_{21} from 2 to 1

$$p_{21} = P(\eta_t = 1 \mid \eta_{t-1} = \bar{\eta}), \quad (13)$$

All expectations are taken with respect to the AR(1) shocks and the persistent shock.

3.1.6 Calibration and Computational Method

The calibration is described in Appendix A.3. The presence of the persistent shock complicates the model solution, as it requires solving the model globally with regime-switching dynamics. To address this issue, Nuño and others (2024) employ an algorithm that extends the “equilibrium nets” methodology of Azinovic and others (2022) to accommodate a Markov-switching environment.

3.2 The Natural Rate and Supply Regimes

3.2.1 Flexible-Price Equilibrium

We first consider the counterfactual equilibrium with flexible prices, that is, when $\theta = 0$. The optimal relative reset prices and price dispersion remain equal to 1, $p_t^* = \Delta_t = 1$, reflecting that individual prices are always optimal. This setup creates a potential wedge between the marginal rate of substitution between consumption and labor and the marginal rate of transformation, as

$$h_t^{*\omega} c_t^{*\gamma} = \frac{A_t}{(1 + \tau_t) \mathcal{M}} = \frac{A_t}{\eta_t \xi_t (1 - \bar{\tau}) \mathcal{M}} = \frac{A_t}{\eta_t \xi_t},$$

where, in the last equality, we apply the fact that the labor subsidy neutralizes the average markup. Here, $\eta_t \xi_t$ represents the cost-push shock, which has a mean of 1 in the normal-times regime, but a mean of $\mathcal{M}$ in the persistent supply shocks regime. Consumption in this case satisfies the equation

$$c_t^* + g_t = y_t^* = A_t h_t^* = A_t^{\frac{1}{\omega} + 1} (\eta_t \xi_t)^{-\frac{1}{\omega}} c_t^{*\gamma}. \quad (14)$$

This can be rewritten as

$$\left(\frac{c_t^* + g_t}{A_t} \right)^\omega - \frac{A_t}{(\eta_t \xi_t) c_t^{*\gamma}} = 0. \quad (15)$$

Notice that consumption now depends on the cost-push shock. We define an ss in this economy as a steady state where the innovations of the temporary and persistent shocks are zero and the temporary shocks remain at their mean values. This is an adaptation of the standard concept of ss to the case of a Markov-switching model, which is instrumental in understanding model dynamics. Given that the persistent shock has two different values, the economy exhibits two sss, one in each regime.

3.2.2 Natural Rates

The real interest rate in the flexible-price economy satisfies the Euler equation

$$1 = \beta E_t \left[\frac{c_t^{*\gamma}}{c_{t+1}^{*\gamma}} \right] (1 + r_t^*).$$

If the economy is in regime 1, this equation implies

$$\frac{1}{\beta(1 + r_t^*)} = c_{1,t}^{*\gamma} \left(p_{12} E_t \left[\frac{1}{c_{2,t+1}^{*\gamma}} \right] + (1 - p_{12}) E_t \left[\frac{1}{c_{1,t+1}^{*\gamma}} \right] \right),$$

where the notation $z_{n,t}$ denotes variable z at time t and regime $n = \{1, 2\}$. The real rate in the ss of regime 1 thus approximately satisfies

$$1 + r_{1,ss}^* \approx \frac{1}{\beta} \frac{c_{2,t+1}^{*\gamma}}{(p_{12} c_{1,ss}^{*\gamma} + (1 - p_{12}) c_{2,ss}^{*\gamma})}, \quad (16)$$

reflecting that if the economy remains in regime 1, consumption remains at its ss value $c_{1,ss}^*$, whereas if a regime change occurs in the next period, consumption jumps to the ss in regime 2, $c_{2,ss}^*$. We denote the ss value of the real rate in the flexible-price economy as the natural rate. Each of these consumption levels is a solution to the ss case of equation(14):

$$c_{n,ss}^* + \bar{g} = (\eta_n \xi_{n,ss})^{-\frac{1}{\bar{\omega}}} (c_{n,ss}^*)^{-\frac{\gamma}{\bar{\omega}}},$$

where $\eta_n \xi_{n,ss}$ equals 1 in regime 1, and $\mathcal{M}$ in regime 2. The values are $c_{1,ss}^* = 0.9377$ and $c_{2,ss}^* = 0.8877$. Since $c_{2,ss}^* < c_{1,ss}^*$, the denominator

on the right-hand side of equation (16) exceeds the numerator $(c_{2,ss}^*)'$. This implies that the natural rate in regime 1, $r_{1,ss}^*$, is lower than that in the efficient allocation, $1/\beta$. Conversely, the natural rate in regime 2, $r_{2,ss}^*$, is higher than that in the efficient allocation. In the calibration, these values are 0 percent and 2.7 percent, respectively, compared to 1 percent in the efficient allocation, as shown in the first column of Table 2.

The large differences in the natural rate as a result of the cost-push shock regime are driven by a precautionary savings motive by households. In normal times, households anticipate that, with a certain probability, the economy may shift to the other regime, where consumption will be lower. In anticipation of this event, they attempt to save more but, given the fixed supply of public debt (i.e., the only asset in this economy), their increased demand for savings merely leads to a fall in the bond return, that is, in the natural rate. During bad times, households are forced to reduce their savings to smooth consumption, which results in a higher natural rate.

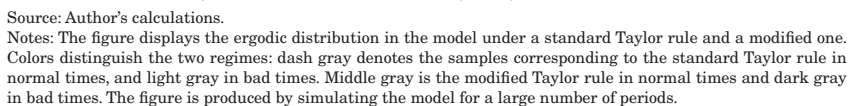
Table 2. Stochastic Steady-State Values

	<i>Flex. prices</i>	<i>Taylor rule</i>	<i>Mod. Taylor rule</i>
Inflation (%)			
normal times	0.0	-0.9	0.0
bad times	0.0	1.6	0.0
Output gap (%)			
normal times	0.0	-0.1	0.0
bad times	-5.5	-5.4	-5.5
Real interest rates (%)			
normal times	0.0	0.1	0.0
bad times	2.7	2.6	2.7
Nominal interest rates (%)			
normal times	0.0	-0.8	0.0
bad times	2.7	4.2	2.7

Source: Author's calculations.

Ergodic distribution and sss. In the baseline case with nominal rigidities and a Taylor rule of the form (10), the central bank controls nominal interest rates to steer the economy towards an inflation level $\bar{\pi}$. Figure 8 shows the ergodic distribution in this case. It is obtained by simulating the economy for a large number of periods. The dash gray bars represent the share of the ergodic distribution that happens during the normal-times regime, whereas the light gray bars correspond to the periods in the persistent supply shock regime.

Figure 8. Ergodic Distribution



Second, long-term inflation in this model is not zero. In the normal-times regime, it is negative (-0.9 percent), and in the bad-times regime, it is positive (1.6 percent). Such deviations from the central bank target $\bar{\pi} = 0$ are the result of the Taylor rule not targeting the adequate natural rate. If we evaluate the Taylor rule in a ss $n = 1, 2$, we obtain

$$i_{n,ss} \simeq \left(\frac{1}{\beta} - 1 \right) + \bar{\pi} + \psi (\pi_{n,ss} - \bar{\pi}) = \bar{r} + (1 - \psi) \bar{\pi} + \pi_{n,ss},$$

where $\bar{r}$ is the real rate target of the central bank, which, under the Taylor rule (10), coincides with the real rate in the deterministic steady state of the efficient allocation, $\bar{r} = \hat{r}$. Replacing the nominal rate using the Fisher equation $i_{n,ss} = r_{n,ss} + \pi_{n,ss}$, we get

$$\pi_{n,ss} \simeq \bar{\pi} + \frac{r_{n,ss} - \bar{r}}{\psi - 1}. \quad (17)$$

Notice how equation (17) can be seen as an ss extension of equation (5) in Section 1 above. It illustrates how long-run inflation deviates from the central bank's target if the monetary policy rule targets an incorrect long-term real rate. In Section 1, the natural rate is endogenous to fiscal policy, whereas here it is the regime-switching nature of the cost-push shock that drives changes in the natural rate. In this model, there is a significant gap between the natural rate in each regime and the central bank's target rate: in normal times, the central bank targets a natural rate that is too high, which tightens monetary policy excessively and explains why inflation is consistently below target: $\pi_{1,ss} \simeq 0.1\% - 1\% = -0.9\%$. Conversely, in bad times, the central bank sets excessively low nominal rates, explaining why inflation is above target: $\pi_{2,ss} \simeq 2.6\% - 1\% = 1.6\%$.

Despite the central bank's failure to stabilize inflation in this economy, it meets its price stability mandate on average. Average inflation in the ergodic distribution is -0.1 percent, and the average real interest rate is 0.9 percent, satisfying equation (17) on average: $0.9\% - 1\% = -0.1\%$.

Third, real rates are slightly higher than natural rates in normal times and lower in the persistent shocks regime. This small divergence between the long-term real rates and the natural rates is due to the different values of ss consumption. Compared to the ex-price allocation, consumption is lower in normal times and higher in bad times: the ss values are $c_{1,ss} = 0.9368$ and $c_{2,ss} = 0.8883$. Following the

logic of equation (16) once more, the jump in consumption between the two regimes becomes slightly narrower, and so does the gap in real interest rates.

The difference in consumption under the ex-price allocation is a consequence of the long-term impact of non-zero inflation on markups. Combining equations (9) and (11) in the steady state, we have

$$w_{n,ss} = A_t (\eta_n \xi_{n,ss})^{-1} \left(\frac{1 - \theta (1 + \pi_{n,ss})^{\epsilon-1}}{(1 - \theta)} \right)^{\frac{1}{1-\epsilon}} \frac{1 - \theta \beta (1 + \pi_{n,ss})^{\epsilon}}{1 - \theta \beta (1 + \pi_{n,ss})^{\epsilon-1}}.$$

In the ex-price allocation, $\theta = 0$ and this expression simplifies to $w_{n,ss} = A_t (\eta_n \xi_{n,ss})^{-1}$, such that in normal times, wages coincide with those in the efficient allocation, $w_{1,ss} = A_t$, whereas in the bad-times regime they are distorted $w_{1,ss} = \bar{A}_t (\bar{\eta})^{-1} < A_t$, which leads to lower labor and consumption in equilibrium. In the economy with nominal rigidities, long-term wages are also affected by long-term inflation. This distortion operates against the effect of persistent cost-push shocks. In the normal-times regime, there is no distortion due to cost-push shocks. Still, negative inflation introduces an additional distortion on wages, which leads to slightly lower output and consumption. In the bad-times regime, however, the distortion due to cost-push shocks is high, and positive inflation mitigates it to a limited extent, thus marginally increasing consumption. This can be confirmed by comparing the values of the output gap, -0.1 and -5.4 percent, with those under flexible prices, 0 and -5.5 percent. In both regimes, non-zero inflation increases price dispersion, but this effect is second order compared to that on the average markup.

3.3.1 Modified Taylor Rule

Finally, we consider an alternative monetary policy rule that is regime-contingent. The new Taylor rule is

$$i_t = \bar{r}_t + \psi (\pi_t - \bar{\pi}), \quad (18)$$

where the Taylor rule intercept equals the natural rate in each regime

$$\bar{r}_t = r_t^*,$$

if the regime at time t is n .

Here r_n^* is the natural rate in regime n , that is, the ss real rate in the counterfactual ex-price allocation. In this case, it is easy to see that equation (17) is compatible with a zero-inflation target $\bar{\pi} = 0$. The third column in Table 2 confirms this: inflation is zero in both sss and real rates, and output gaps coincide with those in the flex-price allocation. The dark gray and middle gray bars in Figure 8 display the ergodic distribution under this modified Taylor rule. They are again centered around the ss values. In particular, the inflation distribution is centered around zero inflation. The variances of the different variables are similar under the original and the modified Taylor rules.

The policy prescription is clear: in the presence of persistent supply shocks the central bank should endogenously adapt its interest rate target to track the natural rate, which becomes a regime-contingent object.

4. CONCLUSION

This paper summarizes recent research in macroeconomics challenging the traditional view that the natural rate only depends on slow-moving structural factors.²³ We show that straightforward extensions of the New Keynesian model, such as considering household heterogeneity or persistent supply shocks, open the door to fiscal and monetary policy affecting the natural rate, and how it may jump depending on the macroeconomic regime. A common feature of these extensions is the central role of precautionary motives at the micro and/or macro level.

The possibility that the natural rate may exhibit medium- and high-frequency dynamics makes central bankers' work more complex. If fiscal policy and persistent shocks, such as tariffs, shift the natural rate, the monetary policy stance, including the long end of the risk-free yield curve, can change abruptly due to factors outside the central bank's control. The optimal reaction of the central bank to these changes should be a key research topic in the years to come.²⁴

23. Complementary empirical work challenging this view can be found in Rogoff and others (2024).

24. Some early results have already been put forward by Daudignon and Tristani (2026) and Nuño and others (2024).

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APPENDIX: CALIBRATIONS

A.1 Calibration of the Model in Section 1

We assume log utility over consumption: $u(c) = \log(c)$. The disutility over hours is parameterized by using a function with a constant Frisch elasticity: $v(n) = v_\varphi n^{(1+1/\varphi)}/(1+1/\varphi)$. We set the Frisch elasticity φ to 0.5. The preference shifter $v_\varphi = 0.791$ is calibrated so that, given all other parameters, total employment is 1 in the steady state. This is an immaterial normalization. We calibrate the discount factor to match a real interest rate of 1 percent annually. This implies a quarterly discount factor of $\beta = 0.992$.

The persistence and standard deviation of income shocks are taken from the estimates of the US wage process in Floden and Lindé (2001). We set the persistence of the income process to match a persistence of 0.91 yearly and the standard deviation of innovations to match the standard deviation of log gross earnings of 0.92. We first convert these values to quarterly frequency and then approximate the income process with a Markov chain with 11 discrete states calculated as in Rouwenhorst (1995).²⁵

We discretize the asset space using a double-exponential transformation of a uniformly spaced grid using 500 grid points, with a minimum asset level of $\underline{a} = 0$ (the borrowing limit) and a maximum asset level of $\bar{a} = 150$. We solve the household problem using the endogenous grid method.²⁶

We normalize the steady-state quarterly output and total factor productivity Θ to 1. This implies that total hours equal output in the steady state. We set the value of elasticity between labor tasks ϵ_w to 10, which is a standard value in the literature.²⁷ We take the slope of the wage Phillips curve $\kappa_w = 0.1$ from Aggarwal and others (2023).

We assume a conventional target of government consumption of 20 percent of GDP, which deviation is close to the US data and is also the number used by Auclert and others (2018). Because we have normalized quarterly output to 1, this implies that $G = 0.2$. We take as a benchmark the case in which the annual real interest rate is

25. The quarterly persistence is calculated as $\rho_Q = 0.92^{1/4} \approx 0.977$ and the quarterly standard deviation of innovation as $\sqrt{(0.91^2/(\sum_{t=0}^3 \rho_Q^{2t}))} \approx 0.476$.

26. See Carroll (2006) and Barillas and Fernández-Villaverde (2007).

27. See, for example, Wolf (2025).

1 percent, and public debt stands at 70 percent of annual GDP. In this quarterly model, the stock of public debt at which the real interest rate is at its steady-state value is, therefore, $\bar{B} = 4 \times 0.7 = 2.8$. The values of the tax rate and net transfers are chosen to balance the budget in the steady state and ensure that public debt remains constant, i.e., that total tax revenue matches government spending plus net transfers and interest payments on public debt. The OECD reports a tax-to-GDP ratio of 0.277 for the United States in 2022. We set transfers to 7 percent of annual GDP, so that $T_{ss} = G_{ss} + T_{ss} + r_{ss} \times B_{ss} = 0.2 + 0.07 + 0.01/4 \times 2.8 = 0.277$. Because $T_{ss} = \tau Y_{ss}$ and $Y_{ss} = 1$, this implies that $\tau = 0.277$. Finally, for the baseline case, we set the parameter φ_G , which governs how quickly G_t responds to deviations from the debt target, to 0.1.

We parameterize the Taylor rule to achieve an inflation target of 2 percent annually and set the Taylor rule coefficient to 1.25.

A.2 Calibration of the Model in Section 2

We set the gross inflation target of the central bank to $\bar{\pi} = \exp(0.02/4)$, so that the annual inflation target is 2 percent. For the Taylor rule, we set the sensitivity of the nominal rate to output deviations from the DSS to $\varphi_y = 0.1$, and that of changes in inflation to $\varphi_{\pi} = 2.5$. We set $\beta = 0.99577$ such that the real interest rate in the DSS of the model equals 1.5 percent.

We calibrate the preference shifter by making the model consistent with the 10 percent frequency of ZLB episodes observed in the US economy in the postwar period,²⁸ by first setting $\rho_{\xi} = 0.6$, in line with the parameterization in Bianchi and others (2021), and then setting $\omega_{\xi} = 0.01225$.

For the labor market, we set the elasticity across differentiated labor services to $\varepsilon = 11$, such that the wage markup is 10 percent. The slope of the Phillips curve is $\kappa_w = 0.11$.

Regarding idiosyncratic risk, we first set $\underline{a} = -0.58$, which equals about two months' average wages. We set the persistence of the income process and the standard deviation of innovations to match the standard deviation of log gross earnings, so that the model reproduces a share of borrowers of 33 percent²⁹ and an average MPC of around

28. See Coibion and others (2016).

29. See Kaplan and others (2014).

10 percent, which is at the lower end of the estimates provided by the literature.³⁰

We calibrate the remaining parameters for households as follows. We assume log utility over consumption: $u(c) = \log(c)$ and set the Frisch elasticity to $\varphi = 1$. Finally, we normalize the disutility of labor to $v_\varphi = 0.8696$, such that the aggregate value of the efficiency units of hours equals 1 in the DSS.

Regarding the fiscal authority, we follow the one-asset calibration strategy of McKay and others (2016) and set $\bar{B} = 25\%$ of annual GDP, in line with the estimate of liquid wealth in the US economy derived by Kaplan and others (2018).

A.3 Calibration of the Model in Section 3

The model outlined in Section 3 is calibrated at a quarterly frequency, and the parameters are reported in Table A. The calibration relies on standard values from the literature as much as possible. Regarding preferences, the quarterly discount factor is 0.9975, implying a real interest rate of 1 percent in the deterministic steady state. The elasticity of substitution across products is $\epsilon = 7$, resulting in a frictionless net markup of $1/6$. The inverse of the intertemporal elasticity of substitution γ is set to 2, and the inverse of the Frisch elasticity ω is set to 1. The long-run productivity level A is normalized to 1, and the government spending constant $\bar{g}$ is set to 20 percent.

The inflation coefficient of the Taylor rule ψ is set to 2, and the inflation target $\bar{\pi}$ is zero.

The TFP, government spending, and cost-push shock parameters are taken from Coibion and others (2012). The value of the persistent cost-push shock is set to $\bar{\eta} = \mathcal{M}$, so that it fully offsets the optimal labor subsidy. The average duration of regime 1 (normal times) is 48 quarters (12 years), to capture a period encompassing a business cycle, giving $p_{12} = 1/48$, while the average duration of regime 2 (persistent supply shock) is set to half of that of normal times, 24 quarters (6 years), meaning that $p_{21} = 1/24$.

30. See Johnson and others (2006), Parker and others (2013), and Broda and Parker (2014).

Table A. Parameter Value

<i>Parameter</i>	<i>Value</i>	
Long-run productivity level	A	1
Inverse Frisch elasticity	ω	1
Inverse of intertemporal elasticity of substitution	γ	2
Discount factor	β	0.9975
Elasticity of substitution among varieties	ϵ	7
Government spending constant	$\bar{g}$	0.2
Calvo constant	θ	0.75
Taylor rule scope	ψ	2
Inflation target	$\bar{\pi}$	0
Labor subsidy	$\bar{\tau}$	$\frac{1}{\epsilon}$
Mean of cost-push shock during persistent supply shock	$\bar{\eta}$	$\mathcal{M} = \frac{\epsilon}{\epsilon-1}$
Transition probability from normal to negative supply times	p_{12}	1/48
Transition probability from negative supply to normal times	p_{21}	1/24
Persistence of TFP shock	ρ^A	0.99
Persistence of cost-push shock	ρ^T	0.90
Persistence of government spending shock	ρ^g	0.97
Standard deviation of TFP shock	σ^A	0.009
Standard deviation of cost-push shock	σ^T	0.0014
Standard deviation of government spending shock	σ^g	0.0052

Source: Author's calculations.

FISCAL POLICY AND REAL INTEREST RATES

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Monetary policy in the United States has been shown to have large effects on foreign economies and financial cycles.¹ This analysis typically focuses on business-cycle fluctuations. Bianchi and others (2022) show that because of structural changes in the Fed's implicit inflation target and level of activism, US monetary policy can also account for decades-long movements in real interest rates and asset prices. However, Bianchi and others (2022) leave the *reasons* for these shifts in the tolerable level of inflation unexplained. In this paper, we conjecture that, at least in part, these changes can be explained by the interaction between monetary and fiscal policy and study the implications of such interaction for low-frequency movements in real interest rates.

We thank Qingyuan Fang for help with the data. The views in this paper are solely those of the authors and should not be interpreted as reflecting the views of Danmarks Nationalbank.

1. See Rey (2013).

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We employ a new class of general equilibrium models with partially unfunded debt, as proposed in Bianchi and others (2023), to study the relation between real interest rates and fiscal shocks. Unfunded fiscal shocks are not backed by future fiscal adjustments and generate a decline in real interest rates, while funded fiscal shocks cause an increase in real interest rates. We use the model to assess the historical path of real interest rates in the United States, traditionally a key driver of international real interest rates. We find that unfunded fiscal shocks have historically played a significant role in explaining low-frequency changes in real interest rates.

To keep the paper self-contained, we first briefly review the distinction between funded and unfunded fiscal shocks. To isolate the key mechanism, we consider only shocks to transfers under the assumption of non-distortionary taxation. Funded fiscal shocks are assumed to be backed by future fiscal adjustments, while unfunded fiscal shocks are not. The central bank accommodates these shocks by responding less than one-to-one to the resulting movement in inflation. We study the propagation of these shocks in two production economies. In the first economy, prices are flexible. Funded fiscal shocks are irrelevant for inflation, while unfunded fiscal shocks cause an increase in inflation accommodated by the central bank. However, under flexible prices, real variables are not affected by inflation, and the real interest rate does not respond to an unfunded fiscal shock to transfers. Allowing the central bank to partially respond to fiscal inflation delivers a more persistent inflation response, while introducing a maturity structure tempers the size of the initial jump; however, in both cases, the real interest rate remains the same.

In the second economy, featuring nominal rigidities, the strict separation between the nominal and the real sides of the economy does not hold, and unfunded fiscal shocks have real effects. Specifically, an unfunded fiscal shock to transfers generates a persistent increase in inflation, a persistent decline in real interest rates, and an increase in real activity. Given that the increase in inflation is front-loaded, a persistent unfunded fiscal shock generates a decline, as opposed to an increase, in the debt-to-GDP ratio. Instead, funded fiscal shocks are still neutral, and they do not affect the real economy and real interest rates because of the assumption of non-distortionary taxation. As explained in detail below, this result changes once richer models featuring distortionary taxation or hand-to-mouth agents are considered.

We follow Bianchi and others (2023) and embed funded and unfunded fiscal shocks to transfers into a quantitative two-agent New Keynesian (TANK) model. As before, the two shocks differ with respect to whether or not they are backed by future tax adjustments. The model also features hand-to-mouth agents. Thus, funded fiscal shocks also influence macroeconomic dynamics and real interest rates. Bianchi and others (2023) show that unfunded fiscal shocks are important to understand persistent movements in inflation in the United States, including the post-pandemic surge in inflation. In this paper, we are mostly interested in their impact on real interest rates, especially with respect to other fiscal shocks. With this goal in mind, we extend the sample to 2024:II and focus our analysis on the relation between real interest rates and unfunded fiscal shocks.

The key insight is that unfunded fiscal shocks generate an increase in inflation and a decline in real interest rates, while funded fiscal shocks generate a modest increase in inflation *and* real interest rates. This is because when the fiscal shock to transfers is funded, the presence of hand-to-mouth agents generates inflationary pressure that the central bank counteracts with a more than one-to-one increase in the policy rate. Unfunded shocks to transfers generate additional inflationary pressure because they are not backed by future tax adjustments. The central bank allows inflation to rise, causing real interest rates to fall rather than rise.

With this understanding of the heterogeneous consequences of funded and unfunded fiscal shocks, we turn to analyze their importance for historical changes in the real interest rate, focusing especially on the post-pandemic period. In what follows, we refer to the level of inflation and real interest rates implied by unfunded fiscal shocks as *fiscal inflation* and *fiscal real interest rates*, respectively. While unfunded fiscal shocks generate large movements in real interest rates, we find that the historical contribution of funded fiscal shocks to changes in the real interest rate has been modest, despite the presence of hand-to-mouth agents.

In the 1960s and 1970s, large unfunded shocks to spending caused a large and persistent decline in real interest rates of around 6 percent. These are the years during which expected spending in the United States increased significantly due to the introduction of the Great Society initiatives. Thus, a large share of the record-low real interest rates of the 1960s and 1970s can be explained by unfunded fiscal shocks that were accommodated by the central bank.

These dynamics started reverting in the mid-1970s, as no new large unfunded fiscal shocks occurred. The increase in fiscal real interest rates accelerated in the early 1980s, during the Volcker disinflation. Overall, between the mid-1970s and 1982, fiscal real interest rates increased by around 6 percent, with a visible acceleration in the early 1980s. This is consistent with the Volcker disinflation being a monetary *and* fiscal phenomenon, as explained in more detail in Bianchi and Ilut (2017) and Bianchi and others (2023). After this large increase, fiscal real interest rates remained fairly constant until the post-millennial period, when they declined by around 1 percent. The zero-lower-bound period was characterized by a further decline, but with higher volatility. During the pandemic, fiscal real interest rates fell to a historic low, as the Federal Reserve partially accommodated the inflationary pressure coming from two extremely large fiscal stimuli. Finally, as in 2024, fiscal real interest rates are back to levels similar to the pre-pandemic period. This is consistent with the fact that no additional large fiscal shocks occurred after the American Rescue Plan Act (ARPA) fiscal stimulus.

Based on these results, we conclude that unfunded spending has played an important role in accounting for changes in the real interest rate, both historically and in the post-pandemic period. Thus, the outlook for future real interest rates depends in large part on the interaction between monetary and fiscal policy. Real rates will be larger if future spending shocks are perceived as backed by future fiscal adjustments. However, if a conflict between the goal of inflation stability and large spending programs were to arise, fiscal real interest rates could drop quickly. Of course, other factors will also play a role. In the pre-pandemic period, external forces such as the increasing level of integration of the global economy contributed to keeping inflation and real interest rates low. If these forces were to disappear, the high levels of fiscal inflation observed in the post-millennial period could become a problem. This might cause a sudden shift in real interest rates, similar to that observed in the early 1980s. However, unlike in that decade, the debt-to-GDP ratio is now at a historic high. This creates a risk of fiscal stagflation if the monetary and fiscal authorities fail to coordinate.²

This paper is part of a well-established literature on monetary and fiscal policy interaction. Key contributions are Sargent and Wallace (1981), Leeper (1991), Sims (1994), Woodford (1994, 1995, 2001),

2. See Bianchi and Melosi (2019, 2022).

Cochrane (1998, 2001), Schmitt-Grohe and Uribe (2000), Bassetto (2002), Benhabib and others (2002), and Bassetto and Sargent (2020). Hall and Sargent (2011) consider a historical decomposition of movements in the US debt-to-GDP ratio. They find that debt stabilization has been achieved through a combination of growth, revaluation effects, and low real interest rates, while fiscal adjustments play a relatively minor role. Bianchi and Ilut (2017) build and estimate a model with regime changes in the monetary/fiscal policy mix. They show that the high inflation of the 1960s and 1970s can be explained by large spending shocks combined with a fiscally-led regime that was in place at that time. Bianchi and Melosi (2017, 2022) argue that the possibility of a return to such a regime can explain the absence of deflation in the aftermath of the Great Recession and the large surge of inflation in the post-pandemic period. Barro and Bianchi (2023) consider a large panel of OECD countries to show that the cross-sectional variation in post-pandemic inflation can largely be explained by differences in the increase in spending, rescaled by the amount and duration of outstanding debt.

1. FISCAL SHOCKS AND REAL INTEREST RATES

To keep the paper self-contained, we explain in detail the distinction between funded and unfunded fiscal shocks introduced in Bianchi and others (2023). Bianchi and others (2023) develop a new class of models in which a monetary-led and a fiscally-led policy mix coexist. In these models, shocks propagate differently based on the shock-specific policy response. We first explain how the two types of shock can coexist using a simple Fisherian model. We then employ a production economy to highlight that under nominal rigidities, unfunded fiscal shocks can generate movements in real interest rates in a representative-agent economy with non-distortionary taxation. We closely follow Bianchi and others (2023). More details can be found in that paper and its various appendices.

1.1 Funded and Unfunded Fiscal Shocks

1.1.1 Fisherian Model

Consider an endowment economy in which an infinitely-lived representative household aims to maximize utility, while the government can provide a subsidy or collect taxes in each period.

The representative household has concave and twice continuously differentiable preferences over nonstorable consumption goods and in each period receives a constant endowment Y of these goods. The government issues one-period debt B_t that can be used by households to smooth consumption over time. The representative household chooses consumption and government bonds so as to maximize:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t U(C_t),$$

subject to the flow budget constraint $P_t C_t + Q_t B_t + P_t T_t = P_t Y + B_{t-1}$, where $\beta < 1$ is the households' discount factor, P_t denotes the price of consumption goods, T_t denotes real lump-sum net taxes, and $Q_t = 1/R_{n,t}$ is the price of the one-period government bond B_t , equal to the inverse of the gross nominal interest rate $R_{n,t}$.

The government budget constraint is $Q_t B_t + P_t T_t = B_{t-1}$. Given that the government only provides a subsidy or collects lump-sum taxes, T_t also coincides with the real primary surplus. The fiscal authority follows the fiscal rule:

$$\frac{\tau_t}{\tau} = \left(\frac{s_{b,t-1}}{s_b} \right)^{\gamma} e^{\zeta_t},$$

where $\tau_t = T_t/Y$ denotes the surplus-to-output ratio, $s_{b,t} = Q_t B_t / (P_t Y)$ denotes the debt-to-output ratio, τ and s_b denote their respective steady-state values, ζ_t is a shock to lump-sum taxes that follows an autoregressive process with one lag, and the parameter γ controls how strongly the fiscal authority adjusts primary surpluses to fluctuations in debt.

The central bank follows a monetary rule:

$$R_{n,t}/R_n = (\Pi_t/\Pi)^{\phi},$$

where $\Pi_t = P_t/P_{t-1}$ is the gross inflation rate at time t , R_n and Π denote steady-state values for the nominal interest rate and inflation, respectively, and the parameter ϕ captures how strongly the central bank reacts to movements of inflation from its target.

The market-clearing condition in the goods market implies $C_t = Y$ in every period. Combining this condition with the household's first order condition returns the well-known Fisher equation connecting nominal interest rates to expected inflation $R_{n,t} = \beta^{-1} E_t(\Pi_{t+1})$.

We can then linearize the model equations around the deterministic steady state and use hatted variables to denote log-deviations from the steady state:

$$\hat{r}_{n,t} = E_t(\hat{\pi}_{t+1}), \quad (1)$$

$$\hat{s}_{b,t} = \beta^{-1} [\hat{s}_{b,t-1} + \hat{r}_{n,t-1} - \hat{\pi} - (1-\beta)\hat{\tau}_t], \quad (2)$$

$$\hat{r}_{n,t} = \phi \hat{\pi}_t, \quad (3)$$

$$\hat{\tau}_t = \gamma \hat{s}_{b,t-1} + \zeta_t. \quad (4)$$

Plugging the monetary rule (3) into the Fisher equation (1) leads to the *monetary block*:

$$E_t(\hat{\pi}_{t+1}) = \phi \hat{\pi}_t. \quad (5)$$

Combining the law of motion for debt (2) with the fiscal rule (4) yields the *fiscal block*:

$$\hat{s}_{b,t} = \beta^{-1} [1 - (1-\beta)\gamma] \hat{s}_{b,t-1} + \beta^{-1} [\hat{r}_{n,t-1} - \hat{\pi} - (1-\beta)\zeta_t]. \quad (6)$$

1.1.2 Existence and Uniqueness of a Solution

In this class of models, there are two regions of the parameter space that deliver existence and uniqueness of a stationary solution.³ In the first region, monetary policy responds more than one-to-one to deviations of inflation from its target ($\phi > 1$) and the fiscal authority implements the necessary fiscal adjustments to keep debt on a stable path ($\gamma > 1$). In this case, fiscal policy is said to be passive because it passively accommodates the behavior of the active monetary authority. Following Bianchi and others (2023), we label this policy combination the *monetary-led policy mix*. In the second region of the parameter space, it is the monetary authority that passively accommodates the behavior of the active fiscal authority. In terms of parameter restrictions, this implies that the response to inflation in the monetary policy rule is less than one-to-one ($\phi \leq 1$), and that changes in primary surpluses are not large enough to keep debt on a stable path ($\gamma \leq 1$).

3. See Leeper (1991).

The first two panels of Figure 1 illustrate the differences between these two parameter combinations by reporting impulse responses of inflation to a fiscal shock. Under the monetary-led policy mix, the macroeconomy is completely insulated from the fiscal block, and a negative shock to primary surpluses does not affect inflation. Households simply increase their bond holdings, expecting that taxes will eventually go up in the future. In this case, fiscal imbalances are irrelevant for inflation determination in equilibrium (*monetary and fiscal dichotomy*). On the contrary, under the *fiscally-led policy mix*, the macroeconomy is not insulated from fiscal imbalances. Inflation jumps to lower the real market value of debt. This is possible because the central bank fully accommodates the increase in inflation ($\phi = 0$).

1.1.3 Shock-Specific Rules and Partially Unfunded Debt

In what follows, we introduce the idea of shock-specific rules. This allows for the consideration of models in which policymakers' behavior changes based on the shock hitting the economy. In this specific case, we are interested in a situation in which the monetary-led and fiscally-led policy mixes coexist. We use the superscript M and F to denote policy parameters that imply a behavior in line with a monetary-led policy mix and a fiscally-led policy mix, respectively.

The linearized fiscal rule reads:

$$\hat{\tau}_t = \gamma^M (\hat{s}_{b,t-1} - \hat{s}_{b,t-1}^F) + \gamma^F \hat{s}_{b,t-1}^F + \zeta_t^M + \zeta_t^F, \quad (7)$$

where ζ_t^M and ζ_t^F denote funded and unfunded fiscal shocks, respectively. The above rule implies that the amount of unfunded debt $\hat{s}_{b,t-1}^F$ accumulated as a result of the unfunded fiscal shocks is not backed by large enough fiscal adjustments: $\gamma^F \leq 1$. The fiscal authority is instead willing to adjust primary surpluses to cover the remaining amount of debt, the funded component accumulated as a result of the funded fiscal shocks: $\gamma^M > 1$. Thus, fiscal policy is passive with respect to the funded component of debt ($\hat{s}_{b,t-1} - \hat{s}_{b,t-1}^F$), while it is active with respect to the unfunded component of debt ($\hat{s}_{b,t-1}^F$).

The linearized monetary rule reads:

$$\hat{r}_{n,t} = \phi^M (\hat{\pi}_t - \hat{\pi}_t^F) + \phi^F \hat{\pi}_t^F, \quad (8)$$

where $\hat{\pi}_t^F$ denotes fiscal inflation, i.e., the amount of inflation that is necessary to keep debt on a stable path in response to the unfunded

fiscal shocks. In terms of parameter values, this implies that monetary policy is passive in response to fiscal inflation ($\phi^F \leq 1$). The central bank is instead active in stabilizing inflation originating from funded fiscal shocks. This is equivalent to saying that monetary policy responds more than one-to-one to deviations of inflation from fiscal inflation: $\phi^M > 1$. If we assume that fiscal inflation is fully accommodated, $\phi^F = 0$, we obtain a monetary policy rule that is isomorphic to a rule with a time-varying target: $\hat{r}_{n,t} = \phi^M (\hat{\pi}_t - \hat{\pi}_t^F)$. However, the time-varying target $\hat{\pi}_t^F$ is not an unrestricted latent variable, but rather an endogenous variable that needs to obey the model cross-equation restrictions.

Substituting the monetary rule (8) into the Fisherian equation (1) yields the monetary block of the model with partially unfunded debt:

$$E_t \hat{\pi}_{t+1} = \phi^M (\hat{\pi}_t - \hat{\pi}_t^F) + \phi^F \hat{\pi}_t^F. \quad (9)$$

Plugging the policy rules in the law of motion of debt (2) yields the fiscal block:

$$\begin{aligned} \hat{s}_{b,t} = & \beta^{-1} [1 - (1 - \beta)\gamma] \hat{s}_{b,t-1} \\ & + \beta^{-1} [(1 - \beta)\hat{s}_{b,t-1} + \hat{r}_{n,t-1} - \hat{\pi} - (1 - \beta)(\zeta_t^M + \zeta_t^F)] \end{aligned} \quad (10)$$

where we have assumed that the fiscal authority completely disregards the amount of unfunded debt: $\gamma^F = 0$.

Bianchi and others (2023) explain that the model can be solved by constructing a shadow economy that keeps track of the amount of unfunded debt. In this shadow economy, only unfunded shocks occur. The resulting inflation and debt dynamics enter the full model as time-varying targets to which policymakers react. In other words, the shadow economy keeps track of the share of debt that is unfunded and expected to be covered by inflation, while the remaining share, which is funded, is expected to be covered via fiscal adjustments. The monetary and fiscal blocks for the shadow economy are:

$$E_t \hat{\pi}_{t+1}^F = \phi^F \hat{\pi}_t^F, \quad (11)$$

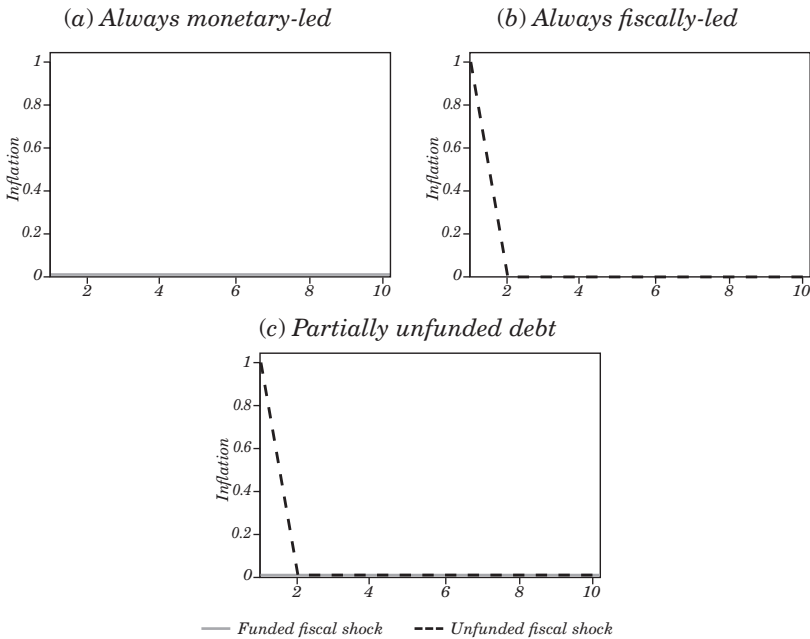
$$\hat{s}_{b,t}^F = \beta^{-1} \hat{s}_{b,t-1}^F + \beta^{-1} (\hat{r}_{n,t-1}^F - \hat{\pi}_t^F) - \beta^{-1} (1 - \beta) \zeta_t^F. \quad (12)$$

The full model with partially unfunded debt is then given by equations (9), (10), (11), and (12). Since the model features two

non-predetermined variables, $\hat{\pi}_t$ and $\hat{\pi}_t^F$, and two eigenvalues outside the unit circle associated, the model satisfies the Blanchard and Khan conditions for uniqueness of a solution.

The impulse responses for the model with partially unfunded debt are reported in the third panel of Figure 1. In response to a funded spending shock (solid line), the impulse responses coincide with what is reported in the first panel, when the monetary-led policy mix is assumed always in place. On the contrary, in response to a fiscally-led policy mix, the inflation response coincides with what is reported in the second panel, where policymakers always follow the fiscally-led policy mix. However, in the model with partially unfunded debt, the two responses coexist. Given that policy responses are shock-specific, the propagation of shocks changes completely between funded and unfunded fiscal shocks. Thus, in a model with partially unfunded debt, debt stability is achieved with a mix of fiscal stabilization and inflation.

Figure 1. Impulse Response of Inflation to a Fiscal Shock



Source: Authors' calculations.

Notes: The figure reports impulse responses to a fiscal shock. The first and second panels refer to the Fisherian model under a monetary-led and a fiscally-led policy mix, respectively. The third panel refers to the model with partially unfunded debt. The parameters are chosen as follows: $\beta = 0.99$ and $s_b = 1$. In the model with partially unfunded debt, the monetary policy parameters are $\phi^M = 2$ and $\phi^F = 0$ and the fiscal policy parameters are $\gamma^M = 20$ and $\gamma^F = 0$. The always-monetary-led model is parameterized as follows: $\phi = \phi^M$ and $\gamma = \gamma^M$. The always-fiscally-led model is parameterized as follows: $\phi = \phi^F$ and $\gamma = \gamma^F$. Fiscal shocks have an autocorrelation coefficient of 0.5, and their variance is scaled to produce a unit response of inflation on impact of an unfunded shock.

1.2 Unfunded Fiscal Shocks and Nominal Rigidities

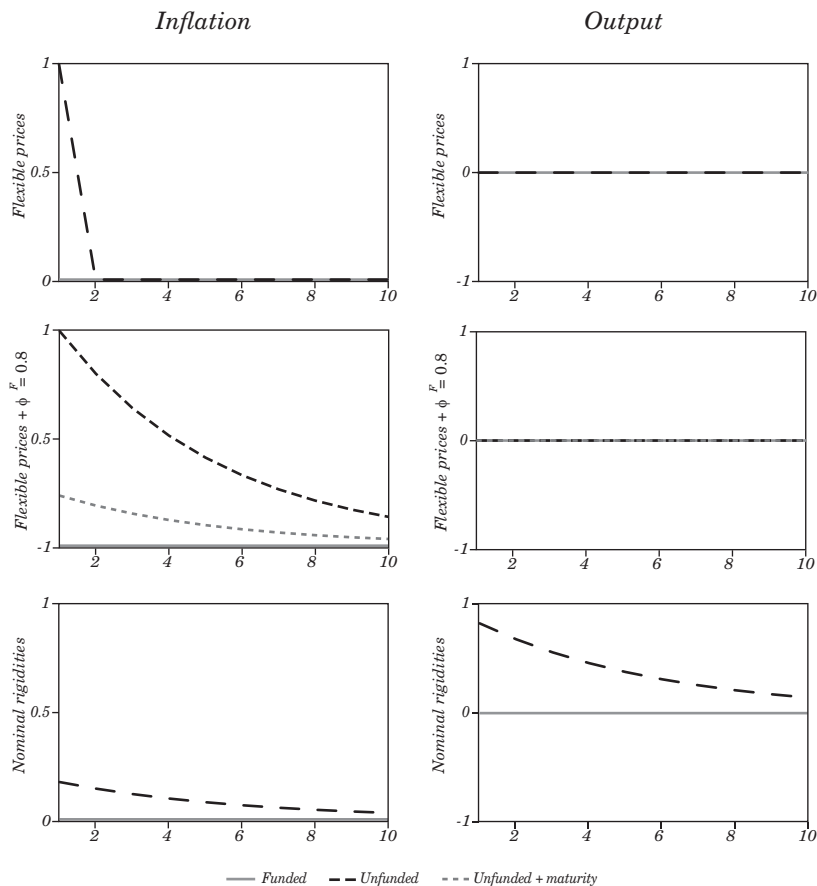
The Fisherian model has the advantage of being extremely tractable. However, it does not present any connection to the real side of the economy, as output is fixed over time. In this section, we introduce a production economy and discuss why nominal rigidities are important to understand the connection between fiscal policy, inflation, and real interest rates.

We assume the period utility function $U(C_t, N_t) = \ln C_t + \phi \ln(1 - N_t)$, where N_t represents hours worked. Households receive real wage income $W_t N_t$ in exchange for supplying labor services to the firms, and the production function is $Y_t = N_t^{1-\alpha}$. All other assumptions are the same as described in the previous section, including the specification of the fiscal and monetary rules. In the case of flexible prices, which provides the benchmark for a classical economy, we assume perfect competition in both goods and labor markets. We calibrate this stylized model consistently with the parameters of the quantitative model of Section 3.

Figure 2 reports impulse responses to funded and unfunded fiscal shocks (the solid and dashed lines, respectively) in the case of flexible prices. As in the simple Fisherian model, fiscal shocks lead to an increase in inflation only if they are unfunded; that is, only if they are not backed by future fiscal adjustments. Furthermore, as in the Fisherian model, inflation jumps on impact and immediately returns to zero after one period. Finally, despite the richer model, the real economy is fully insulated from the fiscal shock. This is consistent with the well-known fact that the real economy can be solved with no regard to inflation when prices are flexible.

The second row of Figure 2 shows that introducing a positive response to deviations of inflation from fiscal inflation, ($\phi^F > 0$), or introducing a maturity structure (dotted line) does not change the fact that output and the real interest rate are insulated with respect to fiscal shocks. In these cases, the persistence of inflation coincides with $\phi^F > 0$ because of the Fisherian relation between nominal rates and inflation. This implies a persistent inflation response, a positive response of interest rates, and maturity-structure revaluation effects that lower the initial jump in inflation. But across all cases, inflation stabilization needs to be reached with movements in inflation, and real interest rates are not affected by fiscal shocks.

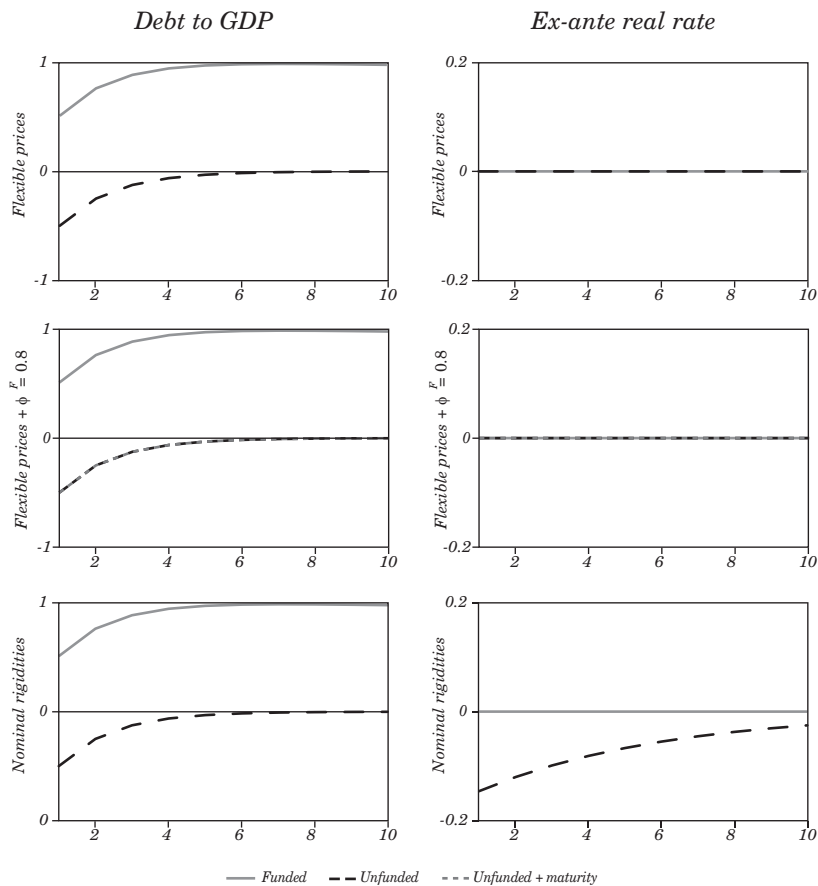
Figure 2. Funded and Unfunded Fiscal Shocks



Source: Authors' calculations.

Notes: The figure reports impulse responses of inflation, output, the debt-to-GDP ratio, and the ex-ante real interest rate to funded (solid line) and unfunded shocks (dashed line) to primary surpluses. The first row reports the propagation in a model with perfectly flexible prices and $\phi^F = 0$. The second row reports impulse responses in a model with perfectly flexible prices and $\phi^F = 0.8$. For unfunded shocks, we also consider the case with a maturity structure (dotted line). The last row reports the propagation of the same shocks under nominal rigidities.

Figure 2. Funded and Unfunded Fiscal Shocks (continued)



Source: Authors' calculations.

Notes: The figure reports impulse responses of inflation, output, the debt-to-GDP ratio, and the ex-ante real interest rate to funded (solid line) and unfunded shocks (dashed line) to primary surpluses. The first row reports the propagation in a model with perfectly flexible prices and $\phi^F = 0$. The second row reports impulse responses in a model with perfectly flexible prices and $\phi^F = 0.8$. For unfunded shocks, we also consider the case with a maturity structure (dotted line). The last row reports the propagation of the same shocks under nominal rigidities.

The third row of Figure 2 reports impulse responses to the same shocks once imposing nominal rigidities. In this case, the model is similar to the prototypical textbook models presented in Galí (2008) and Woodford (2003). To isolate the effects of nominal rigidities, we assume $\phi^F = 0$ case and no maturity structure. Thus, the persistent response of inflation to an unfunded fiscal shock is exclusively driven by the presence of sticky prices. Note that the response of inflation is now largely reduced despite the absence of revaluation effects. This is because an increase in real activity and a persistent drop in the real interest rate contribute to debt stabilization. The other noticeable fact is that debt-to-GDP initially declines, as output and inflation jump.

Summarizing, transfer shocks can have large effects on real interest rates even in a parsimonious economy with non-distortionary taxation if the shocks are not backed by future fiscal adjustments. Noticeably, funded fiscal shocks do not have any impact on nominal and real variables across all cases considered above. This extreme outcome is weakened once hand-to-mouth agents or shocks to government purchases are introduced, like in the quantitative model considered below.

2. A QUANTITATIVE MODEL

In this section, we describe a state-of-the-art TANK model with a rich fiscal block and partially unfunded debt.⁴ The model features traditional business-cycle shocks with respect to which a monetary-led policy mix applies. However, the model also features unfunded fiscal shocks. These shocks to transfers are not backed by future fiscal adjustments, implying that a share of the overall government debt is unfunded. In what follows, we outline the model in detail.

2.1 The Economy

The economy is populated by a unit measure of households, of which a fraction μ are hand-to-mouth consumers. The remaining fraction of households, $1-\mu$, are savers, and we indicate them with an S superscript. Hand-to-mouth households, combined with distortionary taxes, disrupt Ricardian equivalence. As a result, funded transfers become relevant for part of the population, even under a monetary-led policy framework.

4. See Bianchi and others (2023).

Saver Households

A household of optimizing saving agents, indexed by j , derives utility from the consumption of a composite good, $C_t^{*S}(j)$, which comprises private consumption $C_t^S(j)$ and government consumption G_t such that $C_t^{*S}(j) = C_t^S(j) + \alpha_G G_t$. The parameter α_G determines the relationship between private and government consumption. If α_G is negative, the two types of consumption are complements; if positive, they are substitutes. External consumption habits mean that utility depends on consumption relative to the aggregate savers' consumption of the composite good in the previous period, represented by $\theta C_{t-1}^{*S}(j)$, where $\theta \in [0, 1]$ is the habit parameter. Saver households also derive disutility from the supply of differentiated labor services from all its members, indexed by l , $L_t^S(j) = \int_0^1 L_t^S(j, l) dl$. The period utility function is given by

$$U_t^S(j) = u_t^b \left(\ln \left(C_t^{*S}(j) - \theta C_{t-1}^{*S}(j) \right) - L_t^S(j)^{1+\xi} / (1+\xi) \right),$$

where u_t^b is a discount factor shock and ξ is the Frisch elasticity of labor supply.

Households build wealth by accumulating physical capital, denoted as $\bar{K}_t^s$. Capital depreciates at a rate δ and grows through investment I_t^s , adjusted for associated costs. The law of motion for physical capital is:

$$\bar{K}_t^S(j) = (1 - \delta) \bar{K}_{t-1}^S(j) + u_t^i \left[1 - s \left(I_t^S(j) / I_{t-1}^S(j) \right) \right] I_t^S(j),$$

where u_t^i is a shock to the marginal efficiency of investment and s denotes an investment adjustment cost function that satisfies the properties $s(e^{\varkappa}) = s'(e^{\varkappa}) = 0$ and $s''(e^{\varkappa}) \equiv s > 0$, where $\varkappa$ is a drift parameter capturing the logarithm of the gross rate of technology growth in steady state.

Households earn income by renting out effective capital, $K_t^s(j)$, to intermediate firms. Effective capital is linked to physical capital through the relationship $K_t^s(j) = v_t(j) \bar{K}_{t-1}^s$, where $v_t(j)$ is the rate of capital utilization. The cost of utilizing one unit of physical capital is given by the function $\Psi v_t(j)$. Given the steady-state utilization rate $v_t(j)$, the function Ψ satisfies the following properties: $\Psi(1) = 0$, and $\Psi''(1)/\Psi'(1) = \psi/(1-\psi)$, where $\psi \in [0, 1]$. We denote the gross rental rate of capital as $R_{K,t}$ and the tax rate on capital rental income as $\tau_{K,t}$.

Households can save by buying one-period government bonds, which have zero net supply, or a broader portfolio of long-term government bonds, which have nonzero net supply. One-period bonds promise a nominal payoff of B_t at time $t + 1$ and can be purchased at their present discounted value, $R_{n,t}^{-1} B_t$. Here, $R_{n,t}$ is the gross nominal interest rate chosen by the central bank. The long-term bond B_t^m mimics a portfolio of bonds with average maturity m and duration $(1 - \beta\rho)^{-1}$, where $\rho \in [0, 1]$ is a constant rate of decay. This bond has price P_t^m , which is determined by the arbitrage condition

$$R_{n,t} = E_t \left[\frac{(1 + P_{t+1}^m)}{P_t^m} \right] e^{-u_t^{rp}},$$

where the wedge u_t^{rp} can be interpreted as a risk premium shock.

Each period, the household earns after-tax nominal income from labor, after-tax earnings from renting capital to firms, lump-sum transfers from the government (Z_t^S), and dividends from firms (D_t). These funds can be used for consumption, investment in physical capital, and purchasing bonds. To simplify notation, omitting the index j , the nominal budget constraint for the saver household is expressed as:

$$P_t (1 + \tau_{C,t}) C_t^S + P_t I_t^S + P_t^m B_t^m + R_{n,t}^{-1} B_t = \quad (13)$$

$$(1 + \rho P_t^m) B_{t-1}^m + B_{t-1} + (1 - \tau_{L,t}) \int_0^1 W_t(l) L_t^S dl +$$

$$(1 - \tau_{K,t}) R_{K,t} v_t \bar{K}_{t-1}^S - \Psi(v_t) \bar{K}_{t-1}^S + P_t Z_t^S + D_t,$$

where $W_t(l)$ represents the wage rate applicable to all household members, while $\tau_{C,t}$ and $\tau_{L,t}$ are the tax rates on consumption and labor income, respectively. The household seeks to maximize its discounted utility, $\sum_{t=0}^{\infty} \beta^t U_t$, while adhering to the sequence of budget constraints given in equation (13).

Hand-to-Mouth Households

Each period, hand-to-mouth households spend their entire disposable, after-tax income on consumption. This income consists of earnings from labor and government transfers. These households

provide differentiated labor services and set their wages equal to the average wage optimally chosen by saver households, as outlined later. Both savers and hand-to-mouth households are subject to the same tax rates on consumption and labor income. Denoting hand-to-mouth households with the superscript N , their budget constraint can be expressed as:

$$(1 + \tau_{C,t})P_t C_t^N = (1 - \tau_{L,t}) \int_0^1 W_t(l) L_t^N(l) dl + P_t Z_t^N.$$

Final-Good Producers

A perfectly competitive sector of final-good firms produces a single homogeneous product, Y_t , at time t by combining a variety of intermediate inputs. The production process follows the technology

$$Y_t = \left(\int_0^1 Y_t(i)^{\frac{1}{1+\eta_t^p + u_t^{NKPC}}} di \right)^{1+\eta_t^p + u_t^{NKPC}},$$

where η_t^p represents exogenous, independent, and identically distributed (i.i.d.) changes in the elasticity of substitution among different varieties of goods. In the linearized model, these changes affect the New Keynesian Phillips curve (NKPC) and are referred to as cost-push shocks. The variable u_t^{NKPC} also represents a cost-push shock but is assumed to follow a near-unit-root process, capturing persistent external influences, such as international trade, that drive low-frequency inflation trends. Profit maximization leads to the demand function for intermediate goods $Y_t(i) = Y_t \left(P_t(i) / P_t \right)^{-(1+\eta_t^p + u_t^{NKPC}) / (\eta_t^p + u_t^{NKPC})}$, where $P_t(i)$ is the price of the differentiated good i and where P_t is the price of the final good.

Intermediate-Good Producers

Intermediate firms produce output using the technology $Y_t(i) = K_t(i)^\alpha (A_t L_t(i))^{1-\alpha} - A_t \Omega$, where Ω represents a fixed production cost that grows at the same rate as labor-augmenting technological progress (A_t), and $\alpha \in [0, 1]$ is a production parameter. The technological progress, A_t , evolves according to an exogenous process with a stationary growth rate, expressed as $u_t^a = (1 - \rho_a) \kappa + \rho_a u_{t-1}^a + \varepsilon_t^a$, where $u_t^a = \ln(A_t / A_{t-1})$. Intermediate firms rent capital and labor in perfectly competitive factor markets. Labor, L_t , is a composite input derived from all differentiated labor services in the economy, aggregated into a homogeneous form by a labor agency, as described

later. Cost minimization ensures that all firms face the same nominal marginal cost $MC_t = (1 - \alpha)^{\alpha-1} \alpha^{-\alpha} (R_{K,t})^\alpha W_t^{1-\alpha} A_t^{-1+\alpha}$.

Intermediate producers face price-setting Calvo-style frictions. At any given time t , a firm i has a probability ω_p of optimally resetting its price. If it cannot reset the price, it adjusts it partially based on the previous period's inflation rate, following the rule $P_t(i) = (\Pi_{t-1})^{\chi^p} (\Pi)^{1-\chi^p} P_{t-1}(i)$, where $\chi^p \in [0, 1]$ is a parameter, $\Pi_{t-1} = P_{t-1}/P_{t-2}$ is the inflation rate from the previous period, and Π represents the steady-state aggregate inflation rate. Intermediate producers who can reset their prices aim to maximize the expected discounted value of their future nominal profits:

$$\max E_t \sum_{s=0}^{\infty} (\beta \omega_p)^s \frac{\Lambda_{t+s}^S}{\Lambda_t^S} \left[\left(\prod_{k=1}^s \Pi_{t+k-1}^{\chi^p} \Pi^{1-\chi^p} \right) P_t(i) Y_{t+s}(i) - MC_{t+s} Y_{t+s}(i) \right],$$

subject to the demand function of the final-good sector, with Λ^S denoting the marginal utility of the savers.

Wages

We assume that both savers and hand-to-mouth households provide a unit of differentiated labor service, indexed by l . Each period, a saver household has a probability ω_w of being able to optimally adjust the wage rate for all its workers, $W_t(l)$. If the wage cannot be adjusted, it is updated based on the geometric average of the steady-state inflation rate Π and the previous period's inflation rate Π_{t-1} , following the rule: $W_t(l) = W_{t-1}(l) (\Pi_{t-1} e^{\kappa})^{\chi^w} (\Pi e^{\kappa})^{1-\chi^w}$, where $\chi^w \in [0, 1]$ captures the degree of nominal wage indexation. All households, whether savers or nonsavers, provide their labor services to a representative competitive agency. This agency combines the individual labor inputs into an aggregate labor input using the technology $L_t = \left(\int_0^1 L_t(l)^{1/\eta_t^w} dl \right)^{\eta_t^w}$, where η_t^w is an i.i.d. exogenous wage markup shock. The agency rents labor type $L_t(l)$ at price $W_t(l)$ and sells a homogeneous labor input to the intermediate producers at price W_t . The static profit maximization problem yields the demand function $L_t(l) = L_t (W_t(l) / W_t)^{-(1+\eta_t^w)/\eta_t^w}$.

Monetary and Fiscal Policy

Assuming one-period government bonds have zero net supply and all households, whether hand-to-mouth or savers, receive the same transfer amounts, the government's nominal budget constraint can be expressed as:

$$P_t^m B_t^m + \tau_{K,t} R_{K,t} K_t + \tau_{L,t} W_t L_t + \tau_{C,t} P_t C_t = (1 + \rho P_t^m) B_{t-1}^m + P_t G_t + P_t Z_t, \quad (14)$$

where $C_t = \mu C_t^N + (1 - \mu) C_t^S$ and $Z_t = \int_0^1 Z_t(j) dj$ denote aggregate consumption and total transfers, respectively. The budget constraint (14) indicates that the fiscal authority funds government spending, transfers, and the renewal of maturing long-term debt through a combination of taxes on consumption, labor, and capital, as well as by issuing new long-term debt.

We rescale the variables entering the fiscal rules as $g_t = G_t/A_t$ and $z_t = Z_t/A_t$. For each variable x_t , $\hat{x}_t$ denotes the percentage deviation from its own steady state. Let $s_{b,t} = P_t^m B_t^m / P_t Y_t$ be the debt-to-GDP ratio. Similar to the models in Section 1, the deviation of the debt-to-GDP ratio from its steady state, $\hat{s}_{b,t}$, consists of two components: funded debt ($\hat{s}_{b,t}^M$) and unfunded debt ($\hat{s}_{b,t}^F$). As before, superscripts M and F indicate that the monetary-led policy mix applies to funded debt, while the fiscally-led policy mix applies to unfunded debt. For transfer shocks, we use the superscripts only to distinguish between the two types, assuming that all other shocks impact only the funded portion of the debt.

The fiscal authority adjusts government spending $\hat{g}_t$, transfers $\hat{z}_t$, and tax rates on capital income, labor income, and consumption $\hat{\tau}_J$, $J \in \{K, L, C\}$ as follows:

$$\hat{g}_t = \rho_G \hat{g}_{t-1} - (1 - \rho_G) \gamma_G (\hat{s}_{b,t-1} - \hat{s}_{b,t-1}^F) + \zeta_{g,t}, \quad (15)$$

$$\hat{z}_t^b = \rho_Z \hat{z}_{t-1}^b - (1 - \rho_Z) \left[\gamma_Z (\hat{s}_{b,t-1} - \hat{s}_{b,t-1}^F) + \phi_{zy} \hat{y}_t \right] + \zeta_{z,t}, \quad (16)$$

$$\hat{\tau}_{J,t} = \rho_J \hat{\tau}_{J,t-1} - (1 - \rho_J) \gamma_J (\hat{s}_{b,t-1} - \hat{s}_{b,t-1}^F), \quad (17)$$

where $\hat{s}_{b,t-1} - \hat{s}_{b,t-1}^F$ represents the portion of the debt-to-GDP ratio that the fiscal authority is responsible for stabilizing through fiscal adjustments. This stabilization is ensured by setting the reaction parameters γ_G , γ_Z , and $\gamma_J > 0$ to sufficiently high values, ensuring that this portion of debt stays on a stable trajectory. The fiscal authority does not adjust fiscal policy to address the remaining portion of the debt, which is unfunded and represented by $\hat{s}_{b,t-1}^F$. The total amount of transfers is expressed as $\hat{z}_t \equiv \hat{z}_t^b + \zeta_t^M + \zeta_t^F$. The shocks ζ_t^M and ζ_t^F affect the funded and unfunded portions of total transfers, respectively, and are modeled as persistent AR(1) processes to reflect the historical

patterns of transfers in the United States. The term $\hat{z}_t^b$ represents temporary changes in funded transfers and any adjustments made in response to debt levels or the business cycle. Additionally, the fiscal shocks $\zeta_{g,t}$ and $\zeta_{z,t}$ are also assumed to follow AR(1) processes.

The central bank adjusts the short-term interest rate, $\hat{R}_{n,t}$, in response to inflation fluctuations caused by typical business-cycle shocks and funded fiscal shocks, while accommodating the inflation changes needed to stabilize the unfunded portion of debt. As discussed in Section 1, this shock-specific monetary policy is represented by a standard Taylor rule, where the central bank reacts to deviations of inflation from the level required to stabilize the unfunded debt. This inflation level, referred to as fiscal inflation, is denoted by $\hat{\pi}_t^F$. Consequently, the linearized monetary policy rule, incorporating an effective lower bound (ELB) constraint, can be expressed as:

$$\hat{r}_{n,t} = \max \left[-\ln \underline{R}_n, \rho_r \hat{r}_{n,t-1} + (1 - \rho_r) \left[\phi_\pi \left(\hat{\pi}_t - \hat{\pi}_t^F \right) + \phi_y \hat{y}_t \right] + u_t^m \right], \quad (18)$$

where u_t^m is a monetary policy shock.

The parameter $\phi_\pi > 1$ ensures that the Taylor principle is met, making monetary policy active in responding to deviations of inflation, $\hat{\pi}_t$, from fiscal inflation, $\hat{\pi}_t^F$. The variable $\hat{\pi}_t^F$ represents the rise in inflation, relative to the central bank's long-term target (and steady-state rate), that the central bank tolerates to stabilize the unfunded debt, $\hat{s}_{b,t-1}^F$. The policy mix defined by equations (15)–(18) implies that monetary policy actively responds to deviations of inflation from fiscal inflation but remains passive (nonresponsive) to the inflation required to stabilize the unfunded debt's deviation from its long-term target. Concurrently, fiscal policy is passive with respect to its commitment to stabilizing the share of funded government debt $\hat{s}_{b,t-1} - \hat{s}_{b,t-1}^F$, and active (no response) with respect to the unfunded share of debt. Thus, a monetary-led policy mix addresses typical business-cycle shocks, while a fiscally-led policy mix manages unfunded fiscal shocks.

Fiscal inflation $\hat{\pi}_t^F$ is incorporated into the Taylor rule in a manner similar to a time-varying inflation target or an inflation drift often included in medium-scale dynamic stochastic general equilibrium (DSGE) models to account for persistent inflation observed in the data.⁵ In other models, the inflation drift typically follows an exogenous, near-random-walk process. In contrast, fiscal inflation

5. See, for example, Smets and Wouters (2007).

in our model is endogenous, adjusting based on the requirements to stabilize the proportion of unfunded debt. Fiscal inflation $\hat{\pi}_t^F$ arises from the coordination between monetary and fiscal authorities in managing the stabilization of the existing public debt.

2.2 Solving the Model

To solve the model, we begin by detrending the nonstationary variables to address the unit root in labor-augmenting technology A_t . Next, we log-linearize the equations around the deterministic steady-state equilibrium. The log-linearized equations are provided in Appendix A.

As described in Section 1, we construct a shadow economy to track the unfunded portion of debt and its impact on endogenous variables. The shadow economy differs from the actual economy by considering only unfunded fiscal shocks, with policymakers adhering to a fiscally-led policy mix. Apart from this distinction, all other model equations remain the same in both economies. The model is solved by using standard techniques for linear rational expectations models.

3. INFERENCE

The model is estimated using Bayesian methods. The posterior distribution is derived by combining the prior distributions of the model parameters with the likelihood function. The likelihood is computed using the Kalman filter.

3.1 Data

We extend the dataset used in Bianchi and others (2023) from 2022.IV to 2024.II. We do not re-estimate the model but rather filter the series for the extended sample based on the posterior mode parameters obtained in Bianchi and others (2023). Below, we describe how priors are chosen in that paper and discuss the posterior to keep the paper self-contained.

The dataset includes: real per-capita GDP growth; real per-capita consumption growth; real per-capita investment growth; a measure of the hours gap; the effective federal funds rate; the growth of average weekly earnings; price inflation based on the GDP deflator; the growth of real government transfers; the growth of government consumption and investment; the government debt-to-GDP ratio; 5-year breakeven inflation.

The 5-year breakeven inflation is treated as a noisy measure of inflation expectations over the next five years and includes an observation error that captures variations in premia. To account for the federal funds rate being stuck at the effective lower bound for most of the 2008.I–2024.II period, we estimate the model over two subsamples: from 1960.I through 2007.IV and then from 2008.I through 2024.II. When estimating the model on the latter subsample, we add to the dataset the expectations for the federal funds rate one- through ten- quarters ahead, based on overnight index swaps. Following Campbell and others (2012), we use data on market-based future federal funds rates to estimate the model after 2008.IV, taking into account agents' expectations about future interest rates.

3.2 Priors

To determine the prior distributions for the model parameters, we adopt the approach outlined by Del Negro and Schorfheide (2008). Certain parameters are fixed during the estimation process or determined by steady-state constraints. Specifically, the discount factor β is set to 0.99, ensuring the steady-state real interest rate aligns with its sample average. The quarterly capital depreciation rate δ is calibrated to achieve an investment rate of 2.5 percent.

Parameters for steady-state markups on wages and prices are not separately identifiable in the estimation, so they are fixed at 0.14, as in Leeper and others (2017). The elasticity of output with respect to capital in the production function, α , is assigned the standard value of 0.33. Lastly, the parameter s_{gc} , representing the government expenditure-to-GDP ratio, is set to 0.11, following Leeper and others (2017). The steady-state tax rates on labor, capital, and consumption, represented by the parameters τ_L , τ_K , and τ_C , are assigned values of 0.186, 0.218, and 0.023, respectively, following Leeper and others (2017). The consumption tax rate, τ_C , is assumed to remain constant, which leads to setting the parameters γ_C and ρ_C to zero.

Average maturity measures based on the number of bonds outstanding or their value are fairly stable in the United States, fluctuating around 5.5 and 4.5 years, respectively. However, over the past ten years, the means of the average maturities have increased to 6 and 5.8 years. Given that we are particularly interested in recent movements in real interest rates, we set the decay rate of the maturity of long-term bonds, ρ , to 0.9593, a value that implies a 6-year average maturity. This is also in line with Congressional Budget Office (2020) estimates. Our results are robust to choosing a range of alternative values for the average maturity.

The right panels of Tables 1 and 2 present the priors for the structural parameters and exogenous processes, respectively. The priors for macroeconomic and fiscal variables are generally broad. The prior for the share of hand-to-mouth households, μ , is centered at 0.11, reflecting the share of poor hand-to-mouth consumers as in Kaplan and others (2014).

Table 1. Posterior Modes, Medians, 90 Percent Posterior Credible Sets, and Prior Moments for the Structural Parameters

Param	Description	Posterior Distribution				Prior Distribution		
		Mode	Median	5%	95%	Type	Mean	Std
s_b	Debt to GDP (not annualized)	2.4582	2.4512	2.3736	2.5298	N	2.40	0.10
$100\mathcal{K}$	Steady state growth rate	0.3979	0.3910	0.3329	0.4625	N	0.50	0.05
$100\ln\Pi$	Steady state inflation	0.5296	0.5333	0.4643	0.6000	N	0.50	0.05
ξ	Inverse Frisch elasticity	1.7974	1.7440	1.6095	1.8708	N	2.00	0.25
μ	Share of hand-to-mouth	0.0771	0.0787	0.0682	0.0906	N	0.11	0.01
ω_w	Wage Calvo param	0.8151	0.8167	0.7980	0.8335	B	0.50	0.10
ω_p	Price Calvo param	0.8673	0.8651	0.8436	0.8833	B	0.50	0.10
ψ	Capital utilization cost	0.6564	0.6739	0.5897	0.7520	B	0.50	0.10
s	Investment adjust. cost	5.5475	6.2053	5.4031	6.5048	N	6.00	0.50
χ_w	Wage infl. indexation	0.0375	0.0497	0.0126	0.0824	B	0.50	0.20
χ_p	Price infl. indexation	0.2356	0.2354	0.1908	0.3295	B	0.50	0.20
θ	Habits in consumption	0.9134	0.9103	0.9023	0.9174	B	0.50	0.20
α_G	Subs. private/gov. cons.	-0.0514	-0.0760	-0.1692	0.0060	N	0.00	0.10
ϕ_y	Interest response to GDP	0.0014	0.0012	0.0001	0.0034	N	0.25	0.10
ϕ_π	Interest response to infl.	2.0580	2.0826	1.9430	2.1966	N	2.00	0.10
ϕ_{zy}	Transfers response to GDP	0.0823	0.0546	0.0316	0.0804	G	0.10	0.05
γ_G	Gov. cons. response to debt	0.3443	0.3364	0.2874	0.3858	N	0.25	0.10
γ_K	Capital tax response to debt	0.0037	0.0020	0.0003	0.0057	N	0.25	0.10
γ_L	Labor tax response to debt	0.0027	0.0019	0.0002	0.0051	N	0.25	0.10
γ_Z	Transfers response to debt	0.0891	0.0867	0.0359	0.1399	N	0.25	0.10
ρ_r	AR coeff. monetary rule	0.7264	0.7284	0.6803	0.7722	B	0.50	0.10
ρ_G	AR coeff. gov. cons. rule	0.4080	0.4139	0.3150	0.4979	B	0.50	0.10
ρ_Z	AR coeff. transfers rule	0.5394	0.4525	0.3895	0.5843	B	0.50	0.10

Source: Bianchi and others (2023).
Notes: The letters in the column with the heading “Prior Type” indicate the prior density function: N , G , and B stand for Normal, Gamma, and Beta, respectively.

Table 2. Posterior Modes, Medians, 90 Percent Posterior Credible Sets, and Prior Moments for the Structural Parameters

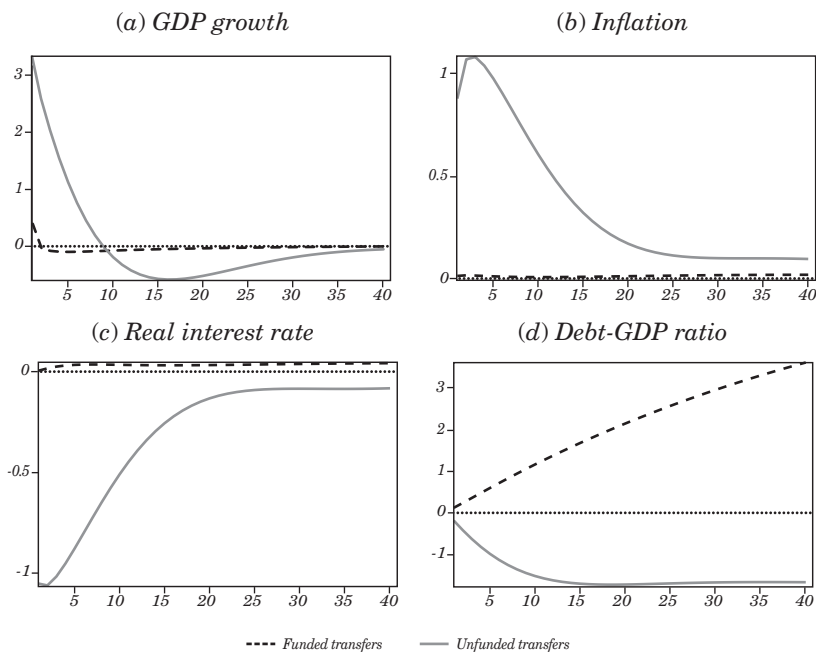
<i>Priors and Posteriors for the Exogenous Processes</i>								
Param	Description	Posterior Distribution				Prior Distribution		
		Mode	Median	5%	95%	Type	Mean	Std
ρ_{eG}	AR coeff. gov. cons.	0.9361	0.9372	0.9096	0.9609	<i>B</i>	0.500	0.100
ρ_{eZ}^M	AR coeff. funded trans.	0.9954	0.9953	0.9936	0.9967	<i>B</i>	0.995	0.001
ρ_{eZ}^F	AR coeff. unfunded trans.	0.9954	0.9953	0.9936	0.9967	<i>B</i>	0.995	0.001
ρ_z	AR coeff. short-term trans.	0.4916	0.3314	0.2669	0.4590	<i>B</i>	0.500	0.100
ρ_a	AR coeff. technology	0.3107	0.2995	0.2156	0.3604	<i>B</i>	0.500	0.100
ρ_b	AR coeff. preference	0.7946	0.8033	0.7642	0.8369	<i>B</i>	0.500	0.100
ρ_m	AR coeff. mon. policy	0.2417	0.2613	0.2068	0.3296	<i>B</i>	0.500	0.100
ρ_i	AR coeff. investment	0.9218	0.9141	0.8982	0.9308	<i>B</i>	0.500	0.100
ρ_{rp}	AR coeff. risk premium	0.9035	0.9000	0.8844	0.9139	<i>B</i>	0.500	0.100
ρ_{μ}^{NKPC}	AR coeff. pers. cost push	0.9966	0.9965	0.9953	0.9975	<i>B</i>	0.995	0.001
σ_G	St.dev. gov. cons.	2.0042	2.0463	1.8965	2.1828	<i>IG</i>	0.500	0.200
σ_Z^M	St.dev. funded transfers	2.9525	2.9530	2.7788	3.2491	<i>IG</i>	0.500	0.200
σ_Z^F	St.dev. unfunded transfers	0.5960	0.5628	0.4639	0.6674	<i>IG</i>	0.500	0.200
σ_z	St.dev. short-term trans.	0.3897	0.3739	0.3165	0.4661	<i>IG</i>	0.500	0.200
σ_a	St.dev. technology	1.2159	1.2243	1.1252	1.3274	<i>IG</i>	0.500	0.200
σ_b	St.dev. preference	4.9930	4.9951	4.9870	4.9994	<i>IG</i>	0.500	0.200
σ_m	St.dev. mon. policy	0.2420	0.2446	0.2228	0.2691	<i>IG</i>	0.500	0.200
σ_i	St.dev. investment	0.4976	0.5007	0.4467	0.5607	<i>IG</i>	0.500	0.200
σ_w	St.dev. wage markup	0.3453	0.3504	0.3217	0.3864	<i>IG</i>	0.500	0.200
σ_p	St.dev. transitory cost push	0.1694	0.1714	0.1534	0.1920	<i>IG</i>	0.500	0.200
σ_{rp}	St.dev. risk premium	0.3824	0.3994	0.3483	0.4509	<i>IG</i>	0.500	0.200
σ_{μ}^{NKPC}	St.dev. persistent cost push	1.3257	1.3196	1.1878	1.6059	<i>IG</i>	0.500	0.200
σ_{GDP}^m	Measur. error GDP	0.4338	0.4343	0.4001	0.4710	<i>IG</i>	0.500	0.200
σ_{by}^m	Measur. error Debt/GDP	0.3245	0.3659	0.3123	0.5153	<i>IG</i>	0.500	0.200

Source: Bianchi and others (2023).
Notes: The letters in the column with the heading “Prior Type” indicate the prior density function: N, G, and B stand for Normal, Gamma, and Beta, respectively.

The autocorrelation coefficients for shocks to funded and unfunded transfers are tightly centered around a highly persistent mean, consistent with the belief that changes in these transfers are very persistent. This aligns with observed data, where transfers exhibit fluctuations around a long-term trend. In contrast, cyclical increases in government transfers are assumed to be offset by higher tax revenues and reduced spending during subsequent economic recoveries.

The prior for the autocorrelation coefficient of the persistent cost-push shock (ρ_{μ}^{NKPC}) is chosen to give the model an alternative mechanism for explaining persistent inflation. This setup permits, but does not mandate, persistent inflation to arise from unfunded fiscal shocks. The autocorrelation coefficients for the tax rules (ρ_K, ρ_L) are set to 0.5, as they are only weakly identified in the estimation process. Additionally, the prior for the standard deviation of the shocks is the same across all shock types.

Figure 3. Impulse Responses to Fiscal Shocks



Source: Authors' calculations.

Notes: Impulse responses of annualized GDP growth, inflation, the real interest rate, and the debt-to-GDP ratio to a shock to funded transfers (dashed line), unfunded government transfers (solid line), and purchases (dotted-dashed line). Units: percentage deviations from steady-state values. The magnitude of the initial shocks is set to be equal to one-standard deviation as estimated in the second sample (2008.I—2022.IV).

3.3 Posterior Distributions

The left panels of tables 1 and 2 present the posterior distributions for the structural parameters and exogenous processes, respectively, based on data from the sample period 1960.I to 2007.IV. The parameters governing the responsiveness of tax instruments to debt (γ_L and γ_K) are positive but relatively small in magnitude. As a result, the stabilization of funded debt largely relies on the higher estimates for γ_G and γ_Z , indicating that adjustments in government spending play a more significant role than tax changes in stabilizing debt.

Our estimates for price and wage rigidities are on the lower end compared to the existing literature, while the habit parameter is closer to the upper range of reported estimates but remains below the values found by Leeper and others (2017). The output coefficient in the Taylor rule is nearly zero and lower than what is typically found in similar model estimations. This suggests that the central bank's interest rate adjustments are largely driven by changes in fiscal inflation rather than fluctuations in output.

4. RESULTS

In this section, we analyze the role of unfunded fiscal shocks in driving fluctuations in real interest rates using the estimated TANK model. We begin by evaluating impulse response functions and then explore the historical context.

4.1 Impulse Responses

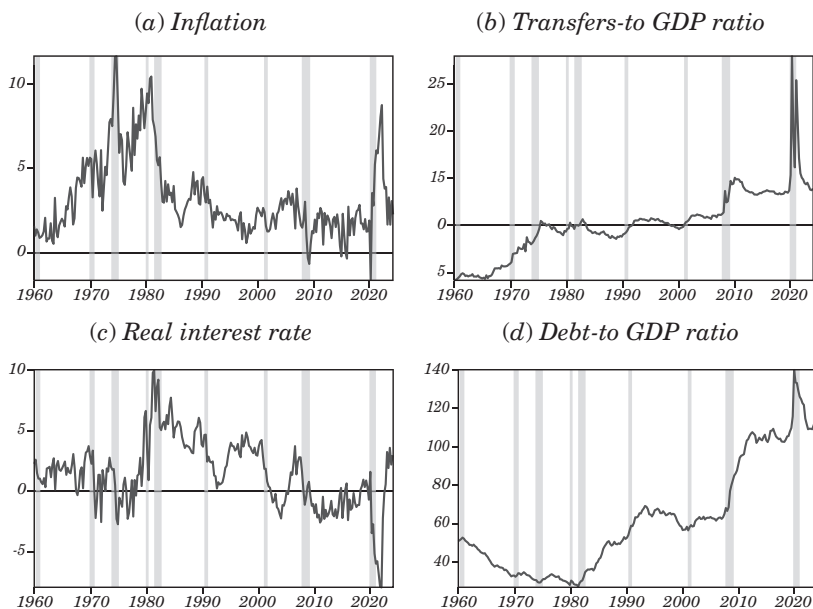
In this subsection, we use impulse responses to highlight the differences between funded and unfunded shocks to transfers. This analysis is also useful to understand how the two shocks are identified in the structural estimation of the model. Figure 3 reports the responses of annualized GDP growth, inflation, the real interest rate, and the debt-to-GDP ratio.

A funded fiscal shock generates only a modest increase in real activity and inflation, despite the presence of hand-to-mouth agents. The increase in growth immediately reverts, as the central bank responds by increasing rates more than one-to-one and real interest rates increase. The debt-to-GDP ratio starts trending up, as the shock to spending is persistent and taxation is slow to react to the increase in

spending. An unfunded fiscal shock has very different effects. Growth jumps and remains elevated for a while. Inflation also experiences a large increase that is accommodated by the central bank. As a result, real interest rates, instead of increasing, experience a large decline. After the initial surge, inflation remains elevated for a long time. Importantly, the jump in real activity and the drop in real interest rates lead to a decline in the debt-to-GDP ratio. This is because the increase in spending is spread over time, while the increase in fiscal inflation and output and the drop in real interest rates are front-loaded.

Summarizing, funded and unfunded fiscal shocks imply very different comovement between macroeconomic and fiscal variables. Real interest rates experience a modest increase following funded fiscal shocks, while they decline by a large amount in response to an unfunded fiscal shock.

Figure 4. Selected Macro Series



Source: Authors' calculations.

Notes: The figure reports the series for inflation, real interest rates, transfers-to-GDP ratio, and debt-to-GDP ratio over the sample 2008.I—2024.II.

4.2 Real Interest Rates and Fiscal Shocks

Before analyzing the historical patterns of funded and unfunded transfers and their relation to movements in real interest rates, it is essential to understand how total federal transfers have changed over time and how these changes relate to movements in other key variables of our analysis. Figure 4 reports inflation, the ex-post real interest rate, the transfers-to-GDP ratio, and the debt-to-GDP ratio over the sample 2008.I—2024.II. The ex-post real interest rate is measured as federal funds rate (FFR) minus realized inflation.

From 1960 to 2024, the US government's transfers-to-GDP have followed distinct phases:

1. Sharp increase in the 1960s and 1970s: During this period, there was a notable rise in government transfers. This growth reflects initiatives from President Johnson's Great Society program aimed at reducing poverty, racial injustice, and crime. The increase continued under President Nixon (1969–1974), as many welfare programs initiated in the 1960s became long-term components of federal spending. During these years, inflation keeps increasing, while the debt-to-GDP ratio and real interest rates decline.

2. Stagnation from the late 1970s to the 1990s: Following this surge, the growth of transfers slowed down and remained stable until around 1990. In the late 1970s and early 1980s, we also observe a quick reversal of real interest rates, triggering a persistent increase in the debt-to-GDP ratio and a relatively quick drop in inflation.

3. Growth in post-millennial period: After the 1990s, transfers grew at a steady, though slower, pace. This period saw consistent, moderate increases in government spending, largely reflecting economic conditions and policy changes. We observe a significant jump in the aftermath of the Great Recession, with large accumulation of debt.

4. Pandemic Surge: During the pandemic recession in 2020–2024, there was an unprecedented jump in transfers, exceeding previous trends. Even as the pandemic subsided. Shortly after inflation experiences a large jump, washing out a large share of the debt accumulated during the recession. Ex-post real interest rates drop dramatically as the Fed initially accommodates the inflation surge.

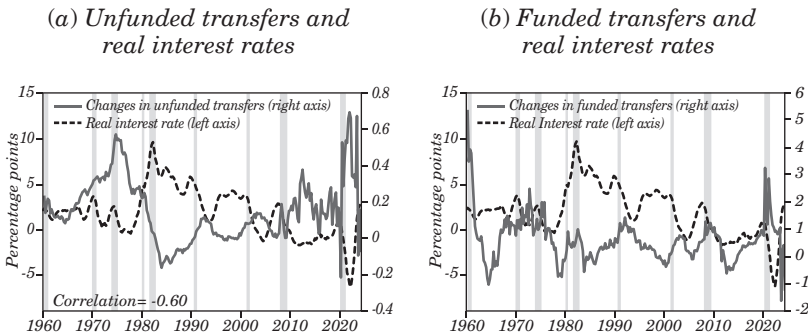
As explained at length in Bianchi and others (2023), the composition of spending between funded and unfunded changes significantly over time. These changes in the composition of spending are central to understanding the relation between spending and real interest rates,

the role of monetary policy, and the consequences for inflation and the debt-to-GDP ratio. Figure 5 reports smoothed changes in unfunded (left panel) and funded (right panel) transfers together with the real interest rates. Unfunded transfers occur when policymakers rely on fiscal measures without adequate funding, leading to inflation and shifts in interest rates. When unfunded transfers increase, real interest rates tend to decrease. This generates a strong negative correlation between changes in unfunded spending and real interest rates: -0.59 . This inverse relationship highlights the coordination between monetary and fiscal policy to manage the fiscal burden resulting from changes in spending. Instead, the relation between funded transfers and real interest rates is weak in the data, with a correlation of -0.08 .

It is then useful to summarize the dynamics of unfunded transfers across the four periods identified above:

1. **1960s–1970s:** The rapid growth of unfunded transfers played a significant role in driving inflation during this time, with increases reflecting rising welfare spending. This increase in unfunded spending coincided with low real interest rates and higher real activity that kept the debt-to-GDP ratio low despite the acceleration in spending.

Figure 5. Federal Transfers and Real Interest Rate



Source: Authors' calculations.

Notes: The two panels report changes in the amount of unfunded transfers (solid line in the left panel) and funded transfers (solid line in the right panel) together with the ex-ante real interest rate (dashed line). The changes in transfers are computed by taking the one-year moving average of the quarter-over-quarter percentage changes in the amount of unfunded transfers predicted by the model (smoothed estimates). The real interest rate is computed by taking the three-year moving average of the annualized ex-ante real rate of interest predicted by the model (smoothed estimates). The sample period is 1960.I–2024.II.

2. Late 1970s–1980s: The growth in unfunded transfers slowed, peaking in the late 1970s and then declining in the early 1980s. This period coincided with efforts by the Federal Reserve, under Chairman Paul Volcker, to control inflation through higher interest rates. In the 1980s, President Reagan arguably played an important role by running on an anti-inflation presidential campaign, advocating for a reduction in spending, and, later in his presidency, increasing the tax base. This policy shift is consistent with a reduction in unfunded spending. During the early 1980s, the United States ran primary deficits, but this was mostly the result of the sharp increase in the cost of borrowing and the recession that came with them. Higher real interest rates and lower real activity led to an increase in the debt-to-GDP ratio. Notice that this is consistent with a shift from unfunded to funded spending, as illustrated in the impulse responses in Section 2.

3. Post 1990: The growth in transfers continued, though at a slower pace. However, the amount of unfunded transfers remained under control. In the 2010s, the share of unfunded transfers increased more rapidly due to accommodating monetary policies that allowed for low or negative real interest rates.

4. Pandemic response: In response to the economic fallout from the Covid-19 pandemic, the federal government sharply increased transfers in 2020 and 2021. Initially, unfunded transfers remained stable, but by the third quarter of 2020, they began to rise, reflecting new monetary frameworks that allowed for inflation to exceed targets. This shift, combined with fiscal stimulus measures like the ARPA, contributed to the post-pandemic inflation surge.

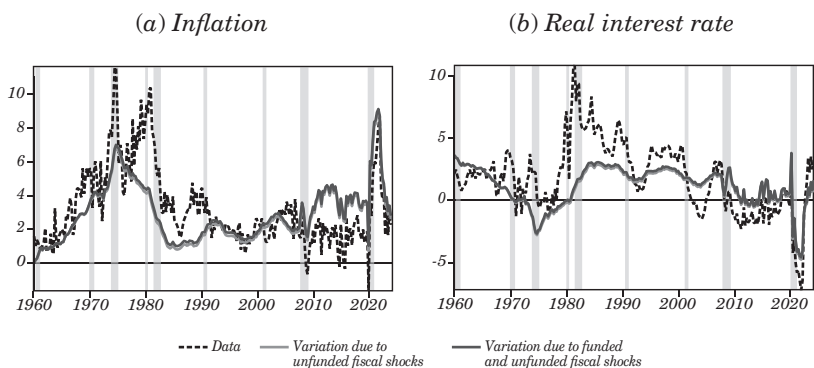
We now examine in more detail the relationship between unfunded transfers and the historical dynamics of inflation and real interest rates. Figure 7 presents a historical shock decomposition of inflation and the real interest rate. In each panel, the dashed line corresponds to the data. In the lower panel, the model-implied ex-ante real interest rate is computed as the federal funds rate minus the one-step-ahead expected inflation. Notice that this measure is slightly different from the real interest reported in Figure 4, where we use current inflation as a proxy for one-step-ahead expected inflation. However, the two series comove quite closely. The solid line corresponds to movements in inflation (top panel) and the real interest rate (lower panel) that can be explained by changes in unfunded fiscal shocks to transfers, while the dashed line also includes funded fiscal shocks.

The main finding from Figure 7 is that fiscal real interest rates—caused by unfunded transfers—account for a large share of the

low-frequency movements in real interest rates. The persistent rise in inflation from the mid-1960s to the mid-1970s is largely explained by the inflationary effects of increased unfunded transfers during that period. This translates to a persistent decline in the fiscal real interest rate of around 6 percent. This is a large change that accounts for most of the low-frequency change in the overall real interest rate. The rise in fiscal inflation, accommodated by the central bank, helped support growth in the 1970s, counteracting the productivity slowdown of those years. Low real interest rates and high real activity lower the debt-to-GDP ratio.

The inflationary effects of this rise in transfers began to diminish in the late 1970s, while nonpolicy shocks were pushing up inflation. Although the share of unfunded transfers rose in the second half of the 1970s, the pace was not fast enough to sustain the high level of fiscal inflation caused by the large expansion in unfunded transfers in the first half. Consequently, fiscal real interest rates steadily increased in the second half of the 1970s, though they remained relatively low at the end of the decade.

Figure 6. Real Interest Rate and Fiscal Shocks



Source: Authors' calculations.

Notes: The figure reports the contribution of funded and unfunded fiscal shocks to changes in inflation (left panel) and the real interest rate (right panel). The dashed line reports the model-implied real interest, computed as federal funds rate minus one-step-ahead expected inflation. The solid line is the value of the real interest rate if only unfunded fiscal shocks had occurred. The dotted-dashed line represents the value of the real interest rate if only unfunded and funded fiscal shocks had occurred. The shaded areas correspond to the NBER recessions. Shocks and their contributions are constructed by using the Kalman smoother with the model parameters set at their posterior mode.

The increase in fiscal real interest rates accelerated in the early 1980s and coincided with the fall in inflation and the reversal of the debt-to-GDP dynamics described above. In the first five years of the 1980s, fiscal real interest rates increased by around 3 percent. The sharp increase in the real interest rate due to the aggressive monetary tightening by the Federal Reserve under Chairman Volcker coincided with a significant fall in fiscal inflation and output growth in the early 1980s. Thus, a policy change occurred before the appointment of Federal Reserve Chairman Volcker in August 1979. However, the early 1980s saw an acceleration in the policy environment change, propelled by President Reagan's election, which arguably provided political backing to the Federal Reserve's resolute disinflation policy.⁶ Thus, the rapid decline in inflation, the slowdown in real activity, and the increase in real rates of the early 1980s are interpreted as a joint monetary-fiscal policy phenomenon.

Fiscal real interest rates remained fairly stable until the post-millennial period. This stability can be explained by the absence of major recessions and fiscal events. After the 2008 financial crisis, fiscal real rates remained very low, but above actual real rates. This is consistent with the fact that, from the early 2000s, fiscal inflation persistently helped avert deflation. In the post-Great Recession period, fiscal inflation offset a deflationary bias caused by nonpolicy shocks—primarily a mix of favorable investment shocks and long-run cost-push shocks. Notably, these nonpolicy forces' deflationary effects are persistent and keep dragging inflation down for a long time. The counterpart of elevated fiscal inflation is a persistent decline in fiscal real rates.

Finally, the pandemic determines a large and unprecedented drop in real rates. This large drop is mostly explained by a large unfunded fiscal shock that was accommodated by the central bank. As explained in more detail in Bianchi and others (2023), inflation was already on an upward trajectory following the Coronavirus Aid, Relief, and Economic Security (CARES) Act, but it accelerated significantly after the ARPA fiscal stimulus, which was implemented when the economy was already on a recovery path. Interestingly, the first change in the amount of unfunded transfers and the associated contribution to the

6. See Samuelson (2008), Bianchi and Ilut (2017), Bianchi and others (2023).

economic rebound did not coincide with the increase in fiscal transfers associated with the CARES Act, but rather with the announcement of the Federal Reserve's policy strategy change. Thus, our model suggests that coordination between monetary and fiscal authorities triggered the large economic rebound and surge of inflation. The increase in funded transfers alone has limited efficacy because it also generates an expectation of large future tax increases. This result holds despite allowing for hand-to-mouth consumers who immediately spend the transfers they receive. Instead, an increase in unfunded transfers leads to a reflation of the economy, a decline in real interest rates, and an increase in real activity.

In this respect, the post-pandemic dynamics align with historical experience. Throughout the sample, fiscal inflation increases and fiscal real rates drop after recessions, consistent with findings documented in Hall and Sargent (2011, 2022). This pattern is particularly visible after the 1973–1975, 1990–1991, 2001, 2007–2009, and pandemic recessions. The only noticeable exception is the early 1980s recession, which is inherently different because the decline in inflation, the jump in real interest rates, and the contraction in real activity were largely caused by a decline in the share of unfunded spending associated with the policy shift. As discussed above, the model interprets the Volcker disinflation and the associated recession as a joint monetary and fiscal phenomenon.

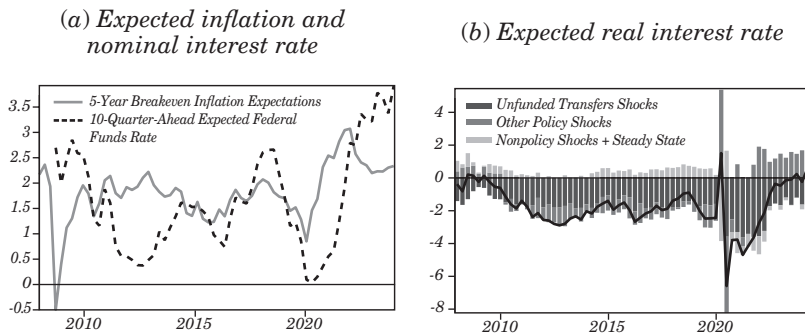
The historical decomposition presented above allows us to further explain how to interpret the policy rules used in the paper. The coordination of monetary and fiscal policies may originate from the need to finance expensive social programs, long wars, or large fiscal stimuli. These are scenarios where the fiscal authority might not realistically be able to raise primary surpluses, leading to inflationary pressure. An example is the launch of the Great Society initiatives, which triggered an upward shift in transfers for several years after President Johnson's 1964 announcement. Financing these expensive, long-lasting social programs with only fiscal instruments could have been perceived as politically unfeasible. This generated inflationary pressure met by dovish monetary policy. In the early 1980s, Federal Reserve Chairman Volcker signaled that inflationary pressure would no longer be accommodated. The Reagan administration, unlike previous administrations, refrained from interfering and advocated for a small government, making this policy change credible.

4.3 Current Outlook for Real Interest Rates

Our analysis has demonstrated that the interaction between monetary and fiscal policies plays a pivotal role in explaining a significant portion of low-frequency movements in real interest rates. An unfunded fiscal shock precipitates a substantial increase in inflation, which is accommodated by the central bank, leading to a consequent decline in real interest rates. Although the initial surge in inflation is relatively short-lived, its inflationary effects persist for decades, thereby exerting long-term downward pressure on real interest rates.

In examining the post-pandemic period, it is therefore interesting to assess market expectations regarding future real interest rates. We utilize 5-year breakeven inflation and 10-quarter-ahead overnight index swaps as market-based measures of expectations for inflation and short-term interest rates, respectively. While these measures are inherently imperfect, they nonetheless provide valuable insights.

The left panel of Figure 7 reveals several noteworthy patterns. Firstly, 5-year breakeven was for many years slightly below the Fed's 2 percent target. It then experienced a visible but relatively modest increase during the pandemic, consistent with the view that the inflation spike was perceived as a temporary response to a significant fiscal shock, rather than a permanent alteration of the inflation target. Secondly, such an increase followed the rapid decline in expected interest rates that occurred in 2020.III, after the Fed completed the review of its monetary policy strategy and claimed that it was ready to let inflation overshoot the target. Finally, after a decline in 2023, 5-year breakeven inflation began to rise again in 2024, potentially reflecting growing market concerns about the future fiscal outlook. Equipped with this information, we ask how the model interprets the current outlook for future real interest rates. The right panel of Figure 7 presents a decomposition of the model-implied 10-quarter-ahead short-term real interest rate. The black, gray, and white bars represent changes attributable to unfunded transfer shocks, other policy shocks, and nonpolicy shocks, respectively. Expected real interest rates have reverted to pre-pandemic levels due to two primary factors: the dissipation of the short-term effects of unfunded pandemic shocks and the upward pressure exerted by other policy shocks, such as monetary policy adjustments. However, the decomposition also indicates that unfunded fiscal shocks continue to exert significant downward pressure on real interest rates.

Figure 7. Expected Real Interest Rates

Source: Authors' calculations.

Notes: In the left panel, the solid line and dashed line correspond to the 5-year breakeven inflation and 10-quarter-ahead overnight index swaps, respectively. In the right panel, the black solid line corresponds to the model-implied 10-quarter-ahead short-term real interest rate. The bars represent the cumulative contributions of unfunded transfers shocks (dark gray bars), other policy shocks (gray bars), and nonpolicy shocks (light gray bars) on the two variables. The white bars also include the steady state and the initial conditions for the two variables. Other policy shocks include shocks to funded transfers, shocks to government purchases, and unanticipated and anticipated monetary policy shocks. Shocks are estimated using the Kalman smoother with the model parameters set at their posterior mode.

5. CONCLUSIONS

In this paper, we extended the analysis of Bianchi and others (2023) to study the role of fiscal shocks in driving fluctuations in the real interest rate. When embedded in a state-of-the art TANK model, funded fiscal shocks cause modest *increases* in real interest rates, while unfunded fiscal shocks determine a large *drop* in real interest rates. This is because unfunded fiscal shocks generate additional inflationary pressure that is accommodated by the central bank.

We find that unfunded fiscal shocks play a key role in explaining slow-moving changes in real interest rates. Fiscal real rates decline in the 1960s and 1970s, while they increase quickly in the early 1980s. They remain roughly stable until the 1990s, while they drop again during the post-millennial period. Unlike during the Great Inflation period, such low fiscal rates do not cause high inflation because they mostly counteract deflationary forces. Finally, the pandemic period is characterized by a sudden and large increase in unfunded spending, resulting in a surge of inflation accommodated by the central bank, with a consequent drop in real interest rates.

These results indicate that fiscal policy will play an important role in the evolution of real interest rates going forward. Spending is still

elevated and the debt-to-GDP ratio is at a historic high. Furthermore, unlike other times in history, such large debt accumulation is not exclusively the result of a major catastrophic event. Surely, the pandemic presents analogies with major events of the past, such as the two World Wars.⁷ However, debt and spending had been climbing before that. In fact, current debt would be significantly higher if not for the large post-pandemic increase in inflation. Given the current fiscal outlook, the extremely low real interest rates of the pre-pandemic period might not be compatible with low inflation, unless world economies resume their path toward increasing integration.

7. See Barro and Bianchi (2024).

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APPENDICES

Appendix A: The Log-Linearized Model

This model features a trend in the state of labor-augmenting technological progress. In order to make the model stationary, we define the following variables:

$$y_t = \frac{Y_t}{A_t}, c_t^{*S} = \frac{C_t^{*S}}{A_t}, c_t^S = \frac{C_t^S}{A_t}, c_t^N = \frac{C_t^N}{A_t}, k_t = \frac{K_t}{A_t}, g_t = \frac{G_t}{A_t}, z_t = \frac{Z_t}{A_t},$$

$$b_t = \frac{P_t^m B_t^m}{P_t A_t}, s_{b,t} = \frac{P_t^m B_t^m}{P_t Y_t}, w_t = \frac{W_t}{P_t A_t} \text{ and } \lambda_t^S = \Lambda_t^S A_t.$$

We list below the equations of the log-linear model, starting with those that characterize the actual-economy block.

Production function:

$$\hat{y}_t = \frac{y + \Omega}{y} \left[\alpha \hat{k}_t + (1 - \alpha) \hat{L}_t \right]. \quad (19)$$

Capital-labor ratio:

$$\hat{r}_{K,t} - \hat{w}_t = \hat{L}_t - \hat{k}_t. \quad (20)$$

Marginal cost:

$$\widehat{mc}_t = \alpha \hat{r}_{K,t} + (1 - \alpha) \hat{w}_t. \quad (21)$$

Phillips curve:

$$\hat{\pi}_t = \frac{\beta}{1 + \chi^p \beta} E_t \hat{\pi}_{t+1} + \frac{\chi^p}{1 + \chi^p \beta} \hat{\pi}_{t-1} + \kappa_p \widehat{mc} + \kappa_p \hat{\eta}_t^p + \kappa_p \hat{u}_t^{NKPC}, \quad (22)$$

where $\kappa_p = [(1 - \beta \omega_p) (1 - \omega_p)] / [\omega_p (1 + \beta \chi^p)]$.

Saver household's first-order condition (FOC) for consumption:

$$\hat{\lambda}_t^S = \hat{u}_t^b - \frac{\theta}{e^\chi - \theta} \hat{u}_t^a - \frac{e^\chi}{e^\chi - \theta} c_t^{*S} + \frac{\theta}{e^\chi - \theta} c_{t-1}^{*S} - \frac{\tau^C}{1 + \tau^C} \hat{\tau}_{C,t}, \quad (23)$$

where $\hat{u}_t^a = u_t^a - \chi$.

Public/private consumption in utility:

$$\hat{c}_t^* = \frac{c^S}{c^S + \alpha_G g} \hat{c}_t^S + \frac{\alpha_G g}{c^S + \alpha_G g} \hat{g}_t. \quad (24)$$

Euler equation:

$$\hat{\lambda}_t^S = \hat{r}_{n,t} + E_t \hat{\lambda}_{t+1}^S - E_t \hat{\pi}_{t+1} - E_t \hat{u}_{t+1}^a + \hat{u}_t^{rp}. \quad (25)$$

Maturity structure of debt:

$$\hat{r}_{n,t} + \hat{P}_t^m = \frac{\rho}{R} E_t \hat{P}_{t+1}^m - \hat{u}_t^{rp}. \quad (26)$$

Saver household's FOC for capacity utilization:

$$\hat{r}_{K,t} - \frac{\tau_K}{1 - \tau_K} \hat{\tau}_{K,t} = \frac{\psi}{1 - \psi} \hat{v}_t. \quad (27)$$

Saver household's FOC for capital:

$$\begin{aligned} \hat{q}_t &= E_t \hat{\pi}_{t+1} - \hat{r}_{n,t} + \beta e^{-\varkappa} (1 - \tau_K) r_K E_t \hat{r}_{K,t+1} \\ &\quad - \beta e^{-\varkappa} \tau_K r_K E_t \hat{\tau}_{K,t+1} + \beta e^{-\varkappa} (1 - \delta) E_t \hat{q}_{t+1} - \hat{u}_t^{rp}. \end{aligned} \quad (28)$$

Saver household's FOC for investment:

$$\hat{i}_t + \frac{1}{1 + \beta} \hat{u}_t^a - \frac{1}{(1 + \beta) s e^{2\varkappa}} \hat{q}_t - \hat{u}_t^i - \frac{\beta}{1 + \beta} E_t \hat{i}_{t+1} - \frac{\beta}{1 + \beta} E_t \hat{u}_{t+1}^a = \frac{1}{1 + \beta} \hat{i}_{t-1}. \quad (29)$$

Effective capital:

$$\hat{k}_t = \hat{v}_t + \hat{k}_{t-1} - \hat{u}_t^a. \quad (30)$$

Law of motion for capital:

$$\hat{k}_t = (1 - \delta) e^{-\varkappa} \left(\hat{k}_{t-1} - \hat{u}_t^a \right) + \left[1 - (1 - \delta) e^{-\varkappa} \right] \left[(1 + \beta) s e^{2\varkappa} + \hat{i}_t \right]. \quad (31)$$

Hand-to-mouth household's budget constraint:

$$\tau_C c^N \hat{\tau}_{C,t} + (1 + \tau_C) c^N \hat{c}_t^N = (1 - \tau_L) w L \left(\hat{w}_t + \hat{L}_t \right) - \tau_L w L \tau_{L,t} + z \hat{z}_t. \quad (32)$$

Wage equation:

$$\begin{aligned} \hat{w}_t = & \frac{1}{1+\beta} \hat{w}_{t-1} + \frac{\beta}{1+\beta} E_t \hat{w}_{t+1} - \kappa_w \left[\hat{w}_t - \xi \hat{L}_t + \hat{\lambda}_t^S - \frac{\tau_L}{1-\tau_L} \hat{\tau}_{L,t} \right] + \frac{\chi^w}{1+\beta} \hat{\pi}_{t-1} \quad (33) \\ & - \frac{1+\beta\chi^w}{1+\beta} \hat{\pi}_t + \frac{\beta}{1+\beta} E_t \hat{\pi}_{t+1} + \frac{\chi}{1+\beta} \hat{u}_{t-1}^a - \frac{1+\beta\chi^w - \rho_a\beta}{1+\beta} \hat{u}_t^a + \kappa_w \hat{\eta}_t^w, \end{aligned}$$

$$\text{where } \kappa_w \equiv \left[(1-\beta\omega_w)(1-\omega_w) \right] / \left[\omega_w(1+\beta) \left(1 + \frac{(1+\eta^w)\xi}{\eta^w} \right) \right].$$

Aggregate households' consumption

$$c\hat{c}_t = c^S(1-\mu)\hat{c}_t^S + c^N\mu\hat{c}_t^N. \quad (34)$$

Aggregate resource constraint:

$$y\hat{y}_t = c\hat{c}_t + i\hat{i}_t + g\hat{g}_t + \psi'(1)k\hat{v}_t. \quad (35)$$

Government budget constraint:

$$\begin{aligned} \frac{b}{y} \hat{b}_t + \tau_K r_K \frac{k}{y} \left[\hat{\tau}_{K,t} + \hat{r}_{K,t} + \hat{k}_t \right] + \tau_L w \frac{L}{y} \left[\hat{\tau}_{L,t} + \hat{w}_t + \hat{L}_t \right] + \tau_c \frac{c}{y} \left(\hat{\tau}_{C,t} + \hat{c}_t \right) = \quad (36) \\ \frac{1}{\beta} \frac{b}{y} \left[\hat{b}_{t-1} - \hat{\pi}_t - \hat{P}_{t-1}^m - \hat{u}_t^a \right] + \frac{b}{y} \frac{\rho}{e^\pi} \hat{P}_t^m + \frac{g}{y} \hat{g}_t + \frac{z}{y} \hat{z}_t. \end{aligned}$$

Fiscal rules:

$$\hat{g}_t = \rho_G \hat{g}_{t-1} - (1-\rho_G) \gamma_G \left(\hat{s}_{b,t-1} - \hat{s}_{b,t-1}^F \right) + \zeta_{g,t}, \quad (37)$$

$$\hat{z}_t^b = \rho_Z \hat{z}_{t-1}^b - (1-\rho_Z) \left[\gamma_Z \left(\hat{s}_{b,t-1} - \hat{s}_{b,t-1}^F \right) + \phi_{zy} \hat{y}_t \right] + \zeta_{z,t}, \quad (38)$$

$$\hat{z}_t = \hat{z}_t^b + \zeta_t^M + \zeta_t^F, \quad (39)$$

$$\hat{\tau}_{L,t} = \rho_L \hat{\tau}_{L,t-1} - (1-\rho_L) \gamma_L \left(\hat{s}_{b,t-1} - \hat{s}_{b,t-1}^F \right), \quad (40)$$

$$\hat{\tau}_{K,t} = \rho_K \hat{\tau}_{K,t-1} - (1-\rho_K) \gamma_K \left(\hat{s}_{b,t-1} - \hat{s}_{b,t-1}^F \right). \quad (41)$$

Monetary rule:

$$\hat{r}_{n,t} = \max\left(-\ln \underline{R}, \rho_r \hat{r}_{n,t-1} + (1 - \rho_r) \left[\phi_\pi (\hat{\pi}_t - \hat{\pi}_t^F) + \phi_y \hat{y}_t \right] + u_t^m \right). \quad (42)$$

The variables with the superscript F in equations (37) to (42) above belong to the shadow economy. In turn, the block of equations that characterizes the shadow economy consists of an additional set of equations (19) to (36), where any variable that refers to the actual economy x_t is replaced by the same variable in the shadow economy x_t^F , plus the rule for the monetary authority

$$\hat{r}_{n,t}^F = \max\left(-\ln \underline{R}, \rho_r \hat{r}_{n,t-1}^F + (1 - \rho_r) \left[\phi_\pi \hat{\pi}_t^F + \phi_y \hat{y}_t^F \right] + u_t^m \right) \quad (43)$$

and the rules for the fiscal authority,

$$\hat{g}_t^F = \rho_G \hat{g}_{t-1}^F - (1 - \rho_G) \gamma_G \hat{s}_{b,t-1}^F + \zeta_{g,t}, \quad (44)$$

$$\hat{z}_t^{b,F} = \phi_{zy} \hat{y}_t^F + \rho_Z \hat{z}_{t-1}^{b,F} - (1 - \rho_Z) \gamma_Z \hat{s}_{b,t-1}^F + \zeta_{z,t}, \quad (45)$$

$$\hat{z}_t = \hat{z}_t^{b,F} + \zeta_t^F, \quad (46)$$

$$\hat{\tau}_{L,t}^F = \rho_L \hat{\tau}_{L,t-1}^F - (1 - \rho_L) \gamma_L \hat{s}_{b,t-1}^F, \quad (47)$$

$$\hat{\tau}_{K,t}^F = \rho_K \hat{\tau}_{K,t-1}^F - (1 - \rho_K) \gamma_K \hat{s}_{b,t-1}^F. \quad (48)$$

Appendix B: The Dataset

Real GDP growth is computed as the growth rate of nominal GDP (GDP), divided by the GDP deflator (JGDP). Real consumption growth is the growth rate of the sum of personal consumption expenditures in nondurable goods (PCND) and services (PCESV), divided by their price indexes (DNDGRG3M086SBEA and DSERRG3M086SBEA, respectively). Real investment growth is the growth rate of the sum of gross private domestic investment (GPDICTPI) and personal consumption expenditures in durable goods (PCDG), divided by the respective price deflators (GPDICTPI and DDURRG3M086SBEA), and scaled by the 16+ US civilian population (CNP16OV). We construct a measure of hours per capita by dividing total hours worked (PRS85006023) by population (CNP16OV). We then construct a measure of the hours gap by taking the difference of hours per capita from its trend, which is computed as a fourth-degree polynomial. We compute a measure of hourly wages by dividing wage compensation (A576RC1) by average weekly hours in the nonfarm business sector (PRS85006023). Based on this series, we create a nominal wage index, which we divide by an index of the GDP deflator (based on JGDP) and take growth rates. The debt-to-GDP ratio is constructed by dividing the nominal market value of gross federal debt (MVGFD027MNFRBDAL) by nominal GDP (GDP). The growth of government consumption and investment expenditures is computed as follows. We add nominal federal government consumption expenditures (A957RC1Q027SBEA) to nominal gross government investment (A787RC1Q027SBEA), divide by the implicit price deflator (A822RD3Q086SBEA) and by an index of the US population, with base 2012.III (CNP16OV), and finally take growth rates. The growth of real government transfers is computed as follows. We add government social benefits (B087RC1Q027SBEA) to other current transfer payments, which include grants-in-aid to state and local governments (FGSL), create an index with base 2012.III, divide by an index of the US population (CNP16OV) and an index of the GDP deflator (GDPDEF) with the same base year and finally take growth rates. Inflation is computed as the rate of growth of the GDP deflator (JGDP), and the interest rate is given by the effective federal funds rate (FEDFUNDS). Finally, we also employ the 5-year breakeven inflation rate as a noisy measure of inflation expectations (T5YIE).

MONETARY POLICY AND BANKING STABILITY

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What are the effects of monetary policy rates for banking stability? For example, when inflation started rising in 2022, central banks raised monetary policy rates substantially, with a more than 400 basis points increase in the United States and in the euro area. As of April 2026, monetary rates in the United States are still high and significantly higher than before 2022. This monetary policy action of raising interest rates implies crucial trade-offs, not only between monetary tightening and the risk of an economic recession, which has been extensively analyzed in policy circles and in academic studies,¹ but also between tighter monetary policy conditions and the risk of financial instability, in particular, the risk of a banking crisis.²

These financial stability concerns due to tighter monetary policy—higher policy rates and potentially quantitative tightening (QT)—may be particularly pertinent after a long period of expansive monetary policy, including too-low-for-too-long monetary rates.

These interactions between monetary policy dynamics and concerns on financial stability have been discussed in recent policy and media debates,³ and are illustrated by the failures of Silicon Valley Bank and Credit Suisse, and broader banking distress in March 2023.⁴ Moreover, during this recent period, there have also been problems in some nonbanks (e.g., hedge funds and pension funds in the United Kingdom in September 2022), problems in commercial real estate (and funds associated with this type of investment), the failure of some

1. See, for example, Blinder (2023).

2. See Jiménez and others (2026), International Monetary Fund (2023), and Schnabel (2023).

3. See, for example, Rajan (2023).

4. Legras (2023); Wall Street Journal, 20 March 2023.

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stablecoins such as Terraluna, and very recent defaults in the private credit market. In addition, there have been tensions in sovereign debt; as an example, a new facility was created in the euro area (the so-called transmission protection instrument) when the European Central Bank (ECB) started raising interest rates in 2022.

Furthermore, the normalization of monetary policy has also been difficult in QT. For example, QT has been recently stopped in the United States, and neither the ECB nor the Fed had conducted any active QT, but just passive QT, allowing assets to mature and not renewing them. Moreover, many commentators believe that monetary policy is dominated by either financial stability concerns or/and that there is a fiscal dominance—i.e., that the extremely high levels of private and public debt determine the actions of monetary policy.⁵

In this essay, I review the effects of monetary policy on financial stability. It is not obvious whether and why monetary policy actions, which are high frequency in nature, may affect financial instability. Banking crises are instead phenomena that tend to occur at a low frequency. Moreover, it is unclear whether lower or higher monetary policy rates are negative for financial stability. On the one hand, there is evidence that lower monetary rates increase lending and asset prices, as well as bank risk taking.⁶ These factors have shown to be strongly associated with future financial crises.⁷ On the other hand, other studies have revealed that monetary rate hikes (as opposed to cuts) may increase crisis risk.⁸

As I discuss in this article, for banking crisis risk, however, the whole path of past and current monetary rates matters, not simply whether monetary policy rates were recently cut or raised. For example, recent theoretical work suggests that periods of expansive monetary policy may create financial vulnerabilities (e.g., elevated credit and asset prices), and subsequent tightening may crystallize these financial vulnerabilities into a crisis.⁹

Crucially, recent evidence shows that the whole path of monetary policy rates affects financial stability, a U-shaped path. In Jiménez and

5. See Schnabel (2020).

6. See, for example, Borio and Lowe (2002), Bernanke and Kuttner (2005), Adrian and Shin (2010), Maddaloni and Peydró (2011), Jiménez and others (2014), Becker and Ivashina (2015), Hanson and Stein (2015), and Di Maggio and Kacperczyk (2017).

7. See, for example, Greenwood and others (2022).

8. See Schularick and others (2021) and Gali (2014).

9. See Diamond and Rajan (2012), Acharya and Rajan (2022), Boissay and others (2026), and Goldberg and López-Salido (2023).

others (2026), we show that a U-shaped monetary rate path increases banking crisis risk via credit and asset price cycles. This analysis is based on an analysis of 17 (relatively) high-income countries over the last 150 years. Monetary rate hikes (raw or instrumented using the international finance trilemma) materially increase banking crisis risk, but only if monetary rates were previously cut for an extended period. These patterns are unique to banking crises (different from noncrisis recessions, even the deep ones), and are stronger for a deeper U (over the systematic monetary policy component). That is, the shaped monetary rate path is crucial for banking crises but not for nonfinancial recessions, even the strongest ones; therefore, the mechanisms at play may be financial ones.

Regarding the mechanisms, monetary rate cuts for a prolonged period increase the likelihood of vulnerable “red zones” of high credit and asset price growth, consistent with credit supply including bank risk-taking—expansions. Subsequent monetary rate hikes strongly reduce credit and asset prices and increase banks’ loan losses and banking crisis risk. Moreover, for this channel of monetary policy dynamics affecting the likelihood of banking crises, the evidence on higher crisis risk stems mainly from credit risk rather than the realization of interest rate risk or liquidity problems related to bank runs. Importantly, only those red zones with U-shaped monetary rates strongly increase banking crisis risk; i.e., monetary policy is at the center of banking crises, not just credit booms and asset price bubble without monetary policy components.

We also find consistent results in administrative, loan-level data from Spain’s post-1995 real-estate boom and subsequent banking crisis. It is important to highlight that anecdotal evidence from emerging markets may give a similar narrative. For example, the Latin America crisis in the 1980s that started in Mexico in 1982 came after a strong U-shaped monetary policy rate in the United States, with important associated capital flows for emerging markets.

Once I have shown that there is a clear connection between monetary policy dynamics and financial stability, an important question then is whether central banks should lean against the wind and raise monetary policy rates during the credit and asset price boom. I discuss the issue in this paper, arguing that monetary policy should take into consideration financial stability implications beyond a simple Tinbergen rule. It is important to highlight that financial crises are very costly, that there is regulatory arbitrage of micro and macro prudential policies that reduce their effectiveness, and that an

important part of the financial system is nowadays nonbank credit (financial) intermediaries, which are less subject to macroprudential policies. Furthermore, even if price stability is important for financial stability, there may be instances in which there are conflicts between the two, as I examine in this paper. In addition, I also discuss that monetary policy actions may also be dominated by financial stability concerns or by fiscal dominance.¹⁰

The plan for the rest of the sections is the following. In Section 1, I review in detail the evidence on the impact of monetary policy and banking crises, as well as the different mechanisms. In addition, I discuss the impact of monetary policy actions in crisis times. In section 2, I discuss some normative implications for policy, including whether monetary policy should take into account financial stability issues and lean against the wind, or whether financial stability considerations should only be dealt with through macroprudential policies. Moreover, I discuss some issues that are more relevant to emerging economies, for example, the US monetary policy and the global financial cycle, the role of prudential capital controls and the future of dollarization and stablecoins. In Section 3, I provide some concluding remarks.

1. MONETARY POLICY AND BANKING CRISES

In this section, I base my analysis on Jiménez and others (2023), in which we study the link between monetary policy rate dynamics and financial stability. In particular, we analyze the impact of the path of monetary rates on the likelihood of subsequent banking crises and the associated mechanisms. Experience of past crises suggests that the full dynamics of monetary rates may indeed matter. For example, important crisis events such as the 1930s US Great Depression, the 2007 US Subprime Crisis, the 1990s Japanese crisis, the post-2008 Spanish banking and real-estate crisis, the 1990s Swedish banking crisis, and the 1890 UK Baring crisis all show that monetary rates display one salient feature: the U-shaped pre-crisis path, consisting of sharp monetary rate cuts approximately eight to three years before the crisis, followed by rate increases in the years running up to the crisis onset.

Analyzing many crises and monetary cycles across countries and time periods, we show that the U-shaped monetary rate path is a key

10. See footnote 5.

driver of banking crisis risk in modern history. Most historical crises are preceded by U-shaped monetary rates. Moreover, raising monetary policy rates (raw or instrumented using the international finance trilemma) materially increases banking crisis risk, but only if policy rates were previously cut for a long period, and especially if these cuts and raises go above and beyond the systematic reaction of monetary policy to business-cycle dynamics. Importantly, these patterns are unique to banking crises as opposed to noncrisis recessions.

As to the mechanisms, a long period of monetary rate cuts (U's first half) raises the likelihood of "red zones" of high credit and asset price growth,¹¹ with evidence consistent with higher credit supply and bank risk-taking (including some mispricing). Moreover, raising monetary rates—in the red zone—greatly increase crisis risk. Consistently, U's second half strongly decreases credit and asset prices, and leads to strong materialization of credit risk and bank stock price crash risk. Importantly, a monetary rate U shape without red zones, or red zones without the U shape, do not strongly raise crisis risk. Finally, Spain's case study using post-1995 administrative data confirms—and allows stronger identification of—credit supply, bank risk-taking, and credit risk as key mechanisms.

More concretely, to study the link between monetary policy dynamics and financial stability, we exploit long-run data for 17 countries going back to 1870 obtained from Jordà and others (2013) and detailed administrative data covering the post-1995 period in Spain obtained from the supervisory credit register, matched to firm and bank administrative datasets. We use the long-run data to study i) the link between the path of monetary rates and crisis risk across many monetary cycles and crises, and ii) the mechanisms linking monetary rate dynamics, financial cycles, and crises. We use the administrative data for a detailed case study of the Spanish crisis of the early 2000s—a real-estate banking crisis, representative of many crisis episodes after World War II. This allows us to validate the main patterns found in the long-run data and explore the loan-level heterogeneities in the build-up and crystallization of risks linked to monetary policy.

We start by documenting the path of monetary rates before historical banking crisis episodes. The patterns documented for the above six crises (US Great Depression, etc.) extend to the average crisis in the overall sample, with (short-term nominal) monetary rates decreasing from about eight to three years before a crisis and

11. See Greenwood and others (2022).

increasing in the three years prior to the crisis. These patterns hold for different crisis definitions—baseline Jordà and others (2013) and robustness Baron and others (2021)—and become stronger for deep (lowest-GDP-growth) crises and after World War II.

Splitting eight-year monetary rate paths into four shapes—the U shape (cuts over five years followed by raises over three years), double cut, double raise, and raises followed by cuts—, we find that most historical crises, and all deep crises after World War II, were preceded by a U shape in monetary rates. These patterns are different for noncrisis recessions (even the deepest, worst ones), with only recent monetary rate increases being crucial (i.e., for non-financial crises, what matters is the recent increase in monetary policy rates, not the U shape). We also study whether higher monetary rates after previous cuts raise subsequent crisis risk.

First, we document three-year crisis frequencies for different monetary rate paths over the preceding eight years. The crisis frequency following U-shaped monetary rate paths is 18 percent, roughly double the unconditional crisis frequency, and substantially higher than for the other monetary paths. As before, these differences become more pronounced for deep crises and after World War II. Consistently, using a regression analysis, we find that the U-shaped monetary rate path materially increases (banking) crisis risk, whereas other monetary rate paths do not.

To mitigate potential endogeneity concerns in such regressions, we use an instrument exploiting the famous trilemma of international finance.¹² The instrumental variables (IV) approach is based on the variation in base-country monetary policy rate changes and their transmission through variations in both exchange rate pegs and openness of capital accounts, following Jordà and others (2020). The IV approach results confirm that higher monetary rates increase crisis risk if monetary policy rates were previously cut over a long period. In particular, a 1 percentage point raise over three years, following monetary rate cuts over the preceding five years, increases the three-year crisis probability by 12 percentage points, more than doubling the unconditional crisis risk.

We further show that these effects are stronger for a deeper U shape (i.e., above the systematic component). To do this, we separate monetary policy rate changes into a proxy for the systematic component predicted by main business-cycle variables (GDP growth,

12. See Mundell (1963).

inflation, and other macro variables, including lags) and residual changes above and beyond this component. We find that residual cuts and raises (i.e., monetary rates above the systematic component) substantially increase crisis risk in the data. Systematic cuts followed by systematic raises are also weakly associated with crises, but the magnitudes are smaller and less robust. Furthermore, we show that the U-shaped monetary rate path is not key for noncrisis recessions, not even the deepest ones or those after World War II. For noncrisis recessions, only recent monetary rate increases are key, irrespective of previous monetary rate cuts.

In the second part of the paper, we analyze the mechanisms behind our main result; in particular, we ask why the U-shaped monetary rate path increases banking crisis risk. Narrative accounts of previous financial crises have argued that monetary policy plays a key role.¹³ Recent theoretical work points to subtle links between extended periods of monetary loosening that foster financial vulnerabilities and subsequent monetary rate hikes that, when these financial vulnerabilities are elevated, can trigger a financial crisis.¹⁴ To test these hypotheses in the data, we study the link between the path of monetary rates and a combined measure of financial vulnerabilities from Greenwood and others (2022), namely “the red zone”, defined as the zone of simultaneous high credit and high asset price growth. We show that high credit and asset price growth (red zone) is the overall main mechanism for our results.

We first show that monetary rate cuts over a long period (raw, instrumented, or above and beyond a proxy for the systematic component) strongly raise the likelihood of financial red zones. This credit expansion is consistent with a credit supply mechanism.

The boom in credit volume is accompanied by low credit spreads, and credit booms associated with ex-ante low (vs high) credit spreads are followed by ex-post worse bank outcomes—lower bank stock prices, lower bank profits, and higher loan losses—not only consistent with credit supply but also with high bank risk-taking and credit mispricing.

Moreover, during the strong boom that defines the red zone, bank equity prices and book capital increase in real terms and relative to nonfinancial firms’ equity, thus facilitating the credit supply boom. Furthermore, proxies for bank equity sentiment also increase (also relative to firms’ equity). Consistently, red zones are associated with

13. See, for example, Taylor (2013).

14. See Boissay and others (2026).

predictably lower future bank stock returns, suggesting excessively high bank stock prices during the boom.

We then show that raising monetary policy rates, once in the red zone, strongly increase the risk of a future banking crisis. Moreover, the combination of the two forces—monetary rate paths and red zones—is key. Red zones are only materially associated with future banking crises if monetary rates were cut for long before entering the red zone and, once in the red zone, crisis risk increases substantially only if monetary rates are raised. To summarize these patterns, we show that, if the economy experiences both a U-shaped monetary rate path and a red zone, the three-year crisis probability is close to 40 percent. Experiencing only the red zone or only the U shape leads to crisis frequencies of around 10 percent, close to the unconditional mean. Again, these differences become starker for deep crises, deeper U shapes (relative to the systematic component of monetary policy), and after World War II.

To understand why the combination of U-shaped monetary rates and red zones increases banking crisis risk, in addition to the above results on credit supply and bank risk-taking, we study links between monetary rate hikes, credit and asset price vulnerabilities, and bank performance. We first show that, while raising monetary rates generally reduces credit and asset prices, it leads to a much stronger reversal if credit and asset prices are already elevated. That is, monetary rate hikes trigger a much larger decline in, for example, house prices when house prices previously expanded rapidly (above the red zone threshold).

Second, we show that raising monetary rates after previous cuts leads to substantial stress in the banking sector, which comes in the form of higher bank loan losses, lower bank profits, lower bank stock returns, and a higher risk of a bank equity price crash. Our results are consistent with a credit risk mechanism but offer little support for an interest rate risk mechanism (based on different measures of bank profits and stock returns). This suggests that monetary rate hikes trigger a reversal in financial vulnerabilities that had built up over the long period of monetary rate cuts (including an expansion of credit supply, bank risk-taking, and asset prices), with a crucial role for realized credit risks in the banking sector.

To further validate these findings we use in a more granular dataset and to study loan, borrower, and bank heterogeneity, including a stronger identification of credit supply and bank risk-taking, we conduct a detailed case study of the 2008 crisis in Spain. This crisis is

representative of many historical crises, especially after World War II, as it was preceded by a large bank credit boom related to real estate.

We use loan-level data on the universe of bank loans and defaults granted by Spanish banks between 1995 and 2008.III via the supervisory credit register, matched to firm and bank administrative datasets. Spain also offers monetary policy conditions which, before the banking crisis, were relatively exogenous to macroeconomic developments in Spain. This was so because Spain had been part of a monetary union since 1989 (the European Monetary Mechanism and then the euro), with monetary policy set at euro-area level and—before the crisis—focusing on core euro-area countries such as Germany, whose macroeconomic dynamics differed markedly from those of Spain.¹⁵

Using these data, we first show that long periods of monetary rate cuts are associated with higher bank credit growth, especially for loans granted by ex-ante riskier banks—those with high ex-ante nonperformance loan (NPL) ratios—to ex-ante riskier firms (those in the construction and real-estate sector). As we control for borrowers' unobservables (e.g., time-varying firm-level credit demand) through firm-time and firm-bank fixed effects, results suggest a credit supply (including bank risk-taking) mechanism.

Furthermore, and consistent again with credit supply, we find that firms ex-ante associated with riskier banks not only obtain higher credit volumes but also lower cost of credit, following cuts in monetary policy rates for lengthy periods. Finally, turning to the crystallization of credit vulnerabilities, we show that raising monetary policy rates are associated with a substantially higher likelihood of ex-post bank loan defaults, especially after previous monetary cuts. Effects are, again, larger for loans made by ex-ante weaker banks to ex-ante riskier firms.

Other related research. There is a contemporaneous paper by Grimm and others (2026), which is closely related to my paper above (Jiménez and others, 2026). In this paragraph, I discuss the differences of our paper with respect to this paper, which finds that, when the real monetary rate is below an estimated natural rate over an extended period, crisis risk increases, and credit and asset prices are key channels. Our main differences are the following.

First, we show that not only loose monetary policy but also the subsequent monetary tightening is key for the crisis to take place.

15. See, for example, Maddaloni and Peydró (2011).

Note also that these U-shaped rate dynamics are crucial for banking crises but *not* for noncrisis (even deep) recessions, which suggests that financial mechanisms are crucial.

Second, we show that, even though red zones unconditionally imply a higher banking crisis risk, a closer look reveals that—to materially matter—red zones need to be accompanied by a monetary rate U shape, and the combination of the two forces is crucial. This result is important not only for the monetary policy literature but also for the literature on the determinants of financial crises.

Third, our paper provides a detailed understanding of the mechanisms behind banking crises and U-shaped monetary rates: the long monetary rate cuts induce financial red zones associated with elevated credit supply, bank risk-taking, and mispricing, while subsequent monetary rate hikes trigger banking crises through a strong reversal in credit and asset prices, materialized credit risks, and bank equity crashes. Crucially, both papers are highly complementary, showing that monetary policy dynamics are key for financial stability.

I would also point out that the paper that I have discussed in this section is different from my papers on the so-called risk-taking channel of monetary policy.¹⁶ These papers show in loan-level analysis that monetary rate cuts increase the risk-taking in credit, a key source of financial instability pointed out in the literature. On the other hand, Schularick and others (2021) show that it is monetary rate hikes, not cuts, that increase crisis risk. We instead show that it is the path of monetary rates (the U shape) that matters for banking crises—on their own, neither monetary rate cuts nor hikes are sufficient.

We also provide evidence for the mechanisms behind our main result. The full path of monetary rates is key to the dynamics of credit and asset price cycles. Notably, we find strong credit supply booms (including bank risk-taking) due to too low for too long monetary rates. Then, after monetary rate hikes, there is a strong reversal of credit and asset prices, the materialization of credit risk (i.e., loan losses), and the risk of a bank stock price crash.

In this paper I have discussed the effects of monetary policy before crisis times, or recessions, but monetary policy is also important for financial stability during crisis times. In this case, monetary policy can support credit supply and hence the overall economy. In Jiménez and others (2012), we analyze the impact of monetary policy on the supply of bank credit. Monetary policy affects both supply of and

16. See Maddaloni and Peydró (2011), Jiménez and others (2014).

demand for loans, thus making identification a steep challenge. We therefore analyze a supervisory dataset with loan applications from Spain. Accounting for time-varying firm heterogeneity in loan demand, we find that tighter monetary and worse economic conditions substantially reduce loan granting, especially from banks with lower capital or liquidity ratios. Finally, firms cannot offset the resultant credit restriction by applying to other banks.

2. POLICY IMPLICATIONS

Taken together, the findings in Jiménez and others (2026) point towards a very nuanced view on the use of monetary policy to reduce financial vulnerabilities. Several prior studies have suggested that, in order to deflate booms in credit and asset prices, policymakers could lean against the wind by raising monetary policy rates.¹⁷ Based on our results, however, once in a red zone that followed cuts in monetary policy rates, such a policy action is much more likely to trigger the banking crisis by crystallizing the financial vulnerabilities that built up during the period of monetary loosening.

Even though the previous empirical analysis provides only reduced-form evidence within a positive analysis, without any analysis of the optimal conduct of monetary policy (nor any normative or welfare analysis), the results presented in the previous section point towards several policy options.

First, if policymakers need to raise monetary policy rates to maintain price stability or rein in a nascent financial boom, doing this preemptively—i.e., before the economy enters the financial red zone—substantially attenuates the risks to financial stability.

Second, if policymakers have to raise monetary policy rates while in the red zone, especially if they have cut monetary rates over a long period previously, moderating the monetary raises and keeping their magnitude in line with the systematic policy reaction to GDP and inflation will, again, attenuate crisis risk.

Third, if policymakers need to tighten policy when the economy is already in the red zone, they can rely on other tools, for example, stronger banking supervision or macroprudential policy.

These recommendations are in line with insights from recent theoretical work. In the model of Boissay and others (2026), optimal

17. See Adrian and Liang (2018), Gourio and others (2018), and Greenwood and others (2022).

monetary policy in the presence of endogenous financial crises involves a preemptive response to impending financial booms and a moderation of monetary rate hikes when financial vulnerabilities are elevated. Goldberg and López-Salido (2023) show that, when in a financial boom, the optimal policy response moderates the pace of rate hikes, for example, by committing to hiking rates in the future instead of immediately, and uses macroprudential tools (one way is to tighten supervision) to rein in financial sector excesses.

Once we have shown that there is a clear connection between monetary policy dynamics and financial stability, an important question then is whether central banks should lean against the wind and raise monetary policy rates during an incipient credit and asset price boom. One could argue, following Greenspan's doctrine, that it is much easier to clean the mess after a financial bubble rather than knowing *ex-ante* that we are experiencing a bubble and acting accordingly with monetary policy—in which case monetary policy should not lean against the wind.

However: (i) Financial crises are very costly in terms of output, employment, innovation, political stability, etc. (ii) Financial crises have clear predictors, or even determinants, such as credit booms, especially when these credit booms are in low productivity sectors, including real estate, or in household loans for consumption or to buy real estate, or credit boom to firms in nontradables sectors, as well as complementary determinants of financial crises, such as asset price booms, and foreign debt inflows.¹⁸

On the other hand, leaning against the wind is difficult when the financial crisis may happen only years ahead and is highly uncertain, while the costs of rising monetary rates are borne immediately by the economy. Therefore, it is difficult (for the central bank) to take away the punch bowl while the party is still on and the banks are still dancing, following the metaphors of William McChesney Martin (then Chairman of the Federal Reserve) and Chuck Prince.

Moreover, if monetary policy does affect financial stability while acting in an optimal way for price stability (including business-cycle stabilization), macroprudential policies could adjust and improve some unintended consequences of monetary policy on financial instability. In other words, with two different objectives (price and financial stability), central banks and public policymakers in general could use two different instruments (monetary and prudential policies) following

18. See, for example, Jordà and others (2013, 2015), and Mian and others (2017).

a Tinbergen rule, with monetary policy pursuing price stability and macroprudential policy pursuing financial stability.

There is, however, regulatory arbitrage of (micro- and macro-) prudential policies that reduces their effectiveness; in addition, an important part of the financial system nowadays consists of nonbank credit (financial) intermediaries, which are less subject to macroprudential policies. Moreover, following Stein (2012), then governor at the Federal Reserve Board, monetary policy “gets all the cracks in”, that is, it affects all intermediaries that are (short-term) leveraged, even the unregulated or the less regulated ones.

Furthermore, one could argue that price stability is the best way for monetary policy to improve financial stability. For example, deflation may give rise to Fisherian debt problems (i.e., higher real value of debt, and hence higher debt problems); by contrast, excessive inflation may be seen as a run on the currency, with less trust in the local money and government debt, including the public guarantees for the banking sector, which are fundamental for its financial stability. That is, either very low or very high inflation are bad for financial stability, and hence a monetary policy that pursues price stability is already very important for financial stability.

However, positive supply shocks, for example those stemming from increased globalization (e.g., China in 2001 or immigration), can reduce prices, and central banks may react to this lower inflation with a long-lasting expansionary monetary policy. This, in turn, may create financial imbalances, such as credit and asset price booms. Furthermore, if monetary policy affects the likelihood of a financial crisis, then monetary policy via financial instability may increase the risk of deflation over the medium term, and hence monetary policy should directly care about financial crises insofar as they affect price and business cycle stability.

There are also instances in which a country has limits to affect monetary policy. First, the US monetary policy affects the global financial cycle,¹⁹ especially in emerging markets.²⁰ Second, some countries may have fixed exchange rates against some other currencies, such as the US dollar or the euro, and following the international trilemma, if there are no frictions in international capital flows, local monetary policy is not independent. This was the case, for example, in Spain and Ireland in the 2000–2007 strong boom period. In this case,

19. See Rey (2013).

20. See Morais and others (2019).

macroprudential policies may be the only solution, and within these policies, there may be useful prudential capital controls, especially in emerging economies.²¹

In Fabiani and others (2026), we show that capital controls, by slowing-down firm debt growth in the boom, improve firm performance during crises. More concretely, we exploit a tax on foreign currency (FX) debt inflows in Colombia before the Global Financial Crisis (GFC) and multiple firm-level and loan-level administrative datasets. We find that capital controls reduce FX-debt inflows. Firms with weaker local banking relationships cannot fully substitute FX-debt with domestic debt, thereby reducing firm-level total debt and imports during the boom. However, by pre-emptively reducing firm-level debt, capital controls boost exports and employment during the subsequent GFC, especially for financially constrained firms. Moreover, capital controls do not significantly alter credit allocation between productive and unproductive firms.

Moreover, in Fabiani and others (2022), we study how capital controls and domestic macroprudential policy tame credit supply booms, either directly or by enhancing the local bank lending channel of monetary policy. We exploit credit registry data and the introduction of capital controls on FX-debt inflows and the increase of reserve requirements on domestic bank deposits in Colombia during a boom. We find that capital controls strengthen the bank lending channel. Increasing the local monetary policy rate widens the interest rate differential with the United States; hence, relatively more FX-indebted banks carry-trade cheap FX funds with expensive Colombian peso lending, especially toward riskier firms. Capital controls in a way tax FX debt and break this carry-trade. Differently, raising reserve requirements on domestic bank deposits directly reduces credit supply, particularly for riskier firms, rather than enhancing the bank lending channel. Importantly, banks differentially finance credit with more domestic vis-à-vis more foreign financing; hence, capital controls and domestic macroprudential policy complementarily mitigate the credit boom and related bank risk-taking.

It is also important to discuss the impact of monetary policy, and in general, central banks' liquidity policies, in crisis times. As Lucas and Stockey (2011) argue, lender-of-last-resort (LoLR) policies are crucial for liquidity-based banking crises, so that the policymaker minimizes bank failures due to bank illiquidity rather than bank insolvency.

21. See Fabiani and others (2022, 2026).

However, monetary policy actions beyond liquidity provision via short-term rates and quantitative easing (QE) can also improve credit supply and debt overhang problems,²² thereby supporting consumption, investment, employment, as well as innovation. In consequence, monetary policy can help financial stability in crisis times by improving the real economy via bank credit over the short run and even the medium run. However, there may be some unintended consequences on credit misallocation (zombie lending) by excessively delaying necessary creative destruction during crisis times. Moreover, too much help from central banks and governments may provide the seeds for the next crisis if monetary policy stays too low for too long, consistent with a moral hazard channel.

Monetary policy actions may also be dominated by financial stability concerns and/or there may be a fiscal dominance. For example, as said above, there may be expansive monetary policy for a long period due to positive supply shocks and monetary policy following a narrow Taylor rule setting, or monetary policy may react to a financial crisis by being expansive over a long period, including forward guidance promises and quantitative easing policies. After such a long period of expansive monetary policy, private and public debt may be too high, and in this case, it may be more difficult to then tighten monetary policy, either with higher monetary rates,²³ or QT (such as in 2019 or 2025).²⁴ More broadly, it has been very difficult to exit the abundant liquidity policies post 2008, also shown by the recent Fed policy of reintroducing asset purchases in December 2025 after tensions in the repo market.

In Acharya and others (2022), the authors analyze monetary policy dynamics in terms of the balance sheet of the Fed rather than in terms of monetary policy rates. When the Fed expanded its balance sheet via QE, commercial banks typically financed reserve holdings with uninsured demandable deposits. They also issued credit lines to corporations. In the aggregate, these bank-issued claims on liquidity did not shrink commensurately when the Fed halted QE and turned to QT. Consequently, banks that increased liquidity risk exposure—especially small and regional banks—became vulnerable to liquidity shocks, necessitating further liquidity provision by the Fed.

22. See Bernanke (1993, 2025), and Jiménez and others (2012).

23. See, for example, the failure of Silicon Valley Bank in 2023, and the discussion in Jiménez and others (2026).

24. See, for example, Acharya and others (2022).

The evidence suggests that the expansion and shrinkage of central bank balance sheets have led to liquidity dependence of banks on central banks.

In Darst and others (2025), we show that the effectiveness of unconventional monetary policy is limited by how banks adjust credit supply and manage liquidity risk in response to fragile nonbank funding. For identification, we use granular US administrative data on deposit accounts and loan-level commitments, matched with bank-firm supervisory balance sheets. Quantitative easing increases bank fragility by triggering a large inflow of uninsured deposits from nonbank financial institutions. In response, banks that are more exposed to this fragility actively manage their liquidity risk by offering better rates to insured deposits while cutting uninsured rates. Doing so, they shift away from uninsured to insured deposits. Importantly, on the asset side, these banks also reduce the supply of contingent credit lines to corporate clients. Firms that are reliant on more exposed banks experience an aggregate reduction in the amount of liquidity insurance they enjoy against future shocks. Our analysis reveals that the fragility of deposit funding can disrupt the complementarity between deposit-taking and the provision of credit lines.

Not only do actual monetary policy actions matter or are important, but also the perceptions from economic agents of central bank's future actions. An important policy after 2008 has been forward guidance, but in general, there is an impression in the market that there is a central bank's put to minimize losses in bad states of nature. These perceptions can create excessive risk-taking as potential losses are minimized. Moreover, governments and central banks try to minimize most of the losses after banking distress episodes, as was clear with the failure of Silicon Valley Bank and other mid-sized US banks in 2023. For instance, some massive deposits from, for example, the stablecoin company Circle or Peter Thiel were guaranteed, despite the huge size of their deposits, hence there is little incentive for bank disciplining from even very large depositors. On the other hand, there was a bail-in of CoCos in the failure of Credit Suisse, but other policymakers said immediately afterward that they were not going to pursue similar policy actions. Moreover, there are calls to reduce not only the complexity of current banking regulations but also potentially the level of regulation. Hence, it is not clear that regulation is the only defense to financial instability, and hence there is a more active role for monetary policy in taking into consideration financial stability.

3. CONCLUDING REMARKS

In this paper, I have discussed whether and how monetary policy affects financial stability, in particular of the banking sector. In particular, I review in detail the evidence on the impact of monetary policy and banking crises, as well as the different associated mechanisms such as, during the boom—such as credit and asset price booms, bank risk-taking, and credit supply versus demand—and, during the bust—such as credit and interest rate risk, bank runs, as well as the collapse in credit and asset prices. Moreover, I discuss whether monetary policy should take into account financial stability issues as well as whether monetary policy should lean against the wind, or whether financial stability considerations should be dealt with only through macroprudential policies. I also discuss some issues which are more relevant to emerging economies, for example, the US monetary policy and the global financial cycle, the role of prudential capital controls.

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LONG-RUN INTEREST RATES: PAST, PRESENT, AND FUTURE

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“It is utterly impossible [...] for the rich to save as much as they have been trying to save, and save anything that is worth saving.”

Marriner Eccles, former Chair of the US Federal Reserve

This paper provides a structural explanation for the persistent global rise in debt and declining long-run interest rates since the 1980s. Figure 1 shows the long-run evolution of two key financial variables in the post-WWII period for the United States: the total credit-to-GDP ratio and 10-year real interest rate, as published by the Cleveland Federal Reserve.¹ Total credit includes both public debt issued by the federal government and private debt taken on by households and the nonfinancial corporate sector. After remaining relatively stable in the post-WWII years, total debt relative to GDP almost doubled since 1980. The situation is remarkably similar across the world as well, with global debt relative to GDP accelerating sharply since 1980.² The large rise in debt globally after the 1980s was accompanied by a fall in interest rates—that is, the price of debt. The ten-year real safe rate declined steadily from a high of around six percentage points in the early 1980s to zero in the post-2008 era, before rising in recent years.

Is there a unified explanation for the rapid and persistent rise in debt and the fall in interest rates that started in the 1980s? Why is it

This article is based on the keynote speech given at XXVII Annual Conference of the Central Bank of Chile in 2024. I thank the conference participants for many helpful questions and comments, and Amil Mumssen for superb research assistance.

1. The real interest rate series starts in 1982, as the very volatile inflation rate environment before that makes it difficult to construct a reliable series.

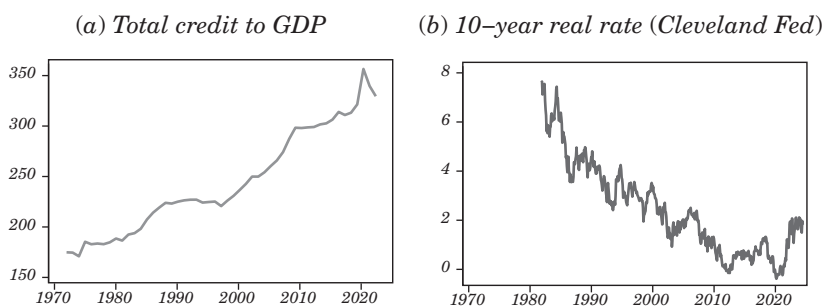
2. See International Monetary Fund (2024).

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that, despite rising debt that posed significant economic risks—such as contributing to the Great Recession of 2008—the total debt-to-GDP ratio continued to rise? In this article, I will argue that there is a possible structural explanation for this: the rise in extreme inequality and the rise in “financialization” after the breakup of the Bretton Woods system. As I explain, these structural shifts have led to a debt-dependent economy. Even the severe 2008 crisis, rooted in excessive borrowing, failed to reduce total debt levels. Instead, overall debt continued rising, as sovereign public debt increasingly replaced private debt growth after 2008. Today, public debt has reached alarming new heights worldwide, notably in the United States, the world’s largest economy. The rise in total debt, the fall in interest rates, the shift from private to public debt after 2008, and the current fiscal crisis in the United States and beyond can all be connected by a single structural explanation: the rise of extreme inequality and financialization.

The world seems “addicted” to debt. Today, there is twice as much debt for each dollar of global income as in 1980. Because income ultimately services debt, this sharp rise in debt relative to income naturally raises concerns about debt sustainability and fragility. What factors drive this global surge in debt? One approach to addressing this question is to determine whether the increase stems primarily from demand-side or supply-side forces in credit markets.

Figure 1. Credit-to-GDP Ratio and 10-Year Real Rate



Sources: IMF Global Debt Database, Federal Reserve Bank of Cleveland.

The left panel of Figure 1 illustrates the growth in total US debt-to-GDP ratio over time, showing an increase from 187 percent in 1980 to 329 percent in 2022, consistent with global trends. This total debt comprises private household debt, private nonfinancial corporate debt, and public government debt. In turn, the right panel of the figure presents the average cost of debt, proxied by the 10-year real interest rate on government bonds provided by the Federal Reserve Bank of Cleveland. The 10-year real rate fell from 8 percentage points in 1980 to zero by 2020, before rising in the wake of the pandemic. An eight-percentage-point decline in the real rate is extremely large. Together, the two panels in Figure 1 offer critical insights into whether supply-side or demand-side factors predominantly drive the observed debt dynamics.

All else equal, if the credit-to-GDP expansion had been driven by increased demand, interest rates would have risen. Instead, interest rates have experienced a substantial and persistent decline from 1980 to 2020. The combination of rising debt and falling interest rates strongly indicates that the primary factor behind increased debt is an expansion in credit supply. Furthermore, because these dynamics have persisted over decades, they imply that structural shifts in the economy underpin the growth in credit supply.

1. DEBT AND INEQUALITY: THE SAVING GLUT OF THE RICH

What factors drove the sustained increase in credit supply? A critical structural shift coinciding with accelerated credit growth is the dramatic rise in extreme inequality, both in the United States and globally. In the United States, the income share of the top 1 percent rose from 10 percent in 1980 to 20 percent in 2023—a 10-percentage-point increase in national income share. Similar trends are evident in other major advanced economies. Between 1980 and 2023, the top 1 percent income share rose by 7 percentage points in the United Kingdom, 4.5 percentage points in France, 1.5 percentage points in Germany, 9 percentage points in China, and 2.9 percentage points in Japan.

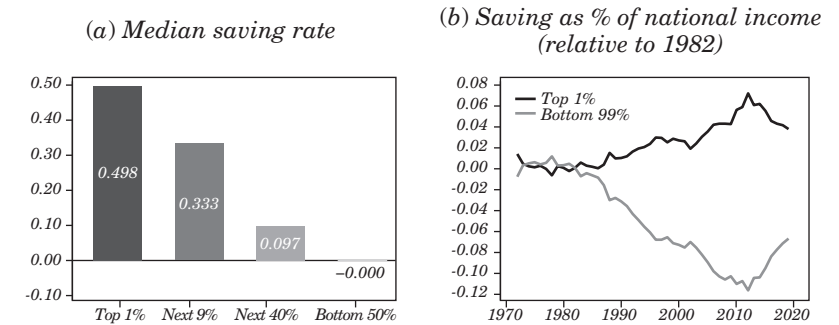
The global rise in extreme inequality significantly boosts the availability of savings because the wealthiest households save at much higher rates than the rest of the population. The left panel of Figure 2 shows median saving rates by wealth-percentile groups in the United States, derived from the Survey of Consumer Finances for nationally representative households tracked from 1983 to 1989. It reveals stark disparities: the bottom 50 percent of households essentially live

hand-to-mouth, with zero savings. Households in the 51st–90th percentile save at a rate of 9.6 percent, and those in the 91st–99th percentile save at 27.9 percent. In contrast, the saving rate for the top 1 percent reaches 41.7 percent, over six times higher than that of the rest of the population.

The substantial gap in saving rates between the top 1 percent and everybody else means that as income distribution shifts toward the wealthiest households, the savings supply from this group significantly expands. This is precisely what occurred in the United States, beginning in the 1980s. The right panel of Figure 2 illustrates the ten-year moving average of total savings contributed by the top 1 percent as a share of national income, with values normalized relative to 1983 levels. These annual savings figures for the top 1 percent are derived from tax-filing data using the imputed wealth methodology developed by Mian and others (2020).

Between 1963 and 1983, savings contributed by the top 1 percent as a share of national income remained stable. However, precisely as inequality began to rise, these savings significantly increased. At their peak, annual savings from the top 1 percent alone rose by more than 6 percent of national income. We label this substantial rise the “Saving Glut of the Rich”. The annual savings flow from the top 1 percent increased by 3.4 percentage points of national income on average after 1982. In 2024-dollar terms, this represents an additional savings flow coming from the wealthiest top 1 percent of over \$800 billion every year from 1982 onward.

Figure 2. Saving across the Wealth Distribution



Sources: US Federal Reserve System, Distributional National Accounts, Survey of Consumer Finances.

Importantly, the rise in the Saving Glut of the Rich did not stem solely from rising inequality; the savings rate of the top 1 percent itself climbed further over the last three decades, amplifying their total contribution to national savings. In particular, the top 1 percent savings rate rose from 42.9 percent during 1963–1982 to 53.6 percent afterwards. An increase in the savings flow of such magnitude coming from the very rich must be absorbed elsewhere in the economy. So, where did these additional savings from the top 1 percent flow to?

Let θ_{top1} and θ_{bot99} represent total private savings from the top 1 percent and the bottom 99 percent, respectively. The national accounting identity linking these variables is given by:

$$\theta_{top1} + \theta_{bot99} = I^n + F - S^g$$

where I^n denotes net investment, F the current account, and S^g government savings. This identity must hold every year. While private savings rapidly increased as a share of national income, net investment as a percentage of national income remained flat or even declined. Additionally, the United States consistently ran a current account deficit, and government deficits did not expand significantly until after 2008. This raises the question: Where did the increased savings from the top 1 percent ultimately go?

The right panel of Figure 2 provides the answer. The increased savings from the top 1 percent were absorbed by the bottom 99 percent through borrowing (and thus dissaving). In fact, the rise in dissaving by the bottom 99 percent exceeded the additional savings from the top 1 percent, as the lower-income group also absorbed the expanding US current account deficit driven by the global saving glut.

A crucial insight emerges from this analysis: rising extreme inequality generated substantial surplus savings from the wealthiest households. Importantly, these savings did not fuel increased real investment. Instead, they financed borrowing and dissaving by other households. The financial sector facilitated this process, and it remains an open and important question why it directed these surplus savings into debt-driven consumption rather than productive investment.

2. THE INDEBTED DEMAND FRAMEWORK

Mian and others (2021) provide a theoretical framework explaining how the high saving propensity of the wealthy leads to increased debt and declining interest rates as income concentration among the top 1

percent grows. A crucial component of their model is non-homothetic preferences in saving decisions, represented by explicitly incorporating wealth into the savers' utility function. As inequality deepens and a larger portion of national income flows to households with strong wealth-driven saving preferences, the credit supply expands and drives equilibrium real interest rates downward.

This increased supply of credit from the wealthy reduces interest rates, which in turn inflates asset prices. Higher asset values enhance collateral, which enables the broader population to borrow more and increase consumption, thus creating debt-driven "indebted demand." However, this debt-driven demand expansion is unsustainable in the long term, as growing interest burdens gradually suppress future demand. Consequently, maintaining indebted demand necessitates a continual decline in the long-run equilibrium interest rate, or r^* . In short, rising extreme inequality expands the supply of credit coming from the top 1 percent. These increased savings have not gone into more productive investment, but rather toward borrowed consumption. However, borrowed consumption—or indebted demand—puts downward pressure on future interest rates as indebted consumers try to service their debt burdens. The indebted demand framework thus offers an integrated explanation for rising inequality, growing dependence on debt-driven consumption, and persistently falling interest rates.

The central insight of the indebted demand framework is illustrated in Figure 3, which plots the long-run equilibrium between the demand for and supply of savings. The intersection of these curves determines the long-run natural interest rate, denoted by r . Holding other factors constant, a decrease in r increases the demand for debt, thus rendering the demand curve downward-sloping, as is standard in most economic models.

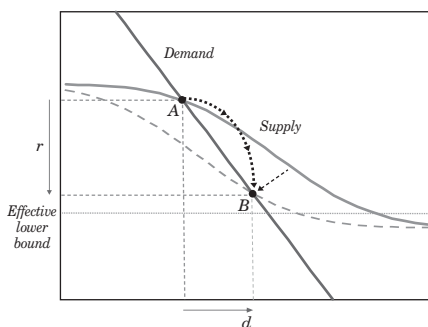
Notably, the supply curve for savings also slopes downward. This occurs because, at lower levels of wealth—when aggregate asset and debt holdings are relatively small—the economy behaves similarly to a traditional Ramsey model, where the interest rate is anchored by a relatively high average discount rate. As the economy grows richer, however, households desire to save a larger fraction of their permanent income due to non-homothetic preferences. This preference-driven increase in desired savings reduces the effective discount rate, which leads the long-run equilibrium interest rate along the savings supply curve to decline.

Consequently, the savings supply curve is downward-sloping in an economy characterized by high savings rates among the wealthy. The initial long-run equilibrium, denoted by point A in Figure 3, can be thought of as representing conditions around 1980. Now consider a permanent increase in income inequality, specifically an increase in the income share captured by the top 1 percent.

With non-homothetic preferences, rising inequality shifts the long-run savings supply curve inward. For any given level of total assets (equivalently, total debt, since debt is the sole asset in this simplified economy), higher inequality reduces the effective discount rate because a larger share of income accrues to households inclined to save more. This inward shift of the supply curve moves the long-run equilibrium from point A to point B. The black boxes depict the short-run transitional dynamics as the economy adjusts between these steady states. Thus, the indebted demand framework effectively explains the key long-run correlation observed since 1980, rising debt accompanied by declining interest rates.

Another significant structural shift beginning in the 1970s, following the collapse of the Bretton Woods system, was the increased financialization of the global economy. Financial markets experienced rapid liberalization during the 1980s, as numerous countries transitioned to flexible exchange rates and reduced barriers to cross-border capital flows. Concurrently, the United States underwent substantial financial deregulation, including bank-branching liberalization, making capital markets increasingly central. Consequently, financial institutions began to rely more heavily on capital markets through practices like securitization and wholesale financing.

Figure 3. Rise in Inequality



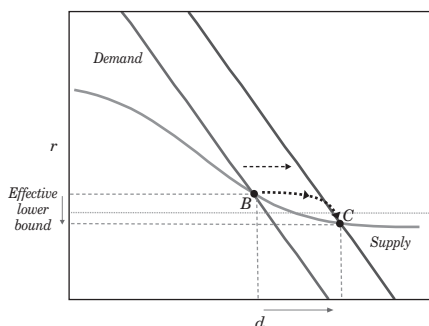
Source: Author's calculations.

A major effect of this financialization was the emergence of easier access to credit. Borrowers could more readily obtain loans, particularly by leveraging assets such as homes and automobiles. Unsecured credit also expanded notably with the proliferation of credit cards and related financial products. From a macroeconomic perspective, financialization can be conceptualized as shifting the long-run demand curve for credit outward, thus enabling borrowers to pledge a larger share of their future income.

Figure 4 shows the effects of this shift in credit demand, starting from equilibrium point B in Figure 3. Remarkably, increased financialization produces the same long-run effects as heightened inequality—a permanent rise in credit demand elevates the steady-state level of borrowing and simultaneously *lowers* the long-run equilibrium interest rate. The intuition that increased credit demand reduces the long-run equilibrium interest rate may seem counterintuitive, yet it is fundamental to the indebted demand framework.

Initially, higher credit demand raises interest rates due to increased borrowing—a conventional short-run response depicted by the black boxes in Figure 4, which illustrates the economy's transition from point B to the new equilibrium C. This short-term interest-rate increase reflects the immediate stimulative effect of additional borrowing and spending. However, increased borrowing eventually constrains future demand as borrowers repay loans at higher interest rates. Because creditors typically represent wealthier individuals with higher savings rates, debt repayments redistribute income toward households less inclined to spend, thereby reducing aggregate demand. The redistributive drag on demand ultimately dominates and thus drives the long-run equilibrium interest rate downward. The economy settles into a new equilibrium C characterized by elevated debt-to-GDP ratios and lower equilibrium interest rates.

Central to the indebted demand dynamic—which drives credit upward and interest rates downward amid rising inequality or rising financialization—is the reality that the private borrowing rate R^{priv} typically exceeds the economic growth rate G . Both macroeconomic models and empirical evidence confirm that households consistently borrow at rates higher than the growth rate of average incomes. This fundamental imbalance makes increasing indebted demand inherently unsustainable unless interest rates continuously decline.

Figure 4. Rise in Financialization

Source: Author's calculations.

But what happens if rising inequality and consequent debt dependency drive the equilibrium interest rate below the effective lower bound (ELB)³ This is illustrated in Figure 4 with the equilibrium interest rate in C being below the effective lower bound for the economy. Under such conditions, the economy falls into a liquidity trap and experiences a demand-driven recession. Crucially, this liquidity trap becomes persistent—as long as high inequality and substantial savings among the top 1 percent continue to exert downward pressure on interest rates, the economy remains trapped indefinitely in a debt-driven liquidity crisis. Thus, unlike typical Keynesian models, the liquidity trap in an indebted demand world is permanent.

3. FISCAL POLICY: THE GOLDBLOCKS CONUNDRUM

Can fiscal policy help an economy that has hit the effective lower bound and becomes trapped in a permanent liquidity crisis? If governments were forced to borrow at the same interest rates as private households, the answer would be no. However, governments in advanced economies typically borrow at significantly lower rates than private entities, even after adjusting for credit risk. The lower cost that the government enjoys is often referred to as *convenience yield*.

Mian and others (2025) demonstrate that if the government's borrowing rate is sufficiently low—specifically, $R^{gov} < G$ —then running large and persistent primary deficits can effectively lift

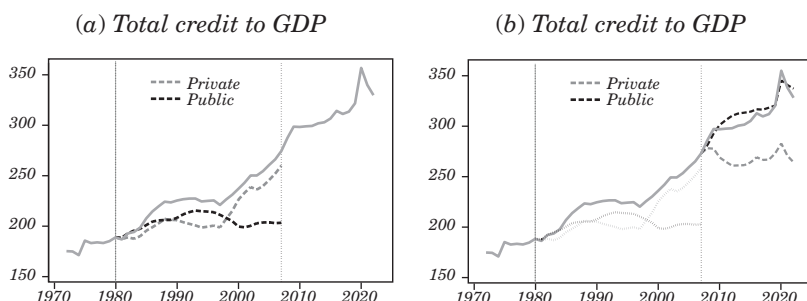
3. The ELB can be the traditional zero lower bound (ZLB) on the short nominal rate set by a central bank.

the economy out of the liquidity trap. When private debt no longer generates sufficient demand, fiscal policy can step in by maintaining sustained primary deficits. Figure 5 illustrates precisely this scenario, highlighting how the US government significantly expanded deficits following the 2008 financial crisis as private households faced pressure to deleverage and interest rates hit zero.

The left panel of Figure 5 decomposes the growth in total US credit since 1980 into private credit (household and nonfinancial corporate) and public credit (government). The graph shows that, between 1980 and 2008, it was private sector borrowing that primarily drove credit expansion. However, the right panel of Figure 5 shows that after the onset of the Great Recession—when the heavily indebted private sector could no longer sustain borrowing—large government deficits stepped in to maintain demand. Indeed, all credit growth since 2008 has been due entirely to rising government debt.

The sharp reliance on government debt to generate demand after the Great Recession is evident in the data. Between 1980 and 2006, the US government maintained a nearly balanced primary budget, averaging a primary deficit of only 0.02 percent of GDP. In sharp contrast, from 2007 onward, the government's average primary deficit increased dramatically to 4.3 percent of GDP. This sudden, substantial rise in primary deficits reflects the structural economic necessity to generate debt-driven demand.

Figure 5. Credit-to-GDP Ratio Decomposition by Private and Public



Source: IMF Global Debt Database.

When $R^{gov} < G$ in an economy constrained by the effective lower bound, governments have the capacity to run fiscal deficits without the need to finance these deficits in the future, thanks to the expansionary impact of government spending. However, this borrowing capacity is not unlimited. Governments face a downward-sloping demand curve for their debt, characterized by the semi-elasticity of borrowing costs with respect to amounts borrowed, denoted as ϕ .

While the convenience yield grants governments a low cost of borrowing, the increasing borrowing relative to GDP eventually raises overall financing costs, with incremental costs determined by ϕ . Extensive empirical research has measured this elasticity in advanced economies. Mian and others (2025) demonstrate that once a government accumulates sufficient deficits to escape the liquidity trap, any additional debt will push up interest rates. Specifically, governments can theoretically maintain primary deficits as long as $R^{gov} < G - \phi$, without incurring future fiscal adjustments through increased taxes or reduced spending. However, beyond this threshold, even if $R^{gov} < G$, the condition $R^{gov} < G - \phi$ implies that governments again face conventional trade-offs due to rising deficits.

In a world characterized by indebted demand and constrained by the effective lower bound, governments face a “Goldilocks zone” on fiscal deficits, in which deficits must be sufficiently large to avoid the effective lower bound, but not so large as to necessitate painful structural fiscal adjustments in the future. Figure 6 illustrates the Goldilocks zone in a debt-deficit diagram. The locus of the arc refers to all debt-deficit combinations that are sustainable in the long run, given the possibility of $R^{gov} < G$. For moderate permanent primary deficits, the government can sustain a constant debt-to-GDP ratio (which is the x-axis in the figure). This reflects the “free lunch” that opens up due to the presence of the convenience yield.

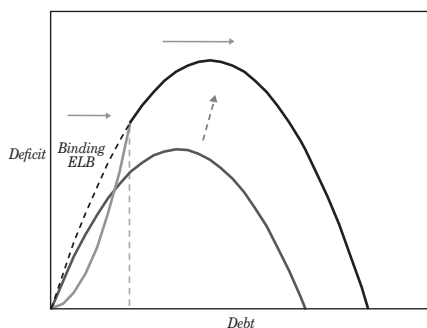
However, because the government faces a downward-sloping demand curve, it cannot run too large a primary deficit forever. The maximum primary deficit is denoted by the maximum height of the arc, which reflects the maximum permanent primary deficit and an interest rate on government borrowing given by $R^{gov} = G - \phi$. Any primary deficit above it is unsustainable in the long run. Figure 6 also shows how a rise in inequality expands fiscal space and makes the presence of the effective lower bound more likely. Since government bonds are held by the rich in equilibrium, an increase in inequality expands the demand for government debt, thus raising the convenience yield and making it easier for governments to fund deficits.

The debt-deficit locus thus expands outwards as inequality rises. At the same time, for reasons already mentioned, increasing inequality pushes aggregate demand down, which opens up the possibility of liquidity traps. Thus, fiscal policy is *required* to run sufficiently high deficits in order to prevent the economy from dipping into the ELB environment. This is reflected by the red kinked line in the debt-deficit diagram: fiscal policy must maintain deficits above the gray line to avoid the liquidity trap.

Our calibration using recent US data indicates that the United States may have exceeded this optimal range in recent times. The current combination of borrowing costs and deficit levels suggests the US economy is now incurring tangible risks from maintaining excessive deficits. The data suggest that the United States will eventually have to undergo some fiscal adjustment, through a combination of higher revenues and reduced spending.

This reliance on debt-driven demand thus introduces a new type of economic fragility: fiscal policy must navigate a narrow path. On one hand, very small deficits risk plunging the economy into recession and hitting the effective lower bound. On the other hand, deficits that become excessively large raise borrowing costs and heighten debt-sustainability concerns, which potentially trigger self-reinforcing financial pressures.

Figure 6. Deficit-Debt Diagram – Rise in Inequality



Source: Author's calculations.

Even if a government carefully calibrates fiscal policy to remain within the Goldilocks zone, external factors can shift its boundaries, triggering the need for continuous adjustments. For instance, increased inequality could expand fiscal space by raising demand for government bonds. Conversely, if top-income savers scale back or inequality decreases, demand for bonds might weaken and push interest rates upward while narrowing fiscal capacity. Moreover, the convenience yield itself can fluctuate due to speculative market forces; asset prices are known to deviate from their long-term fundamentals—a phenomenon known as the “excess volatility puzzle”.

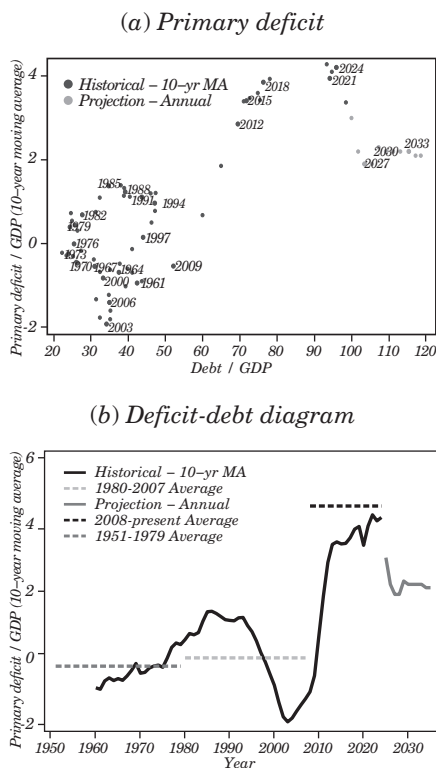
Governments seeking to remain within the Goldilocks range must thus be prepared to adjust fiscal policy proactively in response to potentially adverse market shifts. Fiscal policy management will need to be highly adaptive and nimble. However, doing so effectively is very difficult in practice. In reality, fiscal policy decisions are not made by technocrats in isolation; they are deeply influenced by political dynamics. Political gridlock, disagreements, and delays in policy decisions are common, and it is typically easier for governments to expand fiscal deficits than to adopt the often unpopular measures required to reduce them.

The upper panel of Figure 7 plots the ten-year moving average of primary deficit-to-GDP ratio for the United States. This country has had a primary balance *on average* in the post-WWII period until 2008. However, there has been a massive rise in primary deficits since then. The United States has run an average primary deficit of 4.5 percentage points of GDP since 2008. While the Congressional Budget Office (CBO) projects long-run primary deficit to settle at around 2 percentage points of GDP under current law, there is considerable uncertainty around it.

The lower panel of Figure 7 plots the deficit-debt diagram for the United States since WWII. It highlights the unusual current fiscal position for this country. Both the primary deficit-to-GDP and debt-to-GDP ratios are at historic highs and, as our calibration suggests, quite likely outside of the sustainable long-run path.

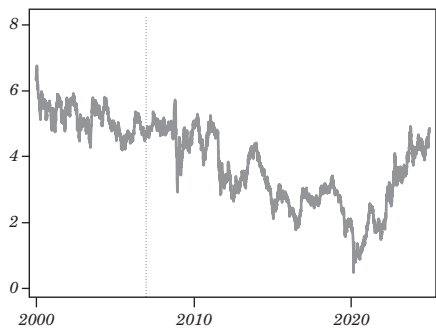
The bottom line is that relying on fiscal policy to address structural problems linked to rising inequality carries substantial risks. Indeed, there are compelling reasons for heightened concern about fiscal sustainability now. A sustained primary fiscal deficit exceeding two percent of GDP may pose significant debt sustainability risks for the United States. In recent years, the US deficit has consistently surpassed this threshold even amidst a relatively tight labor market, thus prompting markets to raise long-term interest rate expectations.

Figure 7. Primary Deficit and Debt



Source: Congressional Budget Office.

Figure 8. 7–10 Forward Rate



Source: US Federal Reserve System.

Figure 8 illustrates the 7–10-year forward interest rates for the United States from 2000 through early 2025. After declining for decades, long-term interest rate expectations reversed sharply following the substantial fiscal expansions during the Covid-19 crisis. These expectations have now risen to levels not seen since before the 2008 Great Recession. The surprise inflation shock after the pandemic, continued large deficits, and heightened political risks in the aftermath of the 2024 elections have all contributed to higher future interest rate expectations.

4. LOOKING AHEAD

A key concern is whether the United States will be able to maintain its exorbitant privilege, or convenience yield, on government bonds. Indeed, the recent “Liberation Day” tariff announcement coming from the Trump administration has sent shock waves around the world. The US dollar has weakened, and many are questioning whether the country will maintain its financial advantage. If this advantage diminishes—due to geopolitical tensions, war, climate-related events, or declining confidence among global investors—, real interest rates could rise further. This would in turn threaten the sustainability of current fiscal deficits as well as private debt. Governments may then resort to financial repression, implicitly taxing other economic sectors to create fiscal space, which would negatively affect long-term growth prospects.

While the indebted demand framework illustrates how public debt can substitute for private debt to sustain aggregate demand in low-interest-rate environments, several risks could disrupt this equilibrium. Erosion of convenience yields, severe external shocks, or even a reversal in extreme inequality could push real rates sharply higher, thus intensifying fiscal sustainability concerns and elevating debt burdens. Today, the global debt-to-GDP ratio is at an unprecedented high, and rising interest rates reflecting market anxiety about government fiscal stability pose significant risks for the world economy.

The global economy’s deepening addiction to debt—fueled by structural imbalances arising from extreme inequality—presents a profound and escalating long-term threat. Rather than confronting the root causes of unequal economic growth, policymakers have increasingly relied on debt-financed consumption to sustain demand. This reliance on debt-driven growth is fundamentally unsustainable

and leaves the world economy dangerously vulnerable. Until we directly address the underlying drivers of inequality, global economic stability will remain fragile and continuously exposed to the risks of a deeply indebted world economy.

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THE IMPACT OF CLIMATE CHANGE AND GEOPOLITICAL TENSIONS ON LONG-TERM INTEREST RATES

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Over the past four decades, estimates of the neutral real interest rate (r^*) appear to have trended downward across both advanced and emerging economies in a broadly synchronized manner. This secular downturn has been documented using a wide range of methodologies, including reduced-form trend extraction, semi-structural models, and asset-price-based measures, and appears robust across countries and estimation approaches. A large literature has emerged to explain this phenomenon, emphasizing structural forces that have persistently shifted the global saving–investment balance. Prominent explanations include demographic aging and rising longevity, which have increased desired saving relative to investment;¹ the global savings glut associated with emergingmarket reserve accumulation and rising income inequality;² a sustained decline in trend productivity growth;³ increasing market power and weaker competitive pressures that have

1. Carvalho and others (2016), Gagnon and others (2021); Auclert and others (2021).

2. See Bernanke (2005), Mian and others (2020).

3. See Summers (2016).

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depressed investment demand;⁴ the growing importance of intangible capital;⁵ and a heightened demand for safe and liquid assets.⁶ Together, these forces provide a coherent account of the sustained downward pressure on equilibrium real interest rates observed since the early 1980s, as synthesized in Obstfeld (2025), Carvalho and others (2025), and Rachel (2025), among others.

In this paper, we argue that this secular decline in r^* has come to an end. Consistent with this view, Carvalho and others (2025) find that demographic pressure on rates has moderated since the pandemic, while fiscal variables have begun exerting upward pressure—a shift that the forces documented in this paper are poised to amplify substantially. We identify two dominant drivers behind this shift. The first is climate change, which—through the scale of required mitigation and adaptation—entails an unprecedented and durable increase in global investment demand spanning energy systems, infrastructure, industry, transport, agriculture, and climate resilience. Of course, as the climate mitigation and adaptation expenses—necessary to protect *physical* capital—continue to be delayed, the large spending needs seem increasingly unlikely in the coming years. However, this only increases the amount of expenses that will be needed in the medium term, but mainly to reconstruct destroyed capital due to physical damage. The second driver is the rise in fiscal spending associated with escalating geopolitical tensions, manifested in a weakening of long-standing alliances, rearmament cycles, higher defense investment, and increased strategic public expenditure across both advanced economies and emerging geopolitical blocs. All these forces operate independently in origin but additively in their macroeconomic effects, jointly shifting the global investment schedule outward.

To assess the quantitative significance of these forces, the paper proceeds in three steps. First, we develop an organizing framework based on a long-run saving–investment equilibrium interpretation of r^* , which allows us to map structural shocks into permanent changes in equilibrium real interest rates. Within this framework, we compile and harmonize estimates of climate-related investment requirements from a wide set of institutional sources, constructing scenarios for the scale and timing of additional global investment needed to meet

4. Caballero and others (2017), Eggertsson and others (2019).

5. See Rachel and Summers (2019a).

6. See Bernanke (2005), Caballero and others (2016, 2017), Del Negro and others (2017).

alternative climate targets. We show that even conservative scenarios imply investment flows several percentage points of global GDP above recent historical norms over the coming decade.

Second, we document the magnitude and persistence of the ongoing geopolitical rearmament cycle. Using historical evidence on the macroeconomic consequences of wars and military buildups, together with current and announced defense spending plans, we quantify the implied outward shift in global investment demand. We further show that, unlike past episodes, the current cycle begins from a special adverse fiscal starting point characterized by historically high public debt, large structural deficits, rigid social spending commitments, constrained monetary financing capacity, and a weakening external demand for safe sovereign assets. These conditions increase the impact of new spending on long-term interest rates. We complement this accounting exercise with financial-market evidence, including event studies, structural VAR decompositions, and commodity price dynamics—showing that markets have already begun to reprice long-term yields in response to geopolitical risk and fiscal expansion.

Finally, we assess the implications for the neutral rate through a calibrated heterogeneous-agent New Keynesian (HANK) model. We quantify the increase in r^* required to stabilize public debt in the face of higher climate- and defense-related borrowing and evaluate whether plausible increases in precautionary saving induced by heightened risk could offset these pressures. The results indicate that, while uncertainty and risk may mitigate the rise in equilibrium rates, they are unlikely to fully counteract the effect of the scale of public investment and debt issuance implied by the new structural environment.

Our analysis contributes to and connects several strands of the literature. It builds on work documenting the longrun decline in the neutral real interest rate and its structural drivers—including demographics, productivity, inequality, market power, and safeasset demand—as emphasized in both academic and policy contributions.⁷ At the same time, it complements a growing body of research highlighting the rising importance of fiscal policy, public debt dynamics, and safeasset supply in shaping equilibrium real interest rates, particularly in environments characterized by elevated debt

7. See Holston and others (2017), Del Negro and others (2017), Rachel and Smith (2015), Summers (2016), International Monetary Fund (2023).

levels and constrained fiscal space.⁸ The paper also relates to emerging research on the macroeconomic and financial implications of climate transition risks and geopolitical fragmentation, which stresses the role of largescale public investment needs, heightened uncertainty, and structural rearmament cycles.⁹ By offering a unified framework that jointly analyzes climaterelated investment, geopolitical forces, fiscal constraints, and financialmarket pricing—rather than treating them in isolation—the paper provides a coherent explanation for why natural interest rates are likely to remain structurally higher than they were in the prepandemic, prerearmament era.

The paper proceeds as follows: Section 1 describes the conceptual framework we use to analyze shifts in long-run investment (funding needs) and savings (supply of funding) that may affect neutral rates. Section 2 presents projections of future spending to mitigate and adapt to climate change risks. Section 3 discusses how geopolitical tensions and wars have affected fiscal spending in previous episodes. Section 4 argues that the current starting point, in terms of fiscal space, is unusually tight, which means that the sensitivity of interest rates to larger funding is higher today than in the past. In this vein, Section 5 presents evidence of the current effects of higher fiscal spending on interest rates. Section 6 argues, using a model, that the upward pressure on neutral interest rates exerted by larger fiscal expenditures will not likely be offset by an increase in precautionary savings arising from larger idiosyncratic shocks faced by agents. Finally, Section 7 concludes.

1. NEUTRAL INTEREST RATE: CONCEPT AND ESTIMATION

The neutral interest rate (r^*), also referred to as the long-run equilibrium real interest rate, is defined as the real rate of interest consistent with an economy operating at full employment and with inflation remaining stable at its target level. In this sense, r^* represents the rate at which monetary policy is neither expansionary nor contractionary over the medium to long term.

The neutral rate is not directly observable and must therefore be inferred from observable macroeconomic and financial variables.

8. See Caballero and others (2016, 2017), Rachel and Summers (2019b), Ferreira and Shousha (2023), Blanchard (2023).

9. See Nabuurs and Mrabet (2022), Mongelli and others (2024), Caldara and Iacoviello (2022), Hall and Sargent (2022, 2025).

A variety of methodologies have been developed for this purpose, often yielding estimates that differ across approaches. In central banking practice, the estimation of r^* plays a key role in defining the neutral monetary policy rate in real terms, which serves as a benchmark for the policy interest rate in the absence of cyclical considerations.

The selection of methodologies used by the Central Bank to estimate the neutral rate is guided by several criteria: (i) consistency with methodologies previously employed, in order to preserve coherence over time; (ii) the extent to which these methodologies are used by other central banks; (iii) their applicability to the Chilean economy; and (iv) the degree of uncertainty associated with the inferred level of the neutral rate. Based on these considerations, three main approaches are employed.

The first approach relies on direct observation of long-term market interest rate expectations. Under this perspective, r^* can be interpreted as the level that the policy rate would converge to in the absence of shocks. It is generally assumed that, over horizons of five to ten years, the cyclical effects of transitory shocks dissipate. Consequently, the expected real interest rate over this horizon provides a plausible approximation of r^* . This measure is derived from financial asset prices, after adjusting for term premia.

The second approach infers the neutral rate from the joint dynamics of inflation and real economic activity, following the methodology proposed by Holston and others (2017) widely used across central banks. This framework estimates the trend component of the real interest rate using information from output, inflation, and interest rates, subject to restrictions grounded in economic theory. These restrictions link economic activity to inflation dynamics and relate the neutral rate to underlying trend growth factors. Estimates obtained using this methodology suggest a declining trend in the neutral rate in recent years. However, it is important to emphasize that the degree of uncertainty surrounding these estimates is substantial.¹⁰

Finally, the third approach infers the trend neutral rate by incorporating information from inflation and a broad set of financial asset prices. Following the methodology developed by Del Negro and others (2017), this framework estimates the neutral rate using observed asset prices, inflation outcomes, and market expectations, while imposing theoretical restrictions and common trend assumptions

10. See Aldunate and others (2019).

across variables. This approach allows financial market information to play a central role in identifying the long-term equilibrium real interest rate.

1.1 A Saving–Investment Framework for the Secular Trend in r^*

In this section, the saving–investment ($S - I$) equilibrium framework is employed to analyze the forces operating on the demand for loanable funds (investment) and the supply of loanable funds (savings). Within this framework, several structural forces—such as demographic change, income inequality, and the scarcity of safe assets—are identified as key drivers that have shifted the global supply of savings, while changes in market power have altered the demand for investment.

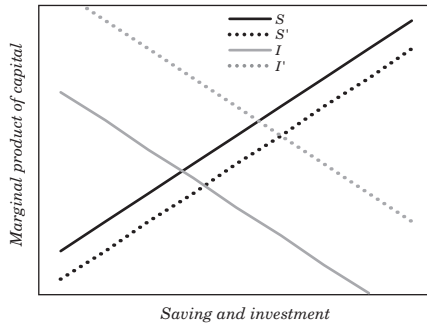
To study the secular trend in the neutral real interest rate (r^*), we adopt a longrun equilibrium perspective in which the real interest rate is determined by the intersection of desired saving and desired investment in the absence of transitory shocks (Figure 1). This approach combines the intuition of the loanable funds’ framework with modern general equilibrium models and can be interpreted as a reducedform representation of the intertemporal equilibrium. Formally, the equilibrium condition is given by

$$S(r^*; Z_S) = I(r^*; Z_I),$$

where $S(x)$ denotes desired saving, $I(x)$ desired investment, Z_S and Z_I are vectors of structural determinants—such as demographics, inequality, trend growth, global financial conditions, and fiscal policy—and r^* is the equilibrium real interest rate. Under standard assumptions, desired saving is increasing in the real interest rate, while desired investment is decreasing. As a result, there exists a unique equilibrium rate r^* that equates both forces.

At this equilibrium real interest rate, the level of aggregate expenditure and investment consistent with potential output is attained. Thus, r^* coordinates the aggregate allocation of loanable funds by ensuring consistency between desired saving and investment at full employment.

Figure 1. $S - I$ Equilibrium



Source: Authors' calculations.

Variations in r^* may arise from several sources. First, shifts in the saving schedule can exert downward pressure on the equilibrium rate. A sustained increase in desired saving—driven, for example, by population aging and rising life expectancy, stronger precautionary saving motives, or increased income concentration among households with a high propensity to save—shifts the saving curve $S(x)$ to the right and lowers r^* . These mechanisms play a central role in explanations based on demographic and distributive factors.¹¹

Second, shifts in the investment schedule can also reduce the equilibrium rate. A decline in desired investment associated with lower trend growth, a slowdown in productivity, increased market power that reduces business opportunities, or technological changes that lower the relative price of capital goods—and thus nominal investment per unit of capital—shifts the investment curve $I(x)$ to the left, exerting downward pressure on r^* .¹²

Accordingly, a sustained global decline in r^* is consistent with an increase in desired saving, a decline in desired investment, or a combination of both forces.¹³

11. See Carvalho and others (2016), Gagnon and others (2021), Auclert and others (2021), Mian and others (2020).

12. See Summers (2016), Rachel and Summers (2019a), Eggertsson and others (2019), Caballero and others (2017).

13. See Rachel and Smith (2015), International Monetary Fund (2022).

1.2 Structural Drivers: What Explains the Decline in r^* ?

The $S - I$ framework developed above provides a disciplined structure for organizing the discussion of the structural determinants of the neutral interest rate. Any persistent variation in r^* must be interpreted as the result of sustained shifts in aggregate saving $S(x)$, aggregate investment $I(x)$, or both. The literature suggests that the secular decline in r^* observed since the early 1980s reflects the joint influence of multiple structural forces. While no single factor appears dominant on its own, their cumulative and global nature has generated a persistent downward trend.¹⁴ For analytical purposes, these drivers can be grouped into three broad categories: macroeconomic, financial, and emerging factors.

1.2.1 Macroeconomic Drivers

Demographics

Changes in fertility and mortality rates exert complex and timevarying effects on the neutral rate by substantially altering global saving and growth patterns. Within the $S - I$ framework, demographic forces tend to raise desired saving, shifting the saving curve $S(x)$ to the right and lowering r^* . Increased longevity raises the need to accumulate assets during working life to finance longer retirement periods.¹⁵ Slower population growth increases the capital–labor ratio, reducing the marginal return to capital, while longer life expectancy raises saving rates during working years.¹⁶ Although these trends are global, emerging economies—particularly China and Southeast Asia—have experienced especially pronounced increases in saving related to demographic transitions.¹⁷ At the global level, however, the net effect on aggregate saving and interest rates remains uncertain, as higher consumption by an expanding inactive population may eventually offset higher saving by the workingage population.¹⁸

14. See Rachel and Smith (2015), Del Negro and others (2017), Shekhar and others (2023).

15. See Auclert and others (2021), Carvalho and others (2016), Gagnon and others (2021).

16. See Hansen (1939).

17. See Acosta and others (2022).

18. See Acosta and others (2022), Goodhart and Pradhan (2020).

Productivity Growth

Total factor productivity (TFP) growth is a central determinant of investment demand. In neoclassical models, higher expected productivity growth raises the marginal product of capital and shifts the investment curve $I(x)$ to the right, increasing the equilibrium real interest rate. Conversely, a persistent slowdown in productivity growth reduces profitable investment opportunities and exerts downward pressure on r^* .¹⁹

Fiscal Policy

Higher public debt may lead to higher interest rates insofar as additional savings are required to finance increased government borrowing. In the $S - I$ framework, a sustained rise in public debt shifts the investment (or demand for funds) curve $I(x)$ to the right, placing upward pressure on r^* . However, the net effect depends critically on the extent to which public borrowing crowds out private investment and on the intertemporal credibility of fiscal policy.²⁰ In an environment characterized by excess saving and structurally weak investment—as observed in recent decades—a more active fiscal stance may prevent an even sharper decline in r^* .

Market Power and the Labor Share

The impact of rising market power on the neutral interest rate is theoretically ambiguous. Higher markups tend to depress future output and investment demand, reducing desired investment and shifting $I(x)$ leftward, thereby lowering r^* . At the same time, increased profits redistribute income from labor to capital owners, and the effect on r^* depends on how these dividends are distributed across cohorts and agents with different saving propensities.²¹

Income Distribution

Rising income and wealth inequality increase aggregate saving because higher-income households exhibit a greater propensity to save. In the $S - I$ framework, greater concentration at the top of the distribution shifts the saving curve $S(x)$ persistently to the right, reducing r^* . Moreover, lower interest rates induce higher borrowing

19. See Solow (1956), Cesa-Bianchi and others (2022), Mankiw (2022).

20. See Eggertsson and others (2019), Rachel and Summers (2019a).

21. See Caballero and others (2017), Eggertsson and others (2019), Ball and Mankiw (2023), Natal and Stoffels (2019), Platzer and Peruffo (2022).

among lower income households, further worsening wealth inequality and reinforcing the downward pressure on rates.²² Since the 1980s, the saving of the top 1 percent has increased dramatically, giving rise to a “rich savings glut” that is comparable in scale to the global savings glut and equally influential in driving demand for safe assets.

1.2.2 Financial Drivers

International Capital Flows and the Scarcity of Safe Assets

Global capital market integration has generated powerful international spillovers affecting the neutral rate. On the one hand, highgrowth emerging economies offer alternative investment opportunities, leading to capital outflows that can raise r^* in advanced economies.²³ On the other hand, the supply of safe and liquid assets—primarily US government bonds—has not kept pace with rapidly growing global demand, particularly from emergingmarket central banks and sovereign wealth funds. This scarcity has increased the price and reduced the yield of safe assets.²⁴

Risk Aversion and Leverage Cycles

Safe and liquid assets command a convenience yield that varies over time and tends to increase during episodes of global stress and deleveraging.²⁵ Given the safehaven status of the US dollar, this mechanism is particularly relevant for US Treasury securities, whose value rises during periods of heightened risk aversion, further compressing real interest rates.²⁶

1.2.3 Emerging Drivers

Climate Change and Defense Spending

The effect of climate change on r^* reflects the interaction of opposing structural forces. The transition to a lowcarbon economy requires massive investment in green infrastructure, constituting

22. See Mian and others (2020).

23. See Clarida and others (2002), Galí and Monacelli (2005).

24. See Bernanke (2005), Caballero and others (2016, 2017), Del Negro and others (2017), Krishnamurthy and Vissing-Jorgensen (2012).

25. See Gourinchas and others (2022).

26. See Gourinchas and others (2010).

a positive investment shock that shifts the investment curve $I(x)$ to the right and exerts upward pressure on r^* . However, this effect is counterbalanced by deteriorating productivity: physical climate risks act as a negative supply shock by destroying capital, reducing labor efficiency, and diverting resources from innovation toward adaptation, thereby lowering TFP and the marginal return to capital. At the same time, heightened climate uncertainty and rising inequality strengthen precautionary saving motives and increase demand for safe assets, reinforcing downward pressure on real rates.²⁷

The theoretical direction of increased military spending is clearer. It acts as an investment shock, shifting the investment curve to the right and pushing up r^* . Increased geopolitical uncertainty could, in principle, trigger risk-off behavior that raises demand for safe assets and mitigates this effect. However, Section 5 shows that since 2022 this channel has been weak or has even operated in the opposite direction.

2. CLIMATE CHANGE INVESTMENT POLICIES

To assess the magnitude of the climate finance challenge, we must first establish the current state of capital flows. These figures are then compared with the investment requirements to maintain a global warming trajectory below 2°C, which entails addressing the abatement of global greenhouse gas (GHG) emissions estimated at $59 \text{ Gt} \pm 6 \text{ Gt CO}_2\text{eq}$ in 2019.²⁸ This section presents aggregated estimates of the additional annual investment required to transition towards a net-zero emissions scenario by 2050—with an evaluation horizon extending to 2030, as projected by various sources—and analyzes the primary drivers underlying these figures. Finally, based on this review, we develop the scenario employed in this document to examine the implications of increased investment expenditure for determining the global natural rate of interest.

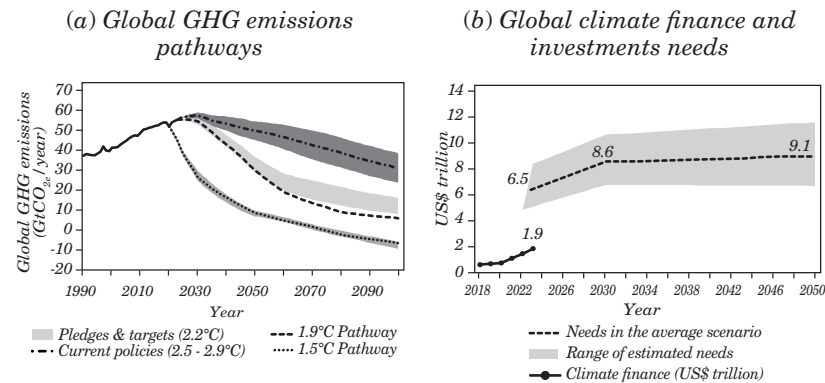
According to the Climate Policy Initiative (CPI) in its annual report “Global Landscape of Climate Finance 2025”, total climate finance reached approximately USD 1.9 trillion in 2023, continuing an upward trend from the USD 1.7 trillion recorded in 2022. Even though this growth in investment is significant, it remains insufficient to align the reductions in CO_2eq emissions with the required scale of investment.

27. See Mongelli and others (2024). See Appendix.

28. See Nabuurs and Mrabet (2022).

In contrast, fossil fuel consumption subsidies have experienced a drastic increase since 2020, reaching a record figure of USD 1.4 trillion in 2022.²⁹ However, this figure refers solely to direct or explicit transfers. If a broader economic definition is considered—one that encompasses non-internalized environmental and health costs (implicit subsidies)—the International Monetary Fund (IMF) estimates that the total real subsidy amounted to USD 7 trillion for the same year.³⁰ This figure, of a magnitude comparable to that of climate finance, illustrates the complexities inherent in the decarbonization process and the global financial system. The challenge, therefore, lies not only in scaling up climate action finance but also, and crucially, in redirecting capital that currently exacerbates the problem.

Figure 2. The Climate Gap: Divergent Emission Trajectories towards Net Zero and Investment Shortfalls



Source: Authors' calculations based on Climate Action Tracker (2025) and Climate Policy Initiative (2025).
Notes: This figure contrasts physical decarbonization pathways with capital requirements. The left panel displays global annual GHG emissions (encompassing both energy and non-energy sectors). It illustrates how "Current Policies" (dashed line) sustain emissions at elevated levels, diverging significantly from the trajectory required to meet the 1.5°C target (solid line). The latter pathway is the only one compatible with achieving net zero by mid-century. Conversely, the right panel depicts the financing gap. The solid line represents current climate finance flows, while the dashed line (average) and the gray band project the estimated annual investment needs through 2050 necessary to achieve net-zero trajectories.

29. See Naran and others (2024).
30. See Black and others (2023).

As observed in Figure 2, it is estimated that an average of USD 8.6 trillion is required annually until 2030 for a 1.5°C scenario.³¹ Furthermore, comparing the CPI scenario with that proposed by International Energy Agency (2024), hereafter IEA, the latter estimates investment solely in mitigation; however, results differ by subcategory, as detailed in Table A1 of the Appendix.

Likewise, the World Economic Forum (WEF), based on CPI data, projects that annual climate finance requirements will increase to USD 9 trillion by 2030 and exceed USD 10 trillion annually starting in 2031.³² This figure represents the upper bound of estimates and likely encompasses a wide range of mitigation and adaptation activities.

The higher figures from the CPI (USD 7–10 trillion) are based on more complex 1.5°C scenarios, which include not only energy but also sectors such as land use, industry, and agriculture, in addition to incorporating adaptation and resilience needs more comprehensively. Comparing these figures with the IEA estimate of USD 4 trillion annually, which focuses on the clean energy transition, reveals that a significant portion of the total required investment lies outside the traditional energy sector. Table 1 below presents a summary of the scenarios shown by various sources regarding additional investment needs in mitigation and adaptation.

Having analyzed the current state of additional investment estimates, we present the investment requirements for mitigation and adaptation and discuss each component.

The energy system constitutes a substantial portion of these requirements. This sector demands an unprecedented shift from fossil fuels toward clean energy sources, accompanied by a massive modernization of grid infrastructure and radical improvements in energy efficiency.

Drawing on the BloombergNEF (2026) scenarios the cost of the transition as a whole is estimated at approximately USD 1.7 trillion, with an incremental value of USD 650 billion. According to the IEA, clean energy investment must reach USD 2.1 trillion per year by 2030 to meet the 1.5°C goal, considering an incremental requirement of USD 1 trillion (International Energy Agency, 2024). Meanwhile, the CPI considers that total investment must reach USD 2.9 trillion, with an increment of USD 2 trillion.³³ Finally, the WEF estimates

31. See Naran and others (2025).

32. See World Economic Forum (2025).

33. See Naran and others (2025).

the necessary annual investment at USD 4.5 trillion, where the incremental need is estimated at USD 2.8 trillion.³⁴

Regarding specific estimates for the energy sector, the figure projected by the IMF in 2022 is also considered, which posits a total of USD 3.3 trillion per year until 2030 to achieve net-zero emissions by 2050. Finally, in its Net Zero 2050 scenario, the Network for Greening the Financial System (NGFS) estimates that global investments in energy must average USD 3.8 trillion per year, with more than one-third allocated to renewable energies, primarily for generating and storing renewable electricity.³⁵

Table 1. Annual Climate Investment Requirements by Source and Category

<i>Investment requirement</i>	<i>Bloomberg</i>			
	<i>NEF</i>	<i>IEA</i>	<i>CPI</i>	<i>WEF</i>
Mitigation Energy	0.65	1.00	2.05	2.76
Renewable generation	0.42	0.55		
Grids	0.23	0.36		
Batteries		0.10		
Mitigation Industry	2.95	1.25	2.61	3.43
Transport	2.24	0.67	1.33	2.40
Buildings	0.70	0.50	0.84	0.72
Industry		0.08	0.56	0.31
Adaptation			1.33	0.34
Adaptation/				
Resilience and damages			0.18	0.22
AFOLU			1.15	0.12

Source: Authors' calculations based on BloombergNEF (2026), International Energy Agency (2024), Climate Policy Initiative (2025), and World Economic Forum (2025).

Notes: AFOLU refers to Agriculture, Forestry, and Other Land Use (Nabuurs and Mrabet, 2022).

34. See World Economic Forum (2025).

35. See NGFS (2024).

2.1 Mitigation Investments in Energy

The capital requisite for the energy transition is not allocated to a singular purpose but is instead distributed across a complex ecosystem of technologies and infrastructures. Institutional qualitative analyses emphasize two primary areas

First, renewable energy generation. The central objective, which was established at the twenty-eighth Conference of the Parties (COP28) in 2023, is to triple global renewable energy capacity by 2030.³⁶ This encompasses solar photovoltaic (PV), wind, biomass, and other sources.

Second, investment in grid infrastructure and storage. Transmission infrastructure constitutes one of the most critical barriers to the transition. Substantial investments are required to modernize electrical grids, expand storage capacity (specifically batteries), and construct interconnectors to effectively manage the variability inherent in renewable energy sources.

2.2 Mitigation Investments in Industry

The decarbonization of industrial sectors—specifically steel, cement, chemicals, and aluminum—constitutes one of the most formidable challenges in the transition toward a zero-emissions economy, parallel to the investment requirements for transport, buildings, and infrastructure.

Predicated on an analysis focusing on energy efficiency and electrification within end-use sectors, the IEA's Net Zero Emissions scenario posits that annual investment must triple, from USD 600 billion to slightly above USD 1.9 trillion, driven by a marked increase in transport electrification.³⁷

Concurrently, the CPI estimates that transport investment will surge from USD 0.5 trillion to USD 1.9 trillion, while investment in the buildings sector will expand from USD 288 billion to USD 1.1 trillion. However, the most critical shortfall is observed in the industrial sector, which currently mobilizes USD 25 billion against a requirement of USD 600 billion—a twenty-four-fold increase.³⁸

BloombergNEF (2026) indicates that total investment needs in the industrial sector amount to USD 3.8 trillion. The most significant

36. See United Nations Framework Convention on Climate Change (2023).

37. See International Energy Agency (2024).

38. See Naran and others (2025).

deficit remains in transport—despite concentrating a substantial portion of current investment, an additional USD 2.2 trillion is required to meet the target. The financing gap in industry and infrastructure approximates USD 700 billion.³⁹

The WEF estimates a total financing gap of USD 3.4 trillion, disaggregated into USD 2.4 trillion for transport, USD 700 billion for buildings and infrastructure, and USD 300 billion for industry.⁴⁰ The primary divergence from other reports is that the WEF records lower levels of baseline current investment, thereby widening the estimated gap.

Investment in the buildings sector centers on enhancing energy efficiency, retrofitting existing structures, and integrating renewable energy sources into the built environment. Key focal areas include efficiency improvements, sustainable construction, and low-carbon heating and cooling systems. To accelerate action within the sector, increased investment in low-carbon construction materials, green buildings, and sustainable urban planning is identified as essential.⁴¹

Regarding investment in industry, financing is essential for deploying next-generation technologies and optimizing industrial processes, particularly within “hard-to-abate” sectors such as aluminum, aviation, cement and concrete, chemicals, shipping, steel, and heavy transport. These industries are significant contributors to global GHG emissions; consequently, implementing innovative solutions—such as carbon capture, utilization, and storage (CCUS), green hydrogen, and enhanced energy efficiency measures—is crucial for decarbonizing industrial processes.

Finally, investment in transport encompasses the costs associated with transitioning to electric vehicles (EVs), developing EV infrastructure, and promoting alternative fuels for other modes of transport, including freight. Low-carbon technologies, such as high-frequency chargers and hydrogen refueling infrastructure, are vital for facilitating the widespread adoption of EVs and other clean fuel technologies.⁴²

2.3 Adaptation Investments

Whereas mitigation focuses on reducing emissions to prevent further climate change, adaptation addresses the imperative of preparing for

39. See BloombergNEF (2025).

40. See World Economic Forum (2025).

41. See Naran and others (2025).

42. See World Economic Forum (2025).

and adjusting to inevitable impacts. This section seeks to estimate the disparity between adaptation financing requirements and the capital flows currently allocated to this purpose. Notably, at COP30, a new indicative target was established to triple adaptation financing by 2035. This measure, formalized within the “Global Mutirão” framework,⁴³ responds to the acknowledgment that current flows are insufficient in the face of accelerating climate risks in developing nations.

The IMF estimates that emerging markets and developing economies (EMDEs) require between USD 140 billion and USD 300 billion annually by 2030 to adapt to the physical consequences of climate change. This figure could escalate significantly to between USD 520 billion and USD 1.75 trillion annually post 2050, contingent upon the efficacy of climate mitigation measures.

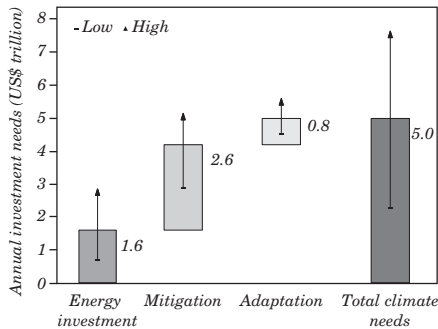
The recent 2025 Adaptation Gap Report of the United Nations Environment Programme (UNEP), which updates the cost of adaptation financing in developing countries, estimates requirements at USD 300 billion for the year 2035 when based on modeled costs. When calculated based on extrapolated needs expressed in Nationally Determined Contributions (NDCs) and National Adaptation Plans (NAPs), this figure rises to USD 400 billion annually. Concurrently, international public finance flows for adaptation in developing countries amounted to USD 26 billion in 2023, a decrease from the USD 28 billion recorded the previous year. Consequently, adaptation financing needs in developing countries are estimated to be between 12 and 14 times greater than current flows (United Nations Environment Program, 2025).

The CPI report acknowledges that adaptation finance falls significantly short of the current USD 46 billion and posits that this figure must increase to USD 200 billion by 2030 and to USD 300 billion for the 2031–2050 period. However, a particularly stark disparity is observed in the agriculture, forestry, and other land use (AFOLU) sector, where flows stand at USD 18 billion against a requirement of USD 1.17 trillion—a 64-fold gap—necessary to abate eight gigatons of carbon dioxide equivalent ($GtCO_{2e}$).⁴⁴ Based on this review of data sources and probable financing scenarios, we develop a scenario for the expansion of investment expenditure up to 2030 associated with climate action.

43. See United Nations Framework Convention on Climate Change (2025).

44. See Naran and others (2025).

Figure 3. Annual Climate Investment Requirements by Scenario and Category



Source: Authors' calculations based on BloombergNEF (2026), International Energy Agency (2024), Climate Policy Initiative (2025), and World Economic Forum (2025).

Notes: The low scenario corresponds to projections from agencies or organizations with a specific sectoral focus, whereas the medium and high scenarios derive from institutions specializing in the field of climate change, which address the challenge comprehensively across all sectors.

2.4 Delayed Climate Transition

Given the large expenditures required in mitigation and adaptation—totaling around USD 5 trillion per year towards 2030, in the “middle-of-the-road” scenario—, the slow progress of climate commitments may lead one to question whether these expenses will materialize. However, it is well understood that postponing mitigation and adaptation expenditures does not eliminate future financing needs arising from climate and environmental change. Rather, it alters their intertemporal profile and economic nature by shifting spending from capital preservation and efficiency-enhancing investment toward replacing capital stocks damaged or destroyed by physical climate risks. This implies that delayed action may increase medium-term investment demand without a commensurate expansion in productive capacity, with important consequences for public and private balance sheets.

Moreover, it is well understood that the costs associated with delaying environmental action are larger than acting in a timely manner. The NGFS, through its Workstream Scenario Design and Analysis, has performed several phases of climate-macroeconomic scenarios, assuming different paths of mitigation and CO₂ emissions.

All scenarios with emissions pathways deviating from net zero towards 2050 involve progressively mounting costs.⁴⁵ For instance, by 2050, the “current policies” scenario, associated with an increase in average temperatures of 3°C from pre-industrial levels, leads to losses in GDP from a baseline with no climate damages of 8 percent from acute impacts (heatwaves, droughts, cyclones, and floods) and 15 percent from chronic impacts. These are about double the effects of the orderly transition scenario, and they are concentrated on physical damage costs rather than transition expenses. These estimates are much larger than earlier rounds of scenarios, as modeling improvements have gradually allowed studying more climate stressors and their interaction simultaneously. They are also consistent with recent empirical evidence from the study of *aggregate* climate fluctuations,⁴⁶ which, as compared to traditional studies based on *local* effects of temperature fluctuations, find costs in economic activity that are an order of magnitude larger. In their baseline estimation, every increase of 1°C of warming leads to a 20 percent fall in GDP within 10 years.

Together, the evidence reviewed in this section indicates that climate-related investment requirements are not only large and persistent but also sensitive to the timing and composition of policy action and cannot be evaluated independently of broader fiscal and macro-financial conditions. Section 4 builds on this insight by examining how the interaction between elevated investment needs and prevailing fiscal constraints shapes long-run interest rate dynamics and debt sustainability.

3. *S*–*I* EQUILIBRIUM, WARS, AND GEOPOLITICAL CONSIDERATIONS

Section 2 documented the first of the two main drivers of the outward shift in the global investment curve: the massive financing needs associated with the climate transition, estimated at approximately USD 5–6 trillion per year by 2030. This section turns to the second driver, which is largely independent in its causes but additive in its effect on the saving-investment (*S* – *I*) equilibrium: the sustained increase in global defense spending driven by deteriorating geopolitical conditions. We proceed in three steps.

45. See the dedicated Scenarios Portal of the NGFS.

46. See Bilal and Känzig (2026).

Section 3.1 characterizes the current geopolitical landscape—marked by declining military unipolarity, the consolidation of rival strategic blocs, and active conflicts on multiple fronts—and argues that it exhibits the structural features historically associated with multi-year rearmament cycles. Section 3.2 uses historical evidence to establish the macroeconomic regularities—in military spending, public debt, and inflationary pressures—that such cycles have typically produced. Section 3.3 documents current and announced spending plans and establishes the aggregate magnitude of the rearmament-driven shift in the global investment curve.

3.1 The Current Geopolitical Landscape

The geopolitical environment has deteriorated sharply since Russia annexed Crimea in 2014 and accelerated further following the full-scale invasion of Ukraine in February 2022, and the deterioration appears structural rather than episodic. Three features of the current landscape are particularly relevant for the macroeconomic argument of this paper: the return of multipolar military competition, the consolidation of rival strategic blocs, and the emergence of active conflicts on multiple fronts alongside a potential great-power flashpoint.

3.1.1 Dwindling Military Unipolarity

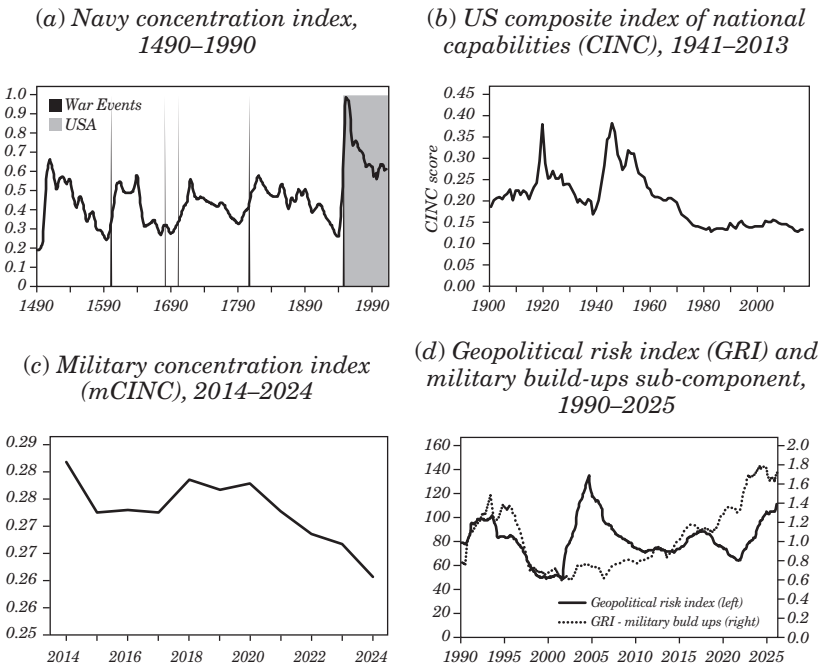
Research in the long-cycle tradition documents a robust historical regularity: periods of declining military concentration—when no single power dominates unambiguously—have systematically preceded major interstate conflicts.⁴⁷ By this measure, the current environment is notably hazardous. The US Composite Index of National Capabilities (CINC) stands near its lowest post-WWII level, reflecting China's sustained military modernization and Russia's partial recovery.⁴⁸ The Military Concentration Index of Bunyavejchewin and others (2024) has declined continuously since the mid-2000s to historical lows (Figure 4, panel (b)), while the Geopolitical Risk Index of Caldara and Iacoviello (2022) and its Military Build-ups sub-component trended sharply

47. See Modelski and Thompson (1988), Thompson (1993).

48. See Correlates of War Project (2023), Figure 4, panel (b).

upward since 2014, with further acceleration after 2022, as shown in panels (c) and (d) of Figure 4. As Dubik (2021) observes, the current confluence of rapid technological change, multiple competitors willing to use force, and ambiguous global leadership closely replicates the structural conditions that have historically triggered major conflict cycles.

Figure 4. Military Power Concentration and Geopolitical Risk Index



Sources: Panels (a)–(b): Modelski and Thompson (1988), Thompson (1993). Panel (c): Bunyavejchewin and others (2024). Panel (d): Caldara and Iacoviello (2022).

Notes: CINC determines states' annual share of global capabilities using six equally weighted indicators: military expenditure, military personnel, energy consumption, iron and steel production, urban population, and total population. The Military Concentration Index (mCINC) is based on defense budgets and military personnel only. The GRI Military Build-ups sub-component is shown as a 3-year moving average.

3.1.2 The Consolidation of Rival Blocs and Active Conflict Fronts

The deteriorating distribution of military power has been accompanied by the rapid consolidation of two competing strategic blocs, as shown in Table A3 in the Appendix. An Eastern grouping centered on China, Russia, Iran, and North Korea has moved since 2022 from informal alignment to a dense web of bilateral treaties, arms transfers, and joint military operations, reinforced by China's expanding economic footprint through its Belt and Road Initiative (BRI).⁴⁹ This backdrop has materialized in active conflict on multiple fronts. Russia's war against Ukraine has continued beyond its fourth year with no resolution in sight. In the Middle East, a June 2025 US–Israeli operation targeting Iranian nuclear facilities was followed in February 2026 by a broader military campaign against Iran's missile arsenal, naval forces, and defense industrial base; although a ceasefire entered into effect in April 2026, the structural conditions underlying the conflict remain unresolved.⁵⁰ These overlapping conflicts have placed simultaneous strain on US defense procurement, munitions stockpiles, and alliance commitments in ways that reinforce the rearmament pressures documented in Section 3.3. The most consequential latent flashpoint, however, remains the Taiwan Strait, where the People's Liberation Army (PLA) encirclement exercises

49. For a detailed chronology of Eastern bloc consolidation developments from 2021 through early 2026—covering military cooperation, bilateral treaties, and economic integration—see Table A3 in the Appendix. Key data: China–Russia bilateral trade reached \$244.8 billion in 2024, more than double its 2020 level, with over 95 percent of transactions settled in local currencies (General Administration of Customs of China, 2025; MERICS, 2026). Approximately 15,000 North Korean troops were deployed to Russia by mid-2025 following the Comprehensive Strategic Partnership Treaty signed in Pyongyang on June 19, 2024 (Carlough and Kennedy, 2025; Bowen and others, 2025). Russia and Iran signed a 20-year Comprehensive Strategic Partnership Treaty on January 17, 2025; it entered into force on October 2, 2025 (Iranian Foreign Ministry, 2025). The BRI encompassed 150 countries with cumulative investment exceeding \$1.175 trillion by May 2025 (Nedopil, 2025). The designations “CRINK” (standing for China, Russia, Iran, and North Korea) and “Axis of Upheaval” have been adopted independently by multiple authoritative organizations. (Kendall-Taylor and Lokker, 2025; U.S.-China Economic and Security Review Commission, 2025).

50. The June 2025 Operation Midnight Hammer targeted Iran's nuclear enrichment facilities at Fordow, Natanz, and Isfahan (Rodgers and Schiff, 2026). The February 2026 Operation Epic Fury campaign was a broader coordinated US–Israeli military operation targeting Iran's missile arsenal, naval forces, and defense industrial base; a ceasefire brokered by Pakistan entered into effect in April 2026 (White House, 2026; Costa and others, 2026).

intensified sharply through 2025.⁵¹ Taiwan produces approximately 90 percent of the world's most advanced semiconductors, meaning any cross-strait disruption would generate supply-side consequences that would dwarf the investment-demand considerations analyzed in this paper. Together, these dynamics imply that defense investment across both blocs is increasingly duplicative and self-reinforcing, amplifying the aggregate outward shift of the global investment curve beyond what any single country's spending trajectory would suggest.

3.2 Historical Evidence: Wars, Military Spending, Debt, and Inflationary Pressures

Before turning to current rearmament trends, it is useful to establish what historical episodes of interstate conflict tell us about the macroeconomic dynamics that precede and accompany major wars. The evidence is remarkably consistent across a wide range of conflicts and time periods: wars are not sudden events in terms of their economic footprint. They are preceded by a multi-year cycle of military spending buildup, produce a sharp in-conflict surge that strains public finances to their limits and leave a legacy of elevated debt and inflation that can persist for a decade or more. We document each phase in turn, drawing on the full universe of interstate wars between 1830 and 2007.⁵²

3.2.1 The Buildup-Surge-Persistence Pattern in Military Spending

Panel (a) of Figure 5 presents an event study of military spending—measured as a share of GDP—around all interstate wars since 1830, aligned to the first year of conflict.⁵³ Three quantitative regularities stand out. First, military spending begins rising measurably well

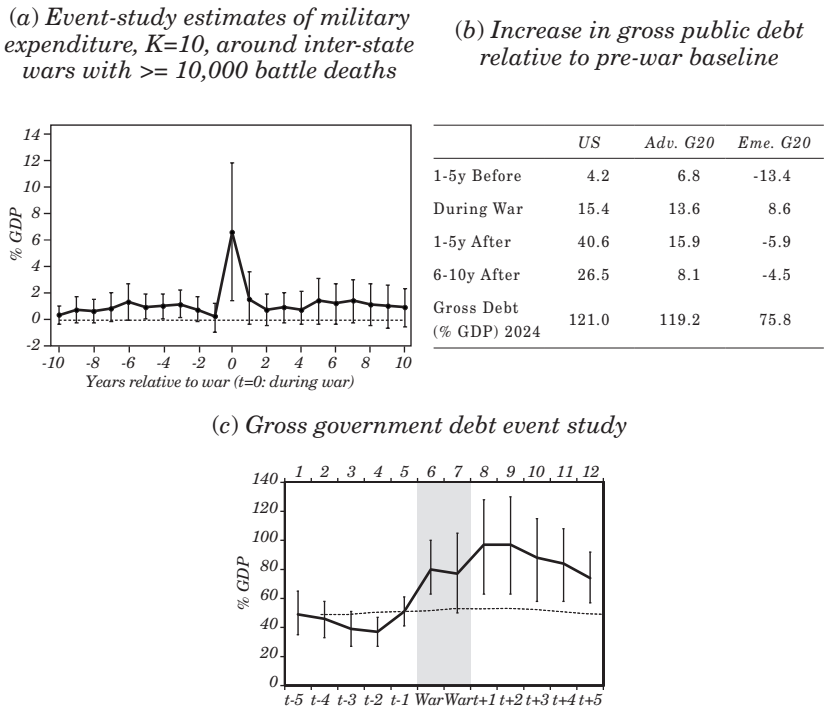
51. In April 2025, the PLA conducted “Strait Thunder-2025A” (135 aircraft sorties, 38 naval vessels); in December 2025, its “Justice Mission-2025” deployed army, navy, air force, and rocket force units across five maritime zones in a live-fire encirclement explicitly rehearsing a Taiwan blockade scenario, triggered by a record \$11.1 billion US arms sale to Taipei (Lin and others, 2026).

52. See Correlates of War Project (2023); Stockholm International Peace Research Institute (2025).

53. The event study covers all interstate wars between states from 1830 through 2007. The military spending series is drawn from SIPRI and the Correlates of War Project (2023). WWII is excluded from the Russia subsample due to data limitations. Sources: SIPRI Military Expenditure Database; Correlates of War Project (2023), *Interstate War dataset*; Federal Reserve Economic Data (FRED); Zucman (2013).

before the outbreak of hostilities: in the five-to-seven years preceding conflict, spending increases by approximately 1 to 1.5 percentage points of GDP above peacetime levels—a pre-war buildup phase that is visible and statistically distinguishable from the pre-period baseline. Second, once conflict begins, spending surges dramatically, reaching more than four times peacetime levels at the peak of active hostilities. Third, the postwar wind-down is slow: military expenditure remains meaningfully elevated for approximately five years after the conflict ends. Taken together, the full conflict cycle spans roughly fifteen years from the onset of the buildup to the return to peacetime norms.

Figure 5. Military Spending and Public Debt around Wars: Historical Evidence



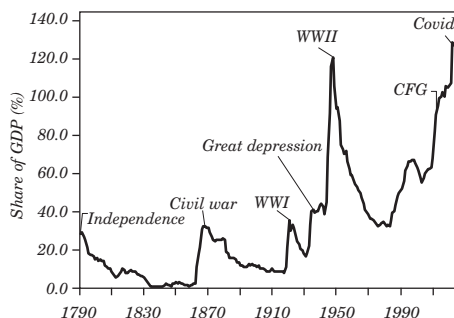
Sources: Panel (a): SIPRI Military Expenditure Database; Correlates of War Project, Inter-State War dataset (wars between states, 1830–2007). Panel (b): US Treasury, Historical Debt Outstanding; IMF, Fiscal Monitor (various years). Panel (c): EBRD (2024). Additional data: Federal Reserve Economic Data (FRED).
Notes: Event study covers all inter-state wars between states from 1830 through 2007. Military spending is measured as a share of GDP; the pre-war baseline is the average over years –10 to –6 relative to war onset. Confidence intervals reflect cross-war heterogeneity. WWII is excluded from the Russia subsample due to data limitations. The “pre-war build-up” annotation (Panel (a)) refers to the period years –7 to –1, over which spending exceeds the peacetime baseline by approximately 1–1.5 percentage points of GDP on average.

The S – I framework developed in Section 1 provides a natural organizing lens for these regularities. Defense expenditure constitutes investment demand in the aggregate S – I equilibrium, even though it does not generate productive capital in the conventional sense. An increase in defense spending, therefore, shifts the investment curve outward, raising the equilibrium marginal product of capital and putting upward pressure on long-term yields and, over a longer horizon, on r^* . Critically, this shift begins during the pre-war buildup phase: the 1–1.5 percentage point of GDP increase in the pre-war window of Figure 5 is already a material outward shift of the investment curve. When this buildup occurs simultaneously across multiple major economies—as is currently the case—the aggregate effect is the sum of multiple independent shifts and is therefore an order of magnitude larger than any single country’s trajectory would suggest.

3.2.2 Fiscal Consequences: Debt Accumulation, War Finance, and Inflationary Pressures

Panels (b) and (c) of Figure 5 documents the fiscal legacy of conflict. For the United States, gross public debt rises by an average of 4.2 percent of GDP in the one-to-five years before conflict, 15.4 percent during active hostilities, and remains elevated by 40.6 percent in the immediate postwar period, as shown in Panel (b) of Figure 5 and in Table A3.⁵⁴ The pattern for Advanced G20 economies is broadly similar, while Emerging G20 economies display smaller and less persistent increases. The event study by the European Bank for Reconstruction and Development (EBRD) shown in Panel (c) of Figure 5 contrasts debt trajectories of countries that fought wars on their own territory against those that did not, showing a sharp and persistent increase reaching approximately 100 percent of GDP at the war peak for the treated group.

54. The gross government debt event study (Figure 5, Panel (c) is drawn from Koczan (2022). The treated group (war on own territory) contrasts with a control group of countries that experienced no war over the same window, providing a quasi-experimental estimate of the war-specific debt increment. Debt increase figures by country group (Figure 5, Panel (b); Table A3) are from the U.S. Department of the Treasury (2024) and from the fiscal monitor of the IMF (various years). Current gross debt levels (2024) are from IMF Fiscal Monitor, October 2024.

Figure 6. US Historical Federal Government Debt Outstanding

Source: U.S. Department of Treasury (2024); International Monetary Fund (2024a).

Notes: Gross federal debt as a percentage of GDP. Key historical peaks annotated: Civil War (32.1%), WWI (35.6%), Great Depression (41.0%), WWII (121.2%), Global Financial Crisis/2010 (91.1%), Covid-19/2021 (127.1%). The 2024 observation (approximately 121% of GDP) is from the IMF Fiscal Monitor, October 2024. Shaded bands indicate major war periods.

Figure 6 places these estimates in a long-run perspective. The 2024 observation of approximately 121 percent of GDP for the United States—reached without any major conflict—is the critical forward-looking datum. The historical template establishes that major wars add 15–40 percent of GDP in gross debt even from peacetime baselines. However, starting instead from current levels, the marginal fiscal cost of the next rearmament cycle would be imposed on already strained public balance sheets, with correspondingly larger effects on term premia and risk-adjusted long-term yields.⁵⁵

War financing has also operated historically through inflation. Governments facing binding limits on debt issuance have repeatedly turned to monetary financing—either explicitly through central bank purchases, or implicitly through financial repression that keeps nominal rates below inflation and erodes the real value of outstanding obligations. Rockoff (2015) documents this pattern systematically across US wars and Hall and Sargent (2022) show that the post-WWII debt reduction was achieved primarily through growth and sustained financial repression rather than primary surpluses. More recently, Eydam and Leupold (2024) provide panel evidence that military hostilities generate statistically significant inflationary pressures

55. See Hall and Sargent (2022, 2025), Rockoff (2015), Ferguson and others (2023).

persisting beyond active fighting, attributable to supply disruptions, commodity price shocks, and monetization dynamics. These inflationary dynamics matter for the $S-I$ framework because they affect not only nominal yields but also real rates: if war-related spending leads to persistently higher inflation expectations, this can affect the conduct of monetary policy over an extended horizon, as central banks may need to devote sustained efforts to re-anchor expectations. The implications of these dynamics for r^* are not straightforward and may be ambiguous, depending on how they ultimately affect fiscal conditions, risk premia, and the global $S-I$ balance.

The historical evidence thus establishes a clear template: geopolitical tension and rearmament shift the global investment curve outward, raise debt supply and term premia through fiscal deterioration, and generate inflationary pressures feeding into both nominal and real long-term rates. Section 3.3 documents that this template is now being activated from a fiscal starting point that, as Section 4 establishes, is severely constrained by historical standards.

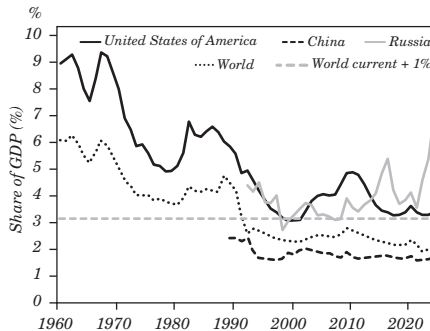
3.3 Current and Announced Rearmament Spending

3.3.1 Realized and Announced Spending Increases

The structural deterioration documented in Section 3.1 became clearly visible in defense budget commitments from 2022 onward. According to Stockholm International Peace Research Institute (2025), world military expenditure reached \$2,718 billion in 2024—a 9.4 percent increase in real terms from 2023 (deflating each country's spending by its national Consumer Price Index), and the steepest annual rise since at least the end of the Cold War. As a share of GDP, the global military burden rose to 2.5 percent in 2024 (Figure 7), up from approximately 2.3 percent in 2023 but still well below historical conflict-period levels.⁵⁶

56. Figure 7 reproduces global military spending as a percentage of GDP from 1960 through 2024, disaggregated for China, Russia, the United States, and the world average, together with a reference line showing the counterfactual implied by a uniform 1 percentage point increase in global military spending above the current baseline.

Figure 7. Global Military Spending



Sources: SIPRI Military Expenditure Database; North Atlantic Treaty Organization (2025).

Notes: Series shown for China, Russia, United States, and World average. The dashed reference line (“World current +1%”) represents the counterfactual trajectory implied by a uniform 1 percentage point increase in global military spending above the 2024 baseline. Series updated through 2024 using Stockholm International Peace Research Institute (2025). Russia’s 2024 figure reflects SIPRI’s estimate of “at least 38 percent” increase; the true figure may be higher due to off-budget financing.

Within the North Atlantic Treaty Organization (NATO), the shift was decisive. In 2024, 18 allies met or exceeded the 2-percent-of-GDP benchmark—a six-fold increase from 2014. Germany raised defense spending by 28 percent to become the world’s fourth-largest military spender (Stockholm International Peace Research Institute, 2025), a trajectory reinforced by the March 2025 constitutional amendment removing the debt brake for defense expenditure.⁵⁷ France spent approximately 1.9 percent of GDP on defense; Poland raised spending by 31 percent to reach 4 percent of GDP; Japan increased military expenditure by 21 percent — the largest annual increase since 1952 — reaching 1.4 percent of GDP, the highest since 1958.⁵⁸ On the Eastern side, China raised its official defense budget by 7.0 percent, extending three consecutive decades

57. On March 18, 2025, the Bundestag voted 512–206 to amend the German Basic Law (Articles 109, 115, and 143h), exempting defense and security spending above 1 percent of GDP from the 0.35 percent structural deficit ceiling and creating a €500 billion extrabudgetary infrastructure fund, of which €100 billion was earmarked for climate-related investment. The amendment passed the Bundesrat on March 21, 2025, completing the constitutional revision (Basic Law, as amended March 2025; Zettelmeyer, 2025).

58. See Stockholm International Peace Research Institute (2025).

of growth, while Russia's budget increased by an estimated 38 percent, with the true figure likely higher given off-budget financing.⁵⁹

The most significant institutional development since the November 2024 conference presentation was the ReArm Europe plan, in March 2025, which mobilized up to EUR 800 billion in additional European defense investment through 2030 via fiscal escape clauses—creating an estimated EUR 650 billion in fiscal space—and a EUR 150 billion supranational loan instrument adopted in May 2025. By February 2026, 17 EU member states had activated the escape clause, and combined EU defense expenditure reached an estimated EUR 381 billion in 2025—a 62.8 percent increase relative to 2020.⁶⁰ At the NATO Summit in The Hague in June 2025, allies endorsed a revised target of 5 percent of GDP by 2035. These developments were accelerated by the US–Israel–Iran conflict of 2025–2026, which exposed simultaneous strains on munitions stockpiles, procurement pipelines, and alliance burden-sharing commitments across the Western bloc, thus reinforcing the urgency of the spending plans already announced.

These commitments, when aggregated across major economies in both blocs, translate to approximately USD 1–2 trillion per year in additional global defense investment above the post-Cold War baseline—the rearmament component of the quantification exercise in Section 5.

The spending trajectory documented here is, in the terms of the historical analysis in Section 3.2, a pre-war buildup—and one occurring simultaneously across multiple major economies on both sides of the emerging strategic divide. Taken individually, each country's increase of 0.5 to 2 percentage points of GDP is consistent with the 1 to 1.5 percentage point pre-conflict buildup that Figure 5 identifies as the historical norm. In turn, taken together, the simultaneity implies an aggregate outward displacement of the global investment curve that is large relative to any single historical episode. Section 5 provides formal empirical evidence that financial markets have already begun to price this new environment. The spending pressures documented here will be financed predominantly through debt issuance. The scale of that challenge, and its interaction with an already severely constrained fiscal starting point, is the subject of Section 4.

59. See Stockholm International Peace Research Institute (2025).

60. See European Defence Agency (2025).

Table 2. Country-Level Defense Spending: Current Levels, Announced Targets, and Timelines

<i>Country</i>	<i>Current Spending 2024 (% of GDP)</i>	<i>Announced Target (% of GDP)</i>	<i>Target Year</i>	<i>Source</i>
United States	3.42%	5%	2035	North Atlantic Treaty Organization (2025)
Germany	1.89%	3.5%	2029	Reuters (23 June 2025)
France	2.05%	5%	2035	NATO / National Defence Planning
Poland	4.15%	4.8%	2026	DeVere Europe – Poland 2026 Budget
Japan	1.37%	2%	2027	Al Jazeera (26 December 2025)
China	1.71%	—	—	North Atlantic Treaty Organization (2025)
Russia	7.05%	—	—	North Atlantic Treaty Organization (2025)
NATO (average)	2.71%	5%	2035	NATO Summit Declaration / El País, 25 June 2025.

Sources: SIPRI Military Expenditure Database; NATO, Defence Expenditure of NATO Countries (2014–2024) communiqué (2025); national budget announcements and press releases for Germany (Bundesregierung), France (Ministère des Armées), Japan (Ministry of Defense), Poland (Ministry of National Defense), China (National People's Congress), Russia (Ministry of Finance); European Commission (2025); North Atlantic Treaty Organization (2025). Notes: “—” indicates no officially announced long-term target.

4. THE FISCAL STARTING POINT

The analysis in Section 3 established that the current rearmament cycle is, by the metric of historical analogues, in its pre-war buildup phase, and that this phase is unfolding simultaneously across multiple major economies. Section 3.2 further demonstrated that the fiscal legacy of such episodes is typically severe: major wars have historically added 15 to 40 percent of GDP in gross public debt to advanced economies, financed through a combination of bond issuance, monetary accommodation, and inflation. What the historical template cannot capture, however, is how the starting conditions shape the magnitude of the macroeconomic impulse. The present section argues that the current rearmament cycle begins from a fiscal position that is uniquely adverse not along one dimension but several simultaneously: the stock of debt is already at or near post-WWII highs before any

major conflict begins; structural deficits are elevated despite non-recessionary conditions; existing spending commitments are rigid and demographically driven to expand; the room for monetary financing is severely constrained by central bank balance sheet legacies and the reputational cost of the 2021–2023 inflation episode; and the external demand for advanced economy sovereign debt is structurally weakening. Together, these factors imply that each additional dollar of defense or climate spending generates a larger upward impulse on long-term interest rates than historical analogues would suggest.

4.1 Debt and Deficit Dynamics

The starting debt levels—US gross federal debt at approximately 121 percent of GDP and the Advanced G20 at a comparable level entering 2025—are already near post-WWII peaks, a situation without precedent in the historical template of Section 3.2. In every previous major rearmament episode since 1830, elevated debt was an outcome of conflict, not its precondition. The US entered World War II with a gross debt of approximately 44 percent of GDP and World War I, with debt below 5 percent. Today’s starting point is structurally different in kind, not merely in degree.

What makes this situation particularly anomalous is the behavior of flow deficits in the absence of crisis. The US federal budget deficit reached 6.3 percent of GDP in fiscal year 2024 and 5.9 percent in fiscal year 2025—both non-recessionary years—against a 50-year average of 3.8 percent. Deficits at this level have been exceeded only eight times since 1946, in each case during or immediately after a major crisis.^{61,62} The IMF Fiscal Monitor of October 2025 projects global public debt to surpass 100 percent of global GDP by 2029—the highest level since 1948—with debt risks widespread and tilted toward accumulating even faster.^{63,64} Running structural deficits of this magnitude during an expansion represents a secular deterioration: governments are borrowing at the top of the cycle, leaving no fiscal

61. See Congressional Budget Office (2025b).

62. The 2025 fiscal year deficit of 5.9 percent of GDP exceeded the 50-year average of 3.8 percent and has been exceeded only eight times since 1946: from 2009 through 2012 and in 2020, 2021, 2023, and 2024 (Congressional Budget Office, 2025b).

63. See International Monetary Fund (2025a).

64. The IMF projects global public debt to rise above 100 percent of GDP by 2029, which would be the highest level since 1948, with debt risks widespread and tilted toward accumulating even faster (International Monetary Fund, 2025a).

buffer for the spending pressures that Section 3 documents are already materializing.

The interaction between the debt stock and the interest rate environment adds a further compounding mechanism. When the interest rate on outstanding debt exceeds the economy's growth rate—the $r > g$ condition—the debt-to-GDP ratio grows automatically even with a primary balance of zero. This dynamic is now clearly operative in the United States: in fiscal year 2025, net interest outlays surpassed \$1 trillion for the first time on record, becoming the second-largest spending category in the federal budget behind only Social Security and exceeding defense outlays by a widening margin.^{65,66} From 2027 onward, the CBO projects interest costs as a share of GDP will exceed their highest level since at least 1940 continuously. The fiscal cost of each additional dollar of defense or climate spending thus includes not only its direct budgetary impact but the accumulated interest it generates on the enlarged debt stock—a cost that compounds over the 15-year rearmament cycle identified in Section 3.2.

In the $S-I$ framework, this fiscal deterioration operates through two reinforcing channels. The first is a crowding-out channel: higher government bond supply competes with private investment for available savings, shifting the investment curve further outward and raising the equilibrium marginal product of capital beyond the direct effect of defense expenditure alone. The second is a risk-pricing channel: elevated and rising debt levels increase the term premium investors demand on government bonds, adding a sovereign risk component to long-term yields that compounds the crowding-out effect. Both channels are quantified in Section 5.

4.2 Structural Spending Rigidities

The fiscal space problem documented in Section 4.1 is materially compounded by the rigidity of existing spending commitments. Public social expenditure, which encompasses pensions, healthcare, and social transfers, has risen across OECD economies from around 8 percent of GDP in 1960 to approximately 21 percent in 2024 on average, with

65. See Congressional Budget Office (2025b).

66. In fiscal year 2025, net interest on the public debt surpassed \$1 trillion for the first time, making it the second-largest federal expenditure behind Social Security (Congressional Budget Office, 2025b; CBO, 2025a).

France, Austria, and Finland exceeding 30 percent.⁶⁷ This expansion is now deeply institutionalized through legal entitlements and political economy dynamics that make sustained reductions extraordinarily difficult. The implication is direct: defense spending increases cannot be financed by cutting welfare, instead, they must be financed through higher deficits and debt or by raising taxes. Both paths put upward pressure on interest rates.

Demographic pressure ensures this rigidity will intensify over the same 10–20 year horizon as the rearmament cycle. Advanced economies—and, crucially, China—face rapidly aging populations that will mechanically increase pension and healthcare spending through the 2030s and 2040s. The IMF has been explicit about the collision: its 2025 Regional Economic Outlook for Europe warns that without policy action, public debt could more than double in the average European country over the next fifteen years under the combined pressure of defense commitments, aging, and rising debt service.^{68,69} The two pressures—rearmament and demographic spending—are therefore not sequential but simultaneous, competing for the same fiscal resources over the same time horizon. Rachel and Summers (2019b) show that expanding fiscal deficits can offset downward rate pressure from a savings glut. The mechanism here operates in reverse: the savings glut is unwinding precisely as fiscal positions deteriorate, so both forces push rates in the same direction.

4.3 Constraints on Monetary Financing

A third dimension of the adverse fiscal starting point is the significantly reduced availability of monetary financing relative to the historical episodes examined in Section 3.2. The post-WWII debt reduction in the United States, as documented by Hall and Sargent (2022), was achieved largely through financial repression—central bank policy kept nominal interest rates below the inflation rate, thus eroding the real value of outstanding debt at a rate that

67. See Organisation for Economic Co-operation and Development (2025). The 1960 figure (7.9% of GDP) is the average across the 17 original OECD member states. The 2024 figure (~21% OECD average) reflects the post-COVID normalization from the pandemic peak of 23% in 2020.

68. See International Monetary Fund (2025b).

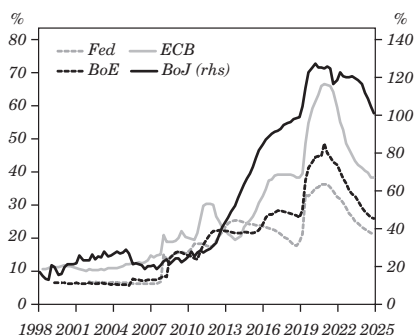
69. International Monetary Fund (2025b). See also International Monetary Fund (2025a), which explicitly identifies “rising defense commitments with aging-related spending pressures” as the central fiscal challenge for European advanced economies.

primary surpluses alone could not have achieved. This route required active Federal Reserve cooperation in suppressing yields, which was politically feasible in the immediate postwar environment of tight capital controls and limited financial market development.

The current environment differs structurally in three respects. First, central bank balance sheets remain far above pre-2008 baselines despite years of quantitative tightening. The Federal Reserve peaked at approximately 35 percent of GDP in early 2022 and ended its balance sheet runoff in December 2025—with only half of the pandemic expansion reversed—leaving its balance sheet at approximately 22 percent of GDP.⁷⁰ The European Central Bank's (ECB) balance sheet peaked at approximately 70 percent of euro area GDP in 2022 and has since declined to approximately 45 percent, while the Bank of Japan remains near 130 percent of GDP (Figure 8). Second, the 2021–2023 global inflation episode—partly a consequence of pandemic-era monetary accommodation of fiscal deficits—has fundamentally altered the reputational cost of monetary financing. Central banks now operate under a credibility framework in which they are prepared to accept significant economic costs—such as lower output—in order to avoid any perception of financing fiscal deficits, especially if such perceptions could lead to a loss of control over inflation expectations. Third, and most consequentially, the Federal Reserve ended quantitative tightening earlier than anticipated, before reversing the bulk of its pandemic balance sheet expansion—a sign that the room for further balance sheet reduction is limited, not that the instrument is available for redeployment. Ferguson and others (2023) document this dynamic in comparative historical perspective, noting that the post-2021 inflation experience has raised the implicit threshold for recourse to monetary financing.

The combined implication is that a larger share of defense and climate spending must clear at market rates—rates already sensitive to the existing debt stock and structural deficit.

70. See Federal Reserve Bank of New York (2025), Labonte (2025).

Figure 8. Central Bank Balance Sheets

Sources: Federal Reserve, H.4.1 statistical release; European Central Bank, Weekly Financial Statements; Bank of England, Asset Purchase Facility; Bank of Japan, Accounts of the Bank of Japan. GDP denominators: national statistical agencies and International Monetary Fund (2024b). All data retrieved via FRED, where available.

Notes: Balance sheet assets expressed as a percentage of annual nominal GDP, 1998-2025. The Federal Reserve concluded its balance sheet runoff (QT) in December 2025, with the balance sheet at approximately 22 percent of GDP—only half of the pandemic expansion reversed. The ECB continues passive QT as of the time of writing. The Bank of Japan peaked at approximately 130 percent of GDP in 2023 and has since declined, but it still remains the largest balance sheet relative to GDP among major central banks.

4.4 External Financing Vulnerabilities

The final dimension concerns the external financing environment. The United States relies heavily on foreign savings to finance its fiscal deficit. According to the World Bank's World Development Indicators, the US gross domestic savings stood at approximately 18.7 percent of GDP in 2024, well below the global average of 26–27 percent and far below China's nearly 44 percent. This structural savings shortfall means that a significant share of U.S. Treasury issuance must be absorbed by foreign investors, making the domestic cost of borrowing sensitive to the preferences and capacity of external creditors.

For much of the period from the mid-1990s to the late 2010s, this dependence was a source of yield suppression. The “global savings glut” identified by Bernanke (2005)—driven by China's reserve accumulation, oil exporters recycling petrodollar surpluses, and other emerging market economies building precautionary buffers—channeled large flows into US Treasuries, keeping yields structurally below what domestic conditions alone would have implied.⁷¹ This

71. See Caballero and others (2016), Caballero and others (2017), Ahmed and Rebucci (2025).

mechanism is now weakening from two sides simultaneously. On the supply side, U.S. Treasury issuance has risen sharply, driven by structural deficits and pandemic-era refinancing needs. On the demand side, China's growth slowdown and current account compression have reduced its reserve accumulation, declining fossil fuel revenues are similarly compressing oil exporters' recycling capacity, and geopolitical fragmentation is providing active incentives for reserve diversification away from dollar assets—a trend documented by the IMF's COFER database and accelerated since 2022.⁷²

The result is a structural widening of the term premium on US Treasuries: the external financing cushion that suppressed long-term yields for three decades is narrowing precisely as the supply of government bonds is expanding.⁷³

The four dimensions documented in this section—elevated debt and structural deficits in a non-recessionary environment, rigid and demographically expanding spending commitments, severely constrained monetary financing space, and a weakening external demand cushion for sovereign debt—are not independent. Instead, they reinforce each other: higher deficits require more market issuance, which pushes up yields, which increases the debt service burden, which widens deficits further, which requires still more issuance. This fiscal feedback loop implies that the marginal impact on long-term interest rates of each additional dollar of defense or climate spending is higher today than in any previous comparable rearmament episode, because each additional unit of bond supply is absorbed by a market that is simultaneously facing higher supply from other sources and weaker structural demand. Section 5 aims at quantifying this compound effect,

72. The IMF's COFER database documents the declining share of US dollar assets in global foreign exchange reserves, from approximately 71 percent in 2000 to approximately 57 percent in 2024. For the acceleration post 2022 and the role of geopolitical fragmentation in driving reserve diversification, see Shekhar and others (2023).

73. The Adrian and others (2013) term premium on the 10-year Treasury, which turned negative during the QE era and averaged near zero from 2015 to 2021, reached its highest level since 2011 in January 2025, briefly exceeding 0.8 percent and accounting for more than half of the contemporaneous rise in 10-year yields (Adrian and others, 2013). Consistent with this, Ahmed and Rebucci (2025) document that the reduction of foreign official dollar reserve holdings by approximately \$113 billion following the September 2024 FOMC meeting coincided precisely with a 70–100 basis point rise in real 10-year yields and term premia, thus providing direct empirical evidence of the external demand channel identified in this section. The dollar's share in global disclosed reserves, meanwhile, has declined from 72 percent in 2001 to 58 percent in 2024 (IMF COFER), consistent with a gradual but persistent structural shift in the composition of global reserve portfolios away from dollar assets.

both through a model-based decomposition of shifts in the global $S-I$ equilibrium and through empirical evidence from long-term interest rates and asset prices. The fiscal constraints documented here apply with equal force to both drivers of the paper: climate transition investment and defense spending together constitute an outward shift in global investment demand of the order of 6–8 percent of GDP annually, as established in Sections 2 and 3, and the fiscal transmission of that shift is amplified, not cushioned, by the starting point this section has characterized.

5. GEOPOLITICAL RISK, DEFENSE SPENDING, AND THE PRICING OF LONG-TERM INTEREST RATES AND COMMODITIES

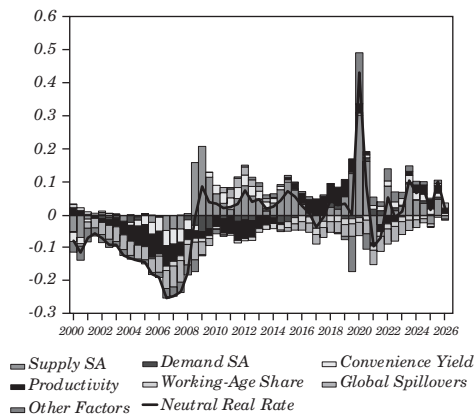
Section 4 established that the fiscal starting point amplifies the interest rate impact of each additional dollar of defense or climate spending through four reinforcing channels: elevated structural deficits, rigid spending commitments, constrained monetary financing, and weakening external demand for advanced economy sovereign debt. The present section provides empirical evidence that these pressures are not merely prospective but are already visible in long-term interest rates and commodity prices. We proceed in four steps. Section 5.1 shows that the deterioration of advanced economy fiscal positions is already being reflected in estimates of the neutral rate, by using the decomposition of Ferreira and Shousha (2023). Section 5.2 provides event-study evidence that market pricing of geopolitical and defense-spending risks has undergone a structural break since 2022. Section 5.3 quantifies the contribution of the geopolitical shock to the US 10-year yield using a sign-restricted structural VAR. Section 5.4 extends the analysis to copper prices, where both the geopolitical and green-transition drivers of this paper leave unambiguous and separately identifiable traces. Oil prices are excluded from the commodity analysis. While the geopolitical landscape tends to increase oil prices, the green transition simultaneously compresses long-run oil demand expectations. These two effects operate in opposing directions, thus making the net impact on oil prices theoretically ambiguous and empirically difficult to identify cleanly. Copper, by contrast, benefits unambiguously from both drivers simultaneously, which renders it the more informative asset for the purposes of this paper.

5.1 The Neutral Rate and the Fiscal Channel: Baseline Evidence

Section 4 characterizes the current fiscal starting point as structurally adverse along multiple dimensions. The decomposition of the US neutral interest rate (r^*) provided by Ferreira and Shousha (2023) shows that this deterioration is already exerting measurable upward pressure on long-run rates, even before the defense and climate spending cycles documented in Sections 2 and 3 have been fully activated. According to their decomposition, increasing fiscal deficits and public debts across advanced economies are causing the supply of safe assets to expand at a faster rate than the market desires to absorb, pushing neutral rates upward through a bond-supply crowding-out channel. Figure 9 illustrates the decomposition of changes in the US neutral rate. The pattern is consistent and economically significant: the safe-asset supply channel—previously a source of downward pressure on neutral rates during the post-GFC period of fiscal consolidation—has reversed sign as deficits have widened and now constitutes a positive and growing contribution to r^* .

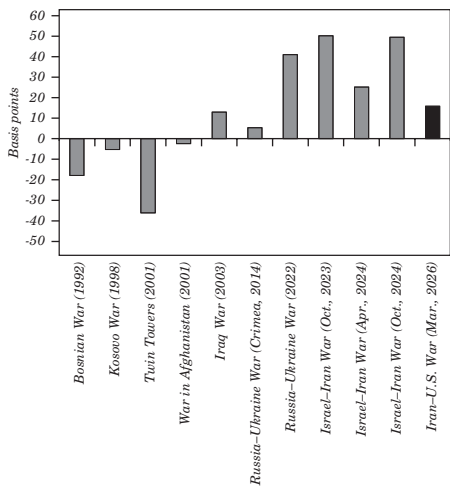
Figure 9. Decomposition of Changes in the US Neutral Rate

*Drivers of change in the US neutral interest rate (R^*):
Safe-asset supply and other structural components*



Sources: Ferreira and Shousha (2023).
Notes: Decomposition of the change in the estimated US neutral rate R^* into structural components including safe-asset supply, demographic trends, productivity, and other factors. The safe-asset supply component captures the contribution of fiscal deficits and public debt issuance to upward pressure on R^* .

Figure 10. US 10-Year Yield Reactions to Geopolitical Events



Sources: FRED, 10-Year Treasury Constant Maturity Rate (DGS10). Event dates identified by authors. Sign-restricted VAR methodology: Cieslak, A. and Pang, H. (2021); extended by Reszczynski and others (2024).
Notes: Each bar shows the cumulative change in the nominal US 10-year Treasury yield over a 30-day window centered on the onset date of each geopolitical event.

5.2 Event-Study Evidence: A Structural Break in the Pricing of Geopolitical Risk

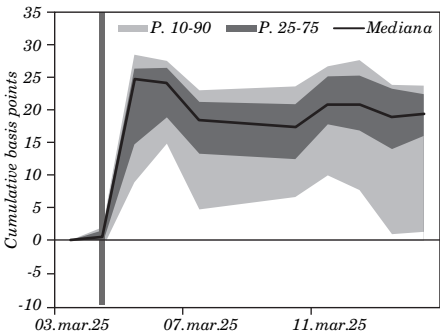
Two complementary event studies establish that market concerns about the fiscal implications of military expenditure are generating economically meaningful effects on long-term interest rates in advanced economies, and that the transmission mechanism has changed qualitatively since 2022.

The first study analyzes the reaction of the US 10-year yield to major geopolitical conflicts. Figure 10 shows the 30-day change in the US 10-year yield centered around each event. The pattern reveals a clear structural break: through the wars in Bosnia (1992), Kosovo (1999), and the September 11 attacks (2001), yields declined or moved little in response to geopolitical escalation, reflecting the traditional safe-haven role of US Treasuries. During these events, heightened uncertainty directed capital flows toward US government debt, thus compressing yields. From the Russian invasion of Ukraine (2022) onward, this relationship has reversed: yields have risen systematically

in response to geopolitical events, including the Israel–Iran–Hamás escalation of 2023–2024 and the US–Israeli military operations against Iran in 2025–2026. This result is not driven by divergent effects on inflation expectations alone: analogous analysis using real interest rates yields qualitatively identical conclusions.⁷⁴ The most natural interpretation is that, in the current fiscal environment, market participants now price geopolitical events not primarily as uncertainty shocks generating safe-haven flows, but as signals of increased future military expenditure that will worsen already strained public finances, which is precisely the mechanism documented in Sections 3 and 4.

Figure 11. Increase in EU 10-Year Sovereign Yields Following the ReArm Europe Announcement

Differential increase in 10-year sovereign yields: EU member states vs. control group following the ReArm Europe Announcement



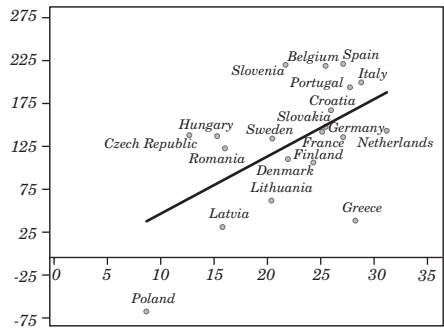
Sources: Authors' calculations based on sovereign yield data from Bloomberg Finance L.P. Identification strategy following Álvarez and others (2025a).

Notes: Difference-in-differences analysis comparing 10-year sovereign bond yields of EU member states (treated group) against a control group of geopolitically aligned but non-EU countries (Australia, Japan, South Korea, Norway). The treated group is subject to the ReArm Europe plan announced on March 4, 2025, which contemplates increasing EU defense spending from approximately 2% to 3.5% of GDP through a combination of fiscal escape clauses and the SAFE loan instrument (EUR 150 billion). For the cross-sectional relationship between yield increase and distance to spending target, see Figure 12.

74. Results for the real interest rate event study are reported in Figure 14 (Annex 2) of Reszczynski and others (2024). The sign reversal after 2022 is robust to using real rates based on Treasury Inflation-Protected Securities (TIPS) and inflation swap-adjusted nominal rates.

Figure 12. Cross-Sectional Evidence: Yield Increase vs. Distance to Spending Target

Increase in 10-year sovereign yields vs. distance to 3.5 percent GDP defense spending target, EU member states



Sources: Authors' calculations. Sovereign yield data: Bloomberg Finance L.P. Defense spending levels: SIPRI Military Expenditure Database; European Defence Agency (2025). Identification: Álvarez and others (2025a), op. cit. Notes: Each observation represents one EU member state. The horizontal axis measures the gap between each country's 2024 defense spending (% of GDP) and the 3.5% GDP core defense target under the ReArm Europe plan. The vertical axis shows the cumulative increase in 10-year sovereign yields in basis points relative to the control group in the two days following the announcement (March 4–6, 2025). The positive cross-sectional slope is consistent with bond markets pricing the sovereign-specific fiscal adjustment burden implied by the program.

The second study exploits the quasi-experimental nature of the ReArm Europe announcement of 4 March 2025. Using the differences-in-differences identification strategy of Álvarez and others (2025a), we compare 10-year sovereign yields of EU member states—the treated group, directly subject to the program's fiscal implications—against a set of geopolitically aligned but non-EU countries (Australia, Japan, South Korea, and Norway) as the control group. Figure 11 shows that, by the day following the announcement, EU sovereign yields had risen to nearly 25 basis points above the control group—a differential that is both economically significant and consistent with a fiscal issuance channel. ReArm Europe explicitly contemplated relaxing EU fiscal rules through national escape clauses and increasing borrowing capacity via the new Security Action for Europe (SAFE) instrument. This raised the expected supply of future sovereign bonds and, with it, the term premium demanded by investors. Figure 12 provides further cross-sectional support: the yield increase is strongly and positively correlated with each country's distance to the 3.5-percent-of-GDP spending target, that is, countries facing the largest implied fiscal expansion experienced the largest relative yield increase, consistent

with markets pricing the sovereign-specific issuance burden rather than a common risk shock.⁷⁵ This evidence aligns both with recent ECB analysis showing that the macrofinancial transmission of defense spending depends critically on private-sector expectations about financing methods and term-premium adjustment⁷⁶ and with Furceri and others (2026), who show that the bond market response to defense buildups is stronger in economies with less fiscal space.

5.3 Structural VAR Decomposition of US Long-Term Yields

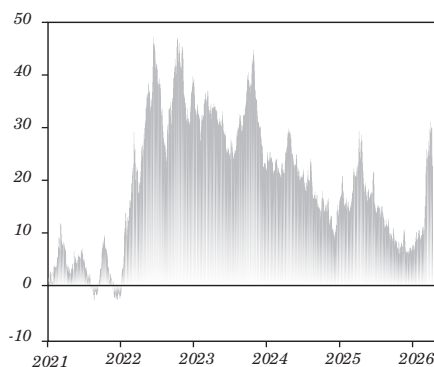
The event-study evidence in Section 5.2 identifies the existence of a geopolitical pricing channel but cannot easily quantify its medium-term contribution to the level of yields across the full post-2021 period. We address this using a structural VAR framework that extends the identification strategy of Cieslak and Pang (2021), following Reszczynski and others (2024).

The model is estimated on daily US data and identifies five structural shocks driving the joint dynamics of the 2-year and 10-year Treasury yields, the S&P 500 (excluding defense-related companies), oil prices, and defense-sector equity prices. The four baseline shocks of Cieslak and Pang (2021)—a US growth shock, a monetary policy shock, a common risk-premium shock, and a hedging risk-premium shock—are identified through sign and magnitude restrictions on the yield curve and the stock-bond covariance. A fifth, geopolitical shock is then identified by augmenting the system: this shock is characterized by a simultaneous rise in oil prices and defense-sector equity prices alongside a fall in non-defense equity prices, capturing the distinct asset-price signature of heightened military activity and conflict risk. Full identification details are reported in Reszczynski and others (2024).

75. The parallel trends assumption underlying the DiD identification—that EU and control-group sovereign yields followed similar trajectories prior to the ReArm Europe announcement—is supported by the pre-event window shown in Figure 6 of the Appendix of Álvarez and others (2025a).

76. See Bokan and others (2025).

Figure 13. Contribution of the Geopolitical Shock to the US 10-Year Treasury Yield



Sources: Authors' calculations. Methodology: sign-restricted structural VAR extending Cieslak and Pang (2021); Reszczynski and others (2024). Full identification details in Table A4 in the Appendix.

Notes: The geopolitical shock is isolated from four other structural shocks—growth, monetary policy, common risk-premium, and hedging risk-premium—via sign and magnitude restrictions estimated on daily US data. The shock is identified by a simultaneous rise in oil prices and defense-sector equity prices alongside a fall in non-defense equity prices. The shaded area shows the 68 percent confidence band around the point estimate.

Figure 13 presents the estimated contribution of the geopolitical shock to the US 10-year yield from December 2021 onward, isolated from the contributions of the growth, monetary policy, and risk-premium shocks through the sign and magnitude restrictions described above. The geopolitical component reached a peak of approximately 45 basis points in 2022, coinciding with the Russian invasion of Ukraine—a result that contrasts sharply with the predictions of models that treat geopolitical shocks as uncertainty events generating flight-to-safety flows.⁷⁷ Following the 2022 peak, the contribution partially reversed, standing at approximately 15 basis points at end-2024, before re-accelerating in 2025 alongside the intensification of rearmament commitments documented in Section 3.3. The pure geopolitical shock pushes yields upward rather than downward, confirming that bond

77. The ~35 basis point contribution cited in the November 2024 conference presentation reflects the geopolitical shock's contribution as of approximately mid-2024, following a substantial partial reversal from the 2022 peak. Both the 60bp peak figure and the 35bp mid-2024 figure are drawn from the same model vintage, applied over different time horizons. The model sample runs from January 2007 through the most recent available date.

markets price the fiscal-spending implications of conflict rather than simply demanding safety—precisely the mechanism identified in the event study of Section 5.2.

5.4 Copper Price Decomposition: Geopolitical and Green Demand Drivers

Copper prices provide a second, independent window onto the same forces. The metal is deeply embedded in both of the paper's main investment drivers: it is an essential input for renewable energy infrastructure, EVs, and grid modernization (the green transition channel), and is a relevant input in weapons systems, military vehicles, and defense electronics (the defense spending channel). Both channels imply persistent demand impulses—not cyclical spikes—because both the green transition and the rearmament cycle operate on 10–20 year structural horizons. Additionally, the deteriorated geopolitical framework adds a demand source related to the need for stockpiling critical materials.

Álvarez and others (2025a) estimate the causal effect of higher military expenditure on copper consumption using instrumental-variable local projections for the United States. Their results indicate that a 1 percentage point increase in the military-spending-to-GDP ratio—approximately \$290 billion—raises US copper consumption by roughly 5 percent in the first year, equivalent to approximately 92 thousand tons of additional demand. Scaling this elasticity to the set of recent defense commitments across advanced economies implies a global demand increase of approximately 485 thousand tons over the coming decade—around 1.8 percent of current world consumption. Under the assumption of sluggish supply adjustment in the short run, this demand shift translates into an estimated 3 to 6 percent upward effect on the copper price.

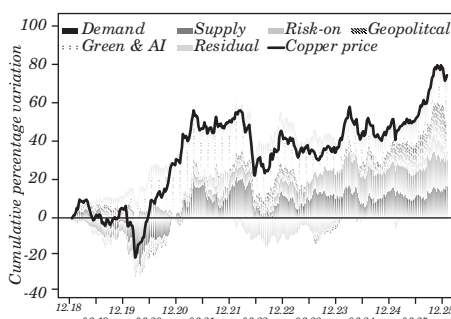
Semi-structural VAR decompositions of weekly copper price dynamics confirm that these forces are already visible in market prices. The identification strategy of Álvarez and others (2025b), estimated on weekly data from the first week of 2014 through December 2025, isolates five structural shocks: a traditional demand shock, a supply and speculation shock, a financial shock, a green and AI demand shock, and a geopolitical shock. The geopolitical shock is identified through sign restrictions requiring that defense-sector equity prices rise relative to the general stock market on impact, capturing strategic stockpiling and rearmament-related demand. The green and AI shock

is identified by requiring a green and data-center ETF to respond more strongly than the general stock market.^{78,79}

Figure 14 presents the cumulative decomposition of copper price into the aforementioned shocks. From 2021 onward, green + AI shocks become more prominent and persistent, while geopolitical shocks appear episodically but with sizable contributions, particularly during periods of heightened volatility. The large contribution in early 2022 aligns with Russia's invasion of Ukraine and, more recently, the renewed spikes in 2024–25 are consistent with Middle East tensions.

Figure 14. Copper Price Decomposition

Historical decomposition of copper price movements by structural shock, February–December 2025



Sources: Authors' calculations following Álvarez and others (2025b). Copper price data: London Metal Exchange (LME) first futures contract via Bloomberg Finance L.P. Defense equity data: market-cap-weighted portfolio of L3Harris Technologies, Howmet Aerospace, TransDigm Group, Northrop Grumman, Taser International, and RTX Corporation. Green and AI factor: first principal component of iShares Global Clean Energy Transition ETF, VanEck Semiconductor ETF, and iShares Semiconductor ETF.

Notes: Bayesian sign-restricted structural VAR with 6 lags, estimated on weekly data from the first week of 2014 through the first week of December 2025. Five structural shocks identified: traditional demand, supply and speculation, financial, green and AI demand, and geopolitical. Geopolitical and green-and-AI shocks incorporate additional magnitude (ranking) restrictions following Amir-Ahmadi and Drautzburg (2021). Cumulative variation measured from early February 2025.

78. See more identification details in Álvarez and others (2025b).

79. See Table A4 in the Appendix for complete sign and magnitude restriction matrix. Defense-sector equity is constructed as a market-cap-weighted portfolio of L3Harris Technologies, Howmet Aerospace, TransDigm Group, Northrop Grumman, Taser International, and RTX Corporation. The green and AI factor is the first principal component of the iShares Global Clean Energy Transition ETF, VanEck Semiconductor ETF, and iShares Semiconductor ETF. Traditional commodities are proxied by the first principal component of lead, iron ore, and Brent crude. The financial factor is the first principal component of the Dow Jones, S&P 500, Nasdaq, Nikkei, and Euro Stoxx 50 indices (Álvarez and others, 2025b).

6. EFFECTS ON THE NEUTRAL INTEREST RATE THROUGH THE LENS OF A MODEL

In this section, we quantify the necessary change in r^* to counteract the increase in financing needs by the government due to climate change adaptation and mitigation efforts, and defense expenditures arising from geopolitical risk. We use a standard HANK model calibrated to the US economy and perform a counterfactual exercise in which we increase public debt by 50bp, a magnitude informed by previous sections.

Moreover, a riskier world due to mounting climate and geopolitical risks would entail an increase in precautionary savings that would, at least partially, counteract the increase in public debt and therefore exert downward pressure on interest rates. Therefore, we quantify the required increase in idiosyncratic risk to completely offset the effect of higher public debt on interest rates.

The model is based on Campos and others (2024). This paper builds a discrete-time HANK model with a monetary authority and a treasury. There are nominal wage rigidities, and labor hours are determined through a union acting on behalf of workers. Firms produce a final good using union-supplied labor. There is (i) a central bank that sets the nominal interest rate, and (ii) a treasury that taxes, spends, transfers, and issues public debt. Fiscal policy is modeled with a rule that stabilizes long-run real debt.

Households $i \in [0, 1]$ maximize expected lifetime utility:

$$V(a_{i,t}, z_{i,t}) = \max u(c_{i,t}) - v(n_{i,t}) + \beta E_t[V(a_{i,t+1}, z_{i,t+1})],$$

subject to the budget constraint:

$$c_{i,t} + a_{i,t+1} = (1 + r_t) a_{i,t} + (1 - \tau) z_{i,t} n_{i,t} + T_t,$$

and the borrowing constraint:

$$a_{i,t+1} \geq 0.$$

Here, $a_{i,t}$ are assets, $z_{i,t}$ is labor productivity, $c_{i,t}$ is consumption, $n_{i,t}$ is labor hours, r_t is the real interest rate, τ is the labor tax rate and T_t are lump-sum transfers.

Idiosyncratic labor productivity follows a Markov process $z_{i,t+1} \sim \Pi(z_{i,t})$, with $E[z] = 1$.

Labor hours are determined by a union. Households take hours as given, so that $n_{i,t} = N_t$. Aggregate effective labor is given by:

$$N_t = \int z_{i,t} n_{i,t} di.$$

Nominal wages W_t are set subject to nominal rigidities. Final output Y_t is produced using union-supplied labor:

$$Y_t = F(N_t).$$

The government issues nominal debt B_t and satisfies the real budget constraint:

$$B_{t+1} = (1 + r_t) B_t + G_t + T_t - \tau W_t \frac{N_t}{P_t}.$$

Here G_t is real expenditure and P_t the price level. Fiscal policy follows a rule that stabilizes long-run real debt at $\bar{B}$. The central bank sets the nominal interest rate according to a Taylor-type rule:

$$i_t = \varphi_\pi(\pi_t - \pi^*) + \text{intercept}$$

subject to the zero lower bound $i_t \geq 0$.

The natural rate r^* is defined as the real interest rate in the deterministic steady state. Here inflation is π_t and the inflation targets is π^* .

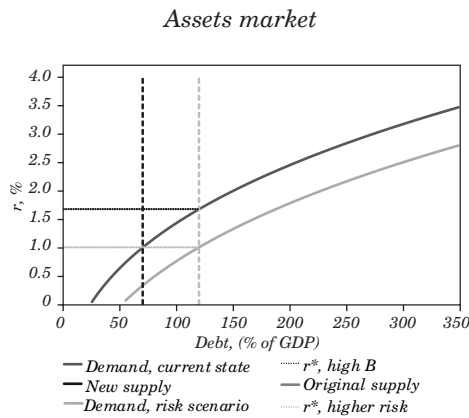
In the HANK model, r^* depends on the long-run stock of public debt, so that $r^* = r^*(\bar{B})$.

The model is parameterized to the US and yields a steady-state annual $r = 1$ percent for a steady-state level of debt/GDP = 70 percent (Figure 15).

We perform the following exercise: we simulate a 50pp increase in the debt/GDP ratio, to 120 percent. Such an increase entails an increase in the real interest rate of 68 percent, so that $r = 1.68$ percent (68 percent increase). This is reflected as a new supply curve in the assets market, to the right of the original one, represented by the dotted light gray line in Figure 15. Next, we compute the increase in the variance of the temporary idiosyncratic log wage shock that would push up precautionary savings enough to counteract this increase in , represented by the gray demand curve in Figure 15. We find that the variance would need to increase by around 55 percent. This is a substantial increase in idiosyncratic risk, as it is almost twice the difference between the variances of the US and Sweden.⁸⁰

80. See Floden and Lindé (2001).

Figure 15. Equilibrium in the Assets Market



Source: Campos and others (2024).

Moreover, this increase in risk should come from risks other than those associated with natural disasters if debt issuance is financing investment in climate change adaptation and mitigation efforts, therefore managing such risk. From the lens of the model, we can conclude that the increase in government financing needs will drive interest rates up in a significant manner, which will probably not be fully counteracted by an increase in precautionary savings.

7. CONCLUSIONS

This paper has examined the implications of climate change and rising geopolitical tensions for the longrun determination of interest rates, with a particular focus on the natural real interest rate, r^* . We have argued that the secular decline in r^* observed over the past four decades is unlikely to persist under the current and emerging structural environment. Instead, a new configuration of forces—centered on large, persistent increases in investment demand and operating under historically constrained fiscal conditions—points toward sustained upward pressure on equilibrium real interest rates.

Our analysis highlights two dominant and largely independent drivers of this shift. The first is the climate transition, which entails an unprecedented scale of investment in mitigation, adaptation, and resilience across energy, infrastructure, industry, transport,

agriculture, and land use. Even under conservative assumptions, meeting internationally stated climate objectives requires a durable increase in global investment flows over the coming decades. The second driver is the resurgence of geopolitical risk and associated rearmament cycles, which translate into sustained increases in defense and strategic public spending across major economies and geopolitical blocs. While distinct in origin, these forces jointly act to shift the global investment schedule outward in the longrun saving–investment equilibrium.

The paper argues that the macroeconomic implications of these forces are amplified by the fiscal starting point from which they operate. Unlike earlier episodes of large public spending expansions, the current environment is characterized by historically elevated public debt levels, sizable structural deficits even outside recessionary conditions, rigid social spending commitments, constrained scope for monetary financing, and a weakening external demand for advancedeconomy sovereign debt. Together, these features imply that additional public investment exerts a larger effect on longterm interest rates than suggested by historical analogues, as the marginal supply of public debt must be absorbed at increasing marketdetermined rates.

We complement this structural analysis with multiple layers of empirical evidence. Eventstudy results, structural VAR decompositions, and assetprice dynamics indicate that financial markets have already begun to reprice longterm yields in response to geopolitical risk and its fiscal implications, reversing the traditional flighttosafety pattern that characterized earlier decades. Evidence from commodity markets—particularly copper—further supports the interpretation that both climaterelated investment demand and defense spending are exerting persistent realside pressures consistent with the saving–investment framework developed in the paper.

Model-based results using a heterogeneousagent New Keynesian framework reinforce these findings. Increases in public debt consistent with the scale of climate and defense spending considered in the paper lead to economically meaningful rises in the steadystate real interest rate. While heightened uncertainty and precautionary saving mitigate part of this effect, the magnitude of risk required to fully offset higher financing needs is implausibly large, suggesting that upward pressure on r^* is likely to dominate in equilibrium.

Taken together, the results point to a structural reconfiguration of the long-run interest rate environment. The forces that drove the prolonged decline in r^* —excess saving, weak investment demand,

and abundant external financing—are weakening or reversing, while new sources of persistent investment demand are emerging under tight fiscal constraints. This shift has important implications for the interpretation of neutral interest rate estimates, the conduct of monetary policy over the medium term, and the interaction between fiscal sustainability and macroeconomic stabilization. More broadly, it suggests that the global economy may be entering a regime in which higher equilibrium real interest rates are a structural feature rather than a cyclical anomaly.

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APPENDIX

Table A.1 Comparison CPI vs. IEA

<i>Boundaries/Sectors</i>	<i>CPI (USD trillion)</i>	<i>IEA (USD trillion)</i>
Renewable power	0.787	0.735
Nuclear and other clean power	Not in scope	0.067
Energy storage	0.042	0.04
Low-emission fuels	Tracked under renewable power	0.02
Electricity grids	0.001	0.375
Electricity grids – New grids and asset replacement	0.086	0
Energy efficiency – buildings and industry	0.312	0.397
Transport	0.539	0.229
Transport – metro	0.132	0
Other Energy, Industry and Buildings & Infrastructure mitigation	0.001	Not in scope
Fossil fuels	Not in scope	1.087
Adaptation finance	0.065	Not in scope
Adaptation finance – households	0.065-0.087	Not in scope
Debt benefits finance	0.058	Not in scope
AFOLU mitigation	0.018	Not in scope
Waste and wastewater Mitigation	0.034	Not in scope
Other cross-sectoral mitigation	0.046	Not in scope
Total tracked by CPI and IEA	1.903	2.907
Total incl. fossil fuel	1.903	1.883
Total including new CPI estimations	2.186-2.008	
Covered and tracked by CPI and the EIA	Under Methodological by CPI for inclusion in future CPI report	Not in scope

Source: Authors' calculations based on Climate Policy Initiative (2025).

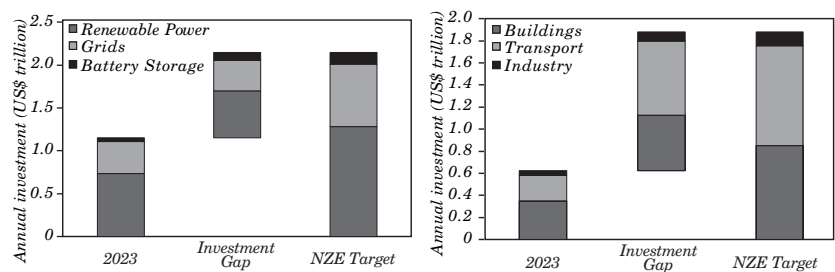
Table A.2 CPI Reduction by Area

<i>Investment requirement by sector (trillion US\$) and the impact (Gt CO₂e)</i>	<i>Flows (2023)</i>	<i>Needs (NZ)</i>	<i>Mitigation Potential (GtCO₂e)</i>
Energy	0.8309	2.875	12.2
Transport	0.5389	1.866	3.2
Buildings & Infrastructure	0.2882	1.131	3.2
Industry	0.0245	0.588	4.4
AFOLU	0.0182	1.169	8
Adaptation	0.046	0.222	

Source: Authors’ calculations based on Climate Policy Initiative (2025).

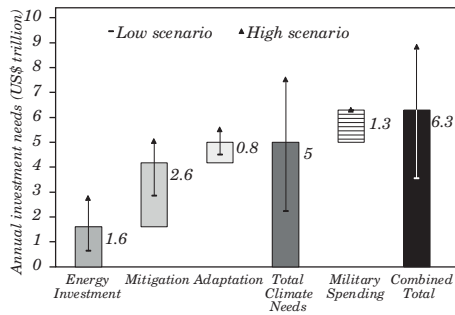
Figure A.1 IEA Gap

(a) Mitigation investment in energy (b) Mitigation investment in industry



Source: Authors’ calculations based on International Energy Agency (2024).

Figure A.2 Annual Climate Needs (Range) vs. Military Spending



Source: Authors’ calculations.

Table A.3 Consolidation of the Eastern Bloc: Key Developments since 2021

<i>Dimension</i>	<i>Development</i>	<i>Actors</i>	<i>Date</i>	<i>Source</i>
Military	China and Russia conduct large-scale joint military exercises, including naval patrols near Alaska and joint bomber flights around Japan (2022) and the first-ever joint bomber patrol in the direction of Tokyo (December 2025).	China–Russia	2022–Dec. 2025	Lin and others (2026).
Military	North Korea transfers >12 million artillery rounds, >100 ballistic missiles, rocket launchers, and self-propelled guns to Russia for use in Ukraine.	DPRK–Russia	2022–2025	Multilateral Sanctions Monitoring Team (May 2025) cited in Congressional Research Service. Bowen and others (2025).
Military	~15,000 North Korean troops deployed to Russia (Kursk region); DPRK formally confirms deployment in April 2025; Kim Jong-un describes alliance as at “historic peak” in October 2025.	DPRK–Russia	Oct. 2024 – 2025	Carlough and Kennedy (2025).
Military	China supplies Iran with HQ-9B long-range surface-to-air missile batteries (advanced air defense system).	China–Iran	Jul. 2025	Brody and Gabber (2026).
Military	Russia and Iran conclude ~\$590 million agreement for portable air defense systems (Verba MANPADS).	Russia – Iran	Dec. 2025	Brody and Gabber (2026).

Table A.3 Consolidation of the Eastern Bloc: Key Developments since 2021 (continued)

<i>Dimension</i>	<i>Development</i>	<i>Actors</i>	<i>Date</i>	<i>Source</i>
Military	First SCO military exercise on Iranian soil (“Sahand-2025”) with China, Russia, India, and six other member states.	China – Russia – Iran	Dec. 2025	MERICS (2026).
Strategic	Russia–North Korea Treaty on Comprehensive Strategic Partnership signed (Pyongyang, June 19, 2024); includes mutual military assistance clause; entered into force December 4, 2024.	Russia – DPRK	Jun. 19, 2024	President of Russia (2024).
Strategic	China and Russia announce “no limits” partnership; bilateral trade more than doubles from \$120 bn (2020) to \$244.8 bn (2024) with >95% settled in local currencies.	China – Russia	Feb. 2022 / Jan. 2025	MERICS (2026).
Strategic	Iran–Russia Treaty on Comprehensive Strategic Partnership (20-year term) signed in Moscow, January 17, 2025; entered into force October 2, 2025; 47 articles covering defense, energy, cybersecurity, finance, and counterterrorism.	Russia – Iran	Jan. 17, 2025 / Oct. 2, 2025	Iranian Foreign Ministry (2025).

Table A.3 Consolidation of the Eastern Bloc: Key Developments since 2021 (continued)

<i>Dimension</i>	<i>Development</i>	<i>Actors</i>	<i>Date</i>	<i>Source</i>
Strategic	China, Russia, and Iran sign formal trilateral strategic pact; a coordinated framework across nuclear sovereignty, military cooperation, and diplomatic strategy.	China – Russia – Iran	Jan. 2026	Solomon (2026).
Strategic	Pentagon Annual Report: China is undergoing the “most rapid and ambitious modernization of its nuclear forces in history.”	China	Oct. 2024	U.S. Department of Defense (2024).
Economic	China absorbs >80% of Iranian oil exports at discounted rates, providing a critical economic lifeline that offsets Western sanctions.	China – Iran	2023–2025	Brody and Gabber (2026).
Economic	China–Russia bilateral trade reaches \$244.8 bn (2024), a record high and more than double its 2020 level; Russia’s oil exports to China exceeded 108 mn tonnes in 2024 (+30% since 2022).	China – Russia	2024	General Administration of Customs of China (2025) and MERICS (2026).
Economic	BRI cumulative engagement surpasses \$1.175 trillion (2013–2024); 150 countries hold active cooperation agreements (May 2025); H1 2025 sets record for BRI engagement at \$123 bn.	China – Global South	2013–2025	Nedopil (2025).

Table A.3 Consolidation of the Eastern Bloc: Key Developments since 2021 (continued)

<i>Dimension</i>	<i>Development</i>	<i>Actors</i>	<i>Date</i>	<i>Source</i>
Institutional	Iran joins the Shanghai Cooperation Organization (SCO) as a full member.	China – Russia – Iran	Jun. 2023	U.S.-China Economic and Security Review Commission (2025).
Institutional	Iran joins BRICS as a full member.	China – Russia – Iran	Jan. 2024	U.S.-China Economic and Security Review Commission (2025).
Institutional	USCC Annual Report formally designates the grouping “Axis of Autocracy” (China, Russia, Iran, North Korea); CSIS and CNAS independently adopt “CRINK” and “Axis of Upheaval” in major analytical reports.	Eastern bloc	Nov. 2025	U.S.-China Economic and Security Review Commission (2025); Kendall-Taylor and Lokker (2025); Hart and others (2025).

Source: Authors’ calculations.
Notes: CNAS stands for Center for a New American Security and CSIS for Center for Strategic and International Studies.

Table A.4 Sign and Magnitude Restrictions SVAR

<i>Sign Restrictions</i>					
	<i>Growth</i>	<i>Monetary Policy</i>	<i>Hedge</i>	<i>Common Risk</i>	<i>Geopolitical</i>
2-year rate	+	+	+	+	NaN
10-year rate	+	+	+	+	NaN
S&P 500 ex defense	+	+	+	+	-
Defense	NaN	NaN	NaN	NaN	+
Petroleum	+	-	+	-	+
<i>Magnitude Restrictions</i>					
	<i>Growth</i>	<i>Monetary Policy</i>	<i>Hedge</i>	<i>Common Risk</i>	<i>Geopolitical</i>
2-year rate >	2-year rate >	2-year rate >	2-year rate <	2-year rate <	NaN
10-year rate	10-year rate	10-year rate	10-year rate	10-year rate	

Source: Álvarez and others (2025b).
Notes: Structural shocks are identified by using sign and magnitude restrictions following Álvarez and others (2025b). Sign restrictions constrain the contemporaneous responses of interest rates, equity prices, and commodity prices, while magnitude restrictions on the yield curve (relative responses of 2-year versus 10-year rates) distinguish demand-type shocks from risk- and coverage-related shocks. The geopolitical shock is identified by an increase in defense-sector equities relative to the broad equity market.

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