

THE IMPACT OF CLIMATE CHANGE AND GEOPOLITICAL TENSIONS ON LONG-TERM INTEREST RATES

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

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editors



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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.

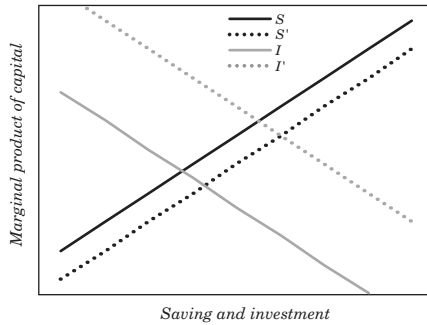
To study the secular trend in the neutral real interest rate (r^*), we adopt a longrun equilibrium perspective in which the real interest rate is determined by the intersection of desired saving and desired investment in the absence of transitory shocks (Figure 1). This approach combines the intuition 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.

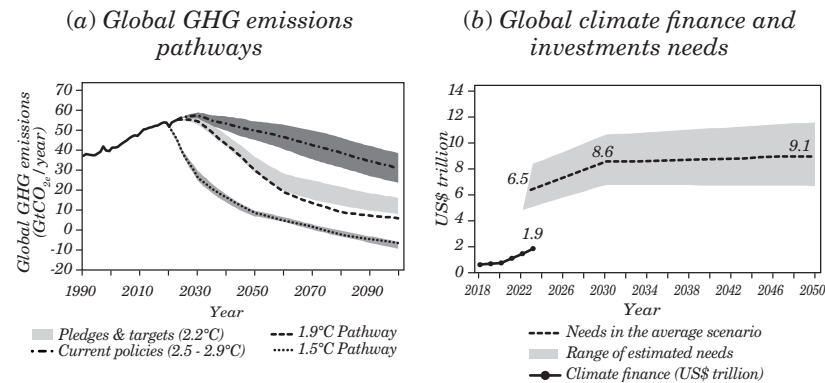
According to the Climate Policy Initiative (CPI) in its annual report “Global Landscape of Climate Finance 2025”, total climate finance reached approximately USD 1.9 trillion in 2023, continuing an upward trend from the USD 1.7 trillion recorded in 2022. Even though this growth in investment is significant, 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.

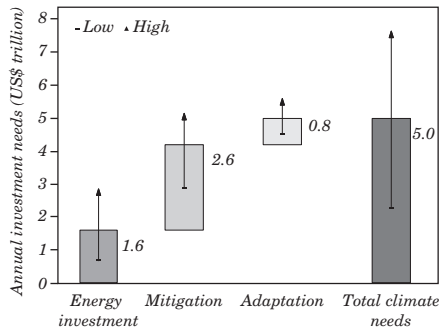
The recent 2025 Adaptation Gap Report of the United Nations Environment Programme (UNEP), which updates the cost of adaptation financing in developing countries, estimates requirements at USD 300 billion for the year 2035 when based on modeled costs. When calculated based on extrapolated needs expressed 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

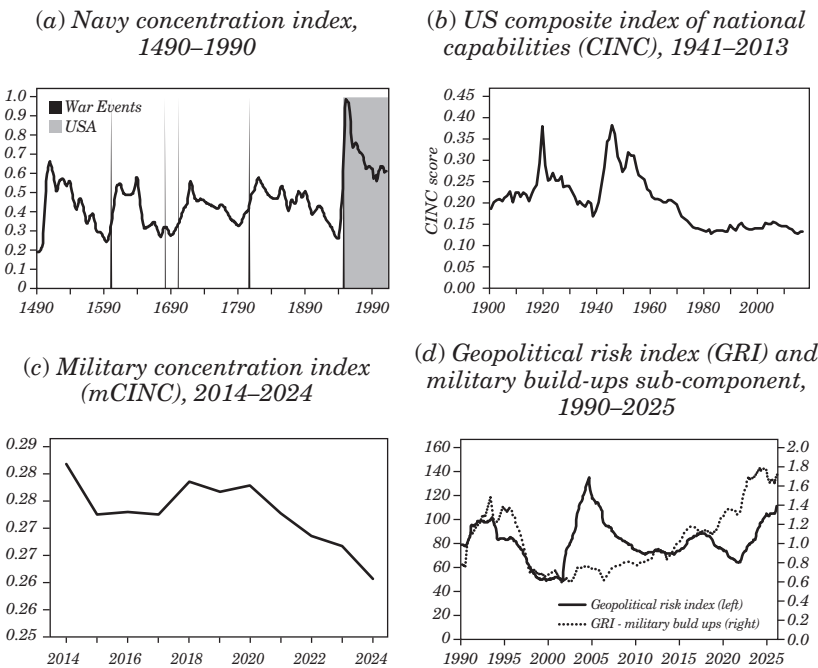
Research in the long-cycle tradition documents a robust historical regularity: periods of declining military concentration—when no single power dominates unambiguously—have systematically preceded major interstate conflicts.⁴⁷ By this measure, the current environment is notably hazardous. The US Composite 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

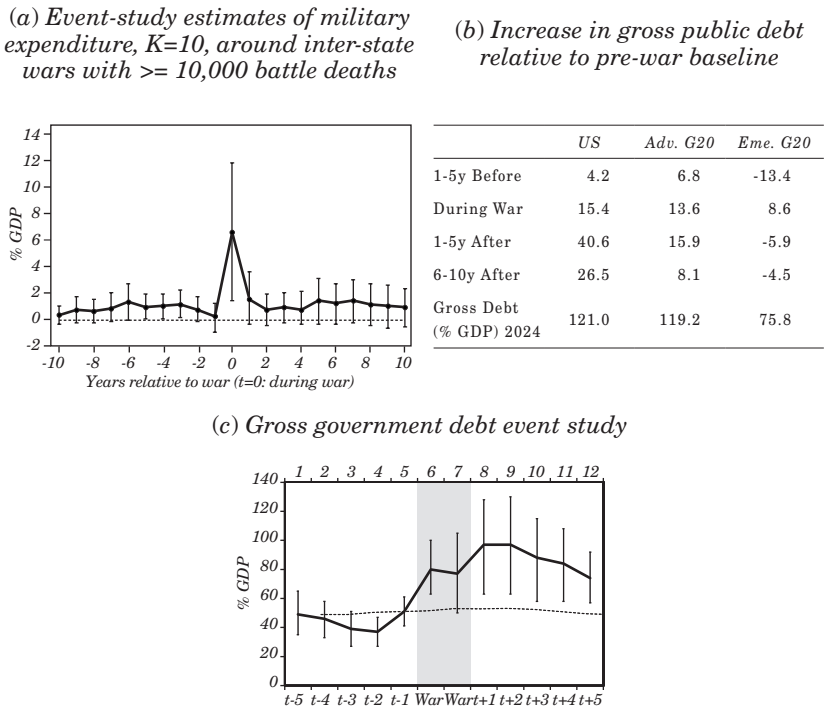
51. In April 2025, the PLA conducted “Strait Thunder-2025A” (135 aircraft sorties, 38 naval vessels); in December 2025, its “Justice Mission-2025” deployed army, navy, air force, and rocket force units across five maritime zones in a live-fire encirclement explicitly rehearsing a Taiwan blockade scenario, 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



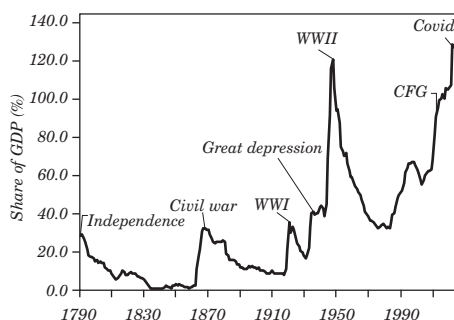
Sources: Panel (a): SIPRI Military Expenditure Database; Correlates of War Project, Inter-State War dataset (wars between states, 1830–2007). Panel (b): US Treasury, Historical Debt Outstanding; IMF, Fiscal Monitor (various years). Panel (c): EBRD (2024). Additional data: Federal Reserve Economic Data (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.

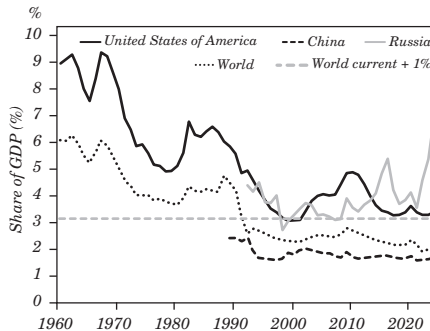
3.3 Current and Announced Rearmament Spending

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).

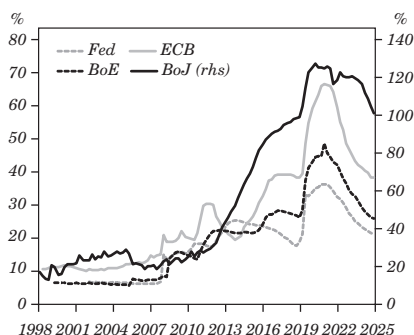
69. International Monetary Fund (2025b). See also International Monetary Fund (2025a), which explicitly identifies “rising defense commitments with aging-related spending pressures” as the central fiscal challenge for European advanced economies.

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

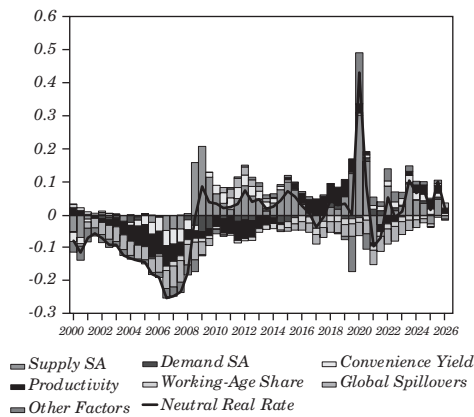
Section 4 established that the fiscal starting point amplifies the interest rate impact of each additional dollar of defense or climate spending through four reinforcing channels: elevated structural deficits, rigid spending commitments, constrained monetary financing, and weakening external demand for 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^* .

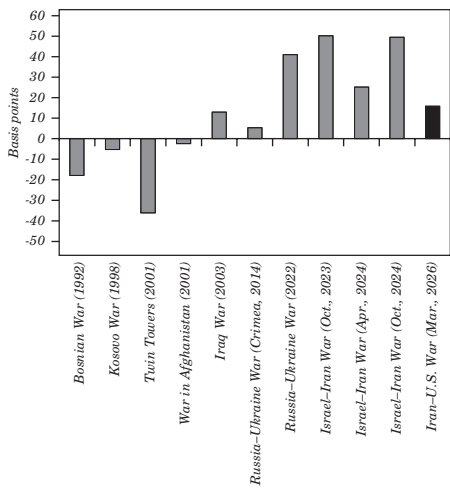
Figure 9. Decomposition of Changes in the US Neutral Rate

*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

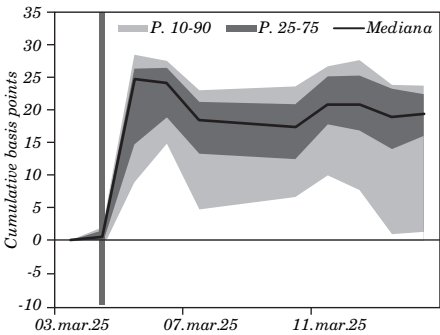
Two complementary event studies establish that market concerns about the fiscal implications of military expenditure are generating economically meaningful effects on long-term interest rates in advanced economies, and that the transmission mechanism has changed qualitatively since 2022.

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



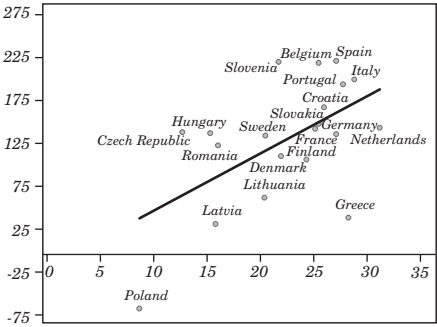
Sources: Authors' calculations based on sovereign yield data from Bloomberg Finance L.P. Identification strategy following Álvarez and others (2025a).

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

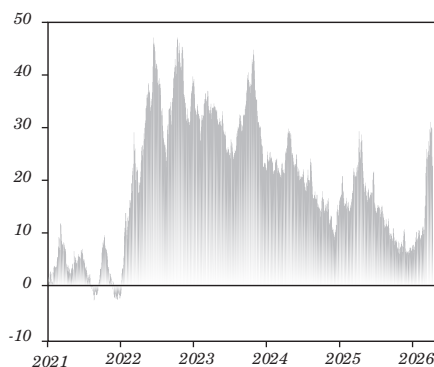
The event-study evidence in Section 5.2 identifies the existence of a geopolitical pricing channel but cannot easily quantify its medium-term contribution to the level of yields across the full post-2021 period. We address this using a structural VAR framework that extends the identification strategy 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.

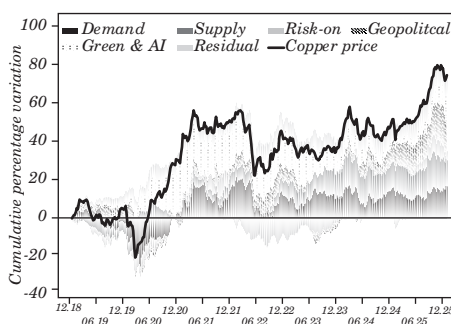
Semi-structural VAR decompositions of weekly copper price dynamics confirm that these forces are already visible in market prices. The identification strategy of Álvarez and others (2025b), estimated on weekly data from the first week of 2014 through December 2025, isolates five structural shocks: a 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^* .

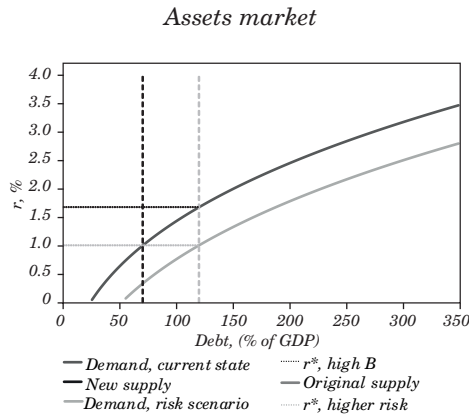
In the HANK model, r^* depends on the long-run stock of public debt, so that $r^* = r^*(\bar{B})$.

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

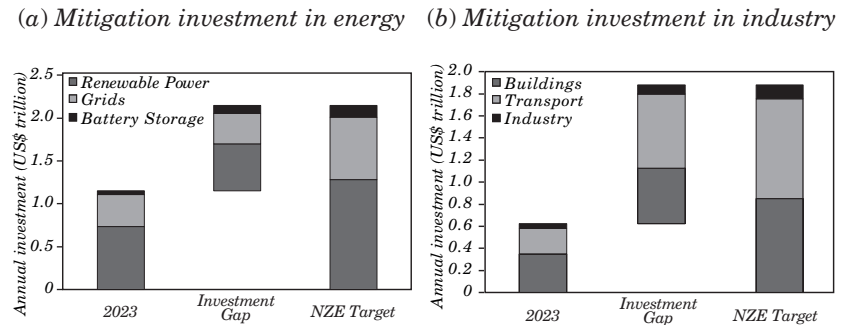
Source: Authors' calculations based on Climate Policy Initiative (2025).

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	

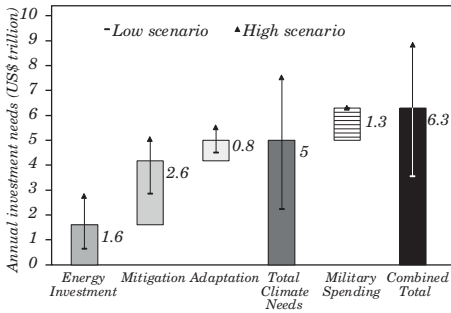
Source: Authors’ calculations based on Climate Policy Initiative (2025).

Figure A.1 IEA Gap



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

Sign Restrictions					
	Growth	Monetary Policy	Hedge	Common Risk	Geopolitical
2-year rate	+	+	+	+	NaN
10-year rate	+	+	+	+	NaN
S&P 500 ex defense	+	+	+	+	-
Defense	NaN	NaN	NaN	NaN	+
Petroleum	+	-	+	-	+
Magnitude Restrictions					
	Growth	Monetary Policy	Hedge	Common Risk	Geopolitical
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.

