Vanguard research | Megatrends

AI, demographics, and the U.S. economy

Quantifying the coming tug-of-war

About the Megatrends series

Megatrends have accompanied humankind throughout history. From the Neolithic Revolution to the Information Age, innovation has been the catalyst for profound socioeconomic, cultural, and political transformation. The term Megatrends was popularized by author John Naisbitt, who was interested in the transformative forces that have a major impact on both businesses and societies, and thus the potential to change all areas of our personal and professional lives.

Vanguard's "Megatrends" is a research effort that investigates fundamental shifts in the global economic landscape that are likely to affect the financial services industry and broader society. A megatrend may bring market growth or destroy it, increase competition or add barriers to entry, and create threats or uncover opportunities. Exploring the long-term nature of massive shifts in technology, demographics, and globalization can help us better understand how such forces may shape future markets, individuals, and the investing landscape in the years ahead.

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Takeaways

- The U.S. economy's coming decade will be shaped by a tug-of-war between artificial intelligence (AI) and demographics-driven deficits. The victor—and its margin of victory—will determine whether economic growth exceeds its disappointing pace since the global financial crisis or slows further.
- We generate and quantify this insight with the Vanguard Megatrends Model™. The model quantifies the impact of slow-moving supply-side forces, or megatrends, on the economy and financial markets. Focusing on four key variables—real GDP growth, inflation, the federal funds rate, and stock market valuations—we review how megatrends have driven economic and financial outcomes over the last 130 years, and we assign probabilities to future outcomes.
- The most likely outcome is optimistic: AI catalyzes a surge in worker productivity, offsetting demographic pressures. But the next most likely outcome is pessimistic: AI fails to meet our expectations, growth tumbles, and this puts pressure on the government's balance sheet. In both cases, the nominal federal funds rate is likely to remain above 4%. And despite its recent spike, inflation is likely to remain contained, consistent with the Federal Reserve Board's price stability mandate. We find little support for the consensus view that the next decade will look like the past decade of slow but modest growth.

Megatrends: Determinants of our past, drivers of our future

What is the outlook for the U.S. economy and financial markets in the next decade? Will we have a future of too few jobs, due to AI, or too few workers, due to the retirement of the baby boomers? Will an aging society, rising fiscal deficits, and waning globalization lead to higher inflation? Will AI be as transformative as electricity?

To answer these questions, one needs a framework that can account for the evolution of and interaction among slow-moving trends that shape an economy's productive capacity over decades. We refer to these supply-side forces as "megatrends." They are:

Technology. Innovations that (a) augment labor (such as power tools), (b) replace labor (such as robotics), or (c) transform economic production and society (such as electricity and computers).

Demographics. Changes in the rate of population growth and the age composition of the population.

Fiscal deficits and debt. Changes in the size and nature of government deficits and debt.

Globalization. Trends in global trade and foreign direct investment.

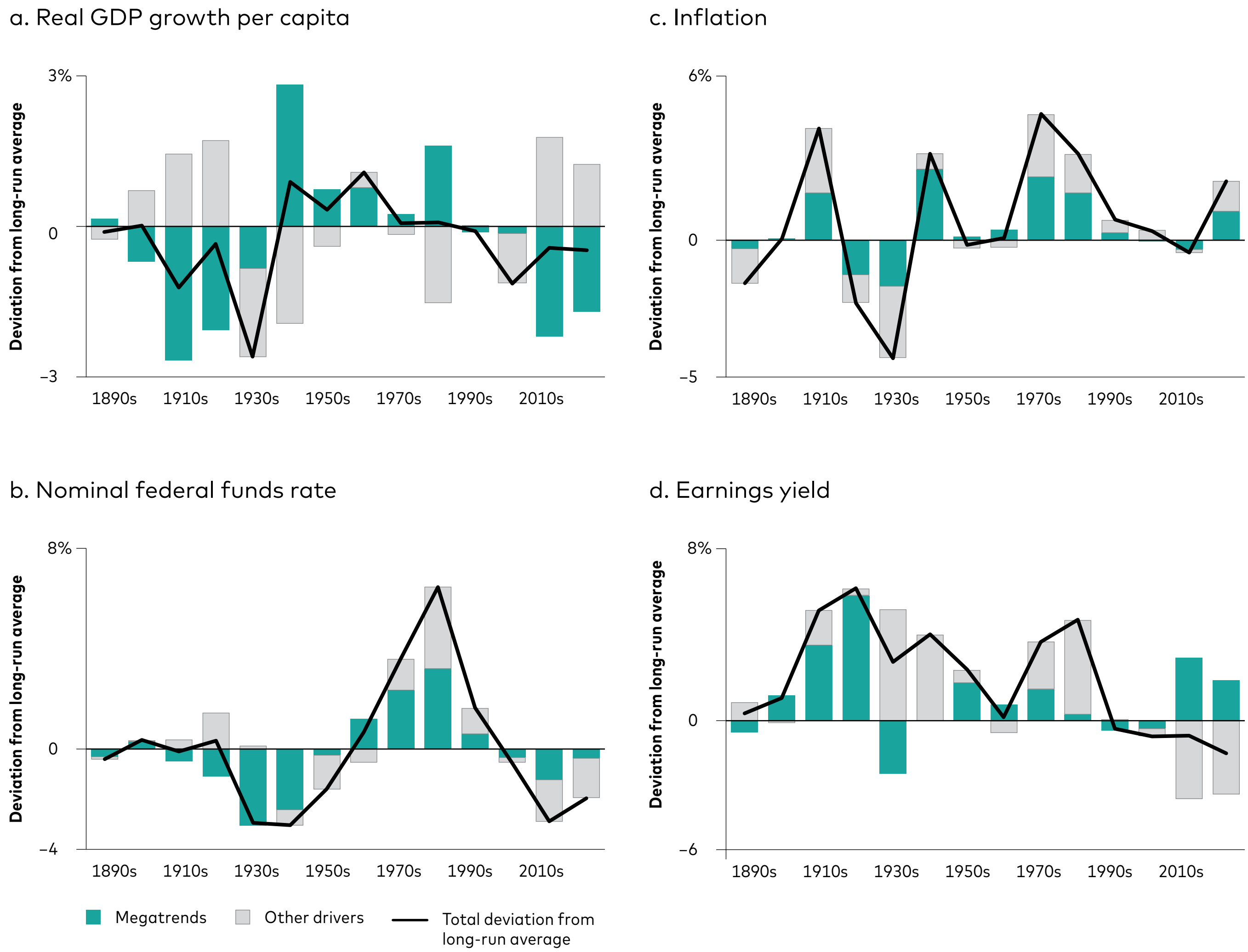
Geopolitical risk. Conflicts that produce economic upheaval and loss of human life. These were most significant in the first half of the 20th century.

We focus mostly on the first four megatrends, though geopolitical risk is captured during World Wars I and II. **Figure 1** shows how these megatrends have driven the economic and financial outcomes that matter to individuals, investors, and policymakers. We call those outcomes "the Big Four": real GDP growth per capita; inflation; the nominal federal funds rate; and earnings yield, a measure of stock market valuation.

Over the last 130 years, megatrends have driven about 60% of the change in per capita GDP growth and earnings yield. They've had a lesser, though still important, impact on inflation and the federal funds rate. These outcomes have responded more to shorter-term business-cycle fluctuations—booms and recessions—and to fiscal and monetary policy.

FIGURE 1

Since 1890, megatrends have been a powerful driver of changes in the Big Four



Notes: The "Megatrends" portions of the bars show, by decade average, the historical contribution of technology, demographics, fiscal deficits, globalization, and geopolitical risk (to account for extreme circumstances during the first half of the 20th century) to the deviation of the Big Four from their long-run average. The "Other drivers" portions of the bars reflect the historical contribution of risk premia, monetary policy, business cycle, and temperature change.

Source: Vanguard.

This 130-year perspective on the role of megatrends in the economy yields a second insight: that megatrends can lead to significant decade-to-decade change in the Big Four. Contrast this historical reality with the muted and clustered consensus outlook for economic growth over the next decade **(Figure 2)**.

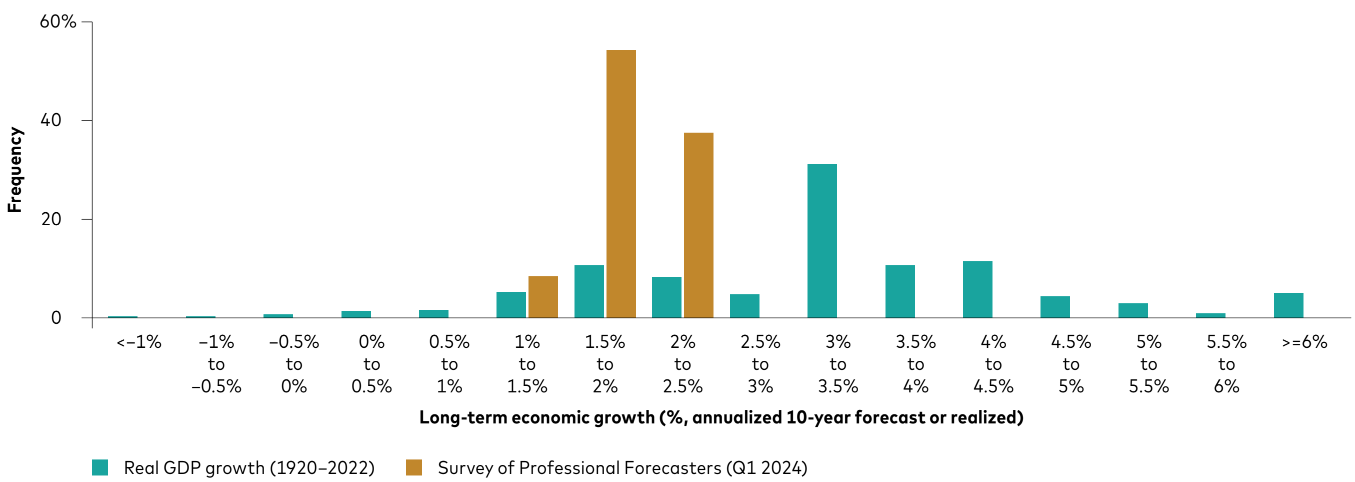
The consensus expects the economic trends that predated the COVID-19 pandemic to persist.[1] The contrast with the historical growth rates is stark. Between 1920 and the present, megatrends have helped drive 10-year real economic growth from below 0% to above 6%. The consensus view seems to reflect a belief that the coming decade will look more like the past decade, with real U.S. GDP growth averaging 1.5%–2%. To the extent that megatrends matter, this consensus view seems to assume they will modestly drag on economic growth.

Our research suggests that this outcome is unlikely. (We're not alone, though the reasons for our dissent are unique.) We review the historical impact of megatrends on the Big Four and use these insights to forecast economic and financial outcomes through 2040. In doing so, we affirm and challenge conventional beliefs about how megatrends affect those outcomes.

Our forecasts suggest the most likely outcome is that AI catalyzes a surge in economic growth and that worker productivity rises, offsetting demographic pressures. The next most likely outcome is that AI fails to meet our expectations, as an aging population fuels rising deficits and debt. The bottom line: The next decade or so will be very different from our recent past.

FIGURE 2

Consensus forecast for growth in the next decade: More of the same



Note: Figure shows the results of the Survey of Professional Forecasters for expected real GDP growth over the next 10 years and the distribution of the 10-year realized average growth rate from 1920 through 2022.

Sources: Vanguard calculations, based on data from Davis, Brandl-Cheng, and Khang (2024) and the Federal Reserve Bank of Philadelphia's First Quarter 2024 Survey of Professional Forecasters.

1 The consensus view is from the Federal Reserve Bank of Philadelphia's First Quarter 2024 Survey of Professional Forecasters. This consensus is broadly shared by credible sources, including the U.S. Congressional Budget Office (CBO) and the Federal Reserve's latest (March 2024) longer-run Summary of Economic Projections.

The Vanguard Megatrends Model: Data and design

We derive these insights from the Vanguard Megatrends Model, which allows us to disentangle the historical contribution of megatrends from other drivers of the Big Four. The model also allows us to quantify—and assign probabilities to—future scenarios. Our model includes three innovative features:

1. A uniquely long and rich historical dataset that captures historical shifts in megatrends across the U.S. and globally.
2. An integrated framework that allows long-term megatrends and shorter-term cyclical and policy variables to compete in explaining economic and financial outcomes.
3. An identification strategy that isolates the distinct structural drivers behind each megatrend—the fiscal or technological forces that may have differing impacts on the Big Four.

Appendix 1 on page 25 provides more detail on the Vanguard Megatrends Model. See also Davis, Brandl-Cheng, and Khang (2024).

Quantifying megatrends' cumulative impact on the Big Four

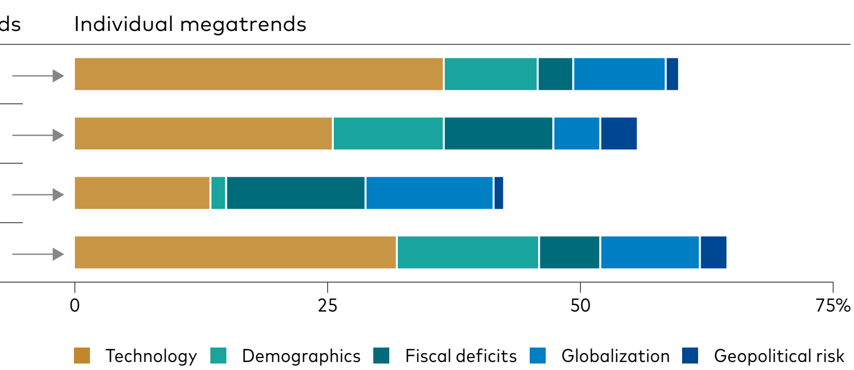
Figure 1 showed how megatrends have driven the Big Four from decade to decade over the last 130 years. **Figure 3** quantifies each megatrend's cumulative impact on the Big Four over the full period, highlighting the relative importance of each megatrend's impact.

The four megatrends have collectively driven roughly 60% of the variation in GDP and earnings yield over the last 130 years—an underappreciated reality. Megatrends have also played an important, though not dominant, role in driving the federal funds rate and inflation. And only technology has materially contributed to all the Big Four variables; the three other megatrends have mattered for just one or two. For example, fiscal deficits and globalization most prominently affected inflation.

FIGURE 3

Megatrends—most powerfully technology—have driven the Big Four

Big Four	**Aggregated drivers**: Other drivers	**Aggregated drivers**: Megatrends
Real GDP growth per capita	**40%**	**60%**
Nominal federal funds rate	**44%**	**56%**
Inflation	**58%**	**42%**
Earnings yield	**36%**	**64%**



Notes: Figure shows the contribution of the megatrends (technology, demographics, fiscal deficits, globalization, and geopolitical risk) to variation in the Big Four (real GDP growth per capita, the nominal federal funds rate, inflation, and the earnings yield) from June 30, 1891, through September 30, 2023. The "Aggregated drivers" columns combine these contributions into the overall megatrends contribution, compared with the contributions from other drivers, such as cyclical fluctuations or monetary policy.

Source: Vanguard.

Challenges to, and validations of, perception and reality

Our quantification yields insights that affirm, refine, and challenge widely held beliefs about how megatrends affect economic and financial outcomes. **Figure 4** contrasts *perceptions* (common narratives about the impact of a megatrend on economic and financial outcomes) with *empirical realities* (facts supported by the Vanguard Megatrends Model). Although we lack space to address all the items in the figure, we explore the most important ones: perceptions and realities about the Big Four.

FIGURE 4

Facts both challenge and validate perceptions of megatrends' role in the Big Four

Perception	Empirical reality	Discussed
Demographic trends are a major driver of inflation.	We do not find a material link between demographic trends— population growth and age structure—and inflation.	✓
Weak demographics and high debt levels guarantee dismal economic growth, as in Japan.	Such a combination is clearly a headwind, but that does not guarantee a Japanese-style stagnation. The Industrial Revolution provides but one counterexample. However, transformative technological advance certainly is needed to overcome the challenge.	
Globalization is a major driver of the disinflation of the last few decades.	Increasing globalization did help lower inflation, but its effects have been fairly modest and episodic.	✓
Globalization is unambiguously positive for growth and the stock market.	This is generally true. But increases in globalization have also lowered domestic investment rates.	
Population growth is a major driver of the neutral real rate (r-star).	There is no strong connection, consistent with a low correlation between the two factors over long time periods.	
Aging of the workforce lowers rates of innovation as skilled workers retire.	Over time, changes in age structure have led to a higher investment-to-labor ratio, a precursor to higher rates of innovation.	
Technological advancements are all the same, and they occur in an unpredictable way.	There are three types of technological advancements, with different effects on the economy. They also come in waves, with a surge in transformation usually followed by rising efficiency gains with automation.	✓
The past few decades of below-trend growth reflect the lack of a new general-purpose technology (GPT).	The lack of a new GPT has weighed on economic growth. Also, the pace of efficiency gains has been below average since the global financial crisis.	✓
All deficits lead to higher bond yields.	This is untrue. The market pays attention to why deficits are rising and differentiates between the drivers.	
Inflation is an entirely monetary phenomenon; rising fiscal deficits don't matter for inflation.	Inflation has mostly been shaped by cyclical fluctuation in the economy and the monetary policy responses. But increases in structural fiscal deficits also lead to higher inflation expectations.	✓
The Fed is powerless to offset the inflationary pressure from rising fiscal deficits, as raising rates only compounds the problem.	Credible monetary policy, when restrictive, can offset inflationary fiscal policy by lowering inflation expectations and flattening Treasury yield curves, at least up to a point.	
Changes in temperatures can have large impacts on the economy.	All else being equal, impacts are lower today than 100 years ago given agriculture's smaller share of the economy. Certain climate events (such as hurricanes), however, can have large effects that we don't explicitly model here.	
Stock market valuation is almost entirely driven by changes in interest rates or sentiment.	Sentiment and discount rates are important, but other drivers (when made explicit) matter just as much, including unexpected changes in technology.	✓
The neutral real rate, r-star, is impossible to track in real time.	Although r-star is unobservable, a sound proxy can be modeled to help understand how megatrends may be affecting it in real time.	✓
High fiscal debt and deficits lead to lower future growth, as they crowd out other productive investment.	The correlation between high debt levels today and future economic growth is weak. The nature of the government spending matters, as do its future trajectory and other megatrends in motion.	

Source: Vanguard.

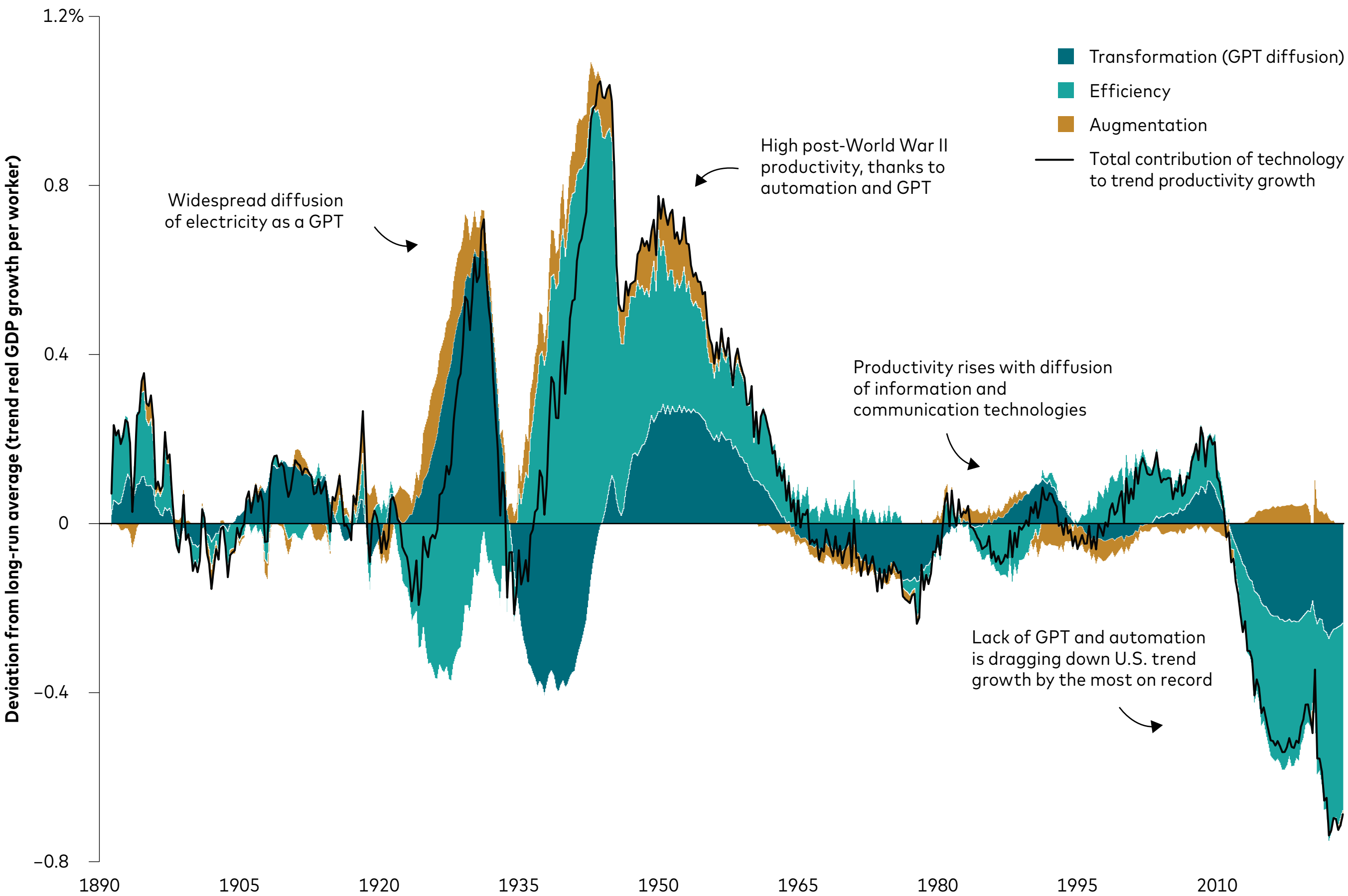
Megatrends and economic growth

Perception 1: Technological change is all the same, and it occurs in an unpredictable way—like a step function.

Empirical reality 1: Technological change is not monolithic. It can be separated into three structural drivers—augmentation, efficiency, and transformation. Each has distinct economic implications (as discussed on the next page). And they follow a predictable pattern, whereby the three drivers come in waves, with a surge in transformation usually followed by rising efficiency gains with automation. Figure 5 shows how these three drivers contributed to the last 130 years of trend real GDP growth per worker in the U.S.

FIGURE 5

Technology and its drivers: augmentation, efficiency, and transformation



Note: Figure shows the historical contributions of transformation, efficiency, and augmentation to the deviation of productivity growth from its long-run average, from June 30, 1891, through September 30, 2023.

Source: Vanguard.

Three drivers of technological advances

Augmentation

refers to advances in technology that raise the productivity of the labor force so that the demand for human labor dominates any displacement effect (described in the next column) across the economy, thereby raising aggregate trend employment. Loosely speaking, humans benefit from machines. Historical examples include the personal computer and power tools.

Efficiency

refers to a technological advance that raises GDP per worker, but usually by automating tasks that used to require human labor—what Acemoglu and Restrepo (2019) refer to as "displacement." Its effect on labor market participation is generally negative. In short, machines replace manual tasks. Historical examples include creation of the assembly line and, more recently, automation of the entire assembly line.

Transformation

refers to a technological advance, a GPT, that unleashes "creative destruction" on a massive scale throughout the economy (eventually).[2] As the GPT cascades across it, the economy is reorganized and a new ecosystem is built around harnessing the GPT's benefits. During this period, there may be a dip in productivity, which is commonly referred to as the J-curve associated with adaptation to the GPT.[3] In short, humans and machines learn to reorganize themselves to produce at higher levels than before.

2 See, for example, Helpman and Trajtenberg (1998) and Acemoglu, Akcigit, and Kerr (2016).

3 As David (1991) famously noted, the arrival of disruptive technology may initially lead to a decline in productivity and an increase in both capital investment and labor as the promising new technology is adopted and replaces obsolete capital. Such so-called J-curve effects were observed in the manufacturing sector with the greater adoption of electricity (see, for example, Jovanovic and Rousseau, 2005), the personal computer, and other transformative technologies. Labor utilization rises while current labor productivity falls as new tasks emerge (the reinstatement effect) until learning-by-doing effects and the displacement effect of existing tasks from automation emerge.

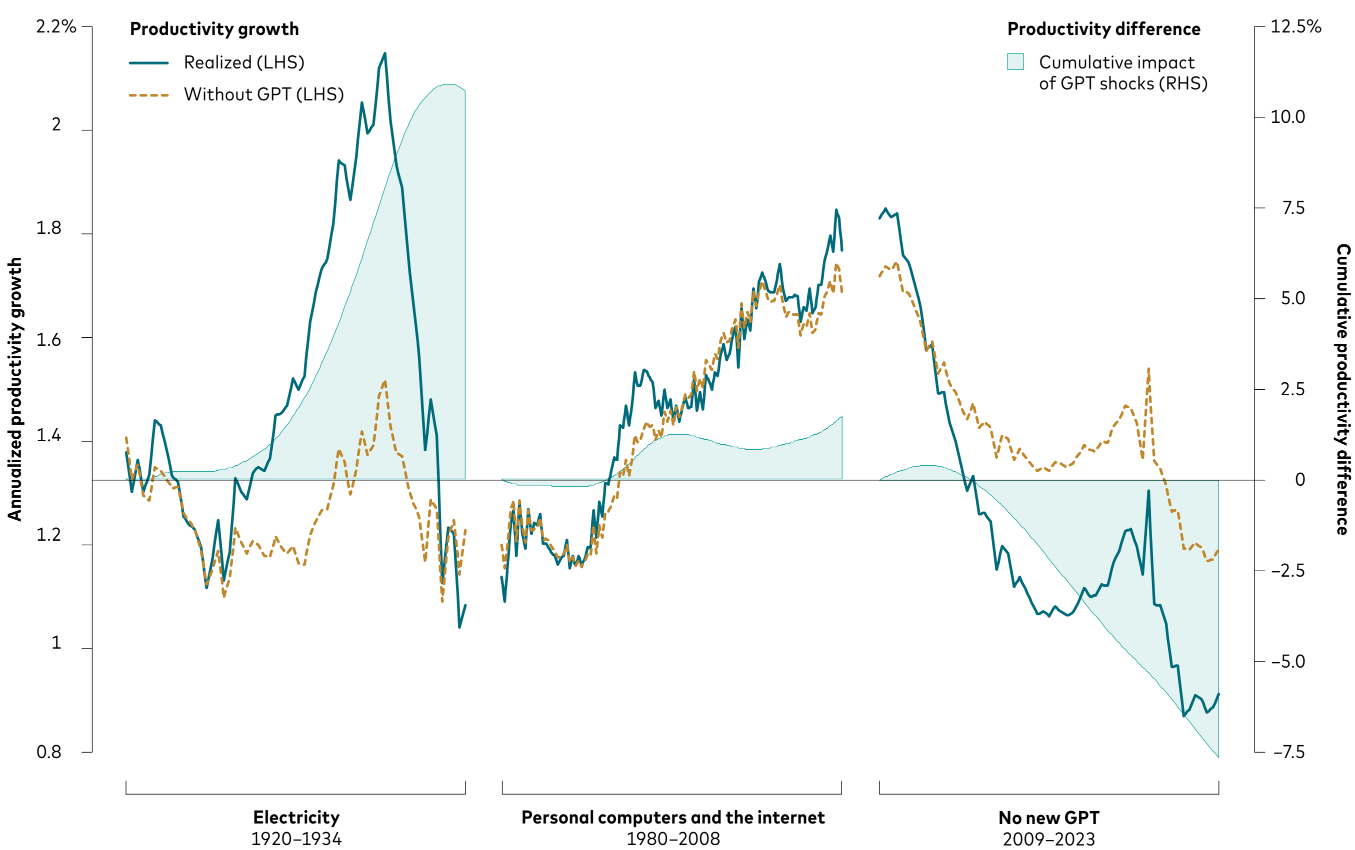
Perception 2: The past few decades of below-trend growth reflect the lack of a new GPT.

Empirical reality 2.1: Our research validates this belief. The lack of a new GPT has weighed on economic growth. But that's only part of the story. A slowdown in automation has also played an important role. Figure 5 shows the drivers behind the stark slowdown in trend productivity experienced since the global financial crisis. Consistent with Gordon (2016), our analysis attributes this slowdown to a lack of transformational GPTs. Another important contributor is the lack of efficiency. Until 2010, efficiency had rarely detracted from long-term average economic growth. It either contributed positively—sometimes massively, as in the decades after World War II—or played a minimal role. Its post-2010 change for the worse suggests there are bottlenecks in the economy that can benefit from additional gains in efficiency.

Empirical reality 2.2: The anemic growth of the past few decades reflects that the information and communication technology (ICT) revolution has transformed the economy far less than previous GPTs. ICT's impact on productivity during the 1980s and 1990s was far less than electricity's impact during the first half of the 20th century **(Figure 6)**. ICT has simply not been as transformative as electricity.[4]

FIGURE 6

GPTs: The good (electricity), the OK (computers and the internet), and the ugly (no new GPT)



Notes: The figure panels show trend productivity growth for each of three time periods: March 31, 1920, through December 31, 1934; March 31, 1980, through December 31, 2008; and March 31, 2009, through September 30, 2023, along with hypothetical trend productivity growth, assuming that the transformation neither added to nor subtracted from trend productivity growth during that period. The shaded area in each panel represents the additional growth (or contraction) in productivity, thanks to the transformative effect of the GPT contribution in each subperiod.

Source: Vanguard.

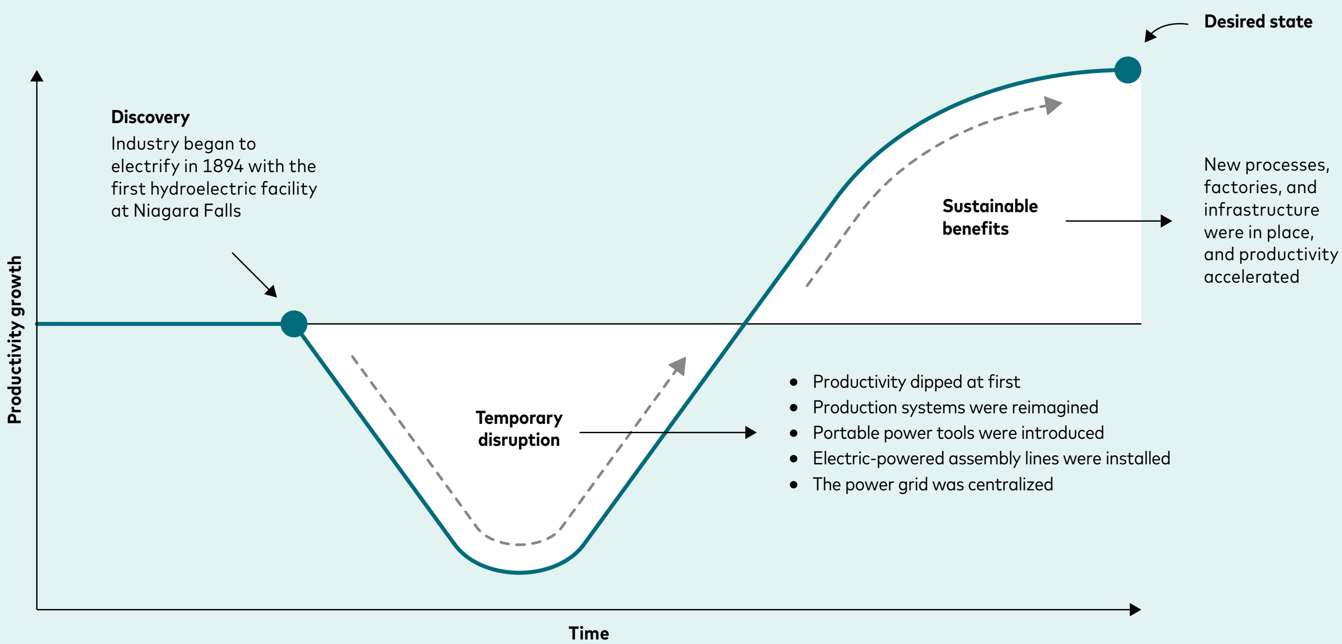
4 The weaker effects of ICT versus electricity are consistent with David (1991), Field (2006), Gordon (2016), and Fernald and Ramnath (2003).

GPTs and the J-curve

While GPTs are transformative, their impact on the economy has typically unfolded over decades. Take, for example, electricity. Industry began to electrify in 1894 with the first hydroelectric facility at Niagara Falls, N.Y. But productivity initially dipped as workers, factory owners, and industrialists reimagined production systems; they introduced portable power tools, installed electric-powered assembly lines, and centralized the power grid—all of which took time.[5] Once the new processes, factories, and infrastructure were in place, productivity accelerated, ushering in the roaring 1920s **(Figure 7)**. ICT displayed a similar dynamic. Digital computers emerged in the 1940s, but their GPT-driven impact on productivity first appeared in the mid- to late-1980s and accelerated in the 1990s and 2000s as ICT work processes were automated. In both cases, the J-curve effect was evident. This calls for a multidecade perspective as we think about how AI—the most likely GPT candidate in today's economy—may affect growth.

FIGURE 7

J-curve in action: A case of electricity and its impact on productivity



Source: Vanguard.

5 See David (1991) and Jovanovic and Rousseau (2005) for more details. The J-curve effect is tightly connected with how labor market transforms. At first, employment rises while labor productivity dips as new tasks emerge, and the economy is not equipped to achieve maximal efficiency. As displaced tasks get automated, and new tasks with a higher value-add potential emerge, overall labor productivity rises.

Megatrends and inflation

Perception 3: The low inflation of the past decades resulted from the "China Shock" and demographic dividends. Inflation is set to rise as these structural benefits fade.

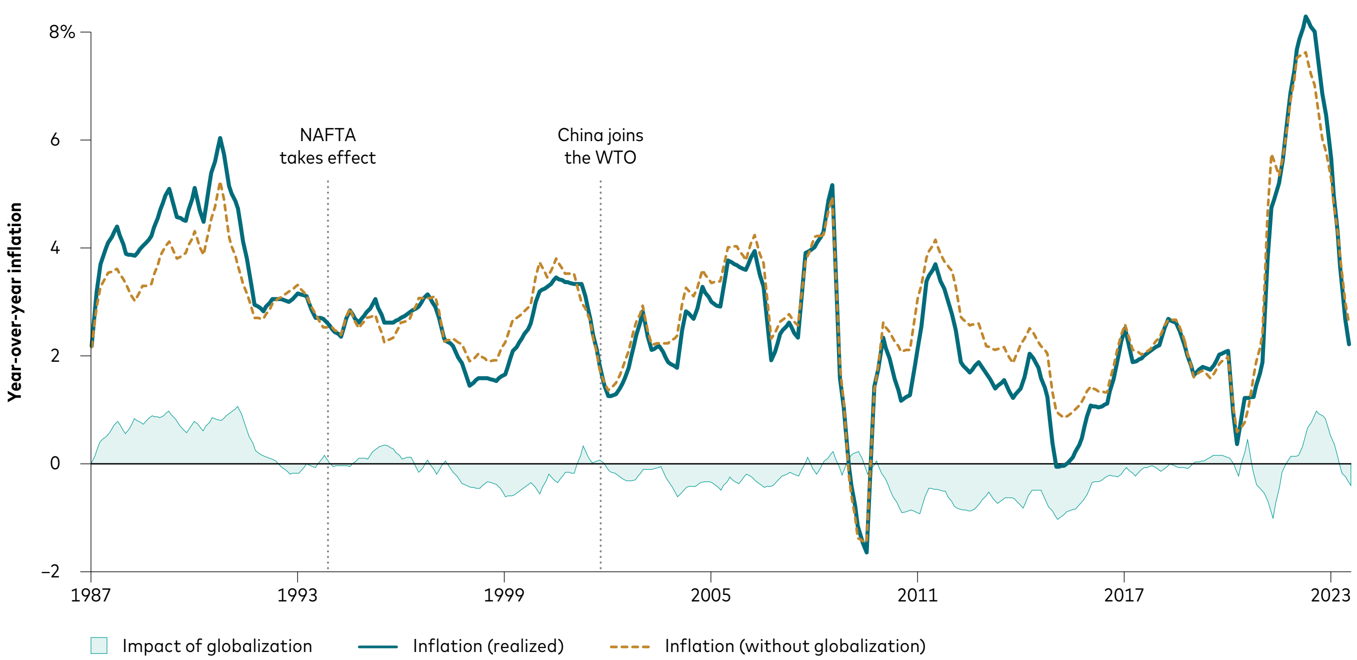
This belief ascribes much of the low inflation of the past four decades to two megatrends: globalization and demographics. The belief about globalization features China, conjecturing that China's integration into the world economy had a massive disinflationary effect on the U.S. economy. The belief about demographics posits that the baby boomers joining the workforce in the 1960s and 1970s kept the labor supply well-stocked, restraining inflation for the subsequent decades.

Empirical reality 3.1 about globalization: The China Shock had a disinflationary effect, but its impact was modest. The key to addressing this belief is quantitative: How critical was the disinflation from trade with China to a low-inflation environment? Our analysis suggests that although the China Shock (and growing globalization and freer trade in the 1990s) reduced U.S. inflation, its impact was modest.[6] **Figure 8** traces globalization's average contribution to U.S. inflation since the late 1980s. Note the minimal divergence between actual inflation and our estimates of inflation without globalization.

These insights inform our expectations about the inflationary effect of today's waning globalization (or what some call "slowbalization"). We may be past the point of globalization's peak impact on inflation, but this megatrend is unlikely to significantly affect inflation in the future.

FIGURE 8

Globalization has mildly lowered inflation, but 'slowbalization' is not to be feared



Notes: Figure shows year-over-year inflation from March 31, 1987, through September 30, 2023, and hypothetical inflation, assuming that the globalization driver neither added to nor subtracted from inflation during that period. The shaded area represents the difference between the two lines. A negative value indicates that realized inflation was lower because of the impact of the changes in globalization. NAFTA stands for the North American Free Trade Agreement, and WTO stands for the World Trade Organization.

Source: Vanguard.

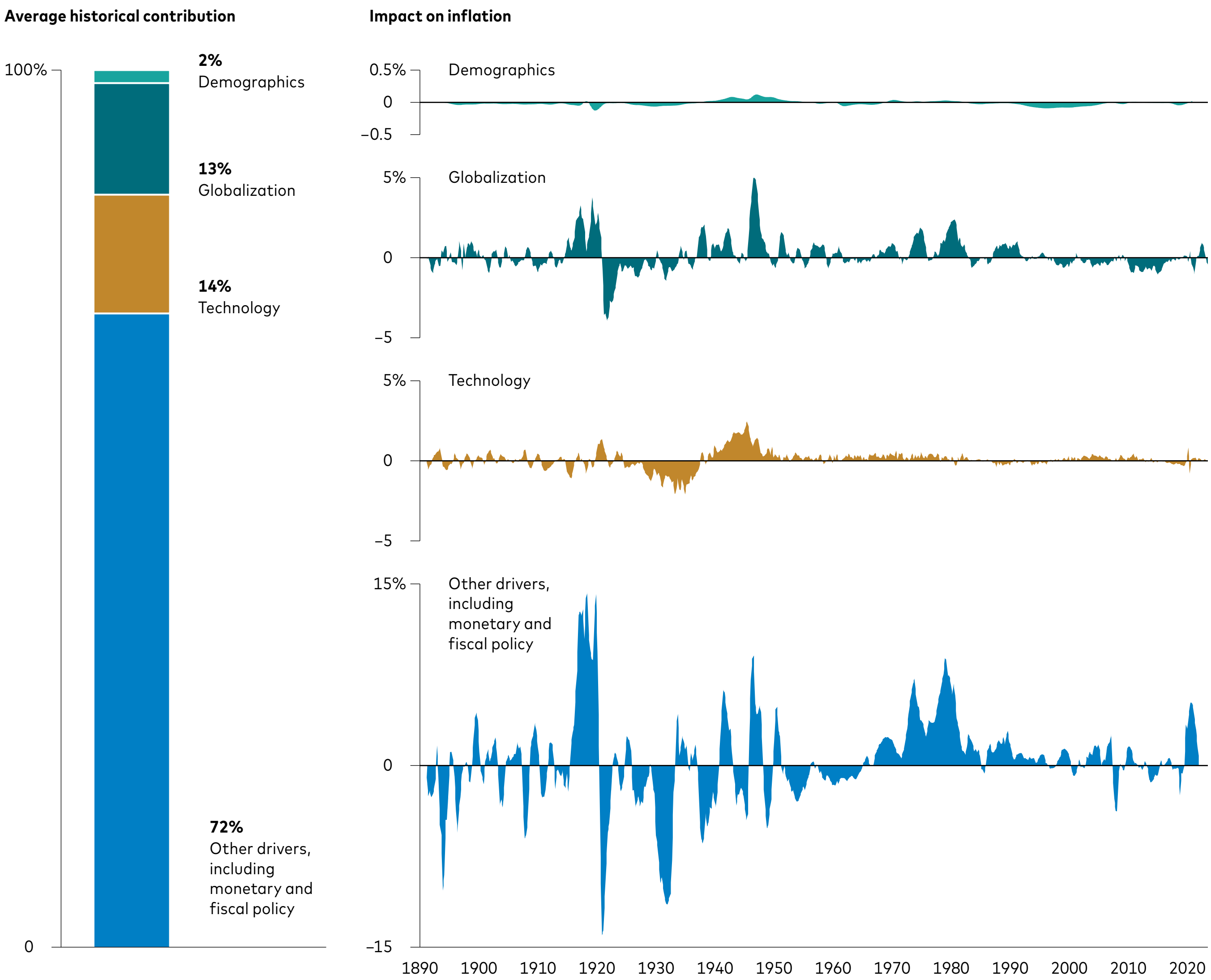
6 Some of this may be due to the U.S. economy's unique role in the global trade ecosystem. While the U.S. has traded extensively, its reliance on the global supply chain leaves much value-add operations within the U.S. (Alfaro and Chor, 2023).

Empirical reality 3.2 about demographics: Demographics have played a negligible role in driving inflation, especially relative to other megatrends **(Figure 9)**. Demographic change barely registers as an inflation driver in the time series from 1890 through 2023. And over the full period, it accounts for just 2% of the cumulative changes to inflation. Demographic change on its own is unlikely to be inflationary (or deflationary).

The great inflationary period of the 1970s and early 1980s illustrates this point well. The workforce influx of the baby boom generation was expected to reduce inflation. But its impact on inflation was inconsequential. Instead, what drove that period's inflation were adverse supply shocks, a wavering monetary policy stance that eventually led to unanchored inflation expectations, and an eventual taming of the inflation—which was also driven by a resolute Federal Reserve led by Paul Volcker (see Bryan, 2013, and Blinder, 2022).

FIGURE 9

Demographic change has had a negligible impact on inflation



Notes: Figure shows the historical contribution of demographics to the deviation of inflation from its long-run average, over the period from June 30, 1891, through September 30, 2023, and contrasts this with the contribution of the globalization and technology megatrends and all other drivers. Those other drivers include cyclical factors and monetary policy, which explain the largest share of the fluctuations in inflation, as shown in Figure 10. Percentages on the bar chart do not total 100% because of rounding.

Source: Vanguard.

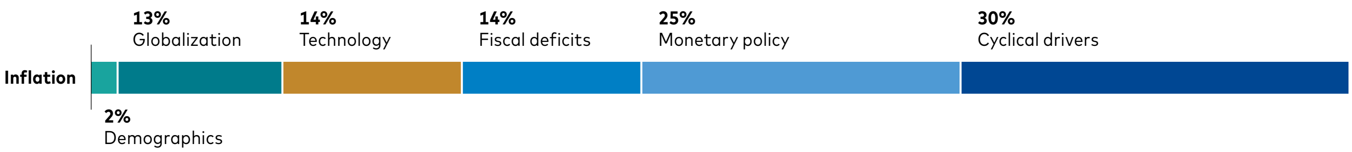
Perception 4: Inflation is an entirely monetary phenomenon; rising fiscal deficits don't matter.

This belief is a sound lesson from history, taken to the extreme. Since the time of Friedman and Schwartz (1963), inflation has been understood as a largely monetary phenomenon. Our analysis also supports this idea. **Figure 10** shows the relative importance of megatrends, the business cycle, and monetary policy for variation in inflation. Inflation has mostly been shaped by cyclical fluctuations in the economy and the monetary policy response to these fluctuations.

Empirical reality 4: This view, however, is incomplete. Inflation is increasingly picking up the rise in U.S. structural fiscal deficits. **Figure 11** shows that up to almost 150 basis points (bps) of inflation over the past few years of high inflation has resulted from rising structural deficits. (A basis point is one-hundredth of a percentage point.) Structural deficits have begun to contribute to inflation for the first time since the 1980s.

FIGURE 10

Inflation is a largely monetary phenomenon—but there are other drivers

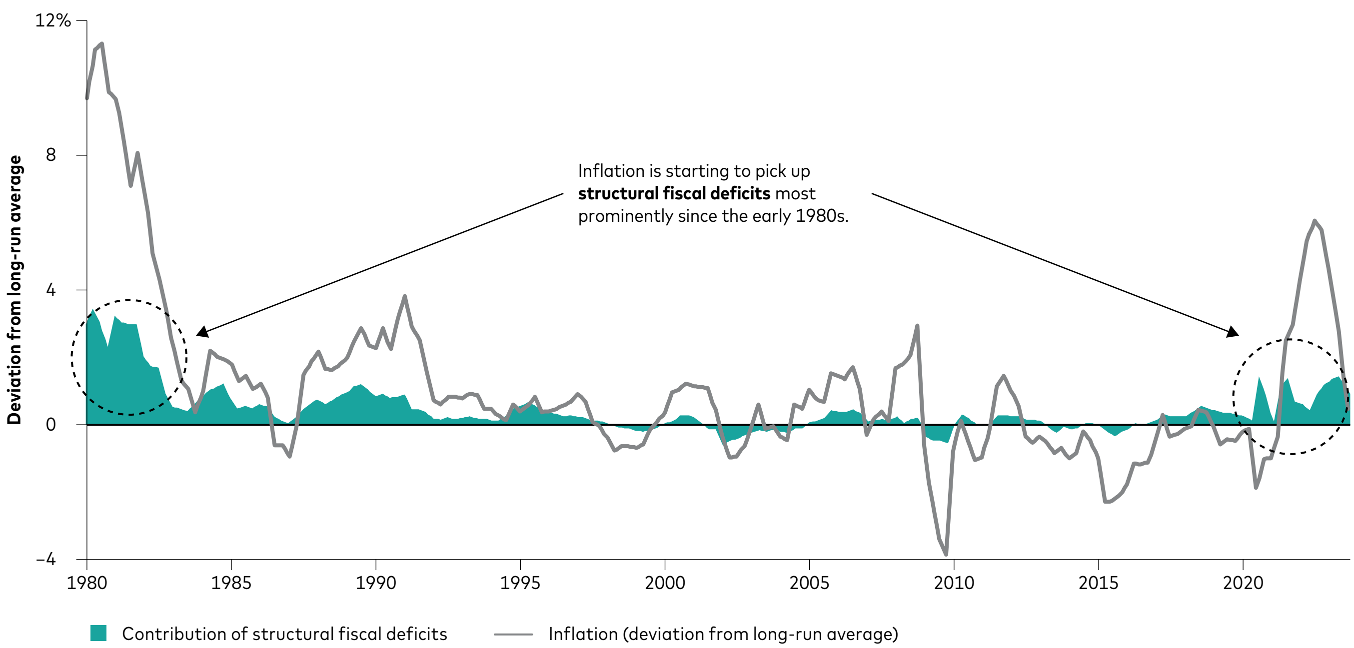


Note: Figure shows the contribution of four megatrends (demographics, globalization, fiscal deficits, and technology) and of monetary policy and cyclical drivers to the variation in inflation over the period from June 30, 1891, through September 30, 2023. Percentages do not total 100% because less significant drivers such as risk premia or temperature change are not shown.

Source: Vanguard.

FIGURE 11

As structural deficits rise for the first time in decades, they're nudging up inflation



Note: Figure shows the historical contribution of structural deficits to the deviation of inflation from its long-run average, from December 31, 1979, through September 30, 2023.

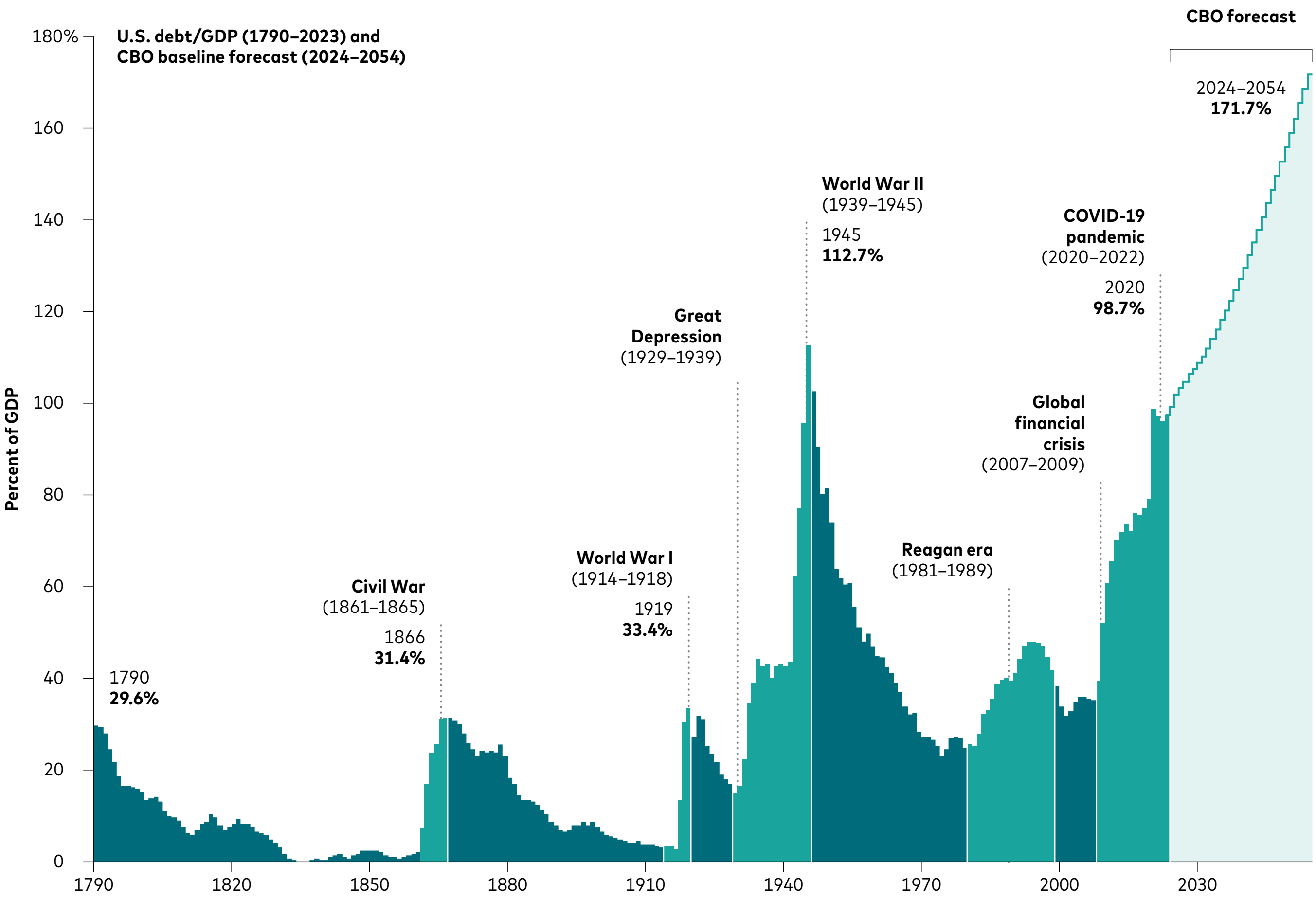
Source: Vanguard.

Note that Figure 11 looks only at structural—seemingly permanent—fiscal deficits, not deficits driven by geopolitical conflicts (to finance wars) or by business cycles (to fight recessions).[7] Not all deficits are created equal. Structural deficits tend to concern the market more and affect inflation to a greater extent. Today's rise in structural deficits is driven by an aging population and the U.S. government's need to borrow in order to finance health care spending and Social Security payments. Spending related to an aging population has been rising and is projected to rise even further over the coming decades **(Figure 12)**.

If structural fiscal deficits rise as projected, they may become a key driver of inflation in the medium run, a concern expressed most recently by Cochrane (2023).[8] Our quantitative reading of the history indicates that this fiscal driver of inflation has played a material role at different points over the last 130 years. It may once again become an inflation driver to rival (or even supplant) the role of monetary policy.

FIGURE 12

As America ages, U.S. debt is projected to set record highs



Notes: Figure illustrates the evolution of the U.S. debt-to-GDP ratio from 1790 through 2023 and the CBO's baseline forecast until 2054. Extended historical periods with a decrease in the debt/GDP ratio have darker shading, while extended historical periods with an increase in the debt/GDP ratio have lighter shading.

Sources: Vanguard calculations, based on data from the CBO.

7 Much of the 1980s, largely coinciding with the Reagan era (1981–1989), saw a then-unprecedented increase in the deficit-to-GDP ratio, which led the debt-to-GDP ratio to rise almost 15% over the decade. This increase was notable given the era's largely benign macroeconomic backdrop (Blinder, 2022). Bond market investors worried, among other things, about its impact on inflation, leading to the coining of the term "bond vigilantes" (Yardeni, 2018).

8 This idea, commonly referred to as the "fiscal theory of the price level," builds on earlier work by Sims (1994) and Woodford (1995). It postulates that inflation expectations will rise if the market participants deem future debt obligations to be on an unsustainable path with regard to expected revenues.

Megatrends and r-star

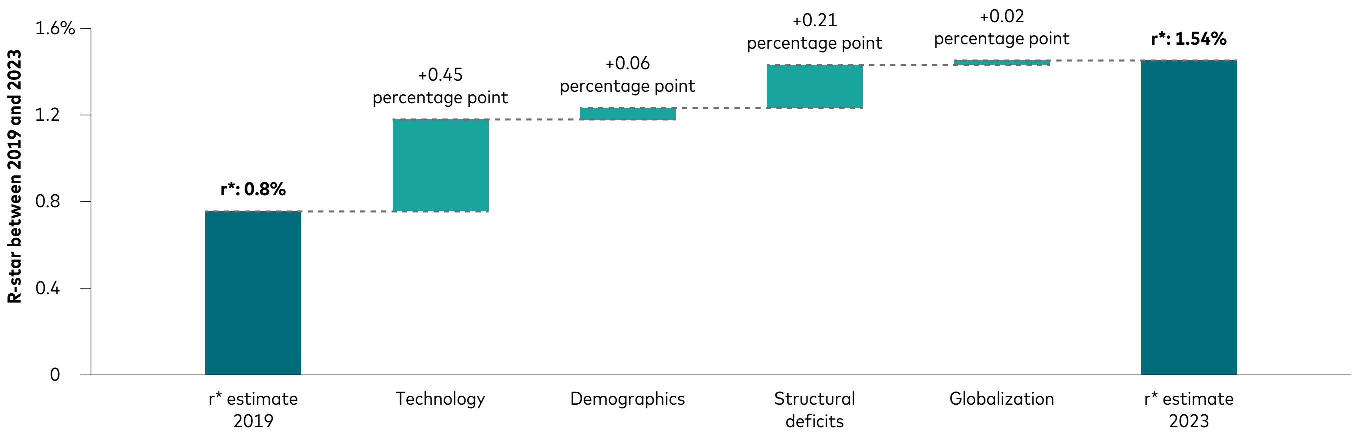
Perception 5: R-star—the unobservable rate of interest that allows the economy to operate at full capacity while containing inflation—remains near its pre-COVID level, unaffected by slowly evolving megatrends.

Empirical reality 5: The Vanguard Megatrends Model allows us to monitor megatrends and estimate changes in r-star (r*). Our framework tells us that the real rate has risen since 2019 because of weakness in technology and structural fiscal deficits.[9] We find that since 2019 (just before the COVID pandemic), r-star has risen from 80 bps to 154 bps. **Figure 13** details the contributors to this rise.

First, most of the increase in r-star—89% of it—came from two megatrends: technology and structural fiscal deficits. A slowdown in technological progress drove 45 bps of the 74 bps increase. As efficiency gains have stalled because of the lack of automation, labor demand has risen, putting upward pressure on the interest rate. Second, structural fiscal deficits have raised r-star by 21 bps. This rise reflects not temporary deficits recorded during the 2020–2022 pandemic, but rather the increase in structural components in fiscal deficits tied to growing entitlement spending.

FIGURE 13

Since 2019, structural deficits and a lack of technological progress have raised the natural interest rate



Note: Figure shows our estimates for r-star (r*) in 2019 and 2023 and decomposes its changes into the contributions of technology, demographics, structural fiscal deficits, and globalization.

Source: Vanguard.

9 Although we do not model the r-star explicitly (as in Laubach and Williams, 2003), we estimate its analog after stripping away the variation in real short rates attributable to cyclical and demand factors. This step allows us to see how much our estimate of r-star has changed over time because of megatrends.

Megatrends and the stock market

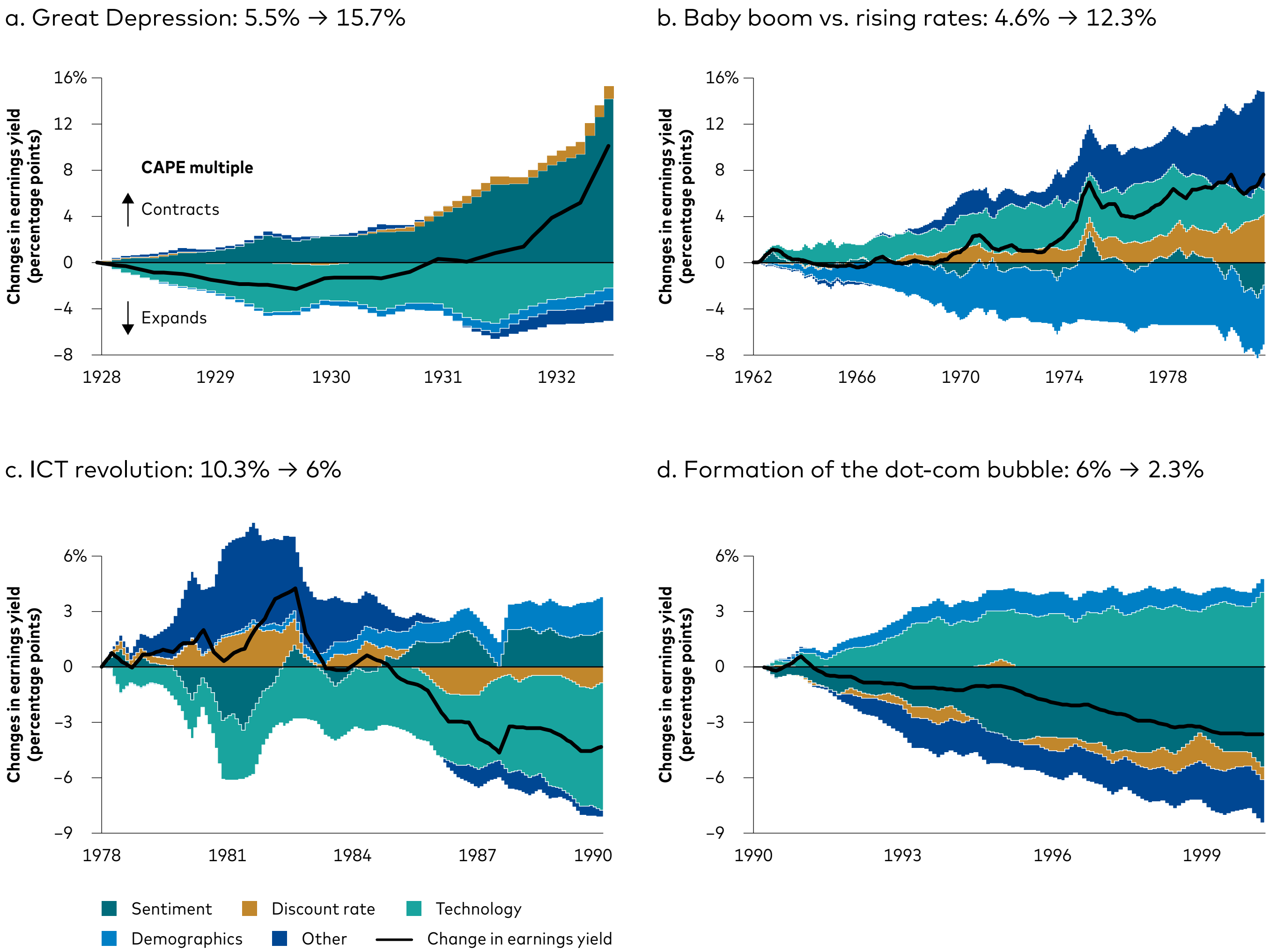
Perception 6: Over the medium run, sentiment and discount rates are the only meaningful drivers of stock market valuation.

Empirical reality 6: Among the Big Four, stock market valuation change has the most diverse set of drivers, making it one of the hardest-to-predict outcomes. **Figure 14** on the next page shows what drove changes in earnings yield (that is, the change in the inverse of the cyclically adjusted price-to-earnings ratio, or CAPE) at different times over the past century. Unlike other Big Four variables, which can be adequately described by just a few megatrends or other drivers, focusing on a subset of factors for the earnings yield would leave out important dynamics.

For example, the earnings yield of the Standard & Poor's 500 Index would have decreased significantly (leading to strong stock returns) during the late 1920s, thanks to electricity, but the collapse in sentiment during the Great Depression masked this entirely. And while an increased labor supply due to the post-World War II baby boom benefited the stock market, it could not overcome the slowdown in technological progress and the impact of higher interest rates and inflation. The ICT revolution also increased CAPE, but by 1990, this technological change was fully reflected in prices. The further increase in CAPE that followed in the next decade was sentiment-driven—an "irrational exuberance" that culminated in the dot-com bubble. The changing nature of these drivers over time explains why predicting valuation change from one decade to the next is so difficult (Vanguard founder John C. Bogle described attempts to forecast valuation change as "speculation"—and for good reason).

FIGURE 14

Stock market valuation changes have had many drivers—a challenge for forecasting



Notes: Figure shows the change in the earnings yield for each of four periods—December 31, 1927, through June 30, 1932; December 31, 1961, through September 30, 1981; December 31, 1977, through March 31, 1990; and March 31, 1990, through March 31, 2000—and the historical contributions of sentiment, the discount rate, technology, demographics, and other drivers (such as the business cycle or inflation). The figure label for each period indicates the earnings yield levels at the start and the end of the period. For example, from Q1 1990 through Q1 2000, the earnings yield of the S&P 500 Index decreased by about 3.6 percentage points, from 6% to 2.3%—or, equivalently, CAPE increased from 17 to 43.

Past performance is no guarantee of future returns. The performance of an index is not an exact representation of any particular investment, as you cannot invest directly in an index.

Source: Vanguard.

Will our economic future be better or worse? A probabilistic assessment

We use these historical insights and the Vanguard Megatrends Model to forecast the Big Four through 2040.[10] The results suggest that our future depends on a tug-of-war between AI-boosted productivity growth and structural deficits driven by an aging society. **Figure 15** depicts the competition and the odds of each potential outcome.

FIGURE 15

The future will be different from the recent past

Vanguard scenario 1

AI fails. Deficits dominate.

AI produces more modest productivity effects that are insufficient to overcome ever-larger structural deficits driven by age-related government spending.

Forecast of average real U.S. GDP growth, 2028–2040:

~1.0%

Scenario probability

30%–40%

Consensus scenario

Status quo.

Economic future will resemble its recent past—anemic productivity growth, low inflation, and near-zero inflation-adjusted returns.

Forecast of average real U.S. GDP growth, 2028–2040:

~2.0%

Scenario probability

10%–20%

Vanguard scenario 2

AI is transformational. Productivity surges.

AI emerges as a significant general-purpose technology whose productivity impact exceeds that of the personal computer and the internet.

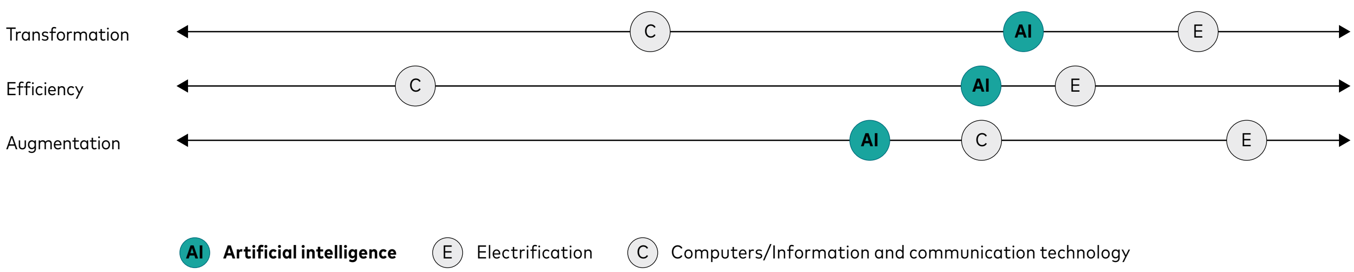
Forecast of average real U.S. GDP growth, 2028–2040:

~3.1%

Scenario probability

45%–55%

Impact on labor and productivity



Note: We define transformation as a shock to the diffusion of GPT, efficiency as a shock associated with automation, and augmentation as a labor-augmenting shock where both output and employment rise simultaneously. Real GDP growth forecasts represent the median forecast across all simulations in each scenario. The placement of AI on each of the arrowed lines indicates Vanguard's scenario 2 for AI's impact on labor and productivity.

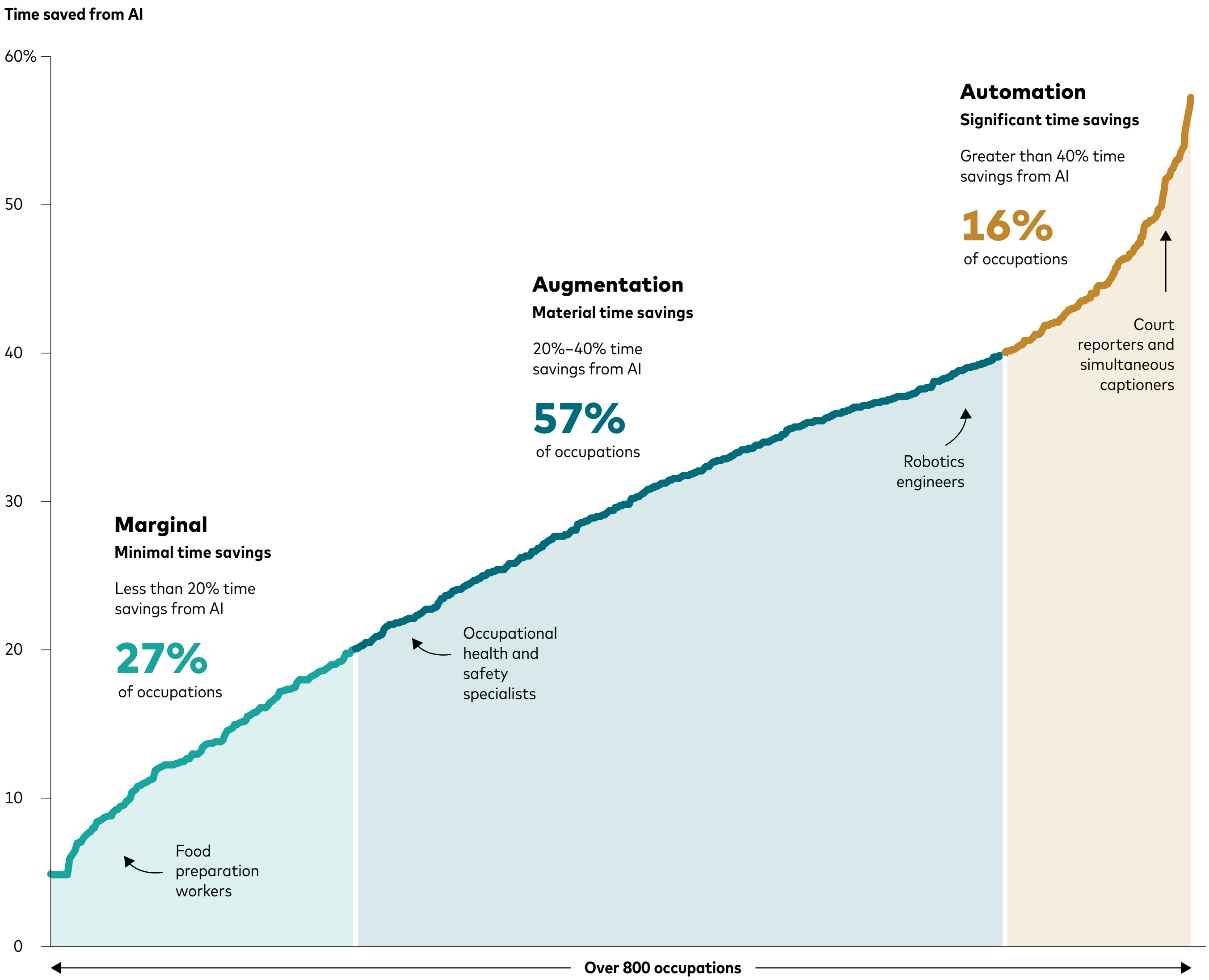
Source: Vanguard.

10 **Appendix 2** on page 30 provides more detail on how we simulate the future with the Vanguard Megatrends Model. See also Davis, Brandl-Cheng, and Khang (2024) for more details.

The swing factor is how transformative AI's impact on the economy and labor force becomes. In Vanguard (2018), we showed that most jobs would be affected by AI, which would generate significant time savings, and that the focus should be on how a job's task composition evolves. **Figure 16** shows our baseline projection of how much time savings AI will generate across over 800 occupations. As more than 20% of tasks are automated away for more than 70% of the occupations, this will inevitably involve considerable evolutions in many jobs—and new types of jobs that require uniquely human tasks will emerge. Our "Productivity surges" scenario is a view in which this transformation proceeds successfully. A disappointing transition on this front, on the other hand, will tilt the economy toward our "Deficits dominate" scenario.

FIGURE 16

AI adoption can generate significant time savings, offsetting demographic drags in the labor supply



Note: Chart shows our estimates for time savings due to AI for over 800 occupations. 73% of the analyzed occupations contain tasks that are complementary to AI and are estimated to see more than 20% of time savings.

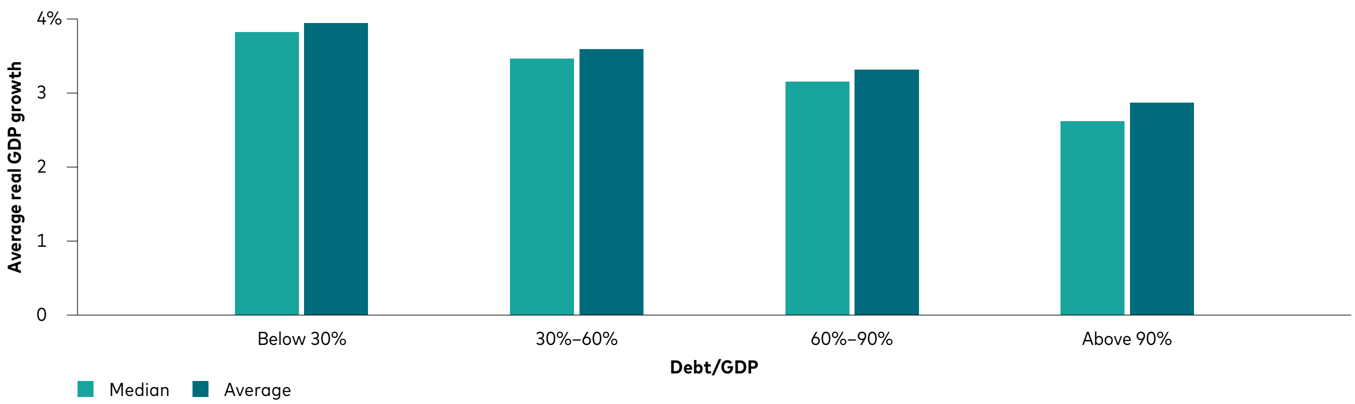
Sources: Vanguard calculations, based on data from the Bureau of Labor Statistics and the Occupational Information Network, as of July 2023.

Historical precedents suggest there have been many instances that resemble the "Productivity surges" scenario. Although high debt levels are on average associated with lower levels of economic growth, it is not uncommon for economies to overcome this debt drag and still deliver robust growth **(Figure 17)**. One example is the post-World War II period in the United States, where urbanization coupled with technological innovation generated enough growth to offset the debt overhang. In a similar manner, in the "Productivity surges" scenario, the boost from AI can be sufficiently strong to overcome any headwinds from rising structural deficits.

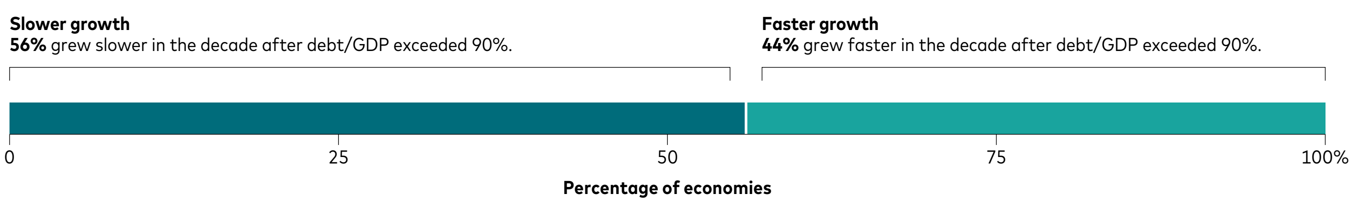
FIGURE 17

Higher debt levels are headwinds to growth, but many economies grew nonetheless

a. Higher debt levels are, on average, associated with lower growth levels



b. But despite a debt/GDP ratio above 90%, many economies were able to deliver strong growth



Notes: This analysis uses over 18,000 annual data points across 150 countries between 1800 and 2022. It compares the debt-to-GDP ratio at each point in time with the average GDP growth rate in the subsequent five years. The sample for Figure 17b includes only those observations where the debt-to-GDP ratio exceeded 90% at the start of any five-year period. The analysis compares average annual GDP growth over the subsequent decade to growth over the previous decade. Observations where differences were less than plus or minus 0.5 percentage point were discarded to avoid spurious differences between time windows.

Sources: Vanguard calculations, based on data from the International Monetary Fund (IMF) Historical Public Debt Database, the IMF Public Finances in Modern History Database, and the IMF Fiscal Monitor.

Why an inflationary future is unlikely

Even with rising fiscal deficits adding to inflationary pressure, a higher-inflation world is unlikely. This is because of the Fed's likely response. To achieve its price stability mandate, the central bank will lean against the inflationary wind caused by deficits and raise its policy rate accordingly **(Figure 18)**. The first panel in the figure shows that with an accommodative Fed, the federal funds rate rises to about 4% in the latter part of the 2030s and inflation settles above 2.5%. In the second panel, however, inflation remains well-anchored to the 2% target because we take the Fed's price stability mandate into account—and the nominal federal funds rate may rise to nearly 5% to keep inflation in check.

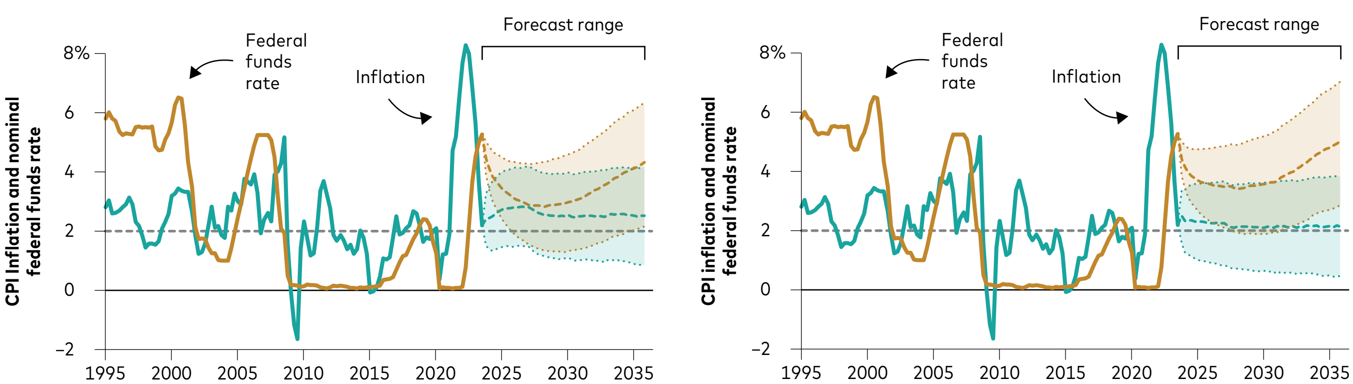
In general, and in sharp contrast to the 2009–2019 post-financial-crisis era, the Fed will have to hold the federal funds rate higher—at least above 4%. This is because rising structural fiscal deficits in the decade ahead will generate inflationary pressure. And this effect is stronger if AI is less transformative than desired (the "Deficits dominate" scenario), with the average nominal federal funds rate averaging about 5.5% in the 2030s. Overall, it's short-term rates that are most likely to be higher in the future, and not necessarily inflation. This is why we believe the future will be characterized by the "return of sound money," with the nominal interest rate being higher than the rate of inflation and, therefore, a positive real interest rate.

FIGURE 18

A higher-inflation world is not likely given the Fed's response

a. Inflation's future path, with an accommodative Fed

b. Inflation stability maintained with higher rates



Notes: The figure's two panels show historical and forecasted year-on-year inflation and the nominal federal funds rate from 1995 to 2035. The first panel shows the forecast assuming an accommodative Fed that is not explicitly responding to inflation deviating from the 2% target, while the second panel assumes that real and nominal interest rates increase when inflation is above 2% and decrease when it is below 2%. Inflation is measured by the Consumer Price Index (CPI).

Source: Vanguard.

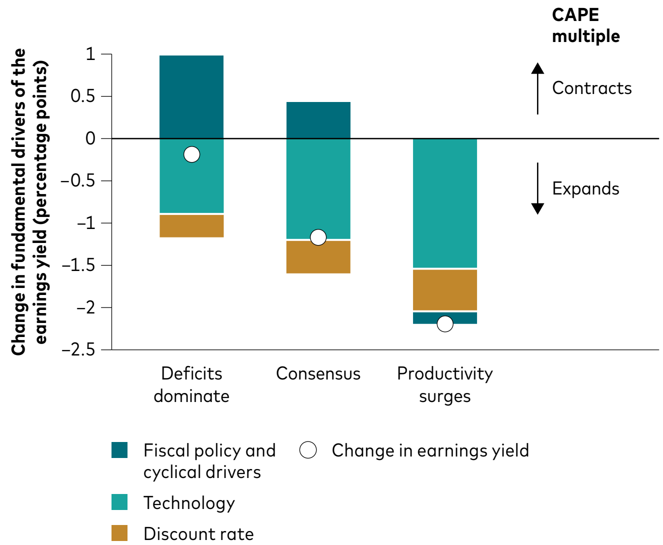
Strong technological developments benefit the stock market

In contrast to the clear message for the bond market with higher rates than in the last decade, the message for the stock market is less clairvoyant, given its many competing drivers and the difficulty of forecasting sentiment. Figure 14 showed that sentiment has been increasing for more than a decade, but this in itself does not help to understand when that trend might reverse. That said, we can see how megatrends will impact earnings yield in relative terms across the three scenarios **(Figure 19)**.

In general, we expect the coming technological advancements to favorably affect earnings yield, with the "Productivity surges" scenario showing a greater benefit. There is another reason why earnings yield would potentially be lower still (and with the price-to-earnings multiple expanding further) in this scenario, relative to others. With strong economic growth, there will be less inflationary pressure from rising fiscal deficits, and that frees up monetary and fiscal policy to be more supportive of the risk asset market. The opposite dynamic would be in play in the "Deficits dominate" scenario. Monetary and fiscal policy would likely be constrained as they fight inflationary pressure, and this would likely undo much of the potential benefit from the technological advancements.

FIGURE 19

AI is expected to aid the stock market, but higher deficits can undo much of that benefit



Notes: Figure shows the projected impact of technology, the discount rate, and fiscal policy and the business cycle on the earnings yield across the three scenarios that were laid out in Figure 15. We do not show the impact of demographics, which is identical across the scenarios, or of sentiment, because of the uncertainty about it.

Source: Vanguard.

Conclusion

The Vanguard Megatrends Model suggests that our economic and financial future depends on a tug-of-war between AI and deficits due to age-related spending.

If AI prevails, growth will accelerate as the technology transforms economic production and society much as electricity did in the early 20th century. Its impact will potentially be greater than that of the personal computer and the internet, at least thus far. This would also be good for stock market valuation, as it would leave monetary and fiscal policy largely unconstrained.

If AI falls short of our expectations, however, deficits will dominate, given the rise in age-related, unfunded government spending. Growth will potentially fall short of the disappointing rates experienced since the global financial crisis of 2007–2009. And stock market valuation will likely be affected by not only low growth but also the central bank's handling of mounting inflationary pressure.

The stakes are high—for workers, investors, and policymakers. But this looming competition between two megatrends is nothing new. Technology and demographics have always competed, as Thomas Malthus articulated in *An Essay on the Principle of Population* (1798). He argued that population growth would lead to war, famine, and disease. In 1798, Earth's population totaled 800 million. But in 2022, eight billion people inhabited a richer, healthier planet. Technological progress neutralized the Malthusian warning that "the power of population is indefinitely greater than the power in the earth to produce subsistence for man."

The tug-of-war continues. Today's struggle is between a slower-growing, aging population and our capacity to improve—or even maintain—living standards. But as economist Ester Boserup observed, "Necessity is the mother of invention." The Vanguard Megatrends Model's probabilities suggest that technology will prevail—we'll innovate faster than we age.

Appendix 1. The Vanguard Megatrends Model

Our model can disentangle the historical contribution of megatrends and other drivers to the Big Four. This allows us to assign probabilities to various scenarios so as to quantify the future to be shaped by megatrends. We highlight three features essential for understanding megatrends and their role in shaping the Big Four:

1. We develop a dataset that captures important historical shifts in megatrends across the U.S. and global economy.
2. We explicitly consider long-term trends and let them compete with short-run cyclical variables in an integrated framework.
3. With a novel identification strategy, we provide an important economic interpretation of how megatrends have shaped the economy.

1. We have more than a century of data on megatrends

Most macroeconomic studies rely on data from the post-World War II period—a limitation in studying megatrends' role in the economy. The half-life of many megatrends is multiple decades. Meaningful changes in technology, demographics, or globalization patterns might measure 10, 20, or even 30 years. To account for megatrends, one needs to look deep into the past. We assembled a new quarterly dataset on the U.S. economy and financial markets that begins in the first quarter of 1890. We gathered proprietary (hand-collected) historical data on the U.S. economy for the pre-World War II period and from other standard sources, including the National Bureau of Economic Research Macrohistory Database, Global Financial Data, and Professor Robert J. Shiller's website. For more details on our data, see our companion paper (Davis, Brandl-Cheng, and Khang, 2024).

By extending our quarterly dataset to 1890, we gain an invaluable set of historical events that are central to developing an informed perspective on megatrends. The 1920s, for instance, witnessed high productivity growth from the diffusion of electricity as a GPT and sharp demographic changes due to restrictions on immigration. Globalization both accelerated and reversed in the period before World War II. That war produced surges in government spending and debt, trend productivity, and inflation. Even so, interest rates remained low as policymakers practiced "financial repression"—artificially suppressing rates to lower debt-burden costs. The 20th century also saw extended periods of both deflation (such as the Great Depression) and high inflation (such as the 1970s). Over the last 130 years, the age structure of the U.S. economy has evolved because of changes in fertility, immigration, life expectancy, and the post-World War II baby boom.[11] Our longer sample allows us to broaden our aperture and capture these changes in a framework that can enhance our ability to forecast the future.

2. Long-term trends and other cyclical variables compete in an integrated framework

We are interested in explicitly capturing time-varying trends, especially on the supply side of the economy. The supply-side trends that vary with time include technology—how the economy produces output given the production factors—and the supply of labor and capital, which are the main inputs to production. To capture how these slow-moving trends vary over time, we apply trend-cycle decomposition techniques to obtain the trend components of real GDP growth, worker productivity, employment-to-population ratio, and capital-to-labor ratio.[12] We also apply a trend-cycle decomposition filter to CPI inflation to carve out the trend component in inflation, and we use that as our proxy for the then-current inflation expectation. **Figure 20** lists the 15 variables featured in our empirical investigation.

11 See Mester (2018) for more details.

12 These techniques seek to identify the proportion of change in these variables that can be attributed to short-term fluctuations (the business cycle) and to longer-term shifts in trends.

FIGURE 20

15 variables in the Vanguard Megatrends Model

Category	Variable	Description	Endogenous	Based on trend-cycle decomposition
Supply-side trends (distinct from megatrends)	pop_t	Population growth	No (exogenous)	No
	age_t	Change in the age structure	No (exogenous)	No
	$\overline{prod}_t$	Trend growth in productivity per worker	Yes	Yes
	$\overline{kl}_t$	Trend in investment/GDP	Yes	Yes
	$\overline{er}_t$	Trend employment-to-population ratio	Yes	Yes
Faster-moving variables (business cycle)	$deficit_t$	Fiscal deficit/GDP	Yes	No
	$g_t - \overline{g}_t$	Cyclical deviation from trend real GDP growth	Yes	Yes
	$glob_t$	Net imports (trade deficit/GDP)	Yes	No
	πgap_t	Cyclical deviation in inflation from inflation expectation	Yes	Yes
	r_t	Real federal funds rate	Yes	No
	$E_t(\pi_{t+1})$	Inflation expectation (trend inflation)	Yes	Yes
Financial markets	brp_t	Bond risk premium (defined as 10-year yield minus nominal federal funds rate)	Yes	No
	erp_t	Equity risk premium (defined as 1/CAPE minus nominal federal funds rate)	Yes	No
Others	geo_t	Geopolitical risk	No (exogenous)	No
	$temp_t$	Temperature change	No (exogenous)	No

Notes: Table shows the definitions of the 11 endogenous and four exogenous variables used in our empirical analysis. Endogenous variables can affect other endogenous variables both contemporaneously and over time, whereas exogenous variables can affect endogenous variables contemporaneously but are not affected by other variables.

The 15 variables comprise five trends on the supply side (distinct from megatrends, which the next subsection defines more clearly); six variables that evolve at a faster rate (for example, business-cycle frequency); two variables that evolve closely with financial markets, and two variables—geopolitical risk and temperature change—that do not fall neatly into the above-mentioned groupings but that may have significantly affected the economy at various times.

Based on these variables, the Big Four can be derived as follows:

- **Real GDP growth per capita** is the sum of trend growth in productivity per work, the trend employment-to-population ratio, and the output gap.
- **Inflation** is the sum of the inflation gap and inflation expectations.
- **The nominal federal funds rate** is the sum of the real federal funds rate and inflation expectations.
- **Earnings yield** is the sum of the equity risk premium and the nominal federal funds rate.

Our analysis is based on a vector autoregression (VAR) framework that features these 15 variables jointly. By explicitly carving out the supply-side trends and featuring them with other more fast-moving variables in our VAR, we can identify the nature of their interrelated dynamics and develop an understanding of their relative importance. VAR estimation results capture the lead-lag correlations within and across all variables in the system and is a standard framework in empirical macroeconomics. What is unique in our setting is that we are letting the long-term trends and higher-frequency quantities—such as the business cycle of interest rates—compete. This allows us to let the data speak on which variables are truly central to driving and shaping the economy.

We estimate the following equation based on our data from the first quarter of 1890 through the third quarter of 2023:

$$y_t = B_1 y_{t-1} + \cdots + B_5 y_{t-5} + Cx_t + u_t$$

where $y_t = (\overline{prod}_t, \bar{k}l_t, \overline{er}_t, deficit_t, g_t - \bar{g}_t, glob_t, \pi gap_t, r_t, E_t(\pi_{t+1}), brp_t, erp_t)'$; $x_t = (pop_t, age_t, temp_t\ geo_t, 1)'$; $B_1, \ldots, B_5$ are the coefficients on the five lag terms of y_t; C is the coefficient on x_t; and u_t is the residual.

Variables in y_t—11 of the 15 variables—are endogenous, meaning that these 11 variables can affect one another over time. An example may be the trend growth rate in per-worker productivity affecting the cyclical growth rate in subsequent quarters. The remaining four variables captured in x_t are exogenous. This means that although these four can affect the 11 variables contemporaneously, the reverse does not hold: The 11 variables do not drive how the four exogenous variables evolve over time. An intuitive example is the relation between population growth and stock market earnings yield. A jump in population growth may have an implication for how stock market valuation changes many quarters later, but the causal flow from stock market valuation change to population growth is unlikely to exist (and is not allowed in our setup). Estimation leverages Bayesian VAR (BVAR) techniques that assume the dynamics among our variables could be changing over time.[13] This allows the model to capture whether trends had time-varying effects on the Big Four and the nature of their variation over time.

3. Identifying structural drivers behind Megatrends

The third and final unique feature of our integrated framework is that we uncover the structural drivers behind the 15 variables in our VAR. This enables us to provide a granular economic interpretation of how megatrends have shaped the economy and financial markets. What are structural drivers, and how do they differ from any of the economic quantities observed in our VAR? We use fiscal deficits to illustrate these concepts. Fiscal deficits rise (and fall) over time for multiple reasons. Historically, several main drivers of fiscal deficits have included:

- recessions, which lead to an expansionary fiscal policy (such as the CARES Act of 2020 in response to COVID-19);
- wartime expenditures (such as the Lend-Lease Act of 1941 and the G.I. Bill of Rights of 1944);
- rising interest rates adding to debt servicing costs (for example, in the 1980s); and
- structural fiscal deficits tied to rising entitlement spending because of the aging population.

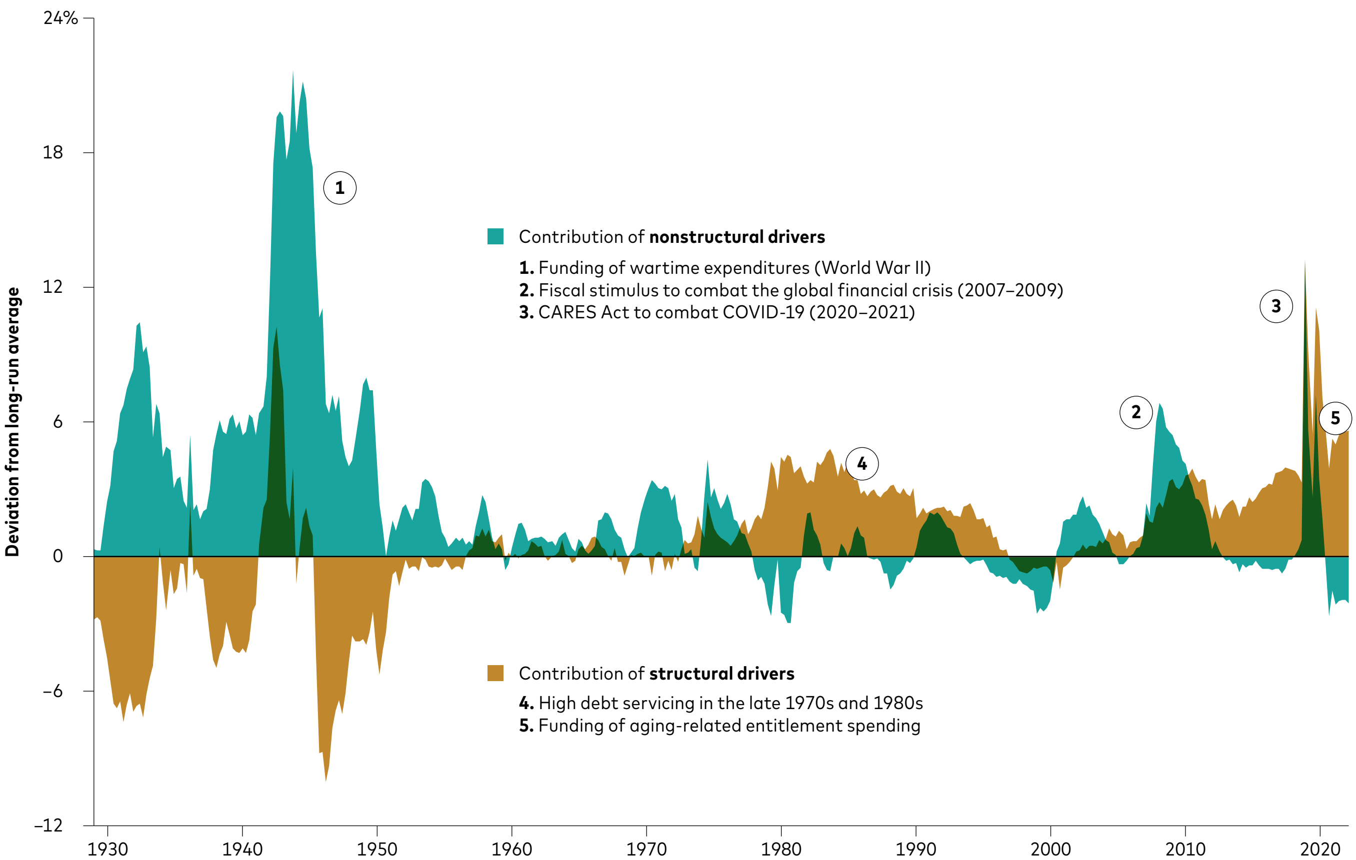
13 Specifically, we estimate a large BVAR with constant coefficients and multivariate stochastic volatility (which drives time-varying covariances), using Minnesota-type priors. Such an approach has increasingly become the standard workhorse for conducting empirical analysis with macroeconomic data and forecasting. See Davis, Brandl-Cheng, and Khang (2024) for more details.

Let's assume we wish to distinguish the first two drivers from the latter two, because the first two are transitory and tend to have an expansionary impact on the economy, whereas the latter two are tied to the economy's long-term conditions. This calls for an ability to distinguish among the four structural drivers behind rising (and falling) fiscal deficits over our sample period. We achieve this through structural VAR identification, a methodology commonly deployed in the macroeconomic literature that enables us to uncover these four main structural factors driving fiscal deficits over our sample period.[14] This allows us to decompose fiscal deficits into those due to the first two drivers and those due to the latter two drivers , as illustrated in **Figure 21**.

The figure shows that the latter two drivers—especially the deficits connected to finance entitlement spending—have been causing fiscal deficits to rise since the global financial crisis. The last time that structural U.S. fiscal deficits were this high was in the 1970s and 1980s, when high inflation and interest contributed majorly to debt servicing costs.

FIGURE 21

Fiscal deficits are increasingly shaped by structural drivers



Note: Figure shows the historical contribution of structural drivers (interest rate on debt service, age-related spending) and of nonstructural drivers (such as rising deficits during wartime or recessions) to the deviation of the fiscal deficit-to-GDP ratio from their long-run average, from March 31, 1929, through September 30, 2023.

Source: Vanguard.

14 Essentially, we apply a standard technique in structural VAR literature and specify a combination of sign restrictions, zero restrictions, and relative magnitude restrictions to identify the structural shocks needed for impulse response functions and historical decomposition. We follow the methodology of Arias, Rubio-Ramírez, and Waggoner (2018). The identification strategy exploits our trend-cycle decomposition to assign contemporaneous restrictions to the shocks of the 15 endogenous and exogenous variables in three interrelated blocks: (1) slow-moving demographic and technology trends; (2) faster-moving cyclical and policy-related variables that move at business-cycle frequency; and (3) other variables that evolve very quickly at the financial markets' cadence. These blocks are generally ordered such that the slow-moving blocks can contemporaneously affect faster-moving blocks but not the other way around, yielding a semi-Cholesky structure. See Davis, Brandl-Cheng, and Khang (2024) for more details.

Appendix 2. Simulating the next decades with the Vanguard Megatrends Model

To simulate the future of the U.S. economy shaped by megatrends, we leverage the Vanguard Megatrends Model and our understanding of the structural drivers behind four emerging megatrends:

- AI-powered technological advances;
- weakening demographics driven by slower population growth and aging society;
- waning globalization; and
- rising fiscal deficits due to rising entitlement spending.

Our simulation approach involves three steps:[15]

4. **Fiscal deficits will rise, and globalization will slow.** We project rising fiscal deficits and slowing globalization as the baseline (this involves the third and fourth megatrends cited above). The baseline path for structural fiscal deficits comes from the CBO. These projections are structural in nature, driven primarily by rising entitlement spending; they do not assume recession or exceptional wartime spending.
5. **AI's transformative impact is the key swing factor.** Next, we simulate AI's impact on the transformation component of the technology (GPT). Historically, an emergence of the transformative impact has a number of properties. First, upon its emergence, a GPT achieves its maximum impact on productivity growth after seven to eight years while continuing to positively affect trend productivity growth for more than 15 years. Second, there is also a J-curve effect, in which the GPT could initially lower productivity. Third, the GPT's explosive impact on productivity is often preceded by a rising investment-to-labor ratio and declining productivity. We take these GPT properties into consideration and generate a range of estimates of AI's potential impact, which in turn propagates through task displacement (or efficiency) and labor augmentation.[16]
6. **Whether AI succeeds or fails, interest rates will likely be higher.** We model interest rate forecasts by assuming a central bank that is targeting 2% inflation and by adjusting the CBO deficit forecast according to our projections for growth and the cost of debt financing. These adjustments imply that in simulations with higher inflationary pressures, real and nominal federal funds rates will be higher (to keep inflation in check). And in simulations with higher interest rates or lower growth rates than those in the CBO forecasts, deficits—including debt servicing costs—will be higher. Both outcomes will lead to higher deficits, creating greater inflationary pressures.

15 Our approach leverages recent work by Antolín-Díaz, Petrella, and Rubio-Ramírez (2021), who introduced a unified framework for conditional forecasts and structural scenario analysis with Bayesian VAR models. For further details on our forecasting methodology, see our companion paper Davis, Brandl-Cheng, and Khang (2024).

16 Our approach is conservative and is informed by the history, with the peak impact of AI in our median forecast well below that of electricity in the 1920s.

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