

Global macro matters

Why is inflation so low? The growing deflationary effects of Moore’s Law

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The paradox of low inflation with full employment

The global economy is at or near full employment, yet inflation trends remain stubbornly low (Figure 1). A decade after the onset of the Global Financial Crisis, central banks in the United States, Europe, Japan, and elsewhere still struggle to achieve their 2% inflation targets despite years of extraordinary stimulus. Globalization, China’s slowdown, demographics, and “transitory factors” are commonly cited reasons for the difficulties central banks face in achieving their mandates.

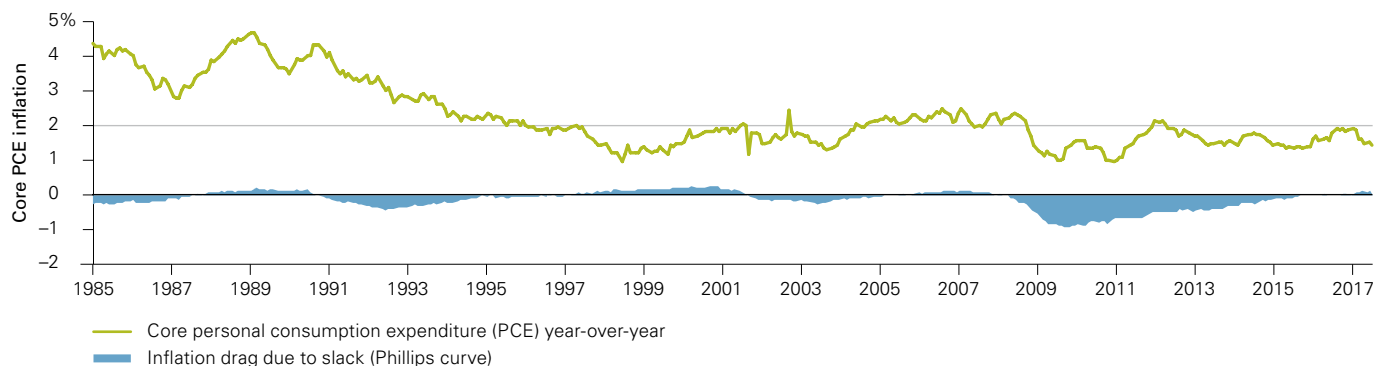
In this paper, we show that *technology* is another important—and often overlooked—factor that explains why inflation has tended to fall short of the 2% targets as much as it has. Our analysis underscores our secular view on inflation and interest rates in the years ahead.

The growing reach of Moore’s Law

Coined by Intel co-founder Gordon Moore, Moore’s Law has become shorthand for the diffusion of ever more powerful and cheaper technologies. As technology continues to improve (faster and more powerful computers, lighter and bigger televisions, more productive smartphone apps, and so on), the relative price of technology continues to plummet. We estimate that lower prices for business and consumer tech products have produced a moderate drag of about –18 basis points per year in the Consumer Price Index (CPI).¹ (A basis point is one one-hundredth of a percentage point.)

But Moore’s Law is about more than technology gadgets and Amazon Prime. Its knock-on effects restrain the need for higher prices in every corner of the economy, not just in high-tech products. This is often missing in the recent discussion of why inflation is so low in the face of full employment.

Figure 1. Core U.S. inflation remains below 2%, even at full employment



Notes: Inflation drag due to slack is calculated from a Phillips curve estimation for deviations of U.S. core personal consumption expenditure (PCE) inflation from a three-year rolling trend in the unemployment gap. That gap is measured by the U3, or official, unemployment rate minus the Congressional Budget Office’s Non-Accelerating Inflation Rate of Unemployment (NAIRU). The data cover January 1985 through July 2017.

Sources: Vanguard calculations, based on data from Thomson Reuters Datastream, the U.S. Bureau of Economic Analysis (BEA), the U.S. Bureau of Labor Statistics (BLS), and the Congressional Budget Office.

¹ In calculating this effect, we have identified technology items in the CPI as TVs; video and audio; video and audio production; information processing; and information technology, hardware, and services. Their weight totaled 5.1% of the CPI in 2016. The contribution of technology prices to the CPI was calculated by multiplying the weight of each tech component by its price index. For CPI minus technology, we subtracted the tech contribution from the CPI and divided it by one minus technology’s weight. The data sample covers January 1994 to April 2017.

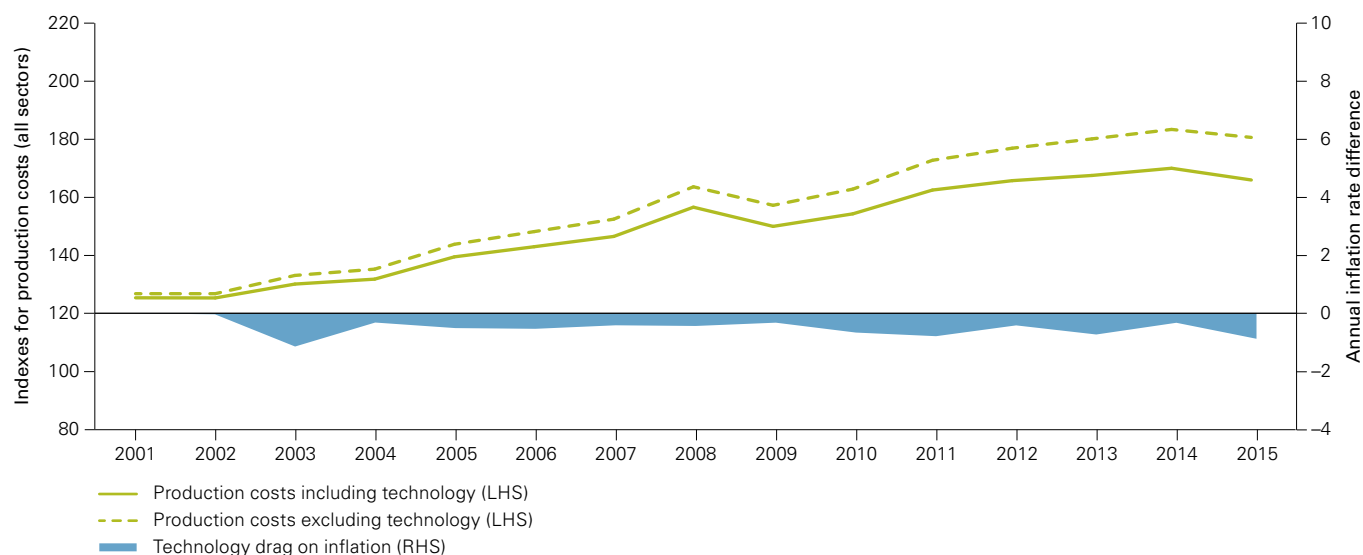
As technology is used more prominently to produce more goods and services, firms across all sectors are realizing lower production costs. Prices charged by companies are a markup over marginal costs, and the continued adoption of new technologies generally translates into reduced unit costs of production. Over time, these benefits make their way to consumers in the form of lower, or less rapidly increasing, final prices, even in sectors not directly related to technology.

We took a novel approach to identifying technology's (growing) role in the U.S. economy's production process by consulting detailed, industry-level input-output data from the U.S. Bureau of Economic Analysis (BEA). To quantify how the increased utilization of technology is making it harder today to achieve 2% inflation, we identified the technology inputs used by each industry, from health care, professional services, and education to agriculture and construction. We then compared the actual

change in prices charged by each industry's products and services (its Producer Price Index) with the change in a hypothetical index that excludes computer-based technology inputs.

Figure 2 shows the striking effect of Moore's Law on the prices that U.S. businesses need to charge. Since 2001, the declining prices of computer and electronic products, computer design and services, and other technology inputs have trimmed 0.5 percentage point per year from production costs and ultimately from final prices. Without Moore's Law, in other words, annualized inflation would have been 0.5 percentage point higher. Without the drag of technology, core PCE inflation would already be at 2%; the Federal Reserve's inflation target would have been achieved years ago, and nominal interest rates would be higher.

Figure 2. Moore's Law is a drag (on inflation)



Notes: In the BEA's input-output data (I-O), we identified technology-related inputs as follows: computer and electronic products; broadcasting and telecommunications; data processing, internet publishing, and other information services; and computer systems design and related services. We identified as closely as possible Producer Price Index (PPI) series for each industry in the I-O, including all four technology inputs. As for the contribution of tech prices to each industry's price inflation, the weightings of the technology inputs were calculated using 2001 prices, reached by deflating both technology and industry data by their respective PPIs. The weightings were multiplied by technology's PPI to arrive at the contribution to each industry's PPI. For each industry's PPI minus technology, we subtracted the tech contribution from PPI and divided it by one minus technology's weight. Industries are defined according to the 2007 North American Industry Classification System (NAICS).

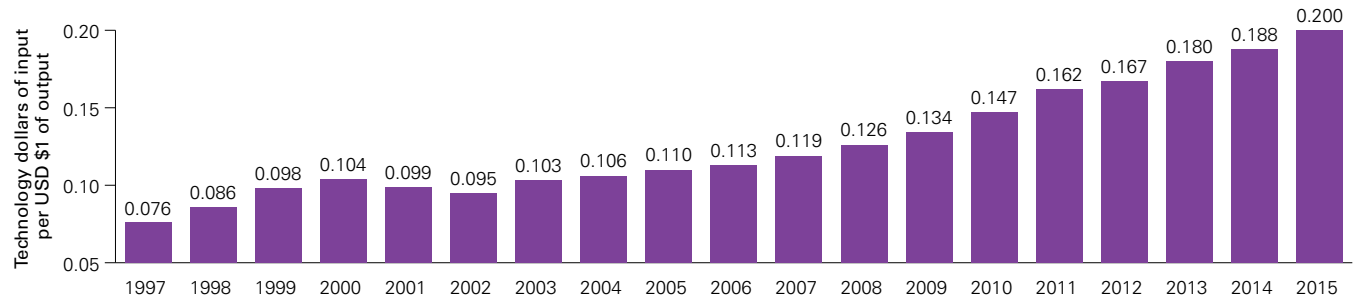
Sources: Vanguard calculations, based on data from Moody's Analytics Data Buffet, Thomson Reuters Datastream, BEA, and BLS.

Technology is a critical—and often underappreciated—challenge that central banks face in sustainably meeting their inflation targets. In part, this drag is bound to become more significant if companies continue to adopt more tech-intensive processes. Replacing older production processes with newer and cheaper tech-intensive ones increases the weight of technology-related inputs and further reinforces the deflationary effect of Moore’s Law. **Figure 3**, also based on industry-level data from the BEA input-output tables, shows that in real terms, the amount of technology used in production processes has more than

doubled since the late 1990s, from \$0.08 per \$1 of output to \$0.20. We have no reason to believe this trend will reverse any time soon.

The impact has been the most pronounced in tech-intensive industries such as information and communications, professional services, and manufacturing. But even sectors that would appear less directly tied to technology—such as health care, education, or retail trade—have seen smaller yet meaningful cost savings (as shown in **Figure 4**).

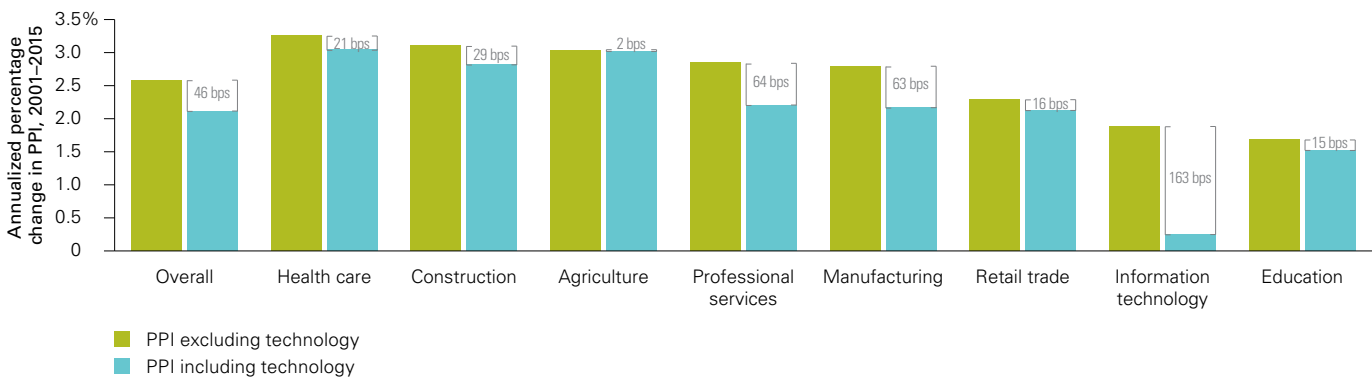
Figure 3. Technology’s role increases as costs continue to fall



Notes: Data cover January 1997 through December 2015.

Sources: Vanguard calculations, based on BEA input-output tables and Thomson Reuters Datastream.

Figure 4. Technology’s effects on prices, by industry



Notes: Data cover January 2001 through December 2015.

Sources: Vanguard calculations, based on BEA input-output tables and Thomson Reuters Datastream.

What are the implications for inflation?

With the global economy at full employment, low inflation is the last obstacle for policymakers to more aggressively normalize monetary policy (which the bond market doesn't currently expect). Vanguard has long held that structural forces (including technology) mean that most economies would struggle at times to achieve sustainable inflation rates of 2% or more over the medium run.

In **Figure 5**, we use the insights from this structural approach to offer a more realistic view of the potential drivers of global inflation. At present, market-based expectations and survey-based projections both indicate a consensus that inflation levels will remain subdued. A key question for investors, then, is what could drive an unexpected turnaround in global inflation trends over the medium term?

Overall, our assessment further bolsters our view that inflation and interest rates will remain historically low for some time. Except for a gradualist approach to monetary policy normalization, we assign a moderate to low probability to each key driver of higher inflation. Moore's Law and the pace of technological innovation are likely to remain an obstacle to central banks' goal of 2% inflation. Should we see higher-than-expected inflation in the next two to three years, it would most likely arise from a combination of materially stronger global growth and accommodative monetary policy that sufficed to counteract the deflationary force of Moore's Law.

Figure 5. Global inflation outlook: What would drive up inflation over the medium term?

Source	Drivers of higher inflation	Description	Probability
Demand-side forces and policies to generate inflation	Gradualist approach by central banks to monetary normalization	Central banks move to a gradual tapering of purchases or reinvestments of securities and slow normalization of policy rates.	High
	Strong coordinated global fiscal impulse	Governments relax fiscal austerity plans and/or adopt globally coordinated expansionary fiscal policies aimed at funding infrastructure investment, reforms, etc.	Low
	Surge in emerging markets growth and commodity prices	Emerging markets growth picks up to pre-financial-crisis levels as demand for commodities and commodity prices recover.	Low
Supply-side structural forces leading to higher inflation	Diminished role of globalization:		
	• Trade protectionism	Tariff and trade barriers lower the growth of global trade, removing its suppressing effect on import prices and consumer price inflation.	Medium/low
	• Decline of global value chains	Tariffs and trade barriers limit companies' ability to export and reimport goods between subsidiaries across borders. Growth in global value chains stalls.	Medium
	• Reforms to China's state-owned enterprises (SOEs)	SOEs adopt market-oriented production to increase efficiency, limiting industrial overcapacity in certain sectors, such as steel.	Medium/low
	Decline in the pace of technology, slowdown of Moore's Law	The pace of technological innovation slows and/or the substitution of cheaper technological inputs declines.	Very low

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