How to solve the puzzle of missing productivity growth

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+ Policy strategies for harnessing the productivity potential of AI in the US

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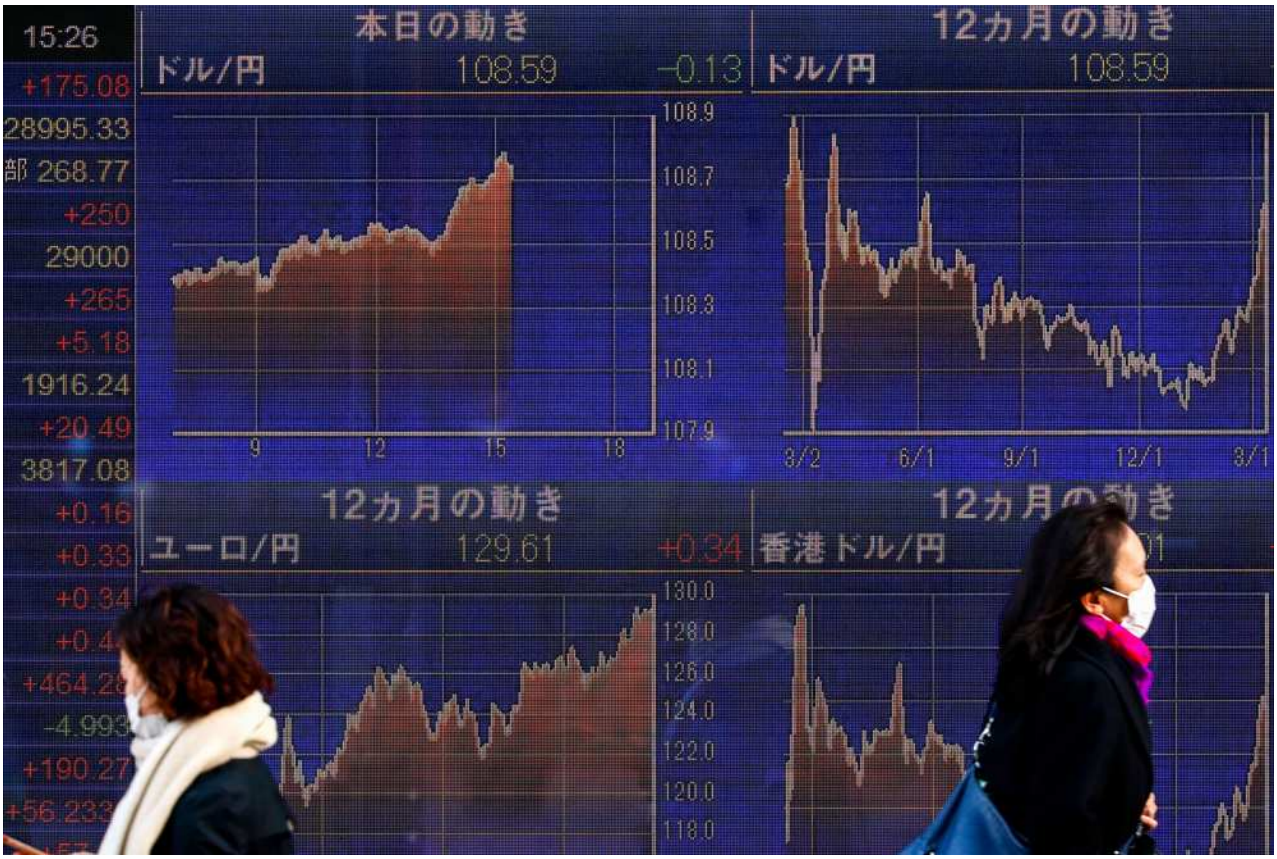
Erik Brynjolfsson, Seth G. Benzell, and Daniel Rock



People walk past an electronic board showing currency exchange rates at a securities firm in Tokyo. (James Matsumoto / SOPA Images/Si via Reuters Connect)

Despite the economic damage wrought by the novel coronavirus over the past year, an analysis published by *The Economist* in December 2020 argues that the COVID-19 pandemic may have made a boom in productivity more likely to happen because "new technologies are clearly able to do more than has generally been asked of them." This would be welcome news to observers who have scratched their heads about why supposedly innovative technologies like cloud computing and artificial intelligence have struggled to materially affect topline productivity growth numbers or the rate of overall GDP growth.

Office closures have made firms invest in automation and digitization and make better use of existing resources. Survey data collected by the World Economic Forum during the pandemic show that more than 80% of employers are planning to accelerate the adoption of advanced technologies and provide more opportunities for remote work, while 50%

plan to accelerate automation of production tasks. In a way not seen for the last two decades, this turn has the potential to provide sustained productivity growth—the ultimate engine of economic activity in the long run.

To take a step back, in the past decade digital goods and services have been criticized for underdelivering on their enormous economic promise. In spite of the emergence of new technologies capable of diagnosing diseases, understanding speech, or recognizing images, these tools have had startlingly little effect on the disappointingly slow productivity growth rate of advanced economies, critics argue. Indeed, the pace of productivity growth has decelerated in the past two decades—from an average of 2.8% per year in the decade ending in 2005, down to 1.3% per year from 2006 through 2019.

In a recent Stanford HAI and Digital Economy Lab policy brief, we took stock of the latest research and identified four potential reasons why productivity growth is slowing. Besides examining each of these four explanations, we want to sketch out what policymakers can do to reverse this trend, reduce income inequality, and make the United States more competitive. This set of policy actions falls into three broad categories:

1. Increasing investments in research and development through direct grants and tax credits.
2. Expanding the human capital available to the economy by boosting our education system and expanding immigration of high-skilled labor.
3. Removing the legal and regulatory bottlenecks that currently exist to entrepreneurship and business innovation.

Establishing root causes

To begin, why has productivity growth slowed in spite of immense technological innovation? First, we have to consider the possibility that today's technological advances simply fall short of the promise envisioned by their developers and that they will never fulfill their expected economic promise. Second, economists might be failing to measure properly all the aspects in which technological changes are affecting the economy. Third, the new technologies under consideration may be privately beneficial to the companies that developed them but have fewer positive effects on the broader economy. Lastly and most compellingly from our perspective, transformative technologies take time to diffuse throughout the economy and must be accompanied by appropriate investments and adjustments. They don't typically translate into improvements in productivity until complementary innovations have been developed.

The argument that tech hype is overblown and will never fulfill supposedly irrational expectations rests on the contested observation that the rate at which innovations are being created is decreasing. This is borne out in some respects, since it is increasingly difficult for researchers to reach the frontiers of their discipline as more specialization is needed per innovation than before. But we do not find as compelling the parallel

argument that productivity gains from the adoption of I.T. systems installed early in the 21st century have run their course and that no additional technological improvements to productivity should be expected.

Moreover, as information flows and knowledge-based work increases in importance, accounting for digital goods and services has become an increasingly important part of the economic conversation. While traditional growth accounting handles the case of economic activity like manufacturing pretty well, instances of unmeasured inputs and unmeasured outputs that stem from what are known as intangible or hidden assets—assets like corporate culture or business processes that are not documented on balance sheets, not kept as inventory in a warehouse, and not easily transferable between firms—have upended the mechanics of economic measurement. This raises questions about whether growth accounting is properly capturing the ways in which digital technologies are changing the economy.

The second explanation, that we may be failing to properly measure new sources of economic activity, enjoys broader support than the overblown hype argument. Since the beginning of the productivity slowdown, the way consumers choose to value search engines and social networks demonstrates considerable fluctuation, as has consumer dependence on goods like mapping software and encyclopedias that were not free before they became digital goods. Improper or uncertain measurement must also be seen in conjunction with the fact that prices for goods such as semiconductors and other specialized computational hardware are increasingly being mismeasured. If economists' estimates of price changes for these new technology products were rising too quickly or falling too slowly over time, the overall amount of productivity growth observed would be understated.

Improper and uncertain measurement is related to the third hypothesis, that lucrative technologies are increasingly used in zero-sum applications that merely shift wealth around and have fewer positive effects on the economy generally. An example of this can be seen in the misalignment of incentives in tax policy that subsidizes capital at the expense of labor and crowds out investment in labor generative technology. Capital subsidies result in firms developing technologies that are only marginally more efficient than workers but not sufficiently better to incentivize additional investment that could complement workers. This can be seen in the case of recent innovator companies who have focused on developing technologies that are just better enough than a worker to lower labor demand, but not better enough to free up additional capital for complementing workers.

Lastly—and most importantly—slowing productivity growth may be the result of technologies taking time to reach their full economic potential. We find this argument most convincing because of the nature of general-purpose technologies (GPTs) like artificial intelligence—those that are generally pervasive and can improve over time but require complementary investments that are both intangible (e.g. in data collection, employee training) and physical (e.g. computers, 5G towers). In the early stages of GPT-related economic activity, it can appear increased tangible costs are required to achieve the same outputs as in the past—before unmeasured capital service flows and unmeasured

costs to create that capital start to balance each other out. This is because of the substantial need for complementary innovations to many intangible assets, especially in the case of fundamental technology advancements such as AI. We have termed this phenomenon the “productivity J-curve.” As we have seen, complementary innovations for productivity enhancing technologies can take years or even decades to create and implement. In the meantime, measured productivity growth can fall below trends since real resources are devoted to investments in these innovations.

Supercharging productivity growth

Taking the above analysis into account allows us to develop the following recommendations policymakers should take to enhance productivity growth. In order to ensure that the economic gains from integrating these hard-to-measure intangible assets are not consumed entirely by the wealthy and privileged, we propose a set of interventions across three broad issue areas that are designed to share prosperity among the entire population.

First, to address inadequate research and development (R&D) efforts, boost levels of spending in both public and private R&D by authorizing large, government-directed research projects, government grants through the National Science Foundation or the National Institutes of Health, and through tax credits for private businesses. Fundamental science is often best carried out by government, academia, or nonprofits while marketable applications of that basic research are often optimized through private development. Thus, the federal government should adopt a diversified approach in building this program in order to reduce overall risk and fund early stage or large-scale projects that the private sector either would not be able to pursue or would not want to pursue. This will increase the likelihood of positive effects from at least one avenue.

The second category of policy actions we recommend involve increasing U.S. human capital. This can be accomplished through shoring up our education system and encouraging high-skilled immigration. Boosting the attractiveness of the United States to high-skilled immigrants is the most simple and important action the country could take today to increase growth. This includes immigrants and refugees who do not have university degrees. Those who come to America tend to be entrepreneurial and ambitious and represent some of the most talented and tenacious individuals in their home countries. Immigration also has the added benefit of expanding market size and providing opportunities for entrepreneurs to serve specialized markets.

The United States should also boost funding and support for schools and universities, including by potentially funding new universities, updating the land-grant process used to create institutions like the University of California system, or by allocating appropriately sized endowments to be administered by the states. In order to better prepare children for college, the United States should do more to improve the quality of primary- and secondary-school instruction through better accountability for teachers, extending the length of school days and the school year, offering optional weekend classes, and

providing one-on-one math tutoring. The goal here is to not only produce more STEM PhDs in the United States, but to promote the training of scientists abroad as well, since R&D conducted abroad is likely to produce positive spillovers in this country.

Our third category of policy interventions involve eliminating bottlenecks to innovation in the legal, regulatory, and tax realms. In order to reduce adjustment costs and lags to the benefits of new technologies, policymakers should pursue legislation to eliminate or weaken the non-compete clauses that prevent skilled engineers from bringing their talents and insights to competitors. Policymakers should further enact intellectual property reforms that push more technologies and artistic concepts into the public domain. Besides investing in infrastructure and public goods, the United States should also reinvigorate antitrust enforcement, including by empowering the Federal Trade Commission to subpoena information needed for better understanding and regulating monopolies.

Rather than focusing on breaking up digital platforms—which might destroy productivity-enhancing network effects—the federal government should promote standards that enable easier market entry and interoperability among competitors. Where this is impossible, regulators should focus on tax policy, regulation, and collective bargaining tools to ensure the benefits from these platforms are more widely distributed. Decoupling healthcare from employment and reforming occupational licensing will help make it easier for people to start a new business and boost entrepreneurship. Lastly, the United States should correct the subsidy it currently provides to capital-intensive automation over the invention of new tasks for labor. Washington should also collaborate with other countries on corporate tax reform in order to prevent a race to the bottom with respect to corporate tax havens in the international contest to attract capital.

Pursuing these policies will reward firms for creating new jobs instead of economizing on labor costs and will ensure that the innovation provided by GPTs accelerates productivity growth across the entire economy. This in turn will help expand wages, reduce income inequality, and ensure that more equitable growth is enjoyed across the country. Addressing the productivity paradox will contribute to the speedy integration of scalable machine intelligence into the global economy and ensure that its integration reflects our fundamental values about the dignity of human work. In sum, we are optimistic that the coming decade will be one of higher productivity growth as firms continue to adjust their business practices because of the COVID-19 pandemic and as policymakers take the reins in making a plan for equitable growth a reality.

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This post is adapted from the Stanford HAI Digital Economy Lab's policy brief, "Building Solutions to the Modern Productivity Paradox"

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POLICY STRATEGIES FOR HARNESSING THE PRODUCTIVITY POTENTIAL OF AI IN THE U.S.

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DESPITE THE EMERGENCE OF NEW MACHINE LEARNING TECHNOLOGIES capable of diagnosing diseases, understanding speech, or recognizing images, the enormous economic potential of many digital goods and services remains largely untapped. Expectations about rapid rates of improvement in the efficiency of each worker over the past two decades have consistently given way to disappointment. A common way to measure this rate of improvement is via the change in output produced per hour work, in other words productivity growth. Measurements show that it has slowed from an average of 2.8 percent per year in the decade ending in 2005 down to 1.3 percent per year between 2006-2019. If U.S. productivity had grown at the same rate from 2005–2019 as it did from 1995–2004, overall GDP would have been about $4.2 trillion higher at the end of 2019 than what the official statistics measured it to be.

A recent paper of ours "Understanding and Addressing the Modern Productivity Paradox," took stock of the latest research. Economists failing to properly measure the output of the digital economy and large technology companies' tendency to take advantage of the monopolies they have created both undeniably play some role in the slowdown. However, in our view the most important factor is that

KEY TAKEAWAYS

- The pace of measured productivity growth in the United States has slowed over the past two decades, resulting in a massive gulf of potential GDP lost. We estimate that this is equivalent to $4.2 trillion lost for the year 2019.
- Failing to properly measure the output of the digital economy and monopolistic behavior by some companies play some role in the slowdown, but the most important factor may be the considerable amount of time and effort required for complementary innovations to keep pace with fundamental technologies like AI.
- Policymakers can boost productivity by increasing investments in research and development, expanding immigration of high-skilled labor and reinforcing our education system, and removing many of the legal and regulatory bottlenecks that currently exist to business innovation and entrepreneurship.

transformative technologies like AI take time to be implemented throughout the economy. Just as earlier innovations like electricity required entirely rethinking the nation's paradigm about factory organization, infrastructure and public utilities, these twenty-first century advances cannot simply be implemented without complementary investments. They must be accompanied by appropriate adjustments, workforce re-skilling and business process innovations in order to ensure that they translate into sustained improvements in productivity.

We propose here a set of policy recommendations that fall into three broad categories that might reverse the recent stagnation in productivity growth, make the United States more competitive, and reduce overall income inequality. First, increasing investments in research and development through direct grants and tax credits. Second, expanding the human capital available to the economy by boosting the nation's education system and expanding immigration of high-skilled labor. Third, removing many of the legal and regulatory bottlenecks that currently exist to entrepreneurship and business innovation. We are optimistic that if policymakers implement the plan for shared prosperity that we outline in this brief, the coming decade will be one of higher productivity growth and one where the United States returns to its historical role as the most dynamic economy in the world.

While traditional growth accounting handles the case of twentieth century economic activity like manufacturing relatively well, instances of unmeasured inputs and outputs that stem from intangible assets . . . have upended the mechanics of economic theory.

INTRODUCTION

As information flows and knowledge-based work increase in importance, the challenging task of accounting for digital goods and services has become an increasingly critical piece of the economic puzzle. While traditional growth accounting handles the case of twentieth century economic activity like manufacturing relatively well, instances of unmeasured inputs and outputs that stem from what are known as intangible or hidden assets—assets like corporate culture or business processes that are not kept as inventory in a warehouse and not easily transferable between firms—have upended the mechanics of economic theory. Among the four explanations analysts have offered for slower than expected productivity growth, one argument posits that the hype around technology is overblown and that the

increasingly difficult path for researchers to arrive at the frontiers of their discipline means we have reached the end of the line in terms of technological innovation. We do not find this argument particularly compelling. The documented improvements of AI calls this into question. Instead we look towards issues with properly measuring economic activity and with creating the optimal environment for advanced technologies to explain how public and private sector leaders can chart the way forward.

A second explanation states that economists may be failing to properly measure new sources of economic activity and points to the rapidly changing way that consumers value platforms like search engines or social networks. Goods like maps and encyclopedias were also generally not free before they became digital goods, and improper or uncertain measurement in how individuals value their use is further complicated by the fact that prices might also be mismeasured.

A third hypothesis is that lucrative technologies are beneficial to the private companies that developed them, but they are not necessarily having positive effects on the economy generally. Economists deem this "rent-seeking" behavior, and it can extend from how a platform interacts with its user base to how companies secure beneficial concessions from the government. As corporations focus on developing technologies that are only marginally more efficient than workers, they are missing out on the opportunities provided by nascent technologies that could expand overall productivity while increasing wages.

The final—and to our mind most important—explanation behind the productivity slowdown is that transformative technologies like AI take time to reach their full economic potential because they require complementary investments. We find this argument convincing because of the intangible nature of general-purpose technologies (GPTs) like artificial intelligence that have the capacity to lead to complementary new advances. In the early stages of GPT-related productivity enhancement, it can appear that increased tangible costs like those traditionally reflected on a firm's balance sheet are required to achieve the same level of output as in the past. Eventually, unmeasured capital service flows and unmeasured costs to create that capital will accrue and start to balance each other out. The official statistics will show measured productivity growth falling below the historical trend line as real resources are devoted to investments in these innovations. This process can take years or even decades to play out as complementary innovations come online and are integrated into the economy in a meaningful way for fundamental advances such as AI.

The official statistics will show measured productivity growth falling below the historical trend line . . . This process can take years or even decades to play out as complementary innovations come online and are integrated into the economy.

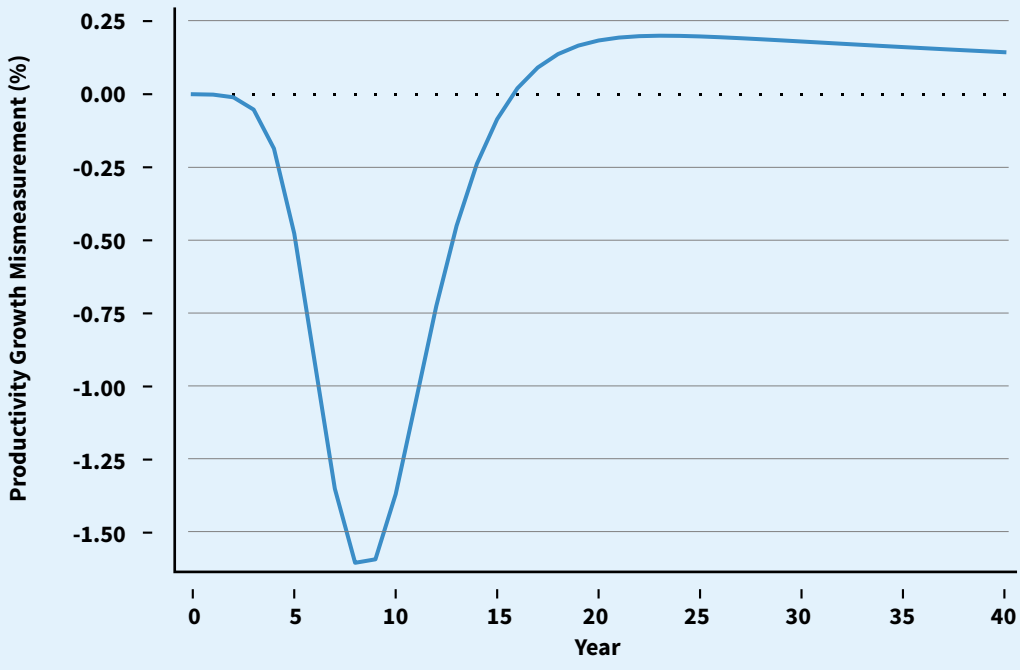
POLICY DISCUSSION

Each of the four arguments offered above are likely to contribute to the productivity slowdown. In order to help make the economic gains not only larger, but also more widely shared, we propose a set of policy recommendations.

These recommendations fall into three broad categories: first, in order to address inadequate research and development (R&D) activity, we propose to boost levels of spending in both public and private R&D by authorizing large, government-directed research projects, government grants through the National Science Foundation or the National Institutes of Health, and through tax credits for private businesses. This approach acknowledges that fundamental science is often best carried out by government, academia, or nonprofits and that marketable applications of that basic research are often optimally delivered through private development. The federal government should adopt a diversified approach in building this program in order to reduce overall risk and fund early stage or large-scale projects that the private sector either would not be able to pursue or would not want to pursue because the private returns might not be worth it, even if the social benefits would be large.

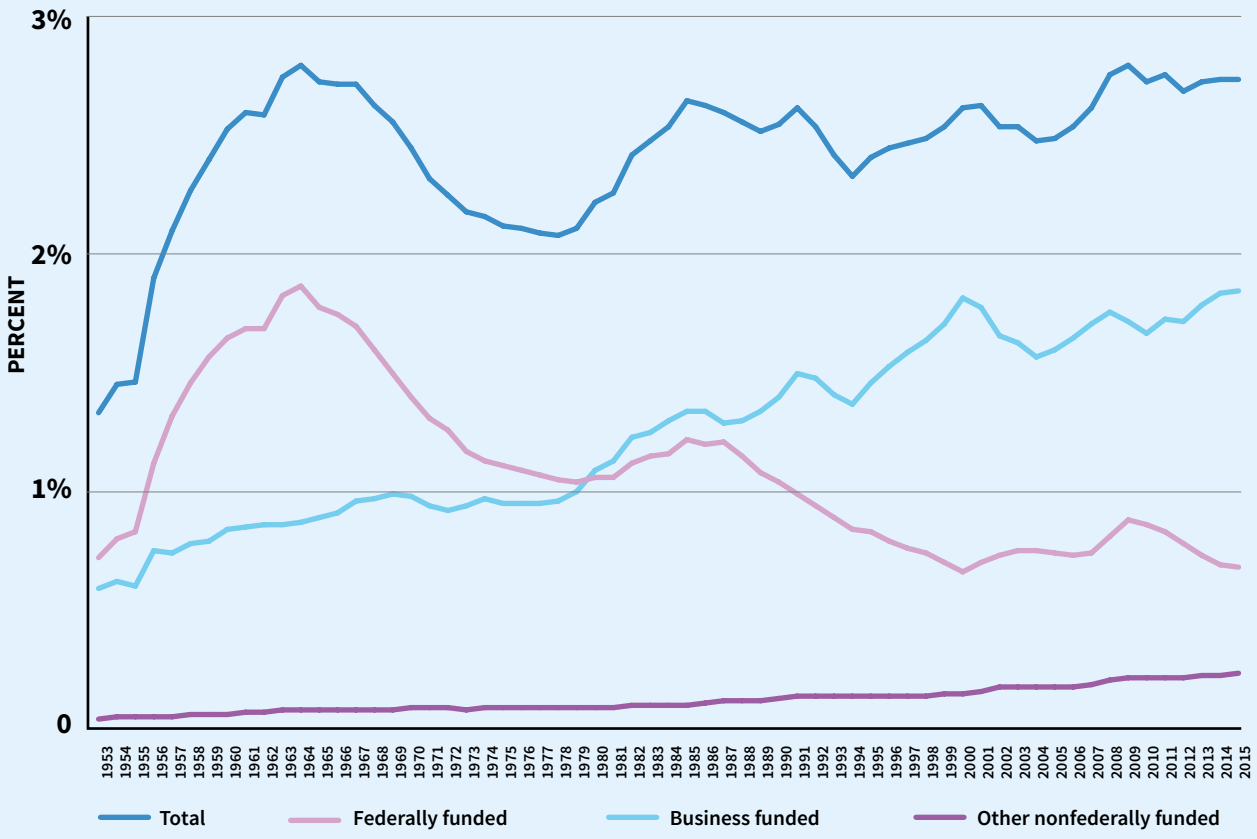
TOY ECONOMY: THE PRODUCTIVITY GROWTH MISMEASUREMENT J-CURVE CALCULATION OF CAPITAL AS SHARE AS 1-(WL/Y)

When the curve drops below zero, the effects of unmeasured output created using measured inputs dominate. Above zero, effects of measured output created using measured inputs are larger.



The second category of policy actions involve increasing the human capital of the country. We propose to accomplish this by reinforcing our education system and encouraging high-skilled immigration. Boosting the attractiveness of the United States to high-skilled immigrants is the simplest and most important action the country could take today to increase growth. Even immigrants and refugees who do not have university degrees may contribute to productivity growth by expanding market size and providing opportunities for entrepreneurs to serve specialized markets. Additionally, the United States should boost funding and support for universities (including potentially funding new universities) either

RATIO OF U.S. R&D TO GROSS DOMESTIC PRODUCT, BY ROLES OF FEDERAL, BUSINESS, AND OTHER NONFEDERAL FUNDING FOR R&D: 1953–2015



Notes: Some data for 2015 are preliminary and may later be revised. The federally funded data represent the federal government as a funder of R&D by all performers and similar for the business-funded data. The other nonfederal category includes R&D funded by all other sources—mainly, higher education, nonfederal government, and other nonprofit organizations. The gross domestic product data used reflect the U.S. Bureau of Economic Analysis's comprehensive revisions of the national income and product accounts of July 2017.
Sources: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series).

through updating the land-grant process used to create institutions like the University of California system or by allocating appropriately sized endowments to be administered by the states. In order to better prepare children and adolescents for college, the United States should do more to improve the quality of primary- and secondary-school instruction through better accountability for teachers, extending the length of school days and the school year, offering optional weekend classes, and providing one-on-one math tutoring. The goal here has to be not only producing more STEM PhDs in the U.S., but promoting the training of scientists abroad as well, since R&D conducted abroad is likely to affect the U.S. in a positive way.

The United States should correct the subsidy that it currently provides to capital-intensive automation over the invention of new tasks for labor.

Finally, our third category of policy interventions is designed to eliminate bottlenecks to innovation in the legal, regulatory, and tax spheres. In order to reduce adjustment costs and the lag time between developing a technology and reaping the rewards, policymakers should pursue legislation to eliminate or weaken the non-compete clauses that prevent too many skilled engineers and other workers from bringing their talents to competitors. They should further enact intellectual property reforms that push more technologies and artistic concepts into the public domain. Rather than focusing on breaking up digital platforms—which might destroy productivity-enhancing network effects—the federal government should promote standards that enable easier market entry and interoperability among competitors. Where this is impossible, regulators should focus on tax policy, regulation, and collective bargaining tools to ensure the benefits from these platforms are more widely distributed. Furthermore, decoupling healthcare coverage from employment and reforming occupational licensing will help make it easier for people to start a new business and boost entrepreneurship. Finally, the United States should correct the subsidy it currently provides to capital-intensive automation over the invention of new tasks for labor. Lawmakers should collaborate with other countries on corporate tax reform in order to prevent a "race to the bottom" with respect to corporate tax havens in the international contest to attract capital.

Pursuing these policies will reward firms for creating new jobs rather than destroying them and will ensure that the innovation provided by GPTs accelerates productivity growth across the entire economy. Supercharging productivity growth will in turn help expand wages, reduce income inequality and ensure that more equitable growth is enjoyed across the country. Addressing the productivity paradox will not only contribute to scalable machine intelligence being integrated into the global economy as quickly as possible, it will do so in a way that reflects our fundamental values about the dignity of human work and ensure that the power of AI is used to improve the human condition, not diminish it.

The original articles, ***"Understanding and Addressing the Modern Productivity Paradox"*** and ***"Artificial Intelligence and the Modern Productivity Paradox: A Clash of Expectations and Statistics"*** can be accessed at: https://workofthefuture.mit.edu/wp-content/uploads/2020/11/2020-Research-Brief-Brynjolfsson-Benzell-Rock.pdf and https://www.nber.org/papers/w24001 respectively.

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