Technological Innovation and Economic Growth: A Brief Report on the Evidence

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ABSTRACT

Technological innovation is a fundamental driver of economic growth and human progress. Yet some critics want to deny the vast benefits that innovation has bestowed and continues to bestow on mankind. To inform policy discussions and address the technology critics' concerns, this paper summarizes relevant literature documenting the impact of technological innovation on economic growth and, more broadly, on living standards and human well-being. The historical record is unambiguous regarding how ongoing innovation has improved the way we live; however, the short-term disruptive aspects of technological change are real and deserve attention as well. The paper concludes with an extended discussion about the relevance of these findings for shaping cultural attitudes toward technology and the role that public policy can play in fostering innovation, growth, and ongoing improvements in the quality of life of citizens.

JEL codes: K2, O3, O4

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Technological innovation is a fundamental driver of economic growth and human progress. Unfortunately, that insight is often lost or underappreciated in technology policy discussions today, which frequently focus on the disruptive effects associated with technological change.[1]

Today's technology critics have moved well beyond traditional complaints about "the cult of convenience"[2] or the supposed "paradox of choice"[3] that innovation creates. Now they claim "it's OK to be a Luddite," because technology is "dehumanizing" and "will eliminate what it means to be human."[4] Technology and automation will not only lead to a "jobless future"[5]—more profoundly, modern innovations represent a "dangerous master" to be feared and resisted,[6] because they pose an "existential threat" to the very future of civilization.[7] Finally, the critics advocate a "radical project of social transformation"[8] and a full-blown "de-growth movement" to slow the pace of innovation.[9]

If these fears and anxieties about technological change come to influence the formation of public policy, they could undermine the profound benefits associated with technological innovation. To inform policy discussions and address

1. See, for example, Graeme Maxton, "Economic Growth Doesn't Create Jobs, It Destroys Them," *Guardian*, April 21, 2015; Martin Ford, *Rise of the Robots: Technology and the Threat of a Jobless Future* (New York: Basic Books, 2015); Wendell Wallach, *A Dangerous Master: How to Keep Technology from Slipping beyond Our Control* (New York: Basic Books, 2015); Evgeny Morozov, *To Save Everything, Click Here: The Folly of Technological Solutionism* (New York: Public Affairs, 2013); Andrew Keen, *The Cult of the Amateur: How Today's Internet Is Killing Our Culture* (New York: Doubleday, 2007).
2. Evgeny Morozov, "The Taming of Tech Criticism," *Baffler*, March 2015.
3. Barry Schwartz, *The Paradox of Choice: Why More Is Less* (New York: Ecco, 2004).
4. David Auerbach, "It's OK to Be a Luddite," *Slate*, September 9, 2015.
5. Ford, *Rise of the Robots*; Rory Cellan-Jones, "Robots on the March," *BBC News*, July 2, 2015.
6. Wallach, *Dangerous Master*. Also see David Brooks, "Our Machine Masters," *New York Times*, October 30, 2014.
7. Franklin Foer, *World without Mind: The Existential Threat of Big Tech* (New York: Penguin, 2017).
8. Morozov, "Taming of Tech Criticism."
9. Evgeny Morozov, "Stunt the Growth," *Slate*, January 22, 2014.

the technology critics' concerns, this paper summarizes relevant literature documenting the impact of technological innovation on economic growth and, more broadly, on living standards and human well-being, as well as the important role that public policy has to play in fostering innovation.

We begin by discussing the nature of innovation in general before reviewing what the essential models of economic growth, such as the Solow model and more recent "endogenous" growth models, have indicated about the role of technological innovation. We summarize some of the growth-accounting literature's early estimates about the contribution that technological change has made to growth, and we document what macroeconomists and economic historians have said about the importance of technological innovation for economic growth.

Innovation as a concept is difficult to define, but economists generally use the term to refer to increases in the quality and variety, or reductions in the cost, of goods and services provided by the market. The concept of *growth*, by contrast, is more narrowly focused on increases in the quantity of goods and services produced—in other words, it refers to overall production. Measured growth does not always reflect every way in which production has increased over time, however. For example, there are well-known limitations to GDP, a main measure of economic growth. Perhaps the best-known limitation is that GDP struggles to take into account quality improvements that occur as old products are made better over time. It also fails to fully consider the rate at which new products replace old ones over time. Since quality and variety of goods and services are closely connected to innovation, the shortcomings of GDP also make it difficult to fully capture the impact of innovation. Thus, we can generally expect conventional national income statistics to understate the true impact of innovation on living standards and well-being. Despite these measurement issues, however, economists still believe innovation to be a key driver of growth.

An important takeaway from the research on the causes of and contributors to growth is the observation that differences in physical capital cannot explain all of the observed variation in growth rates seen among countries. This explains why, over time, economists have shifted their attention away from capital and toward more abstract forces that underlie the process of technological change, such as the processes that engender new ideas. The importance of technology is not in doubt, although it is not always clear what cultural, political, or market systems affect the pace of innovation. What is clear, however, is that innovation is hard to come by. It is expensive to generate, and market and policy imperfections

make it such that we get less of it than is optimal. In other words, we need much more—not less—innovation than presently occurs.

This paper concludes with an extended discussion about the relevance of these findings for public policy. The cultural attitudes of the public, as well as the attitudes of policymakers, are critical for fostering innovation. Without a culture that embraces risk-taking and entrepreneurship, innovation is likely to be thwarted because of its disruptive nature. This would be a tragedy, given the profound benefits that accompany economic growth and technological change.

THE NATURE OF INNOVATION

Although, as mentioned above, the concept of innovation is somewhat hard to pin down, it can be thought of as taking three forms: (1) cost reductions, (2) quality improvements, and (3) increases in the variety of goods, services, and methods of production. Innovation is about finding new and better ways of doing things and introducing new ideas or new types of products and services into the marketplace.

This focus on "new ways of doing things"[10] and "the development and widespread adoption of new kinds of products, production processes, services, and business and organizational models"[11] is what lies at the heart of the process of innovation. But what is crucial about this process is that it serves as a means to an end: it helps drive progress, and human flourishing more generally. "Innovation is more than the latest technology," notes Sofia Ranchordás, a resident fellow at the Yale Law School. "It is a phenomenon that can result in the improvement of living conditions of people and strengthening of communities. Innovation can be technological and social, and the former might assist the latter to empower groups in ways we once thought unimaginable."[12]

While this paper focuses on technological innovation, innovation more broadly has impacts that extend far beyond technology and consumer satisfaction. Social media, for example, is changing the way human beings interact

10. "Innovation has two main themes. One is [a] constant finding or putting together of new solutions out of existing toolboxes of pieces and practices. The other is industries constantly combining their practices and processes with functionalities drawn from newly arriving toolboxes—new domains. . . . The result is new processes and arrangements, new ways of doing things, not just in one area of application but all across the economy." W. Brian Arthur, *The Nature of Technology: What It Is and How It Evolves* (New York: Free Press, 2009), 90.
11. Robert D. Atkinson and Stephen J. Ezell, *Innovation Economics: The Race for Global Advantage* (New Haven, CT: Yale University Press, 2012), 8.
12. Sofia Ranchordás, "Does Sharing Mean Caring? Regulating Innovation in the Sharing Economy," *Minnesota Journal of Law, Science & Technology* 16, no. 1 (2015): 10.

with one another. Such changes create both benefits and new challenges, which extend beyond the number, quality, and variety of goods and services we consume. Innovation changes our culture.

In the short term, changes initiated by innovation can lead to disruption, some of which may be unsettling. Some old business models will fail and some individuals will lose their jobs. In the long run, however, the endless search for new and better ways of doing things drives human learning and, ultimately, prosperity in every sense—economic, social, and cultural. Those who lose their jobs will eventually find other jobs and serve the public in new and different ways. While critics complain about various aspects of technological change, the historical record is unambiguous regarding how ongoing innovation has improved the way we live.

The degree to which a culture is open to experimentation and change, and to new ideas that threaten to upend the status quo, is important. Public institutions also have the potential to evolve over time in ways that can either nurture or hamper innovation.

Robert Bryce explains why innovation culture and policy are important in his recent book, *Smaller Faster Lighter Denser Cheaper: How Innovation Keeps Proving the Catastrophists Wrong*:

> This pessimistic worldview ignores an undeniable truth: more people are living longer, healthier, freer, more peaceful, lives than at any time in human history. . . . The plain reality is that things are getting better, a lot better, for tens of millions of people around the world. Dozens of factors can be cited for the improving conditions of humankind. But the simplest explanation is that innovation is allowing us to do more with less.[13]

"Doing more with less" is the core feature of productivity growth. Over the long term, productivity growth raises the standard of living for citizens as an ever greater number of products and services are produced with the same or fewer production inputs than were required in the past. For example, agriculture was once the dominant form of employment for Americans, but now only a tiny slice of the American population is engaged in farming, even while agricultural output has increased. This change was not easy, but it freed a vast swath of the labor force to explore other modes of production. As will become clear in the following sections, productivity growth and economic growth are inextricable, and

13. Robert Bryce, *Smaller Faster Lighter Denser Cheaper: How Innovation Keeps Proving the Catastrophists Wrong* (New York: Public Affairs, 2014), xxi–xxii.

productivity growth is closely related to the process of generating new knowledge.[14] It should not be surprising, then, that the knowledge-generation process has become a central focus of research on the determinants of economic growth.

New knowledge is hard to come by. For one thing, it has attributes like those of a public good. In economics jargon, this means it is often (though not always) nonexcludable and nonrivalrous. (*Nonexcludable* signifies that, once knowledge exists, it is freely available for anyone to use, and *nonrivalous* indicates that the ability of one person to use knowledge does not impede the ability of another person to use it.) For this reason, it is easy for those who invest nothing in the discovery of knowledge to "free ride" off the inventiveness of others, which can discourage innovators if they cannot capture all the benefits of their inventions.

Consider the ordinary cell phone. Even though the device itself is a private good that can be bought and sold for the exclusive use of individuals, the basic idea of a mobile telephone is available for anyone to use. Once the general concept for cell phone technology exists, any firm around the world can produce its own version of cell phones; the ability of one firm in Japan to produce cell phones, using the cell phone "blueprint," so to speak, does not impede the ability of another firm in, say, the United States to use the same general design.

This "blueprint" quality of knowledge helps explain why innovation is often thought to be closely connected to research and development. The nonexcludable nature of technology is a core reason why patent protections exist to protect inventors. Yet innovation must also be excludable to some extent—otherwise there would be little incentive for businesses to invest in new technologies at all. Excludability implies some degree of monopoly power over new ideas—which can come in the form of business secrets, for example—and by extension implies some degree of suboptimality in markets. Because a monopoly will tend to produce less than is socially optimal, markets often can't be expected to produce as much innovation as we would like.

Market imperfections aren't the only realities that discourage innovation, however. Political forces also stand in the way.[15] The benefits of new knowledge

14. One recent study put it this way: "It is widely accepted that [multi-factor productivity] depends on the creation, transmission and absorption of knowledge." Balàzs Égert, "Regulation, Institutions, and Productivity: New Macroeconomic Evidence from OECD Countries," *American Economic Review Papers & Proceedings* 106, no. 5 (2016): 110.

15. Calestous Juma, *Innovation and Its Enemies: Why People Resist New Technologies* (New York: Oxford University Press, 2016). See also Mark Zachary Taylor, *The Politics of Innovation: Why Some Countries Are Better Than Others at Science and Technology* (Oxford: Oxford University Press, 2016), 213: "Time and again, the losing interest groups created by scientific progress or technological change have been able to convince politicians to block, slow, or alter government support for scientific and technological progress."

are slow to materialize and tend to fall broadly across the entire population, while short-term disruptions caused by innovation often affect well-organized and powerful incumbent interests. For example, recently the hotel industry has fought to limit the growth of Airbnb. Such political forces, in addition to the market forces just mentioned, lead to less new knowledge, and—by extension—to less innovation than is desirable for society.

GROWTH THEORY AND GROWTH ACCOUNTING

The extraordinarily influential Solow growth model kicked off a 20th century revolution in growth theory.[16] The model attempted to explain growth using the basic physical inputs of the production process, labor and capital, along with a generic technological change variable that was assumed to grow at a steady rate, regardless of any factors that might change in the model. Jeffrey D. Sachs (a leading development economist) and John W. McArthur have noted that "Solow did not try to explain the source of that technological advancement; he merely assumed it."[17] This assumption is especially curious given that the source of long-run economic growth in the model was this mysterious technological change variable.

Solow's model did not preclude a role for savings and investment, which contribute to capital formation, but instead predicted that savings and investment would influence only the short-run growth rate of the economy—not the long-run "balanced growth path" growth rate. A key prediction of the Solow model was that, because of diminishing returns to capital, countries with a smaller capital stock would grow more quickly than those with a larger capital stock—so-called "catch-up growth." For this reason, early studies following Solow's often focused on whether this prediction, that lower levels of capital lead to faster short-run growth, held true in the real world.[18]

Explaining the determinants of growth has led to an entire field within economics known as growth accounting, which populates the Solow model, or a model like it, with real-world data in an attempt to empirically measure the

16. Robert M. Solow, "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics* 70, no. 1 (February 1956): 65–94.
17. Jeffrey D. Sachs and John W. McArthur, "Technological Advancement and Long-Term Economic Growth in Asia," in *Technology and the New Economy*, ed. Chong-En Bai and Chi-Wa Yuen (Cambridge, MA: MIT Press, 2002), 160 (emphasis in original).
18. For example, the six "stylized facts" of economic growth identified by Nicholas Kaldor place an emphasis on capital accumulation. Nicholas Kaldor, "Capital Accumulation and Economic Growth," in *The Theory of Capital*, ed. F. A. Lutz and D. C. Hague (New York: St. Martin's Press, 1961), 177–222.

contributors to growth. The modern growth accounting field started with a 1957 article by Robert Solow himself,[19] a follow-up paper to his classic 1956 article. In his 1957 study, Solow attributed just one-eighth of the growth of US output per man-hour to changes in the capital stock, while seven-eighths could be attributed to technological change.[20] A study in 1961 by John Kendrick similarly found that technological change explains on the order of 80 to 90 percent of labor productivity growth, depending on the time period analyzed.[21]

The technological change measures from these studies were actually measures of something called total factor productivity (TFP), which is not the same as technological innovation. TFP is assessed in growth accounting studies through the so-called residual. The residual explains the growth that cannot be accounted for by the differences in measured inputs. While TFP is sometimes referred to as a measure of technological progress, as it was by Solow himself in 1957, in fact, TFP represents all contributors to growth coming from factors aside from the measured inputs. The somewhat embarrassing conclusion that the vast majority of growth cannot be explained by the measurable factors in a growth model is why TFP is sometimes referred to as a "measure of our ignorance."[22]

By equating TFP growth with technological change, the early estimates of economists such as Solow and Kendrick overestimated the contribution of technology to measured economic growth. While considerable uncertainty remains, the current consensus seems to be that somewhere between one-third and three-quarters of economic growth can be attributed to TFP growth.[23] Over time, however, growth accounting exercises have become more sophisticated and have included other determinants of growth beyond capital and labor, including the

19. Robert M. Solow, "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics* 39, no. 3 (1957): 312–20.
20. Solow, "Technical Change and the Aggregate Production Function," 320.
21. John W. Kendrick, *Productivity Trends in the United States* (Princeton, NJ: Princeton University Press, 1961). See also Gerben Bakker, Nicholas Crafts, and Pieter Woltjer, "The Sources of Growth in a Technologically Progressive Economy: The United States, 1899–1941" (Economic History Working Papers No. 269, London School of Economics and Political Science, 2017).
22. Moses Abramovitz, "Resource and Output Trends in the U.S. since 1870," *American Economic Review* 46, no. 2 (May 1956): 11.
23. For a sample of studies looking at historical contributors to US economic growth, see Robert J. Gordon, "Interpreting the 'One Big Wave' in U.S. Long-Term Productivity Growth," in *Productivity, Technology and Economic Growth*, ed. Bart van Ark, Simon Kuipers, and Gerard Kuper (Dordrecht: Kluwer, 2000), 19–65; Moses Abramovitz and Paul A. David, "Two Centuries of American Macroeconomic Growth: From Exploitation of Resource Abundance to Knowledge-Driven Development" (Discussion Paper No. 01-05, Stanford Institute for Economic Policy Research, Stanford, CA, 2001); and Robert Gordon, *The Rise and Fall of American Growth: The U.S. Standard of Living since the Civil War* (Princeton, NJ: Princeton University Press, 2016).

average level of human capital per worker in a country[24] and measures of social infrastructure, which include factors like institutions and government policies.[25]

The Solow model made no attempt to explain technological advancements, but the so-called "new growth theory" has taken on the challenge of identifying the forces underlying technological progress. Much of this work has built on the phenomenally influential model developed by recent Nobel Prize winner Paul Romer, whose work seeks to explain the process of technological change that drives growth.[26] The new growth theory literature inspired by Romer is extensive and tends to emphasize factors such as population size, research and development spending, and spillover effects, as new knowledge spreads from one part of the economy to other areas.

A core assumption in the Solow model was diminishing returns to capital: that is, as more capital is accumulated, its productivity diminishes. This assumption, while intuitive on some level, is also rather extreme in that it downplays the possibility of spillovers—such as the possibility that workers become more productive as they learn on the job, or that physical and human capital accumulation contribute to new knowledge, further enhancing productivity across the economy. Rather, in the Solow model, technological change is handed down like manna from heaven. For this reason, the model implies that policies are unlikely to impact long-run growth. Taxes and regulations that reduce the capital stock might slow the short-run growth rate, but not the long-run growth rate.

New growth theory, with its "increasing returns" models, has very different policy implications from those of the Solow model. These models often assume spillover effects of various kinds. For example, worker productivity might increase through experience—so-called learning by doing.[27] Human capital accumulation might have benefits to all of society, not just to the workers who increase their education. These small changes in modeling assumptions produce dramatically different policy conclusions. Increasing returns models find that policies can influence economic growth rates, such that even small changes in policy can have dramatic effects over long time horizons.

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24. See, for example, N. Gregory Mankiw, David Romer, and David N. Weil, "A Contribution to the Empirics of Economic Growth," *Quarterly Journal of Economics* 107, no. 2 (1992): 407–37; and Robert E. Lucas Jr., "On the Mechanics of Economic Development," *Journal of Monetary Economics* 22, no. 1 (1988): 3–42.
25. Robert E. Hall and Charles I. Jones, "Why Do Some Countries Produce So Much More Output per Worker Than Others?," *Quarterly Journal of Economics* 114, no. 1 (1999): 83–116.
26. Paul M. Romer, "Endogenous Technological Change," *Journal of Political Economy* 98, no. 5 (1990): 71–102.
27. Kenneth J. Arrow, "The Economic Implications of Learning by Doing," *Review of Economic Studies* 29, no. 3 (1962): 155–73.

The current consensus seems to be that capital formation explains perhaps 30 percent of differences in cross-country growth rates,[28] and almost certainly less than half.[29] While this is less than might be expected, this finding suggests that investment and capital accumulation do contribute to growth, and increasing returns models offer an explanation for this empirical result.

Of the remaining unexplained growth, some can be attributed to the discovery of a few breakthrough technologies, known as general purpose technologies (GPTs). A GPT is a generic technology with widespread uses that leads to many subsequent innovations.[30] A classic example from recent years is the internet, which has spawned entire new industries and also has transformed the way existing industries operate. There is considerable evidence that breakthrough, revolutionary technologies like GPTs can affect economic growth rates. Some economists have gone so far as to model growth as a process that is primarily driven by the arrival of GPTs.[31] Other studies have estimated that just a handful of "great inventions," such as electricity, could account for as much as half of TFP growth in the early 20th century.[32]

In more recent decades, some economists have argued that the productivity slowdown of the 1970s was temporarily reversed in the 1990s as a result of the IT revolution that accompanied the creation of the internet. One study found that the internet explained 21 percent of GDP growth in mature economies during a five-year period in the early 21st century.[33] Given renewed concerns about stagnant growth,[34] it appears that one or two large discoveries can be enough to trigger growth for years or even decades.

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28. Francesco Caselli, "Accounting for Cross-Country Income Differences," in *Handbook of Economic Growth*, vol. 1A, ed. Philippe Aghion and Steven N. Durlauf (Amsterdam: NorthHolland, 2005), 679–741.
29. For example, one study noted, "Differences in measured inputs [like capital or labor] explain less than half of the enormous cross-country differences in per capita GDP." See Charles Jones and Paul Romer, "The New Kaldor Facts: Ideas, Institutions, Population, and Human Capital," *American Economic Journal: Macroeconomics* 2, no. 1 (January 2010): 225.
30. For detailed discussion of GPTs, see Richard G. Lipsey, Cliff Bekar, and Kenneth Carlaw, *Economic Transformations: General Purpose Technologies and Long Term Economic Growth* (New York: Oxford University Press, 2005).
31. For examples of these models, see Lipsey, Bekar, and Carlaw, *Economic Transformations*.
32. For discussion of the debate about the contributions of great inventions to productivity growth, see Robert Gordon, "U.S. Economic Growth since 1870: One Big Wave?," *American Economic Review* 89, no. 2 (1999): 123–28; and Bakker, Crafts, and Woltjer, "Sources of Growth in a Technologically Progressive Economy."
33. James Manyika and Charles Roxburgh, "The Great Transformer: The Impact of the Internet on Economic Growth and Prosperity," McKinsey Global Institute, October 2011.
34. For examples of stagnationist views, see Tyler Cowen, *The Great Stagnation: How America Ate All the Low-Hanging Fruit of Modern History, Got Sick, and Will (Eventually) Feel Better* (New York:

Brink Lindsey of the Niskanen Center aptly summarizes what has become a widespread consensus among scholars from many different fields within the economics profession: "The long-term future of economic growth hinges ultimately on innovation."[35] Indeed, as Sachs and McArthur have stated, "The harder we think about it, the more we realize that technological innovation is almost certainly the key driver of long-term economic growth."[36]

In order to boost growth, then, the focus should be on advancing the state of the art, or as economists say, advancing the "technological frontier." A country's distance from the technological frontier, like its level of capital per worker, will influence its growth rate. Innovation shifts out the technological frontier, increasing the global growth rate as "follower" countries are able to adopt new technologies. This general paradigm, whereby some leading countries push out the technological frontier and others follow, means that countries that contribute disproportionately to technological progress also disproportionately contribute to human progress more generally at a global level.

Public policies are vital for nurturing the technological innovation that fuels the engine of global growth. Finding the right mix of policies to foster technological progress is no easy task, and there is no guarantee that this Goldilocks mix can be sustained even once found. If the innovation engine breaks down, it could have dire consequences for the entire world.

WHAT ECONOMISTS HAVE SAID ABOUT TECHNOLOGY, INNOVATION, AND GROWTH

Growth economists, development economists, and economic historians all appear to agree on the importance of technological innovation for long-run economic growth. Indeed, even a recent article in the *Economist* magazine titled "Economists Understand Little about the Causes of Growth" nonetheless conceded that

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Penguin, 2011); and Robert Gordon, *The Rise and Fall of American Growth: The U.S. Standard of Living since the Civil War* (Princeton, NJ: Princeton University Press, 2016).

35. Brink Lindsey, "Why Growth Is Getting Harder" (Policy Analysis No. 737, Cato Institute, Washington, DC, October 8, 2013), 11.

36. According to Sachs and McArthur, "Understanding long-term economic growth requires understanding technological innovation. But the economics profession is somewhat odd. The technically challenging part of the Solow growth models lies in solving a differential equation for how fast the capital stock grows rather than in interpreting the mysterious process of technological change. And so, for the many years following Solow's initial contributions, economists studied the role of savings and investment as the central feature of economic growth, rather than focusing on the sources of long-term technological change." Sachs and McArthur, "Technological Advancement and Long-Term Economic Growth," 157.

"in some fundamental way growth is about using technologies to become more productive and to uncover new ideas."[37] This section provides a cursory review of statements made by a broad swath of leading economists as evidence of how widespread and pervasive this belief is.

Elhanan Helpman, one of the developers of the influential quality ladder model of economic growth, has written, "There is convincing evidence that total factor productivity (TFP) plays a major role in accounting for the observed cross-country variation in income per worker and patterns of economic growth. . . . Technological change is an important determinant of TFP."[38]

Bart Verspagen has written that "it seems beyond dispute that a change of technology in the pure sense, coupled with organization changes at various levels of aggregation, are the main driving factors behind the continuous increase of living standards."[39]

Daron Acemoglu and James A. Robinson, two leading development economists, have suggested that "sustained economic growth requires innovation, and innovation cannot be decoupled from creative destruction, which replaces the old with the new in the economic realm and also destabilizes established power relations in politics."[40] They are referring to what Austrian-born economist Joseph Schumpeter famously spoke of in the 1940s, when he explained how the destruction of old ways of doing things, or what he described as the "perennial gales of creative destruction," are what spur innovation and propel an economy forward.[41]

Another literature focuses on the "deep roots" of economic development,[42] which include factors such as culture and geography. The deep roots of growth focus on the underlying causes of technological change.

Acemoglu and Robinson see institutions as a primary cause of technological change.[43] Douglas North and Barry Weingast also say that institutions,

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37. "Economists Understand Little about the Causes of Growth," *Economist*, April 12, 2018, https://www.economist.com/finance-and-economics/2018/04/12/economists-understand-little-about-the-causes-of-growth.
38. Elhanan Helpman, *The Mystery of Economic Growth* (Cambridge, MA: Belknap, 2004), 33–34.
39. Bart Verspagen, "Innovation and Economic Growth," in *The Oxford Handbook of Innovation*, ed. Jan Fagerberg and David C. Mowery (Oxford: Oxford University Press, 2006).
40. Daron Acemoglu and James A. Robinson, *Why Nations Fail: The Origins of Power, Prosperity, and Poverty* (New York: Crown Business, 2012).
41. Joseph Schumpeter, *Capitalism, Socialism and Democracy* (New York: Harper Perennial, [1942] 2008), 84.
42. Enrico Spolaore and Romain Wacziarg, "How Deep Are the Roots of Economic Development?," *Journal of Economic Literature* 51, no. 2 (2013): 325–69.
43. Acemoglu and Robinson, *Why Nations Fail*.

particularly property rights, are a deep-root cause of growth.[44] More broadly, institutions refer to what Helpman defines as "systems of rules, beliefs, and organizations"[45] or what North refers to as the "rules of the game" or "the humanly devised constraints that shape human interaction."[46] These rules and institutions include the rule of law and court systems,[47] property rights,[48] contracts, free-trade policies, light-touch regulations and regulatory regimes,[49] freedom to travel, and various incentives to invest.[50] The emphasis economists place on institutions, as with the increasing returns models discussed above, strengthens the case that public policy plays an important role in fostering or inhibiting growth. Achieving the right mix of regulation is critical: regulation must be strong enough that property rights are secured but flexible enough that entrepreneurs are not discouraged from risk-taking.

Not all institutions represent formal rules, however. Some are soft rules that take the form of social norms. Economic historian Deirdre McCloskey argues that ideas (and an appreciation of entrepreneurialism, in particular) are at the heart of growth;[51] similarly, Joel Mokyr sees the culture, especially among the intellectual elite, as a historical cause of growth.[52] He defines culture as "a set of beliefs, values, and preferences, capable of affecting behavior, that are socially (not genetically) transmitted and that are shared by some subset of society."[53]

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44. Douglas C. North and Barry R. Weingast, "Constitutions and Commitment: The Evolution of Institutions Governing Public Choice in Seventeenth-Century England," *Journal of Economic History* 49, no. 4 (1989): 803–32.
45. Helpman, *Mystery of Economic Growth*, 115.
46. Douglass C. North, *Institutions, Institutional Change and Economic Performance* (Cambridge: Cambridge University Press, 1990), 3.
47. "Everything else equal, creative destruction and reallocation among firms will be much higher in economies where the rule of law is stronger." Phillippe Aghion, Ufuk Akcigit, and Peter Howitt, "Lessons from Schumpeterian Growth Theory," *American Economic Review* 105, no. 5 (May 2015): 5.
48. "Major technological developments have taken place in countries that protected private property from infringement by individuals and the state." Helpman, *Mystery of Economic Growth*, 140.
49. See the discussion below regarding the differences between the United States and the European Union in the treatment of the internet.
50. Chris Doucouliagos and Mehmet Ali Ulubasoglu, "Economic Freedom and Economic Growth: Does Specification Make a Difference?," *European Journal of Political Economy* 22 (2006): 78. Doucouliagos and Ulubasoglu survey 52 studies that have investigated empirically the links between economic freedom and economic growth and find that "regardless of the sample of countries, the measure of economic freedom and the level of aggregation, there is a solid finding of a direct positive association between economic freedom and economic growth."
51. Deirdre N. McCloskey, *Bourgeois Equality: How Ideas, Not Capital or Institutions, Enriched the World* (Chicago: University of Chicago Press, 2016).
52. Joel Mokyr, *A Culture of Growth: The Origins of the Modern Economy* (Princeton, NJ: Princeton University Press, 2017).
53. Mokyr, 8.

A pro-growth culture, be it among elites or among the general population, will shape the formal and informal institutions of a society, and it will either facilitate or hinder the entrepreneurial activity that drives technological change.

Other economists say that geography is a main determinant of growth. But even these economists often argue that access to natural resources, such as iron, has allowed for faster technological development,[54] or that nature can impede human development and technological progress. For example, disease can delay or destroy economic progress.[55] However, the high living standards of countries like Japan and Switzerland relative to those of resource-rich countries like Iran and Iraq make it abundantly clear that access to natural resources cannot fully explain the large observed differences in living standards among countries.[56]

This small sample of quotations from economists leaves little doubt that a consensus exists about the importance of innovation. To truly appreciate how innovation drives human progress, however, one also needs to understand how even the best estimates of growth are imperfect in ways that are likely to understate the dramatic importance of technological progress for human welfare.

GDP: AN IMPERFECT MEASURE OF WELFARE

Economic growth is usually measured by assessing changes in national production—that is, GDP.[57] Some question whether GDP is useful as a guide for policymakers, because GDP is not an all-encompassing measure of human well-being.[58] George Mason University economist Peter J. Boettke has noted that "economists understand that human beings do not eat growth rates, and instead what matters is steady improvement along a variety of measures of human well-being. What is desired is the opportunity for individuals to live a flourishing life."[59]

GDP has many well-known problems. It leaves out household production, leisure time, the value of changes in nonmarket amenities such as the environment,

54. Jared Diamond, *Guns, Germs, and Steel: The Fates of Human Societies* (New York: Norton, 1997); and Jeffrey D. Sachs, "Institutions Don't Rule: Direct Effects of Geography on Per Capita Income" (NBER Working Paper No. 9490, National Bureau of Economic Research, Cambridge, MA, 2003).
55. Sachs, "Institutions Don't Rule."
56. Nathan Rosenberg and L. E. Birdzell, *How the West Grew Rich: The Economic Transformation of the Industrial World* (New York: Basic Books, 1987).
57. Similar measures, such as changes in GDP per worker, per person, or per man-hour, are also commonly used.
58. See, for example, Joseph Stiglitz, Amartya Sen, and Jean-Paul Fitoussi, *Mismeasuring Our Lives: Why GDP Doesn't Add Up* (New York: New Press, 2010).
59. Peter J. Boettke, *Living Economics: Yesterday, Today, and Tomorrow* (Oakland, CA: Independent Institute, 2012), 30.

and a whole host of other factors that contribute to human well-being. These shortcomings do not make GDP useless. GDP represents one aspect of human living standards: it is an important aspect, but other aspects of living standards also are important. Furthermore, the wealth generated by economic growth allows humans the opportunity to pursue various other aims, including safety,[60] better health,[61] and increased life satisfaction.[62] By extension, limiting production limits our ability to pursue these aims.

The limits of GDP as a welfare measure do not diminish the importance of technological innovation as a contributor to human progress. If anything, GDP's limitations may strengthen the case for innovation, because so many of the benefits of technological progress do not show up in GDP. It is well known, for example, that quality improvements create bias in the inflation indices used to measure changes in real (i.e., inflation-adjusted) GDP from period to period.[63] This is particularly important because so much innovation comes precisely in the form of quality improvements. An automobile, a computer, a camera, and a phone in 1970 were all very different from the items that go by the same names in 2019. While economists do have methods to account for these kinds of quality changes, the methods are imperfect and sometimes fail to account for the full range of benefits associated with technologies, such as these becoming more portable and capable.[64]

Another issue with GDP is that, because it measures the value of market production, the benefits of items given away for free tend to be ignored. Consider social media platforms like Facebook, Instagram, and Twitter, which are free of charge to customers. Sure, advertisers pay to market their products to Facebook users, but there is no market transaction to pay for the social media services themselves,[65] so the benefits to consumers are not captured in GDP—only the

60. See Aaron Wildavsky, "Richer Is Safer," *Financial Analysts Journal* 37, no. 2 (1981): 19–22.
61. On the relationship between income and reduced mortality risk, see James Broughel and Kip Viscusi, "Death by Regulation: How Regulations Can Increase Mortality Risk" (Mercatus Working Paper, Mercatus Center at George Mason University, Arlington, VA, 2017).
62. See Betsey Stevenson and Justin Wolfers, "Subjective Well-Being and Income: Is There Any Evidence of Satiation?," *American Economic Review: Papers and Proceedings* 103, no. 3 (2013): 598–604.
63. For recent discussions of the challenges that quality changes pose to measuring GDP, see Martin Feldstein, "Underestimating the Real Growth of GDP, Personal Income, and Productivity," *Journal of Economic Perspectives* 31, no. 2 (2017): 145–64; Erica L. Groshen et al., "How Government Statistics Adjust for Potential Biases from Quality Change and New Goods in an Age of Digital Technologies: A View from the Trenches," *Journal of Economic Perspectives* 31, no. 2 (2017): 187–210.
64. Marian L. Tupy, "Computers Allow Us to Accomplish More with Less," *Human Progress*, September 20, 2016; Juliette Garside, "Like an Elite Swiss Army Knife, the iPhone Is Now a Multi-Category Killer," *Guardian*, January 10, 2012.
65. Of course, social media companies make money in other ways, such as through advertising. See Adam Thierer, "A Framework for Benefit-Cost Analysis in Digital Privacy Debates," *George Mason*

value of services to advertisers. This is part of a more general problem: consumer surplus (that is, the benefit consumers derive in excess of the price they pay) doesn't show up in any GDP statistic.[66]

These disparities between innovation and what GDP measures can be substantial enough that the two variables can move in different directions at times. Some scholars have described the Great Depression as a period of rapid innovation, despite enormous declines in GDP. Alexander Field, the economist best known for this view, has argued that the 1930s saw some of the fastest TFP growth in the 20th century in the United States.[67] The arrival of new technologies, such as GPTs, may also prove so disruptive at times that they reduce aggregate production for a period of time until the macroeconomy adjusts.[68]

The lesson here is that the benefits of innovation aren't always obvious, they aren't always easily measurable, and they don't always show up in the growth statistics, especially in the short term.[69] Sometimes innovation even reduces measured growth for a period of time. However, in the long run there can be little doubt about the enormous benefits of technological innovation as society adapts to change and learns to harness and exploit the potential of new technologies.

LESSONS FOR POLICYMAKERS

While the historical and empirical evidence linking innovation and long-term growth reveals an unambiguously positive relationship, the short-term disruptions caused by technological change can nonetheless be gut-wrenching for some individuals and entities. In other words, technological change engenders the sort of creative destruction that Schumpeter famously spoke of in the 1940s.[70]

In the modern world, we hear about taxi drivers whose livelihoods are threatened by new companies such as Uber, brick-and-mortar stores competing

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University Law Review 20, no. 4 (Summer 2013): 1066–69.

66. "While consumers obviously care about privacy, they also care about choice, convenience, and low-cost services. The modern data-driven economy has given consumers access to an unparalleled cornucopia of information and services, and it is remarkable how much of that content and how many of those services are offered to the public at no charge to them. That's a real benefit to them and the economy as a whole." Andrea O'Sullivan and Adam Thierer, "California and Europe Put the Squeeze on the Digital Economy," *Bridge* (Mercatus Center at George Mason University), July 13, 2018.

67. Alexander Field, *A Great Leap Forward: 1930s Depression and US Economic Growth* (New Haven, CT: Yale University Press, 2012).

68. For a review of the evidence about short-term cycles induced by GPTs, see Andreas Schaefer, Daniel Schiess, and Roger Wehrli, "Long-Term Growth Driven by a Sequence of General Purpose Technologies," *Economic Modeling* 37 (2014): 23–31.

69. Rosenberg and Birdzell, *How the West Grew Rich*.

70. Schumpeter, *Capitalism, Socialism and Democracy*, 84.

with online outlets such as Amazon, and mom-and-pop shops threatened by big-box retailers such as Walmart. Schumpeterian change has brought citizens many wonderful goods and services that have improved their overall standard of living, but progress occurs precisely because this disruption unsettles so many traditional businesses, sectors, and professions.[71]

This disruption leads many to resist change and try to derail opportunities for entrepreneurship that could lead to more growth and prosperity over the long haul. In fact, a thesis of the book *Why Nations Fail* by Daron Acemoglu and James Robinson is that some countries choose to erect barriers to innovation and growth precisely to protect and entrench favored interest groups.[72] Preserving the status quo to protect incumbent interests is likely a central explanation for why some countries grow rich while others remain poor.[73] Some countries' institutions evolve in ways that foster innovation, while others evolve in ways that protect special interests.

In addition, there is a time-inconsistency problem facing countries and their leaders. Embracing technological change brings short-term disruption, and policymakers have notoriously short time horizons. Furthermore, they are likely to hear disproportionately from concentrated constituencies that are harmed by new technologies.[74] For these reasons a kind of "status quo bias," or resistance to change, may afflict policymakers, as well as their voting constituents.[75]

Meanwhile, the benefits of innovation will tend to show up in measurable form only gradually. These benefits are spread across large numbers of people, and those who stand to gain the most—the least well off in society, as well as future generations whose living standards could be orders of magnitude higher as a result of compounding growth—have little or no political influence. Policymakers rationally responding to these incentives will likely produce suboptimal results for citizens in the long run.

Once the material, and ethical, importance of technological innovation for long-term growth is fully appreciated, the ramifications for public policy should be obvious: lawmakers should make sure that policies maximize breathing room for ongoing economic and social experimentation. Only by embracing

71. Adam Thierer, "You're in Joseph Schumpeter's Economy Now," *Learn Liberty*, February 8, 2017.
72. Acemoglu and Robinson, *Why Nations Fail*, 529.
73. For discussion about the various forms of privilege that government often bestows on firms or particular industries, see Matthew Mitchell, *The Pathology of Privilege: The Economic Consequences of Government Favoritism* (Arlington, VA: Mercatus Center at George Mason University, 2012).
74. This is part of a general problem of concentrated versus dispersed benefits and costs. See Mancur Olson, *The Logic of Collective Action: Public Goods and the Theory of Groups* (Cambridge, MA: Harvard University Press, 1965).
75. Bryan Caplan, *The Myth of the Rational Voter* (Princeton, NJ: Princeton University Press, 2007).

innovation-enhancing values and policies is it likely that countries can experience maximum sustainable economic growth.[76]

Yet this kind of farsightedness may be wishful thinking, especially in politics. Few constituents will complain if the long-run growth rate is lowered. Most won't even realize the change has occurred, and even if they did, tracing the problem back to its root cause would be difficult. Political pressure will generally make it more likely that policymakers choose the short term at the expense of the long term, even though commonsense ethics suggests they should do the reverse.

"Innovation Culture," Incentives, and Growth

The lesson here can be stated simply: policy attitudes matter. Political attitudes and pronouncements help foster an "innovation culture" that eventually infuses a country's policies and institutions.[77] "'Innovation culture' is to be understood in terms of attitudes towards innovation, technology, exchange of knowledge, entrepreneurial activities, business, uncertainty, and related behaviour and historical trajectories."[78]

Political attitudes toward risk-taking affect what economist Mancur Olson refers to as the "structure of incentives" that determines a nation's economic potential. Olson reinforces the idea that "the great differences in the wealth of nations are mainly due to differences in the quality of their institutions and economic policies."[79]

There is an obvious interplay between these institutions and incentives and a society's cultural attitudes toward entrepreneurial activities more generally.[80] "If we learn anything from the history of economic development," argued David Landes in his magisterial *The Wealth and Poverty of Nations*, "it is that culture makes all the difference."[81]

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76. Adam Thierer, "Embracing a Culture of Permissionless Innovation," *Cato Online Forum* (Cato Institute), November 17, 2014.
77. Stephen Ezell and Philipp Marxgut, "Comparing American and European Innovation Cultures," in *Shaping the Future: Economic, Social, and Political Dimensions of Innovation* (Austrian Council for Research and Technology Development, August 2015).
78. Maike Didero et al., "Differences in Innovation Culture across Europe: A Discussion Paper," *TransForm*, February 2008, 3.
79. Mancur Olson, "Big Bills Left on the Sidewalk: Why Some Nations Are Rich, and Others Poor," *Journal of Economic Perspectives* 10, no. 2 (Spring 1996): 19, 22.
80. "Culture is a significant determinant of a nation's ability to prosper because culture shapes individuals' thoughts about risk, reward, and opportunity." Stace Lindsay, "Culture, Mental Models, and National Prosperity," in *Culture Matters: How Values Shape Human Progress*, ed. Lawrence Harrison and Samuel Huntington (New York: Perseus Books, 2000), 282.
81. David Landes, *The Wealth and Poverty of Nations: Why Some Are So Rich and Some Are So Poor* (New York: Norton, 1998), 516.

For progress and prosperity to be possible, a sociopolitical system must respect what economic historian Deirdre McCloskey refers to as the "bourgeois virtues" that incentivize invention and spur growth.[82] "A big change in the common opinion about markets and innovation," she has argued, "caused the Industrial Revolution, and then the modern world. . . . The result was modern economic growth."[83] That attitudinal shift helps explain the Industrial Revolution, as well as the more recent Information Revolution.[84]

Research by marketing experts Paul Herbig and Steve Dunphy finds that "existing cultural conditions determine whether, when, how and in what form a new innovation will be adopted."[85] They, along with other scholars,[86] have surveyed the elements that contribute to a vibrant innovation culture. Some of the common variables include the following:[87]

- trust in the individual and openness to individual achievement
- positive attitudes toward competition and wealth creation
- support for hard work, timeliness, and efficiency
- willingness to take risks and accept change (including failure)
- long-term focus
- openness to new information and tolerance of alternative viewpoints
- frequent travel and freedom of movement
- positive attitudes toward science and development
- advanced education systems
- religious openness toward commercial activity and profit-making
- impartial administration of justice

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82. Deirdre N. McCloskey, *The Bourgeois Virtues: Ethics for an Age of Commerce* (Chicago: University of Chicago Press, 2006); Deirdre N. McCloskey, *Bourgeois Dignity: Why Economics Can't Explain the Modern World* (Chicago: University of Chicago Press, 2010).
83. Deirdre N. McCloskey, "Bourgeois Dignity: A Revolution in Rhetoric," *Cato Unbound* (Cato Institute), October 4, 2010.
84. See Adam Thierer, "How Attitudes about Risk & Failure Affect Innovation on Either Side of the Atlantic," *Medium*, June 19, 2015.
85. Paul Herbig and Steve Dunphy, "Culture and Innovation," *Cross Cultural Management: An International Journal* 5, no. 4 (1998): 14.
86. Herbig and Dunphy, "Culture and Innovation." For a summary of other scholars' findings, see Ezell and Marxgut, "Comparing American and European Innovation Cultures," 158–62.
87. For further summaries of these values, see Didero et al., "Differences in Innovation Culture across Europe"; Mariano Grondona, "A Cultural Typology of Economic Development," in *Culture Matters: How Values Shape Human Progress*, ed. Lawrence Harrison and Samuel Huntington (New York: Perseus Books, 2000), 44–55.

Getting innovation culture right has implications for countries, particularly for their global competitiveness. And efforts to prevent innovation may ultimately prove pointless. "Cultures that attempt to block technology for reasons that appear desirable will, all things equal, eventually be dominated by those that embrace it," argues Braden Allenby. Thus, "in a highly competitive global environment, where many cultures are jostling for position, technological evolution will be difficult, if not impossible, to stop."[88]

Where countries fail to adopt sensible innovation policies, they may have to deal with the reality of "global innovation arbitrage."[89] Capital can move around the globe in search of the highest returns, and the same is increasingly true of innovation. Innovators can, and increasingly will, move to the cities, states, countries, and continents that provide a legal and regulatory environment more hospitable to entrepreneurial activity.[90]

One recent example involved commercial unmanned aircraft systems, more commonly known as drones. In late 2013, American tech giant Amazon decided to begin researching the possibility of delivering its packages using drones. Unfortunately, its experiments were so constrained by US Federal Aviation Administration regulations that the firm opted to move much of its research and development, as well as operational testing, abroad to the United Kingdom and Canada.[91] An expert panel assembled by the National Academies of Sciences, Engineering, and Medicine has criticized the Federal Aviation Administration's approach to domestic drone deployment as "overly conservative" and "a significant barrier to introduction and development of these technologies."[92] While the Federal Aviation Administration has begun changing this risk-averse culture, the changes have not happened fast enough for many innovators. By the time US regulators finally approved Amazon's initial application for drone delivery

88. Braden Allenby, "The Dynamics of Emerging Technology Systems," in *Innovative Governance Models for Emerging Technologies*, ed. Gary E. Marchant et al. (Northampton, MA: Edward Elgar, 2013), 33.
89. Adam Thierer, "Innovation Arbitrage, Technological Civil Disobedience & Spontaneous Deregulation," *Medium*, December 7, 2016.
90. "Entrepreneurs can take advantage of the difference between opportunities in different regions, where innovation in a particular domain of interest may be restricted in one region, allowed and encouraged in another, or completely legal in still another." Marc Andreessen, "Turn Detroit into Drone Valley," *Politico*, June 15, 2014.
91. Ed Pilkington, "Amazon Tests Delivery Drones at Secret Canada Site after US Frustration," *Guardian*, March 30, 2015; Ruth Reader, "Amazon Spurns Slow FAA, Reveals It's Been Testing Drones Abroad," *Venture Beat*, March 24, 2015.
92. National Academies of Sciences, Engineering, and Medicine, *Assessing the Risks of Integrating Unmanned Aircraft Systems (UAS) into the National Airspace System*, Consensus Study Report, 2018, S-2.

services, for example, the firm was no longer operating the particular prototype for which it had originally applied for permission.[93]

The early history of the internet and e-commerce is also instructive in this regard.[94] Since the rise of the commercial internet in the mid-1990s, the United States and the European Union have adopted starkly different visions of the digital economy and innovation policy more generally.[95] At the macro level, the European Union has instituted highly restrictive policies governing online data collection and use. Most recently, in May 2018, the European Union adopted stringent data regulations that have already hurt competition and innovation.[96] Moreover, at the country level, the European Union suffers from a culture that discourages risk-taking more generally.[97]

By contrast, the United States innovation culture is one that, at least for much of the modern information-technology economy, has embraced risk-taking and tolerated business failures and cultural disruptions.[98] As a result, a natural experiment has been playing out on either side of the Atlantic over the past two decades, and it has yielded fairly clear results: digital innovation has languished in the European Union and blossomed in the United States.[99] America's information technology sectors (computing, software, internet services, etc.) and companies (Google, Microsoft, Facebook) are household names across the world, including in Europe. A recent report on the world's most innovative companies revealed that nine of the top ten are based in the United States and that most of them are involved in computing.[100] But no European companies were on the list.

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93. Pilkington, "Amazon Tests Delivery Drones."
94. Thierer, "How Attitudes about Risk & Failure Affect Innovation."
95. Ezell and Marxgut, "Comparing American and European Innovation Cultures," 193.
96. Adam Thierer, "GDPR Compliance: The Price of Privacy Protections," *Technology Liberation Front*, July 9, 2018; Alice Calder and Anne Hobson, "Data Privacy at a Price," *Medium*, May 25, 2018.
97. Matt Moffett, "New Entrepreneurs Find Pain in Spain," *Wall Street Journal*, November 27, 2014; Anna Prior, "How Fear Can Derail an Entrepreneur," *Wall Street Journal*, August 24, 2015. The latter article quotes Philipp K. Berger: "There's a huge difference between the U.S. culture and the German culture. In the U.S., it seems to be a lot more acceptable to fail. It's the 'fail and stand up' culture. It's accepted to some degree as part of the normal part of the entrepreneurial process. That's different in Germany. There's more of a stigmatization of a failed entrepreneur, so that drives more fear."
98. James B. Stewart, "A Fearless Culture Fuels U.S. Tech Giants," *New York Times*, June 18, 2015.
99. "The 28-nation bloc [the European Union] is, above all, lacking in the risk-taking culture and financial networks needed to grow Internet startups into globally dominant companies." Matti Huuhtanen, "Why Europe Isn't Creating Any Googles or Facebooks," *Business Insider*, September 22, 2015. See also Larry Downes, "Europe's Innovation Deficit Isn't Disappearing Any Time Soon," *Washington Post*, June 8, 2015.
100. Barry Jaruzelski, "The Top Innovators and Spenders, 2013," *Strategy&*, accessed October 15, 2014.

Reviewing the situation on either side of the Atlantic 20 years after the advent of widespread digital commerce, innovation scholars Stephen Ezell and Philipp Marxgut come to the following conclusions:

> Cultural aspects have a significant impact on innovation and inform how entrepreneurial countries, organizations, and people can be. The United States maintains the world's most vibrant innovation culture, where risk and failure are broadly tolerated, inquiry and discussion are encouraged, and the government's role in business plays a less prominent role. . . . There are elements in the European innovation culture that need improvement: a simpler regulatory environment, a broader availability of risk capital, and more tolerance of risk and change being critically important.[101]

The United States is a global leader in information technology. But the current situation isn't guaranteed to last forever—the innovation culture fostered in the United States is vulnerable to the same forces that have hindered similar development in Europe. Because destructive changes to this culture have the potential to cause global harm, it's particularly important for the United States to continue nurturing a culture that embraces innovation, risk-taking, and change, especially with respect to new technologies.

"Permissionless Innovation" as the Optimal Policy Default

While there are limits to how much policymakers can influence how society values innovation, at a minimum they should appreciate how growth-oriented innovation policy begins with a favorable policy disposition toward technological change.[102] As Mokyr notes, "Technological progress requires above all tolerance toward the unfamiliar and the eccentric."[103] For innovation and growth to blossom, entrepreneurs need a clear green light from policymakers that signals a

101. Ezell and Marxgut, "Comparing American and European Innovation Cultures," 193.
102. "When entrepreneurship is seen as the engine of growth, the emphasis shifts toward the creation of an environment within which opportunities for entrepreneurial activity are created, and successful entrepreneurship is rewarded." Randall Holcombe, "Entrepreneurship and Economic Growth," *Quarterly Journal of Austrian Economics* 1, no. 2 (Summer 1998): 58.
103. Joel Mokyr, *Lever of Riches: Technological Creativity and Economic Progress* (New York: Oxford University Press, 1990), 182. See also Lawrence Harrison and Samuel Huntington, eds., *Culture Matters: How Values Shape Human Progress* (New York: Perseus Books, 2000).

general acceptance of risk-taking—especially risk-taking that challenges existing business models and traditional ways of doing things.[104]

Policy impediments to growth take several forms. First, there are policies that punish risk-taking and new technologies directly. High capital taxes are one example. Another is the precautionary principle in regulation, whereby new technologies are outlawed until permission is granted by regulators.[105] But there is yet another impediment, which relates to privilege. If industries are protected from competition or somehow guaranteed a high rate of return by the government, then they have little incentive to take risks. This helps explain why industries such as the taxi industry and public utilities are notoriously slow to innovate.[106]

To allow for creative destruction to take hold, established interests must not be too powerful, or else they are likely to find ways to thwart the onset of new technologies that could upend their status. This may explain why innovative societies often have decentralized political authority.[107] But even where authority is centralized, the default should be to allow innovation, even though the outcomes from innovation are unclear ex ante, and innovation will always be accompanied by some degree of risk.

This incentivizing ethic can be encapsulated in the phrase permissionless innovation, which communicates the idea that experimentation with new technologies and business models should generally be permitted by default.[108] Unless a compelling case can be made that a new invention will bring serious harm to individuals, innovation should be allowed to continue unabated, and problems—if they develop at all—can be addressed later.[109] To the extent policy remedies are needed, those solutions should be ex post in character to ensure a wide berth for

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104. "Economic and social institutions have to encourage potential innovators by presenting them with the right incentive structure." Mokyr, *Lever of Riches*, 12. See also Bret Swanson, "More Disruption, Please," *TechPolicyDaily*, August 20, 2014: "To reignite economic growth, we need a broad commitment to an open economy and robust entrepreneurship."
105. Adam Thierer, *Permissionless Innovation: The Continuing Case for Comprehensive Technological Freedom*, rev. ed. (Arlington, VA: Mercatus Center at George Mason University, 2016).
106. These problems are sometimes referred to as x-inefficiencies. See Harvey Leibenstein, "Allocative Efficiency vs. X-Efficiency," *American Economic Review* 56, no. 3 (June 1966): 392–415.
107. Rosenberg and Birdzell, *How the West Grew Rich*.
108. Thierer, *Permissionless Innovation*. See also Rosenberg and Birdzell, *How the West Grew Rich*, 34: "Growth is, of course, a form of change, and growth is impossible when change is not permitted. And successful change requires a large measure of freedom to experiment. A grant of that kind of freedom costs a society's rules their feeling of control, as if they were conceding to others the power to determine the society's future. The great majority of societies, past and present, have not allowed it. Nor have they escaped from poverty."
109. Thierer, *Permissionless Innovation*.

entrepreneurial activities, to allow for the knowledge-generating process to play itself out, and to make room for the new forms of innovation that result.

Importantly, this general freedom should include a tolerance for occasional failure, which should not be viewed as a disaster to be avoided at all costs, but rather as a learning experience from which wisdom is born. After all, innovation is, at root, a form of problem-solving.[110] Somehow we must learn what works and what doesn't. Without trial and error and the corresponding failures and corrections, there can be no learning.

The ethic of permissionless innovation must be constantly nurtured because, as Mokyr concludes, technological innovation and economic progress are like "a fragile and vulnerable plant, whose flourishing is not only dependent on the appropriate surroundings and climate, but whose life is almost always short. It is highly sensitive to the social and economic environment and can easily be arrested by relatively small external changes."[111] Permissionless innovation must be reflected in institutions and policies,[112] because powerful financial, psychological, and social pressures will always exist that fight to slow innovation and preserve the status quo.

To be clear, permissionless innovation is not synonymous with anarchy.[113] If policymakers are concerned that potential harms might be associated with new technologies, precautionary restrictions may be in order. Regulatory restraints on innovation should be subjected to careful benefit-cost analysis to formally identify the tradeoffs associated with regulatory proposals, thereby ensuring that proposed rules make sense. Many regulatory restraints will be able to pass such a test.

Generally speaking, however, permissionless innovation represents the sensible, innovation-maximizing policy default because it allows trial-and-error experiments to continue in pursuit of new and better ways of doing things. Furthermore, many legitimate concerns about new technologies are better dealt with by using existing legal mechanisms, such as the courts, or nonlegal solutions, such as insurance markets, than by turning to precautionary regulation.[114]

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110. See Adam Thierer, "Failing Better: What We Learn by Confronting Risk & Uncertainty," in *Nudge Theory in Action: Behavioral Design in Policy and Markets*, ed. Sherzod Abdukadirov (Palgrave Macmillan, 2016), 65–94; Megan McArdle, *The Up Side of Down: Why Failing Well Is the Key to Success* (New York: Viking, 2014).

111. Mokyr, *Lever of Riches*, 16.

112. "The ability of a country to grow also depends on its ability to accommodate [technological] change, and the ability to accommodate change depends in turn on a country's economic and political institutions." Helpman, *Mystery of Economic Growth*, 140.

113. Adam Thierer, "Does 'Permissionless Innovation' Even Mean Anything?," *Technology Liberation Front*, May 18, 2017.

114. Thierer, *Permissionless Innovation*, 33–38.

Permissionless innovation is already the default in the IT sector as well as in a number of emerging tech sectors, such as 3-D printing, virtual reality, robotics, and artificial intelligence. These technologies could be considered to be "born free" in the sense that innovators in these fields do not face preexisting laws and regulatory regimes that could limit their ability to experiment with new ideas.[115] The question is, can permissionless innovation be preserved for these sectors and simultaneously expanded to cover other technologies that have been "born captive"?

"Captive" sectors or technologies confront preexisting precautionary policies and regulatory regimes that treat new goods and services as essentially guilty until proven innocent. This is the sort of problem that commercial drones and driverless cars face. Policymakers may attempt to box these new technologies into older regulatory schemes meant for traditional aircraft and automobiles, respectively. A similar problem haunts many new media and communications networking technologies when policymakers attempt to pigeonhole internet-era devices and networks into regulatory regimes developed for broadcast media and the "Ma Bell" era.

When disruptive technologies challenge old regulatory regimes in this fashion, the best way to level the proverbial playing field is not to attempt to harmonize regulatory treatment by shackling new goods and services with archaic rules that do not fit new technological and marketplace realities. Such a response will delay and discourage the innovations so desperately needed to reinvigorate economic growth. The better solution is to use the situation as an opportunity to rethink the wisdom of laws and regulations that may have outlived their usefulness, and to reform them accordingly. Policymakers should achieve parity between old and new technologies by maximizing opportunities for new entry, for competition, and for innovation.[116]

CONCLUSION

Lawmakers risk triggering economic stagnation, lower living standards, and decreased economic dynamism if they discourage technological innovation and

115. Adam Thierer, "What 20 Years of Internet Law Teaches Us about Innovation Policy," *Federalist Society Blog*, May 12, 2016.
116. Adam Thierer, "Converting Permissionless Innovation into Public Policy: 3 Reforms," *Medium*, November 29, 2017; Patrick McLaughlin, "Regulatory Accumulation: The Problem and Solutions" (Policy Spotlight, Mercatus Center at George Mason University, September 2017); James Broughel, "A Reform That Offers Hope for Centrists," *Washington Post*, March 14, 2018.

the risk-taking needed to create it. That said, there remains an important role for policy in fostering innovation. Encouraging research and development is one obvious component of this role, but it is far from the only component or the most important one. Policy should protect the property rights of citizens and set predictable rules of the game to incentivize reasonable forms of risk-taking.

The consequences of poor public policy decisions extend far beyond the citizens that vote for these policies. The benefits of technological change extend around the globe and beyond the present moment in time. The compounding nature of economic growth means that a slowing of the growth rate today has dire consequences for the well-being of our children, our grandchildren, and those who come after them.[117]

In this sense, fostering innovation requires a certain amount of self-sacrifice. Sometimes we must tolerate disruption today for a better world tomorrow. This is most true for those countries, like the United States, that are currently disproportionate contributors to global innovation. Fostering a culture that embraces technological innovation is not just a good recommendation based on a careful assessment of costs and benefits—it has a moral dimension as well. Nurturing innovation is part of being good stewards of human civilization during the short time we inhabit this earth.

117. See Tyler Cowen, *Stubborn Attachments: A Vision for a Society of Free, Prosperous, and Responsible Individuals* (San Francisco: Stripe, 2018).

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