WHAT DRIVES INNOVATION?

PUBLISHED ON PROJECT SYNDICATE ON JANUARY 20, 2023

After decades in the wilderness, industrial policy is now being rediscovered as a tool for addressing climate change and navigating a fraught new geopolitical environment. This development is long overdue, and fully justified by economic history since the dawn of the Industrial Revolution.

CAMBRIDGE – "Make a better mousetrap," Ralph Waldo Emerson once wrote, and "the world will make a beaten path" to your door. The economics of innovation is central to understanding the dynamics of economic growth. Its focus is on how entrepreneurs and those who finance them address two fundamental challenges. The first, which has commanded the most attention among academics and the popular press, is technological. As my old boss, Pike Sullivan, Chairman of F. Eberstadt & Co., used to ask: "If you plug it in, does it light up?"

But as important as that question is, the second question for innovators and investors is key: Even if it lights up, does anyone care? Or, as I used to say to entrepreneurs looking for venture capital: "Tell me exactly whose problem you propose to solve. How many of them are there, do they have budgets, and how do you propose to find them when they *don't* beat a path to your door?"

The leading academic approach to modeling the innovation process puts success in overcoming technological risks up front. The Schumpeterian theory of growth that Philippe Aghion and Peter Howitt have advanced over the past 30 years hinges on the competition to invent new, cheaper, faster, better *intermediate* goods that are needed for final products that are already in demand. Market risk does not enter into the analysis. Yet, regardless of where the locus of innovation is found, the importance of market risk has been apparent from the deep history of the First Industrial Revolution through the current digital age.

One recurring feature of that history has been the procurement power of governments. Freed from the necessity of abiding by a neat cost-benefit calculation, the state has repeatedly helped overcome market risk by pulling innovative suppliers down the learning curve to the point where they can offer low-cost and reliable products to commercial markets. In these cases, "product-market fit" results from a state-initiated dynamic process that succeeds in aligning an immature "product" with a nascent "market."

THE BIOTECH PARADOX

I came to grasp the strategic significance of market risk by considering one domain of frontier innovation where it does not seem to exist. Since the mid-1970s, biotechnology has been second only to information technology as a focus of VC. Given the daunting scientific and technological challenge of moving from the laboratory to the clinic, the path from start-up to profitability is not only fraught with risk but also very long – far longer than the contractual 10- to 12-year life of the initial VC funding.

Nonetheless, VCs have consistently furnished tens of billions of dollars to biotech start-ups. The first answer to this biotechnology paradox is that VCs have been able to realize returns on their investments in public equity markets, which have welcomed such ventures ever since Genentech went public in 1980. But what explains the appetite of public investors for cash-burning biotech companies still years away from the clinic? The longer answer is that the market for diagnostic and therapeutic products is unique.

Not only is the target market – those with a specified medical condition – already known and quantifiable from the moment a research project is defined, but the demand for the product is guaranteed to be financed by third parties. In most developed countries, the state is the primary funder; in the United States, it is a mix of private insurance companies and public programs like Medicare. Either way, the elasticity of demand is low to non-existent: even an exorbitantly high price (as with many cancer treatments) will not reduce demand for the product.

Accordingly, from the moment a start-up is launched, its founders and funders can realistically estimate the prospective revenues that will follow if they can make the technology work. The same cannot be said for information technology, even in the case of products and services addressing enterprise markets (never mind consumer IT).

WHICH RISK?

In biotech, as elsewhere, state procurement has proved to be a powerful force, as demonstrated by the recent success of Operation Warp Speed in the US, which used "advanced purchase payments" to deliver COVID-19 vaccines faster than almost anyone expected.

More than 200 years earlier, at the dawn of the Industrial Revolution, the British Army used public procurement to achieve similarly stunning results. In *Empire of Guns: The Violent Making of the Industrial Revolution*, Priya Satia of Stanford University shows that, from the Glorious Revolution of 1688 to the Battle of Waterloo in 1815, the British Army's annual demand for firearms rose from just 10,000 into the millions. As a result, the gun industry made radical gains in productivity through ever finer divisions of labor, as Adam Smith had anticipated. Birmingham, England, the home of the gun industry, emerged as the first workshop of the world – all because of the "pull" of state-assured non-market demand.

But Birmingham's guns were all hand-crafted. The Industrial Revolution's truly revolutionary innovation came a little later with the ability to manufacture goods from interchangeable parts. Here, the signal breakthrough in manufacturing technology emerged from the US armories at Harpers Ferry, West Virginia, and Springfield, Massachusetts, in the decades before the US Civil War.

As the historian of manufacturing David Hounshell has shown, interchangeable parts depended on the development of machine tools of unprecedented precision, and as these technologies spread across industries, productivity rose exponentially. Yet in two new industries of profound economic significance – sewing machines and agricultural machinery – the leading firms, Singer Sewing Machine Company and McCormick Harvesting Machine Company, each deliberately refused to adopt interchangeable parts. They owed their respective triumphs instead to marketing, innovative promotion and distribution techniques, and customer financing, which helped them win dominant shares of their respective markets and then set prices well above their apparently uncompetitive production costs. In other words, their success in overcoming *market risk* outweighed their refusal to produce at the technological frontier.

Manufacturing with interchangeable parts reached its apotheosis with Henry Ford's mass-production factories. Ford was determined to eliminate the need for "fitters" – the armies of workers, equipped with metal files, who finished component parts so that they could be fit together into a completed working product. He achieved this goal in 1910.

Ford's initial dominance of the global automobile industry was driven entirely by this success in overcoming the challenges of mass production and bringing about an unprecedented reduction in costs and prices. In stark contrast to the Singer Sewing Machine Company and McCormick Harvesting Machine Company, he openly denigrated marketing as a competitive tool, famously telling customers: "You can have any color, as long as it's black." For some 20 years, the Ford Motor Company produced only one product, the Model T, but it did so at a historically unprecedented scale.

In time, however, the broader automobile industry would demonstrate the competitive salience of marketing. By the mid-1920s, General Motors had overtaken Ford thanks to Alfred Sloan's strategy of brand differentiation and annual model updates. In fact, Ford's manufacturing process was so optimized to produce the Model T that, when its micro-managing owner-entrepreneur finally saw the need for a change, it took two painful years (punctuated by a complete shutdown of production) to introduce the Model A.

THE COMMERCIALIZATION CHALLENGE

The tension between market risk and technology risk is fully illustrated by the history of another great twentieth-century company, E. I. du Pont de Nemours. For 100 years from its founding in 1802, DuPont produced black powder explosives for the US Army and Navy. With the military underwriting its market risk, its single most significant source of uncertainty was the incidence of war. But when a younger generation of DuPonts bought out the company from their elders and embarked on a new path of investment in research and development, they positioned it to become the dominant American player in the first "scientific" industry: chemicals.

In *Science and Corporate Strategy: Du Pont R&D, 1902-1980*, Hounshell and John Kenly Smith, Jr., mine the company's archives to explore two independent dimensions of its innovation strategy. The first was "buy versus build," a principle that it exemplified by aggressively acquiring relevant process technologies in order to enter new markets – starting with dyestuffs, where it initially lagged far behind the German pioneers, and then with titanium dioxide for the coatings market.

But it was in the second dimension that the balance between market and technology risk came into play. From the 1930s through the postwar generation, DuPont focused intensely on developing entirely new synthetic fibers, achieving an early straightforward success with Nylon. Even though "what the new fiber might be good for could not be determined from the small samples that were made in the laboratory," it soon proved to be a manifestly better silk than natural silk, and the market for women's stockings was there for the taking.

But other synthetic-fiber products, such as Orlon and Dacron, presented daunting market challenges, because their seemingly obvious intended markets fell through. The company discovered that its resilient new fibers delivered the greatest competitive advantages in applications where it already had established franchises (Rayon and Acetates). In the end, management bit the bullet and shut down the plants that had accounted for its largest investments. Critically, DuPont's monopoly power endowed it with the resources to confront market risk successfully.

THE DIGITAL AGE

In the decades after World War II, the US Department of Defense set the direction and pace of innovation in all the technologies that would later drive the digital revolution. Upstream, the DoD funded the academic disciplines of computer science and solid-state physics

(which received additional support from the National Science Foundation). On the supply side, it became the dominant funder of R&D for computers and for the semiconductors that powered them; and on the demand side, it served as the strategic customer for the first prototype computers, the first microelectronic components, and the first running software applications.

Not until the early 1980s did the DoD cease to be the dominant force in the digital domain. By then, the falling costs and improved reliability of semiconductors had reached a point that allowed for the transition to large-scale commercial markets. IBM's introduction of the company's first PC was the key positive signal of this development. Another (negative) signal was Intel's refusal to participate in the DoD's next-generation microprocessor competition, which placed absolute performance above the commercially relevant metric of "price/performance."

Of course, military needs continued to shape the evolution of digital technologies – as they still do today. Channeled through the Defense Advanced Research Projects Agency (DARPA), military demand for linking computer networks through open protocols, and for global positioning capabilities, drove the technological advances that formed the foundations of the internet and the rest of the digital age. But as the digital revolution matured, the state that had nurtured it failed to buffer its constituents from its economic effects.

The emergence of commercial markets for computing in the 1980s coincided with the rise of neoliberalism, which held that unfettered markets would always deliver fair, efficient solutions to all problems, and that government interventions could therefore only ever lead to worse outcomes. But the digital revolution produced three big consequences that have forced a reconsideration of neoliberal dogma.

First, digital computers and networks allowed for an extraordinary global extension of supply chains – both for services and products – with far-reaching distributional effects that can be seen in geographical employment and electoral data and in the economic fragilities that the COVID-19 pandemic exposed. The second effect is increased automation, reflected in wage and salary levels across the income distribution. And, lastly, digital technologies played a unique and decisive role in financialization – the transformation of ever more assets into financial securities that are subject to bubble-and-crash dynamics – which reached an unprecedented scale and culminated in the 2008 financial crisis.

These economic and political outcomes are already sufficient to discredit the neoliberal paradigm. But two additional existential crises have emerged to undermine it further, and to legitimize a more positive, active role for the state in the economy: namely, climate change and the rise of China.

REDISCOVERING INDUSTRIAL POLICY

China has proved to be the most successful "follower economy" in history, surpassing even the rise of the US in the nineteenth century. Like the US back then, it has appropriated, by fair means or foul, every bit of intellectual property it can lay its hands on. Ironically, China's most strategic appropriation was the twentieth-century American public-private-partnership model for advancing the technological frontier. It proved so successful for China that the Biden administration has now rediscovered and revived it at home, through policy packages such as the CHIPS and Science Act.

On climate change, the US, tragically, was a laggard for some 30 years. But finally, in the (ludicrously named) Inflation Reduction Act, the Biden administration has succeeded in framing the looming climate crisis as a legitimate occasion for state intervention in markets.

True, most of the IRA's financial carrots take the form of tax incentives. But the door has now been opened for more direct state action to reduce both the market and the technological risks that have been standing in the way of an effective response. A key missing component (but not the only one) is the development and deployment of advanced energy-storage systems that can operate at grid scale to accommodate intermittent sources of renewable electric power.

The emerging new paradigm for public policy is being promulgated under the banner of "market shaping," which first took root in the field of public health 15 years ago, when the Global Fund deployed it to support the development and distribution of vaccines and therapeutics for diseases that the for-profit pharmaceutical industry had neglected. The Global Fund's Advance Market Commitments program was the model for Operation Warp Speed.

This terminological innovation marks a substantive change in public-policy debates. Among its most high-profile champions has been the Nobel laureate economist Michael Kremer, who runs the Development Innovation Lab within the University of Chicago's Becker Friedman Institute, once a bastion of neoliberal dogma. The DIL's website features"The Case for Market Shaping," which highlights the role of "market shaping 'pull' funding … [to] … signal to firms there will be demand for socially useful innovations."

Today's responses to today's challenges amount to a repudiation of Ronald Reagan's notorious assertion, 40 years ago, that "government is not the solution to our problem; government is the problem." Whether expressed through government procurement contracts or advance market commitments for missing therapeutics, demand pull by non-market customers to reduce market risk is the key to accelerating innovation.

Rediscovering this empirical truth will offer promise in a time of domestic and transnational conflict. Yet that promise must be tempered by consideration of the complex interplay between our two biggest crises. After all, it is difficult, if not impossible, to imagine an effective response to climate change that does not build on collaboration between the US and China.

Unlikely partnerships have emerged before in the face of sufficiently large common threats: Hitler drove Churchill and Stalin into an alliance even less likely than the partnership the world needs today. Climate change already constitutes such a transformative challenge. The question now is whether we and our prime competitor will awaken to that fact.