

THE ECOLOGY OF INNOVATION

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Ever since Joseph Schumpeter developed his theory of economic development, economists have been updating and filling in the gaps in his growth model. More than just a uniquely powerful insight, "creative destruction" has been an invitation for scholars to think both broadly and deeply about how innovation works.

- **Philippe Aghion, Céline Antonin, and Simon Bunel**, *The Power of Creative Destruction: Economic Upheaval and the Wealth of Nations*, Harvard University Press/Belknap Press, 2021.
- **Dan Breznitz**, *Innovation in Real Places: Strategies for Prosperity in an Unforgiving World*, Oxford University Press, 2021.

CAMBRIDGE – The two books under review are further vindication of Isaiah Berlin's famous contrast between the fox, "who knows many things," and the hedgehog, "who knows one big thing." Dan Breznitz is an empirical fox who has studied regions that have achieved rising prosperity by exploiting various opportunities for innovation in different ways. Philippe Aghion is a hedgehog who for 30 years has played a leading role in formalizing the growth model pioneered by Joseph Schumpeter and using it to understand today's economy. Together, the two books offer a broad yet rigorous education in the economics of innovation.

Methodologically, however, the two approaches could hardly be more different. Breznitz, a professor at the University of Toronto's Munk School of Global Affairs and Public Policy, approaches the subject through fieldwork, constructing rich case studies of different regions and strategies. By contrast, Aghion, who holds professorships at the Collège de France, INSEAD, and the London School of Economics, mobilizes a vast array of empirical economic research to demonstrate the power and reach of his model.

MODELS OF ECONOMIC GROWTH

Aghion and his co-authors, Céline Antonin of Sciences Po and Simon Bunel of the French National Institute of Statistics and Economic Studies, build on the model of economic growth originally developed by MIT's Robert Solow (for which Solow was awarded the Nobel Prize in economics in 1987). Solow elegantly showed how increasing the application of the two factors of production, labor and capital, would increase output. But the mathematics underpinning his initial model was too simple. When applied to measured increases in output, it explained far too little: higher quantities of labor and capital accounted for less than half of observed economic growth. The remaining share came to be known as the "Solow residual."

It did not take long for economists, beginning with Solow himself, to recognize that the missing contribution came from innovation. Technological progress – embodied in physical capital (machines), intangible capital (ideas), and human capital (education) – increases the productivity of the factors of production and overcomes the diminishing returns that would otherwise follow from simply accumulating more of the same.

With this insight in mind, a succession of models sought to overcome the tyranny of diminishing returns, for example, by adding a fixed technological multiplier to the Solow growth equation, or by showing how multiplying the number of products would in aggregate generate more growth before diminishing returns could kick in. Most notably, Paul Romer showed how the instinctive characteristics of knowledge can open a path of persistent economic growth (for which Romer, too, received the Nobel Prize in economics, in 2018).

The key point to understand about knowledge – including new and innovative ideas about how to develop, produce, and distribute goods and services – is that it can be consumed by multiple people simultaneously. It is "non-rivalrous," in today's economic jargon, and thus calls for various contractual arrangements, including state-issued patents, to "exclude" others (actual or potential competitors) from making free use of it.

Given the uncertainty of the potential returns to new knowledge, and given that exclusion is hard to enforce even with patents in place, the late Nobel laureate economist Kenneth Arrow and Columbia University's Richard Nelson had demonstrated a generation earlier that for-profit companies in a competitive economy would tend to under-invest in research and development. Accordingly, they saw a clear case for public investment in the production of knowledge, such as the funding programs overseen by the US Defense Advanced Research Projects Agency, the National Institutes of Health, and the National Science Foundation.

THE SHADOW OF GROWTH

While Romer was publishing his Nobel Prize-winning work, Aghion was already taking analysis of the growth process further, to account for outstanding missing links. Romer's model lacked an engine that would drive the creation of productivity-enhancing knowledge in an economy populated by incumbent competitors. With a series of collaborators, notably Brown University's Peter Howitt, Aghion found such an engine in the Schumpeterian growth model.

The key to Aghion's analysis is that it encompasses both sides of Schumpeter's notion of "creative destruction." One must account not only for the creation of new, more competitive products and processes, but also the destruction of the existing, established products and processes. In *The Power of Creative Destruction*, Aghion and his colleagues expand the reach of the model to define a "new paradigm" for evaluating economic history and policy.

The authors' paradigm applies to a wide range of relevant and timely issues, from economic development in one country to the globalization of markets and the supply chains that link them, and from the post-2000 slowdown in productivity growth to growing concern about sustainability in the context of climate change. The overarching theme is that promoting creative innovation and mitigating its destructive consequences should form the two poles of public policy.

Aghion's long commitment to this research program fits squarely within the mainstream of neoclassical economics. Yet this book and the ongoing research that it inspires (both by Aghion and many others) also demonstrate how that mainstream has been evolving. By seriously addressing the downside of Schumpeterian destruction as well as the upside of creation, Aghion and his co-authors find roles for the state in the market economy both as "investor" and as "insurer."

In their conclusion, they identify a "Golden Triangle" where the interaction of state and market is extended to include the influence of "civil" society, here defined as the cultural norms that inform economic and political actors' behavior (both individually and jointly). The book thus moves the debate a long way past the old idea that the only role for the state is to interfere with the smooth operation of otherwise efficient markets. Gone is the extreme "methodological individualism" exemplified by former British Prime Minister Margaret Thatcher's claim that "there is no such thing as society."

MODELING CREATIVE DESTRUCTION

The mathematical model underpinning this research program is not presented in *The Power of Creative Destruction*. A brief examination of it, however, can illuminate how Aghion's paradigm works and, more generally, how a mathematical model abstracted from the real world can guide practical policies to shape behavior.

At the core of Aghion's model is an ongoing competition to become the monopoly provider of an intermediate product essential to the production of a final good. With this position comes economic "rents" – profits captured above and beyond the cost of the capital expended in the competition.

The model's most radical abstraction is that the final good is sold in a perfectly competitive market where, by definition, price equals marginal cost. This means that competing inventors can know *in advance* what the price of their invention will be, the extent of monopoly profits at stake for whomever wins the competition, and how much investment is needed to win. Of course, perfect competition is at the extreme end of the spectrum of market conditions. But this condition is necessary to work out the model's logic; it is not, and need not be, a reflection of economic reality.

The innovation engine in the model also incorporates a set of parameters that jointly define the productivity of R&D. And though these parameters are exogenous and thus appear to be arbitrary, they offer serviceable targets for policies designed to increase the rate of innovation and economic growth. For example, the value of the parameter for research productivity can be enhanced by public investment in education.

Similarly, the profits earned from winning the competition depend on the degree of protection offered by the patent system. But this cuts two ways, because a stricter intellectual-property regime can strengthen an incumbent's power to block competition from innovators. Competitive conditions can also cut two ways: "neck-and-neck" competition at the frontier stimulates investment in innovation; but if the gap between leader and follower is too large, potential innovators may withdraw and seek to protect their own niches. This is why antitrust enforcement plays such an important role in the innovation economy.

MISSING MARKET RISK

Comprehensive as Aghion's paradigm is, it is not complete. The process of innovation implied by the underlying mathematical model is of the simplest kind. It assumes both that the market for a new product already exists, and that it will absorb all that can be produced. Historically, however, the innovations that have generated the most growth and the greatest profit have been those that created entirely new markets for goods and services that the world had never seen before. Think of railroads and automobiles, or the near-infinite array of goods and services enabled by electricity and computing.

In other words, the real market risk that all entrepreneurs face is outside the model and thus tangential to the paradigm. But it is worth remembering that the costly trial-and-error search for new applications derived from advancing technology is categorically different from inventing a new product for an application that is already defined.

Much also depends on another dimension of risk: the availability of finance for a radically uncertain investment. One of the virtues of Aghion's Schumpeterian paradigm is that it encompasses this tension between the financier and the entrepreneur over the sharing of authority and potential profits. (The entrepreneur, Schumpeter observed, is the one who "loses other people's money.")

But Aghion's model does not encompass the contributions made by waves of speculative excess, even though such funding has been key to most transformational technological revolutions. Consider, for example, the nineteenth-century railway manias; the great bull market of the 1920s, which financed electrification; and the dot-com bubble that laid the foundation for the digital age. In fact, the word "bubble" does not appear in the book's index.

Ultimately, *The Power of Creative Destruction* implies a universal relevance for the Schumpeterian growth model. The authors consider the broader context in which economic growth has been achieved historically, as well as examples of efforts to generate it that have seemingly run out of steam. In the early pages, they consider how the West escaped from the "Malthusian trap," which for centuries – even millennia – had meant that any increase in productivity was offset by an increase in population. They also confront the contemporary "middle-income trap," which describes how the institutions that help developing countries approach the technological frontier by imitating global leaders suddenly become obstacles to further income gains.

Yet even when the authors open up the "black box" of the model, they remain committed to a linear process of innovation that centers on the entrepreneur. This perspective will be well received in Silicon Valley, but, as Breznitz shows, it is hardly the only way to see things. In his work, the role played by the entrepreneur-icon occupies a special but limited space alongside other "strategies for prosperity" that have succeeded under different conditions and in very different contexts.

THE VALUE-CHAIN GANG

Innovation in Real Places starts with the "fragmentation of production" over the past 40 years. The steamship, the railroad, the telegraph, and the telephone enabled the first globalization of production and consumption, around the end of the nineteenth century. But the second wave of globalization that began in the 1980s, driven by information technology, has gone much further. The digitalization of order-processing and the containerization of goods transport has made physical supply chains vastly more efficient. But digitalization also has led to fragmentation of services and outsourcing of more and more work.

Breznitz identifies four distinct stages of production, each of which offers an opportunity for "specialization and capacity-building" that in turn can generate "economies of scale and scope." First is the "Novelty" stage, when original inventions are transformed into commercially significant innovations. This is when venture capitalists come together with entrepreneurs to invent the future, exemplified by Silicon Valley. But it is also at this stage that numerous state actors and market players have been led down blind alleys (or "boulevard[s] of broken dreams," in Josh Lerner's memorable phrase) in an attempt to conjure up their own "Silicon-Hyphens."

Here, Breznitz delves into one success story that stands out for its rarity and for the special circumstances in which it emerged: Israel and its world-class software industry. He also surveys various failures, noting that even the successes come with a curse: the extreme inequality to be found both in the San Francisco Bay area and in Israel. Success in stage one typically does not spill over to generate broad regional prosperity, not least because much of the production and support jobs are outsourced nowadays.

Breznitz's most original and strategically significant contribution lies in his detailed examination of the three other stages of production. His second stage comprises "design, prototype development, and production engineering," and focuses on the "original design manufacturers" (ODM) of Taiwan, who transform novel concepts into products that can be mass-produced.

ODMs have come to have a hand in virtually every digital product – from laptops to earbuds – regardless of where it is conceived. In addition to the well-known Asian players, Breznitz also calls attention to less celebrated hubs, such as Alto Livenza and Brenta in Italy. In the former, creative designers of furniture can have their high-design concepts turned into replicable realities. In the latter, the high-end fashion shoe industry can acquire cutting-edge designs for new models that can actually be manufactured and put on people's feet.

In his third stage, Breznitz examines practitioners of "second-generation product and component innovation," many which can be found in the German automobile industry. In the digital domain, the Taiwan Semiconductor Manufacturing Company (TSMC) has become the world leader in producing semiconductor chips that have been designed by others to the most demanding specifications. Less well known is another Taiwanese leader, MediaTek, which pioneered the mass production of core processors for consumer electronics. In fact, Taiwan as a whole has tapped into prosperity largely by innovating within stage three.

Breznitz's last stage concerns "production and assembly." This might at first sound like the most routine and boring of the four, but through his study of China's fast-growing Shenzhen region, he shows what can be achieved through innovation to maximize flexibility in handling rapid shifts in demand. Success at this stage depends on the local availability of a wide range of human capital and manufactured components, all of which can atrophy if neglected. Tellingly, when Apple recently tried to move some of its assembly operations back from southeast Asia to Austin, Texas, it not only had trouble finding the right skills. As Breznitz observes, "it could not even source the right screws."

GENERALIZING THE SPECIFICS

Breznitz links his case studies through what he calls the "Four Fundamentals" of successful innovation at each of the different stages of production. These include flows of local-global knowledge, demand, and input; the supply and creation of public and semi-public goods; a local ecosystem that reinforces the firm-level benefits of the first two fundamentals and allows access to critical resources, such as finance or legal services; and co-evolution of the previous three fundamentals, implying the need for public-policy reforms as the locale grows and excels.

Innovation in Real Places concludes by addressing three “dysfunctionalities” that inhibit the successful implementation of innovation policies. The first is the extreme expansion of IP rights, which can empower “patent bullies” and limit the productive spillovers of knowledge that otherwise would feed regional prosperity and global innovation. The incentives that patents provide now force a never-ending competition to establish countervailing power in negotiation and litigation.

Financialization is the second dysfunctionality, because it decouples investment return from operational success. Particularly in the domain Breznitz explores, it provides incentives for innovative start-ups to be acquired by large companies before they can mature to create the direct jobs and demand for ancillary services upon which regional prosperity depends. Here, the best response is to encourage local growth and discourage cashing out, by providing patient finance to support companies that can achieve the sustainable positive cashflow needed to support debt.

Ironically, over the past decade or so, financial conditions have evolved to create arguably too much of a good thing. Around the world, central banks responded to the 2008 global financial crisis by driving interest rates and returns on safe assets to historically low levels, and they have renewed their commitment in response to the COVID-19 pandemic. As a result, “unconventional” investors – including mutual funds, hedge funds, and sovereign wealth funds – have poured unprecedented amounts of cash into new ventures. Some of these will evolve into financially sustainable businesses. As for the rest, as Warren Buffet famously put it, we will find who has been swimming naked when interest rates normalize and the tide retreats.

Finally, Breznitz turns to the continuing, exponentially increasing generation and capture of the data that power the digital giants. Creating a property regime for data will be a daunting task, given its distinctive attributes: zero-marginal-cost reproduction; its “non-rivalrous” nature; increasing returns to its exploitation; and the seemingly endless applications of data analysis. For his part, Breznitz recommends multiple exercises in experimentation, citing as a useful example Estonia’s e-government initiative.

More generally, the abiding message of Breznitz’s book is that it is a mistake to assume that “what works in one time and one place will always work across time and space.” Only public and private entrepreneurs who realistically assess their region’s distinctive capabilities and location in the multidimensional networks of demand and supply can effectively deploy the Four Fundamentals. Because capabilities and location will evolve in unpredictable ways beyond direct local control, he concludes with “a defense of experiments, mistakes, and the right to choose.”

MELDING THE METHODOLOGIES

Despite their very different approaches to the same topic, a conceptual thread linking the work of Breznitz and Aghion can be found in the Schumpeterian growth model’s failure to consider the risk that a technological innovation may fail to find a market. In the world of IT and its applications, the Schumpeterian model sits squarely in Breznitz’s stage of “second-generation product and component innovation,” where competition focuses on innovating cheaper, faster, and better ways to serve already established markets.

The Schumpeterian model also applies to today’s health-care sector, much of which is structured around third-party funding of drugs, diagnostics, devices, and the science they exploit. Here, new products that satisfy regulatory requirements are highly certain of finding a market. It is a domain largely constructed and supported by what Aghion calls an “investor and insurer” state. And precisely because market risk is so low, venture capitalists since the genetics revolution of the 1970s have braved enormous technological risks at a scale second only to IT.

As it happens, neither book devotes much space to exploring how the record of VC can serve as a lens for understanding the dynamics of the innovation process more generally. Aghion refers to sound theoretical work on the contest between entrepreneurs and VCs over control and valuation, and to equally sound empirical research on the outperformance of VC-backed start-ups versus comparable ventures with VC engagement. And Breznitz correctly, if derisively, stresses that VCs are in it for the money, not for the broader economic and social spillovers that come with successful innovation.

Yet the rise of professional VC runs parallel to the digital and biotechnology revolutions that have driven the innovation economy of the last half-century. In each case, the US government served both as an upstream investor in science and as the first, collaborative customer for the outputs of new technologies that were too costly and unreliable for commercial deployment. And in each case, the highly skewed super profits reaped by a few persistently successful VCs have leveraged recurrent waves of speculative excess, as investors and market incumbents come to realize that a “new economy” might be in the making.

VCs show up at the dance when there is a platform built for them by the state, from which they can attract the attention of buyers seeking to translate an uncertain future into cash today at speculative prices. But this “three-player game” is not the whole story, just as Silicon Valley is not the sole site of successful innovation, and just as the mathematics of the Schumpeterian model does not capture the full dynamics of innovation.

There is one other place where the radically different styles of scholarship deployed by Aghion and Breznitz converge. Aghion’s “Golden Triangle” (the state, the market, and civil society) is, after all, a description of the ecosystem in which Breznitz’s Four Fundamentals can be most effectively combined. For entrepreneurial initiatives to succeed at a regional, let alone national, scale, they need to be embedded in an ecosystem of innovation that spans markets and the state, and whose culture sanctions supportive institutions.¹

Aghion’s abstract model and Breznitz’s case studies extend economic analysis to illuminate a wide range of contemporary political and cultural issues. And in their own ways, this is the most important contribution that Aghion and Breznitz offer.

