Volume Title: The Changing Frontier: Rethinking Science and Innovation Policy

Volume Author/Editor: Adam B. Jaffe and Benjamin F. Jones, editors

Volume Publisher: University of Chicago Press

Volume ISBNs: 0-226-28672-X, 978-0-226-28672-3

Volume URL: http://www.nber.org/books/jaff13-1

Conference Date: August 2-3, 2013

Publication Date: July 2015

Chapter Title: Comment on "Algorithms and the Changing Frontier"

Chapter Author(s): Timothy Simcoe

Chapter URL: http://www.nber.org/chapters/c13031

Chapter pages in book: (p. 410 – 414)

Swann, G. M. P. 2009. "International Standards and Trade: A Review of the Empirical Literature." Paper presented at the conference on Barriers to Trade: Promoting Good Practice in Support of Open Markets. http://www.oecd.org/trade/non-tariffmeasures/43685142.pdf.
Terlaak, A., and A. A. King. 2006. "The Effect of Certification with the ISO 9000 Quality Management Standard: A Signaling Approach." *Journal of Economic Behavior and Organization* 60:579–602.
Trajtenberg, M., R. Henderson, and A. Jaffe. 1992. "Ivory Tower versus Corporate Lab: An Empirical Study of Basic Research and Appropriability." NBER Working Paper no. 4146, Cambridge, MA. http://www.nber.org/papers/w4146.
Turner, F. J. 1894. "The Significance of the Frontier in American History." State Historical Society of Wisconsin.
United Nations Industrial Development Organization (UNIDO). 2012. "Study into the Value of ISO 9001." Accessed September 25, 2012. http://www.iaf.nu/articles/Study_into_the_value_of_ISO_9001_/279.
Vanderbilt, T. 2012. "The Single Most Important Object in the Global Economy." *Slate*, August 14. http://www.slate.com/articles/business/transport/2012/08/pallets_the_single_most_important_object_in_the_global_economy_.2.html.
Weitzman, M. L. 1998. "Recombinant Growth." *Quarterly Journal of Economics* 113 (2): 331–60.
Winter, S. G. 1968. *Toward a Neo-Schumpeterian Theory of the Firm.* Santa Monica, CA: Rand Corporation.
World Trade Organization. 2005. *World Trade Report 2005: Trade Standards and the WTO*. Geneva, Switzerland. http://www.wto.org/english/res_e/publications_e/wtr05_e.htm.
———. 2008. *World Trade Report 2008: Trade in a Globalizing World.* Geneva, Switzerland. http://www.wto.org/english/res_e/reser_e/wtr08_e.htm.

Comment

Timothy Simcoe

This chapter by Agwara, Auerswald, and Higginbotham (AAH) is an ambitious and thought-provoking attempt to describe how innovation at the "algorithmic frontier" links process innovation to globalization and economic growth. They begin with a historical discussion that emphasizes how ideas about the nature of the frontier have changed over time, gradually shifting from geographic expansion, to industrialization, to the scientific frontier described by Vannevar Bush and commemorated in this volume. The chapter's main thesis is that the scientific frontier has been replaced by an "algorithmic" frontier characterized by IT-enabled business process innovation and increasingly fragmented global supply chains. After describing this new frontier, the authors consider its implications for science and innovation policy.

Timothy Simcoe is associate professor of strategy and innovation at Boston University and a faculty research fellow of the National Bureau of Economic Research.

For acknowledgments, sources of research support, and disclosure of the author's or authors' material financial relationships, if any, please see http://www.nber.org/chapters/c13031.ack.

One major goal of the chapter is to draw economists' attention to several issues that deserve more scrutiny. These issues include business process innovation, the important role of standardization in the economy, and the gradual replacement of industrial R&D by decentralized innovation. Overall, I am sympathetic with this goal and the views expressed by AAH. Their chapter reminds us that process innovations, while difficult to measure, may be just as important as the patents and papers that are more frequently the object of statistical inquiry.

The chapter's second, more ambitious goal is to articulate a theory of "algorithmic production" and to explore its implications for trade, growth, and innovation. While AAH make some interesting progress on this front, it is not clear to me whether the kernel of a theory provided in this chapter can be developed into a full-fledged alternative to existing models of production or innovation.

This short response to AAH is organized into three parts. I begin by noting that the idea of algorithmic production is closely related to the management literature on firm-level routines and capabilities, and shares many of that literature's strengths and weaknesses. My second set of comments considers the hypothesized link between standardization, the algorithmic frontier, and global trade. I conclude by highlighting some potential implications of this chapter's thesis for science and technology policy.

Algorithmic Production

One of AAH's recurring themes is that economics neglects the important role of variation in production processes. Their starting point for this argument seems to be neoclassical production theory, in which perfectly competitive markets push atomistic firms relentlessly toward the most efficient technologies available. AAH argue that in reality, firms rely on different "recipes" or algorithms to produce similar goods and services, and that these differences in the methods of production are closely linked to differences in the rate and direction of technological change.

This is an important idea, though AAH are not the first to suggest it. In their path-breaking work, "An Evolutionary Theory of Economic Change," Nelson and Winter (1982) argue that heterogeneity in firm performance is driven by variation in the underlying methods of production, and that technological change occurs through a process of trial-and-error learning under selection pressure, as opposed to invention followed by rapid adoption of a single profit-maximizing technology. These ideas launched a multidecade research agenda within the field of business strategy to measure firms' routines and capabilities, and to link those constructs to variation in performance. Many of AAH's ideas are closely related to a more recent branch of that literature that models business process innovation as search on a complex landscape (e.g., Rivkin 2000).

AAH's use of the algorithmic metaphor in this chapter is an innovation relative to the business strategy literature, which typically describes the dif-

ferent production processes of seemingly similar firms in terms of "routines" or "capabilities." The algorithmic metaphor has both strengths and weaknesses. One strength of AAH's metaphor is that it highlights how key assumptions of the strategy literature diverge from classical economic theory. Just as many different algorithms can produce a similar computational result (albeit at differing levels of flexibility or efficiency), real firms operating in identical markets do seem to use very different processes to transform a particular mix of capital, labor, and knowledge into final goods and services. Moreover, there is an intriguing parallel between organizational and algorithmic design—in both settings complex problems are often broken into discrete steps that can be addressed independently in order to compartmentalize certain tasks and isolate interdependencies. In general, these design questions have received less attention within organizational economics than more familiar incentive and informational problems that are amenable to traditional modes of theorizing, and perhaps less context dependent.

The algorithmic metaphor also shares some key weaknesses of the management literature on firm capabilities. First, it neglects the idea that business processes are designed and managed by people, as opposed to machines. While individuals may lack either the information or incentives required to move quickly to an idealized production possibilities frontier, they do adapt, learn, and respond to local incentives. These latter ideas are not always easily accommodated within the algorithmic framework.

Second, an algorithmic theory of production typically takes a very reduced-form approach to the problem of demand discovery, often assuming that it can be represented by myopic search on some exogenously shifting landscape. For AAH, this approach to demand discovery strikes me as somewhat ironic, since their chapter suggests that economic frontiers have moved beyond the perfection of mass production techniques that exploit classical supply-side economies of scale. An alternative view of the contemporary frontier is that it rewards firms like Apple or Google that have developed the ability to anticipate consumer needs or rapidly solve difficult demand-side matching problems.

Finally, the strategy literature has struggled for years with the problem of measuring routines or capabilities in a manner that does not require making inferences based on past performance. Recent efforts to systematically survey management practices (e.g., Bloom and Van Reenen 2010) may herald some progress on this front. However, rather than attack this problem directly, AAH propose an alternative measurement strategy based on linking algorithmic innovation to the diffusion of management standards, notably the ISO 9000 series of quality standards.

Standards and Globalization

AAH's idea that the diffusion of business process standards can be used to measure the advancing algorithmic frontier is novel and creative. However,

it is not clear that this measure does precisely what the authors would like, and in my view they push the underlying analogy too hard when arguing that process innovation has opened new frontiers in global trade.

A key piece of AAH's argument is the idea that standards "enable the interoperability of firm-level recipes . . . [by turning] a firm-level recipe into a subroutine of a larger program containing many different recipes." In support of this claim, AAH briefly describe several standards, such as uniform shipping containers and pallet sizes, that arguably played an important role in promoting global trade. Their thesis would be strengthened by unpacking these examples in more detail, and by describing some other important business process standards, such as Universal Product Codes (Basker 2012) or Electronic Data Interchange. Focusing on a wider variety of standards would also reduce the chapter's emphasis on ISO 9000. While ISO 9000 is widely adopted, and easily measured because of its certification program, it is not clear whether the specification promotes coordination among firm-level recipes in the sense emphasized by AAH, as opposed to providing a simple method of signaling that adopters have acquired some baseline level of managerial competence.

The chapter should also be careful about claims that increased globalization is "better understood" as the advance of an algorithmic frontier. The implicit baseline for this comparison is a vast literature on trade and development, a large part of which is concerned with firm-level relationships between productivity and trade (see Bernard et al. 2012). Standards are clearly important to trade. However, the idea of the advancing algorithmic frontier needs to be made more explicit if it is to be distinguished from the view that today's disintegrated design and production processes are a natural consequence of increasing returns to specialization, declining transport costs, and falling tariffs.

Concluding Thoughts

Given the focus of this volume, I will conclude with three short observations about this chapter's implications for science and innovation policy.

First, AAH draw our attention to the importance of business process innovation. Much of the economic literature on innovation focuses on easily measured inputs (R&D spending) or outputs (paper and patents). While it has become de rigeur to note that this is an example of "looking for our keys under the lamppost," AAH actually take a position on what we are missing. It is not clear to me that this observation corresponds to a change in the frontiers of innovation. For example, Paul David (1990) shows organizational innovations were an important complement to technical innovation during the late industrial revolution. However, AAH's emphasis on standards may highlight a genuine shift in the direction of inventive activity to the extent that today's IT-enabled frontiers require greater levels of interfirm coordination.

Second, AAH's idea of an advancing algorithmic frontier highlights the role of actual algorithms in contemporary innovation. Digitization is continuing to exert a major influence in the way that science is organized and practiced, both directly—through advances in measurement, computation, and instrumentation—and indirectly, through lowering the costs of collaboration and facilitating new practices such as open-access publishing or real-time remote access to shared facilities. These topics provide grist for the remainder of this volume.

Finally, AAH's chapter poses the interesting question of whether the decline of industrial R&D corresponds to the closing of the scientific frontier as envisioned by Vannevar Bush. At one level, the answer is "surely not." While it is intriguing to ponder the decline of Bell Labs, the data show that large firms still conduct the overwhelming majority of R&D. Nevertheless, there are clear indications that innovation has become more decentralized (e.g., Greenstein and Ozcan 2013). Perhaps this simply reflects a swing of the Schumpeterian pendulum back toward smaller firms, or the maturing of key segments within the IT-producing sector. On the other hand, it could reflect structural changes in the organization of innovative activity that present new challenges and opportunities for policymakers. This is an important question, and a nice contribution to a volume that emphasizes the changing innovation policy landscape fifty years after the idea of the scientific frontier was first put forward.

References

Basker, E. 2012. "Raising the Barcode Scanner: Technology and Productivity in the Retail Sector." *American Economic Journal: Applied Economics* 4 (3): 1–27.

Bernard, A., J. Bradford Jensen, Stephen J. Redding, and Peter K. Schott. 2012. "The Empirics of Firm Heterogeneity and International Trade." *Annual Review of Economics* 4 (1): 283–313.

Bloom, N., and John Van Reenen. 2010. "Why Do Management Practices Differ across Firms and Countries?" *Journal of Economic Perspectives* 24 (1): 203–24.

David, Paul A. 1990. "The Dynamo and the Computer: An Historical Perspective on the Modern Productivity Paradox." *American Economic Review* 80 (2): 355–61.

Greenstein, S., and Yasin Ozcan. 2013. "The (de)Concentration of Sources of Inventive Ideas: Evidence from ICT Equipment." Working paper presented to NBER Summer Institute 2013.

Nelson, R. R., and Sidney G. Winter. 1982. *An Evolutionary Theory of Economic Change*. Cambridge, MA: Harvard University Press.

Rivkin, J. 2000. "Imitation of Complex Strategies." *Management Science* 46:824–44.