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Thinking about the future of technology: Rates of improvement and economic feasibility

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ABSTRACT

This paper uses data on rates of improvement to discuss when new technologies or systems composed from them might become economically feasible. Technologies must provide some level of performance and price for specific applications before they will begin to diffuse and technologies that experience rapid rates of improvement are more likely to become economically feasible for a growing number of applications than are other technologies. Drawing from a large data base on rates of improvement, this paper describes a set of plausible futures that are very different from ones that are presented in public forums.

1. Introduction

Many social scientists argue that creative destruction is a large source of economic growth (Schumpeter, 1934; Rosenberg, 1982a, 1994; Acemoglu & Robinson, 2012). Technologies such as steam engines, electricity, automobiles, aircraft, integrated circuits, computers, Internet search, social networking sites, and smart phones destroyed an existing order and created a new one. The new technology also provided significantly higher economic value to users than did the old one, enabled dramatic improvements in economic productivity and thus living standards (Solow, 1957), created winners and losers at the individual, firm, and country level, had a large impact on our ecological and social environment (both negative and positive), and proposed solutions for climate change and other global problems imply positive predictions about new technologies. For example, the Intergovernmental Panel on Climate Change's recommendations (IPCC, 2013) are partly based on their predictions of technological change.

But when do new technologies become economically feasible? The predominant viewpoint is that new technologies proceed through distinct stages of invention, commercialization, and diffusion (Rogers, 1983) in which there are advances in science, new prototypes, design changes and improvements in cost and performance (Arthur, 2007, 2009; Balconi et al., 2012; Funk & Magee, 2015). Others use the terms R&D, basic and applied research, invention, and innovation (Rosenberg, 1982b). Whatever words are used, however, advances in science play an important role in this process of technology change

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because they facilitate the refinement and improvement of both concepts and prototypes over many years (Arthur, 2007a) in which cost and performance trajectories (Dosi, 1982; Dosi & Nelson, 2010) experience improvements as new product and process designs are implemented in university and corporate laboratories.

An alternative model emphasizes the relationship between rapidly improving components and the emergence of new systems (Kurzwell, 2005). Many scholars call these rapidly improving components or systems, general purpose technologies (GPTs). For example, technologies such as steam engines, railways, internal combustion engines, motor vehicles, integrated circuits, computers, lasers, and the Internet have been defined as GPTs due to their large impact on productivity growth and thus standard of living, often through their impact on higher-level systems (David, 1990; Bresnahan & Trajtenberg, 1995; Helpman, 2003; Lipsey, Carlaw & Bekar, 1998). Looking at one example in more detail, improvements in integrated circuits and other electronic components enabled improvements in computers (and other electronic products such as smart phones) and improvements in computers enabled increases in productivity in a number of industries (Oliner & Sichel, 2002; Oliner, Sichel, & Stiroh, 2007; Jorgenson, Ho, & Stiroh, 2008), including manufacturing, banking, insurance, retail, and wholesale (Cortada, 2004, 2005). Some of these new systems were predicted forty years ago in which post mortem analyses have found that the veracity of the predictions depended on the existence of rapidly improving technologies (Albright, 2002).

This paper uses the alternative model to think about when new technologies and in particular new technological systems might become economically feasible. Economic feasibility is defined as a cost and performance comparison by the marketplace between new and old technologies. This economic feasibility is different from barriers to change that often exist at the organizational, legal, and regulatory levels. These barriers to change are particularly important for large complex systems and ones with strong network effects.

Consistent with the above references, this paper argues that technologies that are experiencing rapid rates of improvements are more likely to become economically feasible than are other technologies. A second variable that impacts on economic feasibility is the amount of improvements that are needed before a technology in the laboratory becomes economically feasible, before a commercialized technology becomes economically feasible for a growing number of applications, and before improvements in existing components lead to changes in the way higher level systems are defined. Combining the amounts of improvements that are necessary with the rates of improvement defines a 2-by-2 matrix (see Fig. 1) in which the *x*-axis represents rates of improvement and the y-axis represents amount of improvement needed. Technologies in the upper right quadrant have recently or will soon become economically feasible. Ones in the bottom left will probably never be economically feasible and ones in the other two quadrants may or may not become economically feasible in the near or far future.

In focusing on technologies with rapid rates of improvement, the paper is not arguing that these technologies are more important than other technologies. Nor is it arguing that these technologies will be easily implemented. Instead it is arguing that rapidly improving technologies such as electronic components have had and are having a large impact on our current world and thus rapidly improving technologies will likely have a large impact on the future of technology including the future of new products and services. Rapidly improving technologies are more likely to become economically feasible and more likely to enable changes in higher level systems. Understanding the types of these new systems that might become economically feasible in the near future, whether they be new products or services, is important for policy makers, entrepreneurs, managers, and university professors.

This paper first summarizes technologies that are experiencing improvements of greater than 10% per year and the technical drivers of these improvements. Second, the impacts of these rapid rates of improvement on economic feasibility and thus plausible futures of technology are then described. Third, this paper summarizes the implications of these plausible futures and how governments, firms, and universities can better think about the futures of technology.

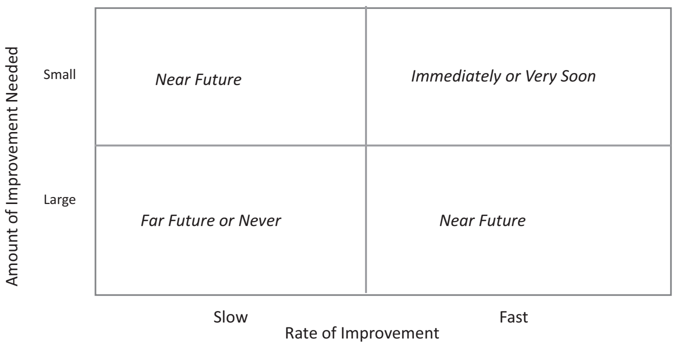

Fig. 1. When will new technologies become economically feasible?