Innovation slowdown

In a provocative research paper from a couple of years ago, economist Robert Gordon of Northwestern University in the USA asked if economic growth has essentially come to an end (http://www.nber.org/papers/w18315). He wondered if the rapid economic and technological growth of the past few centuries, so familiar to us today, might turn out to have been only a temporary thing. It might largely be over, despite current belief in the wildly creative and 'disruptive' nature of today's high-tech industry.

Growth of this kind, he noted, is certainly not the norm for human history. Before about 1700, humans had lived in pretty much the same way for many thousands of years. Then, abruptly, the transformation of the industrial revolution arrived, bringing waves of change through science and technology. We stand today at the trailing edge of this explosion, and most people expect it to continue, and perhaps even accelerate, propelling us endlessly into a future that we can barely imagine. An alternative possibility, Gordon suggested, is that the past two hundred years reflected our intellectual expansion into an open domain of relatively easy discoveries. We may have already tamed the most basic technologies — chemistry, sanitation, light, electronics and so on — and may face greater difficulties in making new discoveries with comparable impact on human well-being.

Indeed, some evidence suggests that technological advance has slowed down, at least in certain areas. As of 1800, the fastest travel came by way of the horse; it then advanced to the steam train and motorcar, and still later to the airplane and jet aircraft, ultimately reaching speeds of 500 mph in the mid-1950s. Today, 65 years later, speed of travel remains stuck just where it was back then, and has even dropped due to the need to conserve fuel.

This is all speculation, of course, as no one can truly see into the future. But it is possible to look back at data about the history of technologies, and of the inventions to which they gave rise, and to chart the pace of innovation over time. A team of scientists has recently done this (Youn *et al.*, preprint at http://arxiv.org/abs/1406.2938; 2014) using patent data over more than 200 years, and their analysis suggests that there is something real to the notion that innovation

For the past century at least, we've been making inventions faster than new technologies.

is slowing. The discovery of completely new technologies does seem to be increasing less frequent. Maybe Gordon has a point.

The United States Patent and Trademark Office offers patent protection on inventions, which it defines as bundles of technological capabilities. In describing patents, it labels each one with a set of 'technology codes' describing the collection of technological capabilities the associated invention employs. Youn *et al.* show that the resulting record of patents and codes reveals some interesting trends. In the nineteenth century, for example, nearly half of all patents were single-code inventions, meaning that they achieved their useful ends by exploiting a single, new technology. This proportion steadily decreased over the twentieth century, and currently stands at about 12%.

As time passes, in other words, it seems that single-technology inventions have become less common, whereas combinatorial invention has become the norm. For the past century at least, we've been making inventions faster than new technologies.

The shift to combinatorial innovation — associated with the difficulty of finding completely new technologies — also shows up in the comparative growth of the total number of patents, distinct codes and combinations of codes through time. Starting in 1790, all three grew exponentially for the first 80 years, during a period (closely linked to the beginning of the Industrial Revolution) when most new inventions involved a new technology. Things changed abruptly around 1870, when growth in the number of distinct technology codes slowed, falling behind the number of patents and new combinations.

After 1870, in other words, the nature of invention changed — people slowed in their invention of new technologies, but turned out new inventions just as quickly as before by putting old technologies together in new ways. Since then the process of invention has been driven almost entirely by combining existing technologies.

Youn *et al.* also show that in this combinatorial era, invention seems to have conformed to a fairly regular law reflecting a balance between exploitation of existing ideas and exploration for new ones. Consistently, over the past 150 years, roughly 40% of inventions have reused a previously existing combination of technologies, whereas 60% have introduced a totally new combination of technologies.

Even so, the data indicate that the invention process has been more creative in some periods than in others. Using the technology codes, it's possible to calculate the fraction of inventions in any period that were created by putting together widely different technologies, and to compare this to those mingling technologies only from a limited domain. You might call the former 'broad' inventions, and the latter 'narrow' inventions. Before about 1930, the data show, roughly half of all new inventions were broad combinations, but this abruptly increased to 70% in the decades following WWII, widely described as a particularly innovative period for the economy in the USA. Then, starting around 1970, the proportion of broad technological combinations again fell to around 50%.

All in all, this analysis shows that the introduction of new technologies — currently, and also for quite a while in the recent past — plays a minimal role in fuelling invention. This is at least consistent with Gordon's contention that we've found and mastered the easy, 'low hanging' technologies, and that the advance of technology could be slower in the future, or at least more incremental.

If so, it's likely that the slowing pace of innovation will have big consequences for economic organization, as today's economies require rapid innovation. Alternatively, perhaps we only await the moment when we break through into some new domain of science, radically different from anything we currently envision, where easy innovation again becomes possible. There are certainly promising domains, such as synthetic biology or nanoscience. Or maybe we'll find rapid innovation where we truly need it most — not in physics and engineering, but in technologies for tackling social problems and encouraging cooperation on global issues. That would be a surprise. ❐

MARK BUCHANAN