Why isn’t digitalisation improving productivity growth?

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CHAPTER FIVE

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"Digital technology is everywhere, and the pace of innovation if anything seems to be increasing with the latest advances in generative AI."

Innovation of new products and processes is the engine of long-term productivity growth. This puts the current wave of innovations at the heart of the productivity puzzle. From biomedicine to advanced materials to AI, there is astonishing scientific progress, and yet this is not showing up in overall productivity growth.

This paradox echoes Robert Solow's famous 1987 comment: "You can see the computer age everywhere but in the productivity statistics." Some economists argue that digital technologies are simply less important than past waves of innovation. Yet a minority of firms are using them successfully to enhance their productivity. The real puzzle is why the majority of firms are so slow to adopt the new technologies.

Pace of innovation

Digital technology is everywhere, and the pace of innovation if anything seems to be increasing with the latest advances in generative AI. This highly visible technological progress makes the poor productivity performance in the UK and other OECD countries all the more puzzling.

There are competing explanations for this digital paradox. One is that current digital innovations are simply less valuable than older ones such as electricity.[1] Another view is that it always takes time for businesses and consumers to adopt a new technology,[2] and that diffusion and adoption are slower with current technologies because they involve complex software.[3]

As digital innovations and data are enabling a minority of already high-productivity businesses to pull further ahead of others in their industry,[4] such that their productivity is growing faster, and their market shares are increasing, the balance of evidence is tilting toward the latter explanation. But this in turn raises further questions about how adoption might be speeded up and what the barriers are to using digital tools to drive faster productivity growth.

Are new ideas getting harder to find?

Modern economic growth, leading to steadily rising living standards and improved health and longevity, came about because of new ideas and discoveries. New technologies, from famous inventions such as the railways and steam engines to less well-known innovations such as the Bessemer process for mass producing steel, or the use of steel hulls on ocean-going ships, drove increases in economic output per person at historically unprecedented rates.

More important than the ideas and inventions, however, is firms turning them into innovations – practical applications that diffuse through the economy and are taken up by businesses and consumers.[5] The economic value of the ideas lies in how useful they are.

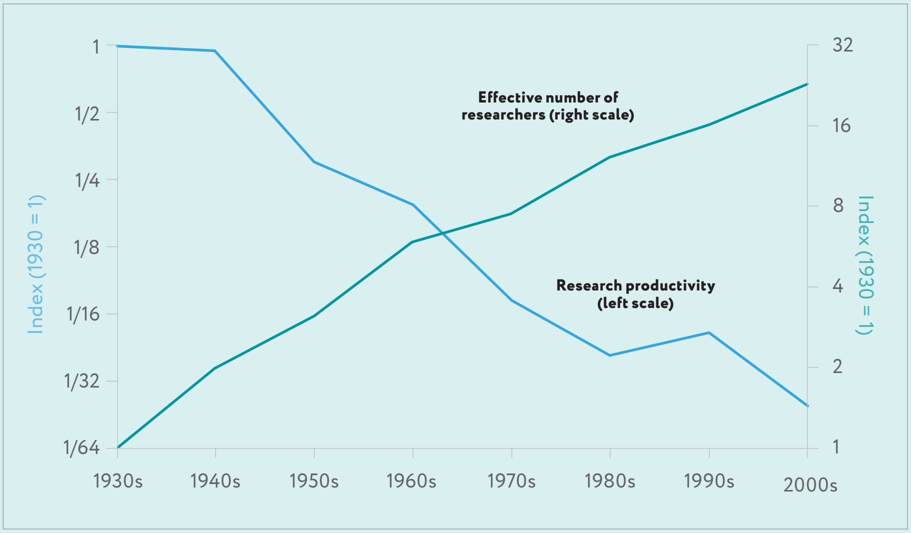
One reaction to the fact that the most recent wave of digital innovations is not translating into productivity growth (more economically valuable output produced using the available inputs of labour, capital and materials) is that they are simply not as useful as previous innovations.

Robert Gordon in his book *The Rise and Fall of American Growth (2016)* has argued that new technologies such as smartphones and social media cannot be compared in their economic value to early 20th century technologies including electricity, indoor sanitation and modern transportation. This line of argument has gained support from a high-profile empirical study of how much output has resulted from the effort put into research and development across a range of technologies.[6]

Their answer to the question posed in the title of their paper – Are New Ideas Getting Harder to Find? – is yes. Whether looking at specific examples such as computer chips (where Moore's Law seems to have broken down) or grain yields, or looking at how much more slowly TFP (Total Factor Productivity) per researcher has increased since the 1930s, there seems solid evidence of a slowing down in the arrival of economically valuable new ideas (see Figure 1).

"More important than ideas and inventions is firms turning them into innovations."

Figure 1: Slowdown in research productivity



Source: Bloom et al (2020)

The productivity J curve

The counter argument is that it takes time for innovations to be widely used and for people to recognise their value. In a famous 1990 case study the economic historian Paul David traced the spread of electricity use in the United States in the early 20th century.

The productivity benefits took around 50 years from the original late 19th century scientific discovery and inventions, with the electricity generation, transmission and distribution networks having to be built. For businesses to use electricity in production also required new low-level factory buildings because each machine was operated by a dynamo, in contrast to multi-storey steam-powered factories using one, or a few, steam engines driving many machines from a drive shaft. Consumer use needed homes to be wired and consumer devices to be invented, and these came down in price slowly as the market grew.

A large academic literature has explored how inventions diffuse, dating back to a classic Griliches (1957)[7] study looking at the spread of hybrid corn seed use by farmers through the American Midwest.

The typical S-shaped (or logistic) pattern of diffusion is now well-known - the spread is slow, then very fast, then slows down again as saturation level approaches. The timing of the acceleration in the early stages depends, among other things, on the cost structure of production (how high the upfront fixed cost is) and on how quickly prices fall as the market grows.

More recent tools such as generative AI are still in the early stages of adoption, but the emerging evidence confirms that the use of AI is strongly associated with higher productivity.

With digital technologies there is generally a high upfront cost (developing the code) and low marginal cost (copying software is essentially free for example), so it can take a long time to get to the critical mass. But then usage grows dramatically, especially if there are network effects whereby all existing users benefit more, the more new users there are (as in a telephone network). Other influences matter too. For example, personal networks and face to face contact can help spread the technology.[8]

Adding in the fact that it takes time to learn how to use new digital tools effectively, there may even be a reduction in firms' productivity at first, followed by a later acceleration. This has been labelled the 'productivity J-curve'.[9] If this is correct, the productivity dividend from recent digital innovations will eventually arrive. For example, it might take the form of digitally discovered new drugs or materials, or improved prediction and reduced inventories as firms adopt AI tools.

Since the arrival of the smartphone, 3G and beyond mobile networks, and the explosion of data use and the apps market since 2007, there has been a dramatic change in both consumer behaviour and business models.

Most of us spend hours a day online, and many firms have adopted a digital platform model or become part of a production network or ecosystem enabled by digital communication. It would be hard to understand why this structural change had come about if businesses and consumers did not find the technology economically useful.

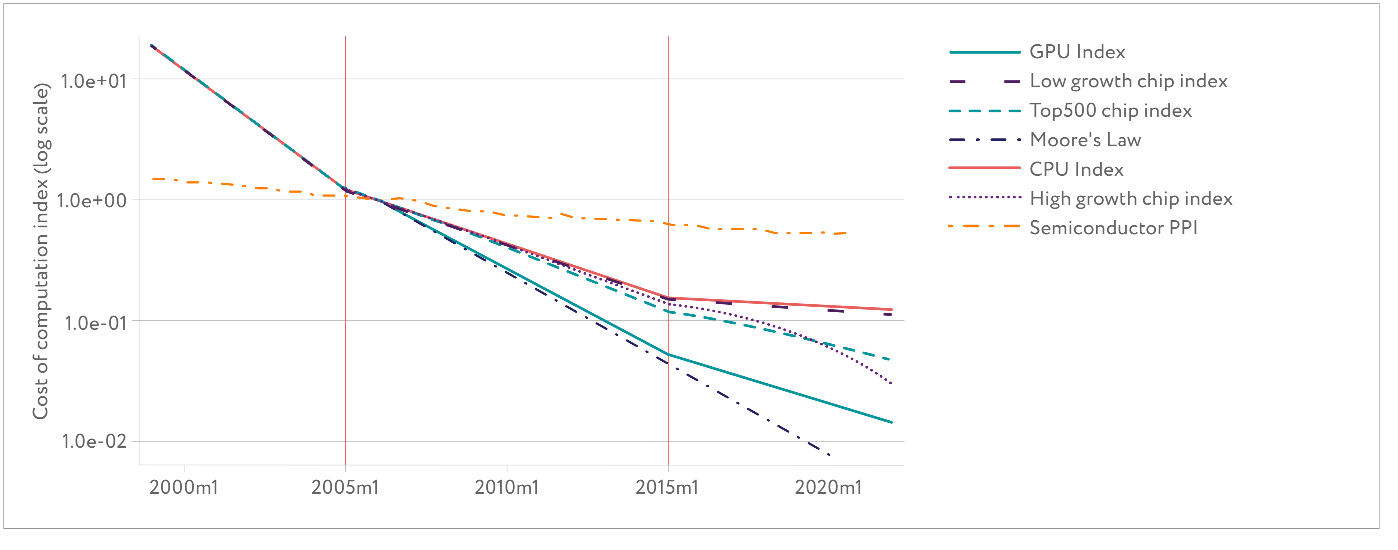
A number of studies[10 & 11] have estimated the value consumers assign to digital services they do not have to pay for directly, and have found that the stated values can be high. For instance, search and email stand out as particularly highly valued.

There might also be some artefacts of the way output is measured that mean the productivity gains from digital have been underestimated. For instance, the price index for telecommunications services in the UK has been revised following research showing that their prices had been falling substantially faster than the previous official statistics.[12, 13 & 14]

Similarly, it seems likely that official data have understated the speed with which software prices have been declining.[15] Similarly, the cost of computation using successive versions of chips (see Figure 2) has continued to fall so rapidly that it is not a binding constraint on using digital technologies, and it has certainly fallen faster than the official price index for computer chips.[16]

There may also be other measurement challenges not yet uncovered. While these might not add up to a large impact on measured productivity, they help chip away at the puzzle.

Figure 2: The cost of computation



Source: Coyle & Hampton 2023

Where are digital and AI enhancing productivity?

There are some businesses already successfully adopting digital tools to enhance their productivity. Indeed, a striking phenomenon of the productivity puzzle since the mid-2000s is the increased dispersion of productivity among different firms (see Chapter Three).

The top five or ten per cent in terms of performance have pulled further and further ahead of the average and this phenomenon has been observed across the OECD economies (See Figure 3).[17] Some researchers have linked this to increasing concentration and market power in many industries, with the consequent decrease in competition itself reducing productivity growth on average.[18 & 19]

One possible explanation for the diverging fortunes of the best and the rest is that the high productivity firms are precisely those which are using digital technologies. For example, one study found that US manufacturing firms using big data for predictive analytics had significantly higher sales and productivity than others – as long as they had made appropriate complementary investments in hardware, skills and workplace organisation (Brynjolfsson et al, 2021).

Again for the US, Acemoglu et al (2022) found digital automation was associated with about 11% higher firm level labour productivity. Cathles et al (2020) also found that the use of digital tools such as robotics or 3D printing characterised high productivity EU firms. Similarly, among UK firms, higher productivity is linked to the use of digital tools and skills, and the more so for those using more than one digital technology and combining this with in-house skills.[4 & 20]

Impact of AI

More recent tools such as generative AI are still in the early stages of adoption, but the emerging evidence again confirms that the use of AI is strongly associated with higher productivity. For example, Czarnitski et al (2023)[21] use survey data on German firms to demonstrate this, with good evidence that it is a causal relationship.

Calvino and Fontanelli[22] use data (from Calvino et al 2022) for businesses in 11 OECD countries (Belgium, Denmark, France, Germany, Ireland, Israel, Italy, Japan, Korea, Portugal and Switzerland) to uncover some of the characteristics of firms using AI. They found that, firstly, these firms tend to be larger and/or younger. And secondly, the ICT and professional services sectors are the most intensive AI users. This is intuitive as the effective use of AI requires appropriate skills and pre-existing digital infrastructure. These complementary assets are important enablers of the productivity advantages that accrue to the AI-using firms.

Given this mounting evidence that digital use, including AI, can and does enhance productivity at the level of individual businesses or plants, the aggregate productivity puzzle becomes a question of why the majority of firms are non-adopters.

Figure 3: Divergence in Total Factor Productivity between frontier firms and the rest

Source: Andrews et al (2019)

What makes it harder for new innovations to be used?

If some firms can use digital technologies so successfully, why can the rest not manage to do so? The answer seems linked to those complementary investments - the general challenge of reorganising production to adopt innovations, and to some specific features of the digital revolution.

Research on the 1990s dot com boom found that businesses then adopting digital needed to make investments in reorganisation that were about much more than the investment in computer and telecommunications equipment itself.[23] The authors note: "Firms that are intensive IT users are also more likely to adopt work practices that involve a specific cluster of organizational characteristics, including greater use of teams, broader distribution of certain decision rights, and increased worker training," (p.2). This early work also found that it could take years for the full value of ICT and organisational investments to be realised.

Costs and skills

The reason is that these technologies change the cost of transferring information, which can make for better decisions, but only if people in the business are able to use the information. They might need new skills, but they will also need to have invested in the data required and to have the authority to make decisions.

The delayering of corporate hierarchies is therefore one of the consequences of the earlier digital phase, as is the development of long and spatially extended production networks as businesses outsource more stages of production in their supply chains.[24] Digitally- and data-intensive firms have generally invested more in their 'organisational capital', as compared with counterparts who have not done so.[25] They are also more likely to be data gatherers and users. Although there is no consensus about how to value data, its use clearly makes a big difference to the performance of firms able to use it effectively.

Data adoption

It is also likely that data- and software-enabled change is inherently harder to adopt than previous technologies. There is more tacit knowledge involved – that is, the kind of know-how that is not written down but shared among co-workers – because activities involving data science and manipulating software are not very standardised.

In his recent book The New Goliaths, James Bessen (2022)[26] argues that much of the intangible knowledge involved is now proprietary to individual firms, which has reduced innovative new entry and led to a decline in business dynamism. According to Bessen:

"Across a wide range of industries, dominant firms are employing large-scale information systems to outflank their competitors, including innovative start-ups. They are using proprietary software to better manage complexity and thus differentiate themselves from rival firms. And this has allowed them to increase their market dominance and avoid being overtaken by rivals."

This might change if the new generation of foundation AI models make using digital tools more systematic and routine. In earlier work, Bessen (2015)[27] used the historical example of the early cotton industry to argue that new technologies start out by requiring scarce skills and knowledge, but as they become standardised they become easier to use and spread more quickly. It is possible that chatbots and application programming interfaces will make AI models easier to use. But for now there seems to be a high productivity premium for the very specific digital skills and software involved in running a high productivity modern business.

Why does digital adoption matter?

It is easy to be dismissive about the digital revolution and see some of its manifestations such as social media and clever AI chatbots as frivolous – or even productivity-destroying. This overlooks the high value consumers place on digital services even when they do not have to pay for them.[11] In any case this focus on consumer activities – or even on product innovations and digital gadgets from smartphones to robotic vacuum cleaners – is to ignore the genuine productivity potential of the ability to convey and use information rapidly at low cost.

Looking at the history of advanced economies since the early Industrial Revolution, although some product innovations (such as antibiotics or indoor sanitation) have without question been profoundly important, the main long-run driver of productivity growth has been process innovations (see Chapter Four). This refers to ways of producing output, rather than the output that is produced. The unprecedented growth of the past 250 years has been a succession of revolutions in production, as the table below shows.

Evolution

It seems quite likely that the latest wave of digital technologies will pave the way for another key step in the evolution of process innovations. In the decade and a half since the iPhone appeared in 2007, consumer behaviour has changed to the point where the average adult in the UK spends 28 hours, more than a whole day a week, online according to Ofcom survey data.[28]

More to the point here, business models have also been transformed. Many big digital companies and start-ups operate as platforms (or multi-sided markets). Just as in a conventional production network, a company like Nike can thrive without manufacturing footwear in-house at all. In a digital platform market a company like Airbnb or Booking.com can operate without owning or managing any accommodation at all.

The business model of such companies is using data and sophisticated software to co-ordinate the allocation of resources in the economy. It is not just the well-known big tech companies that operate a platform model, this can be found everywhere from pet insurance to spare parts for the auto industry. The new foundation AI models will without question disrupt business still more, although it remains to be seen how and how quickly.

One point underlined by this perspective on process innovation is that the time taken to produce is a fundamental productivity metric. This is implicit whenever we look at labour productivity, which measures how much output is produced per hour worked. Thinking about production processes makes it explicit - productivity has advanced by using information as well as physical technology more effectively to produce faster.[29]

Table 1: Key process innovations

Source: Author's own

DATE	PROCESS INNOVATION	DESCRIPTION
Early 19th century	American system of manufactures	Use of interchangeable parts in mechanised production processes
Mid-late 19th century	Factory system	Capital-intensive large scale (steam-based) production involving division of labour
Early 20th century	Assembly line (Fordist production)	Reorganisation of production in sequence of small steps, using affordances of the electric dynamo
Late 20th century	Lean manufacturing/Just-In-Time (The Toyota Way)	Elimination of waste and time spent in production, using new control software and computer-aided design and manufacturing, and authorising workers to control quality on the assembly line
Late 20th century	Production networks	Division of production into sequence of increasingly specialised activities more of which could be outsourced, using 1980s onward advances in ICT technologies

Policy implications

Looking at the extent of the changes in consumption and production since 2007 underlines the productivity puzzle. How we spend our days, how we work, how at least some businesses are organised has changed dramatically without moving the dial on measured productivity.

So how can the benefits of continuing technical change – in other areas such as energy and biomedicine as well as digital and AI – be crystallised? The need to speed up diffusion in use of the technologies to generate economically valuable products and services points to the important policy levers.

Using the new technologies requires *complementary investments*. These are needed in physical (wired and wireless broadband and data centre) infrastructure, and in organisational change. Of these, the latter seems to be the hardest. One area for additional policy intervention may be in transferring the necessary know-how and management practices between firms. Management quality may be a more tightly-binding constraint in a business using complex software and data.

Skills

Investment in appropriate *skills* is also required. The wage premium for software engineers and data scientists suggests their skills are in short supply in the UK.[30] The House of Lords technology committee concluded, in a 2002 report,[31] that government policy had so far failed to address businesses' skill needs, and there is no sign of improvement since then. Given the policy focus on ensuring the UK is a world leader in at least some areas of AI, the skill shortfall is likely to need even greater focus.

Competition

The winner-take-all dynamics of digital markets and increasing concentration in some parts of the economy put the spotlight on competition policy. Business dynamics, the entry of new firms and exit of less productive firms, make an important contribution to productivity growth.

Yet digital markets are often dominated by large incumbents, which might either use their data advantage or their ability to acquire potential competitors to cement their advantage. The Furman Review[32] paved the way for the eventual establishment of the CMA's (Competition and Markets Authority) Digital Markets Unit, and the CMA has signalled its intention to play an active role in enforcing competition including the implications of new foundation AI models.[33]

Resisting the lobbying of big tech companies to enable new entry in relevant markets will be essential for the UK to take advantage of its strengths in areas of AI innovation.

Data

Relatedly, the role of data is becoming a key issue. AI runs on data, and firms become more productive through their use of data. The data hoard of big tech companies forms a competitive 'moat' in some markets. What's more, there are emerging areas where the use of data across a whole supply chain or cluster of businesses will be needed to deliver the potential productivity benefits of digital technologies.

Examples include construction projects, 'smart city' networks of sensors, and also events such as the petrol or product shortages that emerged during the pandemic when supermarket chains needed to share information about stocks and sources of supply. Given that competition law rules out much information sharing between firms (as it enables collusion), careful thought needs to be given to data policy.

All of these areas speak to how easy it is to adopt the new technologies to increase productivity. New ideas do not seem much harder to find, but they are perhaps getting harder to use.

Key takeaways

There are emerging areas where the use of data across a whole supply chain or cluster of businesses will be needed to deliver the potential productivity benefits of digital technologies.

Resisting the lobbying of big tech companies to enable new entry in relevant markets will be essential for the UK to take advantage of its strengths in areas of AI innovation.

Investment will be needed in data and in organisational change to get the full productivity benefits of digital technology.

The UK skills shortfall needs even greater focus and investment in appropriate skills is required.

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