A Fourth Industrial Revolution?

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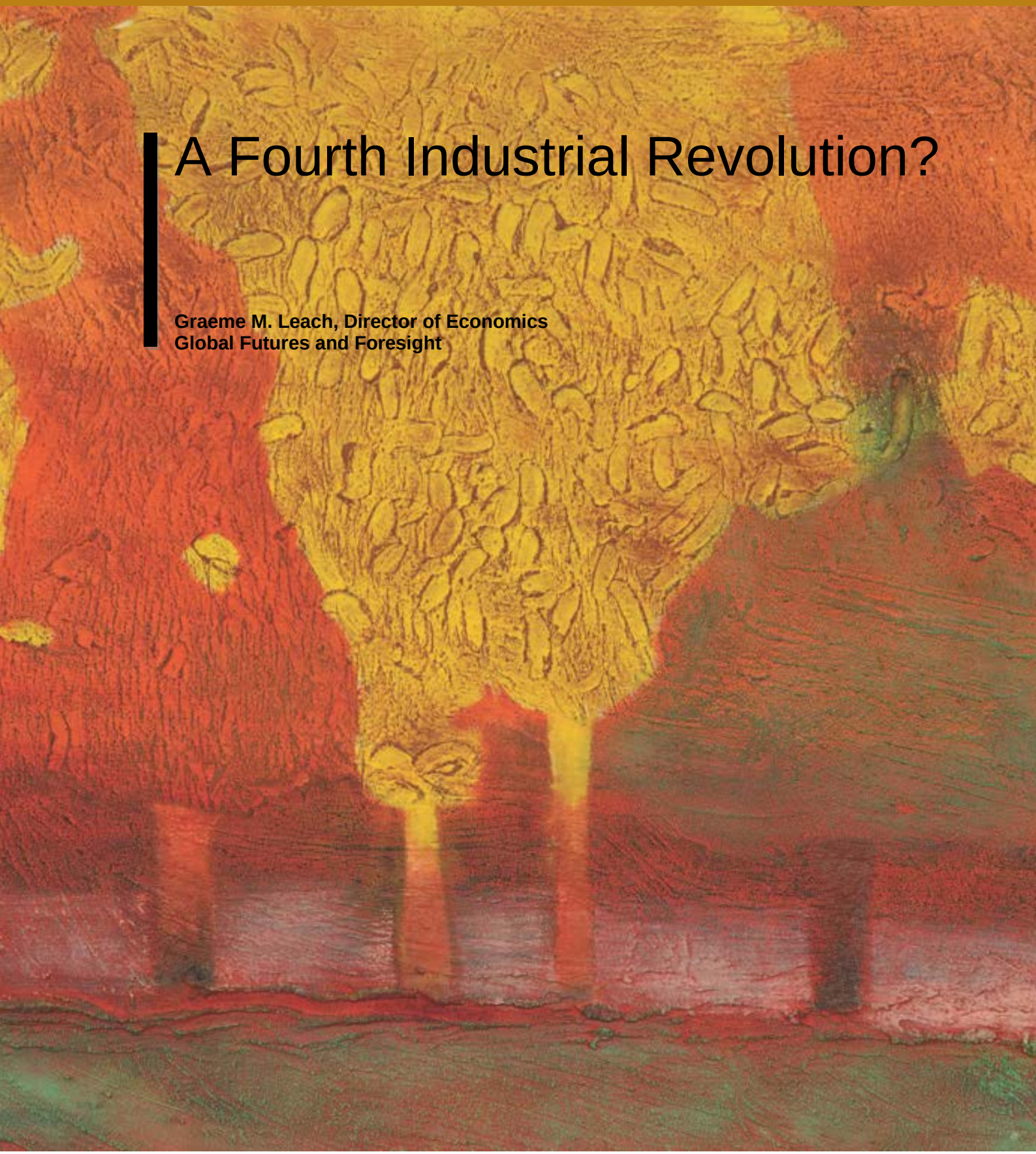

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Technology optimism and pessimism

A battle is raging in the war of ideas. The battle is over just how much technological change we can expect over the coming decades, and the impact this will have on business.

What makes the battle of ideas so interesting at present is the wide spectrum of views. The debate is highly polarised, partly because economists and technologists are talking past each other. Economists tend not to fully understand the technology and its potential, and technologists tend not to understand the economics.

Moreover, envisioning the future is no easy task. Linear extrapolation of the present and the past has a poor record – you end up in a world of personal jet packs. But exponential extrapolation is fraught with difficulty as well, with a reluctance as humans, to envisage faster and faster change. However, Moore's Law (whereby computing complexity, as measured by the number of transistors on an integrated circuit, doubles every 2 years) suggests the impact of technology may be closer to exponential than linear extrapolation.

Writing for the World Economic Forum (WEF)[1] Charles Schwab has stated that, *"We are at the beginning of a revolution that is fundamentally changing the way we live, work and relate to one another. In its scale scope and complexity … the Fourth Industrial Revolution is unlike anything humankind has experienced before. We have yet to grasp fully the speed and breadth of this new revolution."*

The list of future technologies which could combine to create a Fourth Industrial Revolution is breathtaking: Artificial intelligence, robotics, autonomous vehicles, 3D printing, nano-technology, biotechnology, materials science, energy storage and quantum computing. Specific technologies, such as Blockchain, display vast potential for transforming how we do business.

Table 1 **Fourth Industrial Revolution Technologies?**
Internet of things – everything connected to everyone.
Artificial intelligence
Robotics
Nano technology
Autonomous vehicles
New materials
Energy storage and superconductors
3D printing
Automation
Biotechnology and genome sequencing
Payments revolution and Blockchain

[1] *The Fourth Industrial Revolution*, Charles Schwab, World Economic Forum, 2016.

Newsweek magazine[2] has written that: *"each [technology] will be huge by itself. Together they will swirl into a roaring tornado, blowing down industries and institutions in its path."*

Perhaps most significant of all, will be the development of artificial intelligence. Huge resources are being channeled into AI research by leading companies (IBM has Watson, Apple has Siri, Amazon has Alexa, together with large research laboratories by Google, Facebook and Microsoft) and venture capital start-ups.

All these research programmes are very much rooted in potential reality. Companies are not investing in science fiction fantasies. They're researching to make money.

There is an excitement among optimists about potential Fourth Industrial Revolution technologies for 2 reasons:

- Firstly, because of the potential for the individual technologies, in and of themselves.

- Secondly, because of the potential combined effect of these technologies feeding off each other, creating exponential potential.

One might also add that the excitement is added to by the potential for human flourishing that comes in the wake of greater prosperity. In his book, *The Rational Optimist*, Matt Ridley[3] has pointed to the long-term economic gains produced by new technology raising prosperity. Around 1900 the average American had to spend three-quarters of their income on food, clothing and accommodation. Fast-forward a century and the proportion falls to one-third.

Ridley also highlights how an average worker in 1900 had to work around 5,000 hours to afford to buy a Model T Ford. Nowadays an average worker has to work around 1,000 hours in order to buy an average car, which is immensely superior in quality.

In sharp contrast to the optimists, pessimists also point to economic arguments and argue that the impact of digitization, has been seen and gone. Pessimists acknowledge there was faster productivity growth in the USA in the late 1990s and early 2000s, but then point to its absence thereafter. This is a modern day rehash of the famous phrase from the Nobel Laureate economist, Robert Solow, that he could see computers everywhere but the productivity statistics. A central argument of this paper is that whilst the productivity test has been failed thus far, that does not mean it is the end of the story. Moreover there are some serious measurement issues which need to be incorporated into how people's approach to, and methods of working, have changed over the decades.

Central to the debate is the issue of general-purpose technology (GPT). GPT are technologies (such as steam power and electricity) which impact the entire economy and change the structure of business and society (see Table 2).

[2] *The Robot Economy*, Newsweek, 9th December 2016.

[3] *The Rational Optimist*, Matt Ridley, 2011.

Table 2 **Industrial Revolutions: Past, present & future**			
1st Industrial Revolution	**2nd Industrial Revolution**	**3rd Industrial Revolution**	**4th Industrial Revolution?**
Late 18th to mid 19th century	Late 19th century to around 1970	1970 +	Now to 2040?
Steam engine and railways.	Electricity, internal combustion engine, telephone, television, chemicals and plastics.	Simple digitization, information technology, telecommunications and computing.	Complex digitization, Internet of things, artificial intelligence, robotics, nano-technology and genetic engineering.

Mild optimists in the debate are those who assert that we are seeing some form of GPT effect, but that it is not captured in conventional economic statistics[4]. The obvious examples are Google and Facebook, where advertising revenue will be captured in official statistics, but the value of surfing the web, creating content and communicating with others free of charge, will be missed.

Further to the right of the optimism-pessimism spectrum stronger optimists argue that the scale of the GPT effect will be so great, we are on the cusp of a Fourth Industrial Revolution. To quote Winston Churchill, "*Now this is not the end. It's not even the beginning of the end. But it is, perhaps, the end of the beginning."*

This has been described as the Second Machine Age[5], and an inflection point where the full force of digital technologies could be seen.

Digital technology with computer hardware, software and networks, is hardly something new. But the potential difference now is the level of sophistication and integration, and we are only just beginning to realize the intellectual implications of this revolution. The difference between a GPT effect and a Fourth Industrial Revolution is largely determined by scale and intensity:

Pervasive impact (width) – An impact across the whole of business, with a general-purpose technology effect e.g. electricity.

Profound impact (depth) – An impact on the structure of companies, challenging existing structures and business models.

[4] There are also problems in quantifying intangibles such as software and brands, both of which are core assets in the new economy.

[5] *The Second Machine Age: Work, Progress and Prosperity in a Time of Brilliant Technologies*, A McAfee and E. Brynjolfsson, 2014.

The Singularity

There is an even more optimistic school of thought attached to the idea of the singularity.

The economic singularity is said to occur when we reach the point of abundance for all, a genuine leisure society and the complete automation of work[6]. This is a utopian nirvana of increasing returns and massive technological change, where exponential growth in computing power leads towards a utopia, when advances in artificial intelligence and computing exceed human intelligence, with exponential growth and an age of abundance the result.

One of the central tenants of the uber optimism school is that the sum will be greater than the parts, that the interaction between Fourth Industrial Revolution technologies will have a pervasive and profound effect, creating an exponential environment.

The impact of exponentials is illustrated by the following[8]: *"Imagine that you stand up and take 30 paces forward. You would travel around 30 metres. Now imagine that you take 30 exponential paces, doubling the length each time. Your first pace is 1 metre, your second is 2 metres, your third is 4 metres and so on. How far do you think you would travel in 30 paces? The answer is, to the moon. In fact, to be precise, the 29th pace would take you to the moon, the 30th pace would bring you all the way back."*

Utopians foresee the coming decades delivering more progress than the combined effects of the 1st, 2nd and 3rd Industrial Revolutions - over the past 200 years – put together. In 1930 John Maynard Keynes, the famous economist, thought we could all be working no more than 15 hours per week by 2030.

For the purposes of this paper we will leave aside the singularity. It appears highly improbable[7]. The concept has triggered intense debate but in our view remains much too far-fetched, on any timescale relevant to business today. What isn't too far-fetched however is the idea that GPT effects could be so great, the coming decades could mark the Fourth Industrial Revolutio

The impact of exponentials explains the enthusiasm for concepts such as the singularity. And whilst we don't subscribe to the idea of a looming singularity, it does suggest how powerful Fourth Industrial Revolution technologies could be when they complement each other. Even if a singularity remains a distant dream, there could still be faster technological change than ever before.

Amara's Law states that we tend to overestimate the impact of technology in

[6] Technology optimists can be optimistic or pessimistic about the economic impact of technological change e.g. an age of mass unemployment attributable to technology, with a very wide distribution of income, versus the leisure society and a universal basic income for all.

[7] Recommended business books on the future impact of technology are: *The Inevitable: Understanding the 12 technological forces that will shape our future* (Kevin Kelly, 2016), *The New Digital Age: Reshaping the future of people, nations and business* (Eric Schmidt and Jared Cohen, 2013), *The Industries of the Future* (Alec Ross, 2016), *Abundance: The future is better than you think* (Peter Diamandis and Steven Cotler, 2012), *The zero marginal cost society* (Jeremy Rifkin, 2014).

[8] *The Economic Singularity*, Calum Chace (2016).

the short-term and underestimate the impact in the long-term[9]. Optimists argue that we are underestimating the long-term impact of technology on business and the economy, because of the difficulty articulating the complex future interaction of technologies.

So whilst pessimists might argue that there is little or no evidence to date of a GPT or Fourth Industrial Revolution effect on productivity, optimists would reply be patient, it won't be long.

One example illustrates the scale of potential change. Newsweek[10] recently reported that McKinsey predicts that within a decade, one third of trucks on US roads will drive themselves.

Such predictions strike fear into the hearts and minds of many, but they shouldn't. 40 years ago most petrol stations in the United States and the UK had an attendant at the pump to fill your car. 40 years later the attendants have virtually all disappeared. Petrol stations have transformed over recent decades, in terms of the quantity and quality of the services they provide. Few people nowadays would want to go back to the old model.

Here and now

Eric Schmidt (Executive Chairman, Google) and Jared Cohen (Director, Google Ideas), in their book, *The New Digital Age: reshaping the Future of People, Nations & Business*, show that the impact of Fourth Industrial Revolution technologies is not some fanciful, imaginary, futuristic world, but one very much rooted in the present and in the business plan of companies such as Google right now.

The 'Tipping Points' in Table 3 below shows the views (percentage agreeing) of 800 senior executives and technology experts - in a survey conducted by the World Economic Forum – on whether individual technologies will go mass-market over the coming decade.

Table 3, based on expert opinion, predicts profound and pervasive change not in 20 or 30 years, but within a decade. If you look at the individual technologies in Table 3 you very quickly realise 2 things:

- The sheer potential of the individual technologies.
- The immense societal change, which will be part and parcel of those innovations.

[9] Illustrated in the Gartner hype cycle curve, with technology overhyped in the short-term and underhyped in the long-term.

[10] *The Robot Economy*, Newsweek, 9th December 2016.

Table 3

Table 1: Tipping points expected to occur by 2025

	%
10% of people wearing clothes connected to the internet	91.2
90% of people having unlimited and free (advertising-supported) storage	91.0
1 trillion sensors connected to the internet	89.2
The first robotic pharmacist in the US	86.5
10% of reading glasses connected to the internet	85.5
80% of people with a digital presence on the internet	84.4
The first 3D-printed car in production	84.1
The first government to replace its census with big-data sources	82.9
The first implantable mobile phone available commercially	81.7
5% of consumer products printed in 3D	81.1
90% of the population using smartphones	80.7
90% of the population with regular access to the internet	78.8
Driverless cars equalling 10% of all cars on US roads	78.2
The first transplant of a 3D-printed liver	76.4
30% of corporate audits performed by AI	75.4
Tax collected for the first time by a government via a blockchain	73.1
Over 50% of internet traffic to homes for appliances and devices	69.9
Globally more trips/journeys via car sharing than in private cars	67.2
The first city with more than 50,000 people and no traffic lights	63.7
10% of global gross domestic product stored on blockchain technology	57.9
The first AI machine on a corporate board of directors	45.2

Source: *Deep Shift – Technology Tipping Points and Societal Impact,* Global Agenda Council on the Future of Software and Society, World Economic Forum, September 2015.

The gap between the optimists and pessimists essentially boils down to a debate between simple and complex digitisation. Simple digitisation is what we have experienced to date. To use an analogy, simple digitisation is the dots. Complex digitisation is joining those dots together.

It is not the purpose of this paper to examine in detail the range of technologies that are expected to work together to create a GPT effect and a Fourth Industrial Revolution. Rather the intention is to provide a framework within which to judge potential future change.

For those interested in a non-technical guide to future technologies, *The Fourth Industrial Revolution*[11] from the World Economic Forum is recommended reading. Readers may also find *The Economic Singularity* useful[12].

[11] *The Fourth Industrial Revolution*, Charles Schwab, World Economic Forum (WEF), 2016.

[12] *The Economic Singularity*, Calum Chace, 2016.

The Fourth Industrial Revolution is underway, but we are only seeing the beginning of it. Other factors as well are playing out, creating what might be loosely described as a pause in revolutions, between the end of the third and the beginning of the fourth. This shouldn't surprise because even an exponential curve can be flat before it rises rapidly.

The pause

The argument that the Fourth Industrial Revolution is only just beginning, that we are approaching an inflection point, is based on:

- One of the characteristics of a general-purpose technology is the lag between the development of the new technology, and its maximum impact on the economy. Looking back at economic history, one finds that the full impact of steam-power on the economy didn't emerge until almost 100 years after its invention by James Watt in 1769. In the case of electricity, the maximum effect on productivity wasn't felt until the 1920s, around 40 years after its invention.

- The impact and legacy of the financial crisis. In an environment of extraordinary monetary policy, zero interest rates and the shrinkage of bank balance sheets, these cyclical effects are likely to swamp the early stages of underlying structural change.

- Previously stated issues regarding problems of measurement. In other words statistics which more accurately reflected how we lived, worked and what we did with our working and leisure time would show greater evidence of a Fourth Industrial Revolution already. One of the obvious areas is business investment in an environment where fixed capital investment is increasingly focused on intangibles such as software.

Joining the dots

Here are 10 reasons why we think the pervasive and profound impact of technological change amounts to a GPT that could well result in a Fourth Industrial Revolution:

Exponentials - The idea that the bringing together of new technologies has thus far only scratched the surface in terms of its impact on business and society. The networked world has developed a global computing cloud, moved our shopping, friendships, work and entertainment on-line. As complex digitization widens its reach, these examples will provide role models and a springboard for even more. Artificial intelligence will itself take over new technology and innovation from humans.

Disruption – The idea that your biggest competitor doesn't yet exist, and new business models will emerge, as in the so-called sharing economy, where under utilized assets are monetized. The largest taxi company in the world (Uber) owns no taxies. The largest hotel provider (Airbnb) in the world owns no hotels. The most valuable retailer in the world (Alibaba) owns no inventory. At the same time, companies can go from hot to not with startling speed, just ask the investors in Nokia, Blackberry or Yahoo. Incredible amounts of corporate volatility are the new normal. Countries could become disruptive as well, or at the very least create the ITC infrastructure under which their

companies could rapidly become so. In 2015 Sri Lanka signed an agreement with Google, to become the first country with blanket wi-fi coverage.

Moore's Law – In very general terms Moore's Law refers to the computing power of $1,000 of kit doubling every couple of years. In 2015 Moore's Law celebrated its 50th anniversary. There is a debate over how long this will continue, and whether or not it has slowed in recent years. The consensus appears to be that it hasn't slowed, and that 3D chips and new architecture will sustain it into the future. An IPAD of today has the processing power of 5000 computers when this author started work. The cost of 1Gb of storage is essentially zero today, whereas 20 years ago it cost around $10,000.

Service & manufacturing sector impact – The Fourth Industrial revolution is likely to impact the service sector as much as manufacturing. The difficulty in improving productivity in people centered activities is long recognized (e.g. in the case of health and education and so-called Baumol's Disease[13]). But Fourth Industrial Revolution technologies display a real potential for overcoming these difficulties. In manufacturing the potential is similarly radical, with the possibility that 3-D printing radically bringing down the cost of manufacturing, with the result that such manufacturing moves closer to the end developed economy consumer.

Business models – How do you create value added in an economy where price equals marginal cost, and marginal cost is often near zero? One alternative business model is fixed fee then free e.g. Spotify. Many business models in the new economy flip the conventional mix between capital and current expenditure, because of near zero marginal costs. However, it is also the case that many new companies develop with modest injections of capital, such as Instagram and WhatsApp. Lower costs of entry present huge challenges. The costs of entry are software and brand recognition. On the demand-side network externalities mean that one person's demand depends on how others use it. This can mean that when significant market share is acquired, such companies can be difficult to budge, at least until the next technology development comes into play.

Intensity – Friction free capitalism, joining buyers and sellers and lenders and borrowers, on-demand real-time, and a shrinking global village due to the death of distance and language. Rates of progress to date suggest the ability to listen and speak in any language, with automatic translation, will be a reality within a decade. Image, speech and language recognition are improving at a rapid pace.

The big picture – Accelerating technological change and interconnectedness are not the only big picture forces at play. 4 key global drivers of disruption are generally identified: accelerating technological change, greater interconnectedness, mass urbanization and demographics. The scale of these big picture changes is magnifying and intensifying the external environment under which companies are operating e.g. it is estimated that around half of global GDP growth between 2010 and 2025 will come from 440 cities in emerging markets[14]. The shift in the global economic centre of gravity is occurring

[13] Where wage rises are not tied to any productivity gains.

[14] Source: McKinsey Global Institute.

simultaneously with profound technological change.

Virtual workers – This is a world where driverless cars refuel while you sleep, augmentation and digital assistants monitor your every move and artificial intelligence anticipates your next move. IBM's Watson supercomputer already recommends tailored treatments for cancer. The Laundroid robot can already fold a shirt in 4 minutes. Some US hotels are examining the use of robots to fold and deliver towels.

Platforms – The top digital brands are platform orientated. The global Apps market reached $100 billion in 2015, bigger than the global film industry, and only started in 2008.

Velocity – Advances in ITC, together with ubiquitous social media, speed up the dissemination and reach of new ideas. Future developments in transformational technologies are likely to speed up connectivity, connexity and connectography - shrinking the global village. The future is happening sooner than we think. In 1997 this author wrote a report[15] on life in 2020. All the suggested technological developments were actually achieved by 2010.

The importance of agility

Economists and politicians have all too often concluded that productivity is the most significant indicator of future prosperity. However, this could be described as a proximate, or indirect, indicator, whereas the most important focus should be on ultimate indicators, such as agility.

The difficulty with focusing on productivity is the emphasis it places on incremental change. In the Fourth Industrial Revolution, radicalism not incrementalism will win the day. Mastering entrepreneurship not managing mature processes, will become much more important, in a world of disruptive change. We are already seeing that openness to new products and processes and the rapid assimilation of innovation are vital

The idea of a River of Prosperity[16] helps explain the importance of agility in exploiting future technological potential. The River of Prosperity examines prosperity as a function of upstream and downstream sources. The further downstream you go, the more proximate are the drivers of economic growth. The further upstream you go the closer you are to the ultimate sources of growth.

Productivity and competitiveness are seen as downstream sources. Mid-stream sources are the role of institutions, which in this context are the rules of the game such as tax and regulation. Upstream is the ultimate cause, which is culture. Culture is best understood as attitudes, beliefs and values, and as business guru Peter Drucker is reputed to have said: *"culture eats strategy for breakfast".* This difference between upstream and downstream sources of growth has profound implications for GPT and the Fourth Industrial Revolution.

A culture of openness and willingness to embrace change will be critical to the future development of Fourth Industrial Revolution technologies.

[15] *2020 Vision*, The Henley Centre, 1997.

[16] Developed by: Global Futures & Foresight.

Conclusions

We are increasingly seeing signs of a new industrial revolution, moving on from the first steam revolution, the second electricity revolution, the third electronic and automation revolution, to now, the fourth information and intellectual revolution.

Ultimately, long-term growth and prosperity are going to depend on the ability of individual businesses, and broader economies and societies, to embrace the Fourth Industrial Revolution.

The difference between a general-purpose technology (GPT) effect and a Fourth Industrial Revolution is the breadth (pervasive) and depth (profound) of technological change.

In the Fourth Industrial Revolution agility will be up front and central. This will be a world where disruption and radical change will be more important to success or failure than incrementalism and productivity growth. Openness to new products, processes and business models, together with the rapid acceptance of innovation, will be key.

The Fourth Industrial Revolution has been enabled by the spread of information technology, but its impact is going to be because of how it deals with information and the intellectual analysis of that information.

This hinges on simple versus complex digitisation. To use an analogy, most of the digital revolution to date could be described as the dots. The digital revolution to come could be described as joining the dots together.

About the author

Graeme Leach is Director of Economics at Global Futures and Foresight. He is one of Britain's leading economists and a former Chief Economist and Director of Policy at the Institute of Directors (IoD), where he was also a member of the Board. Graeme represented the IoD in economic discussions with the Chancellor and 10 Downing Street. He is a visiting professor of economic policy and a senior fellow of the Legatum Institute in London. He is also a member of the IEA Shadow Monetary Policy Committee (SMPC).

Graeme has spent a lifetime in economics, futures and foresight, having started his career at The Henley Centre for Forecasting.

Over recent decades Graeme has made 100s of speeches on the future economy and megatrends, in more than 25 countries across the globe.

Graeme has also undertaken 100s of live television and radio interviews on BBC News, Sky News, Radio 4's Today Programme and others. Over the past 5 years he has written a weekly column for the City AM newspaper and numerous articles for the Daily Telegraph.

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About Global Futures and Foresight

Global Futures and Foresight is a research and consulting firm that helps organisations be better prepared to embrace change, innovate and develop new strategies and solutions and helps clients to avoid the risk of being blindsided by external disruptive change.

The GFF has been engaged by some of the most prestigious firms from around the world including: The European Commission, NATO, BBC and financial services firms including HSBC, Lloyds/TSB, Atom Bank, RBS, Lloyds, More Than, e-sure, Travelers, Allianz, QBE and Lloyds syndicates along with many other prestigious firms including CSC, Unisys, Cisco, Microsoft, Siemens, Deloitte, Ernst & Young, PWC, Linpac, Kraft, Heinz, John Lewis, Roche, Philips, Ogilvy etc. He is also a regular lecturer at business schools across Europe.

The GFF is a Futures Framework supplier of futures methods and insights to the UK government via the Department for Business, Energy and Industrial Strategy.

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About Marcela Lopez, Artist (Front cover by Marcela).

Marcela Lopez, Colombian artist with European influences based in UK. Commissions and artwork for sale. My subject matter is landscape. Using my hands I choose plaster to capture the movement of water and trees on wooden boards. Through my artwork I intend to invite viewers to a peaceful moment of reflection. I see my artworks gently brightening up any space and being a source point of serenity and com