CONNECTED THINKING

ANALOGIES AND MODELS

CORRELATIONS

ANATOMY OF AN INVESTMENT IDEA

WHY CITIES WIN OR LOSE

AIQ

ISSUE 010

LINK

The power of connected thinking

AVIVA INVESTORS

Together Stronger

Economist W. Brian Arthur described the machine power of the Industrial Revolution as a trigger for the economy to develop a muscular system. Now, in the age of the digital revolution, he sees it developing a neural system – adding a brain to the brawn. His metaphor is powerful and clever. More to the point, it embodies the focus of this edition of *AIQ:* Connected thinking.

The world is increasingly connected and complex. In our cover story, we explore why understanding the links between people and ideas is critical to success, in everything from business to financial markets. This requires creativity and diversity of thought – but that is easier said than done.

Analogies, metaphors and models can allow us to think about problems differently: to understand them more clearly and come up with novel solutions. To help us understand the thinking behind connected thinking, we interviewed leading experts in the field, including David Epstein, Dedre Gentner, Scott E. Page and Carl Benedikt Frey. Meanwhile, Marte Borhaug from our responsible investment team unravels the complications inherent in trying to do the right thing.

The rest of this issue considers how connected thinking can be used to improve our understanding of economies and markets which, in theory, should lead to more informed investment decisions. With seemingly not a week going by without some escalation or receding of the threat of a US-China trade war, we take a closer look at why global supply chains and geopolitics are hard to untangle.

In other articles, we look at how the changing nature of correlations between and within asset classes influences how asset managers manage money; why connected thinking helps to explains the cities winning – and losing – the battle for capital and talent; the rise of automation; and whether the public, private and third sectors can work in tandem to solve the world's most pressing problems. We also take a visual approach to explain how connected thinking can be applied to 5G and blockchain.

We welcome your feedback, so please send any comments to me at the email address below.

I hope you enjoy the issue.

Rob Davies,

Head of PR and Thought Leadership, Aviva Investors

AIQ Editor

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ANALOGIES AND MODELS: TWO APPROACHES TO THINKING CONNECTEDLY

In an effort to understand how best to approach idea generation and collaboration, two critical components of successful investing, *AIQ* speaks to leading academics in the fields of analogical and model thinking.

To make sense of complex situations, using and contrasting multiple models that complement each other's "blind spots" is extremely powerful. But to spark the insights that allow us to identify hidden patterns, we have yet to find a better tool than the human brain to draw analogies.

In this article, *AIQ* looks to uncover the secrets of how we approach idea generation and collaboration to maximise the efficiency and effectiveness of output. Contrasting two approaches, we speak with Dedre Gentner, professor in the Department of Psychology at Northwestern University and a prominent researcher in the study of analogical reasoning, and Scott E. Page, social scientist and John Seely Brown Distinguished University Professor, Ross School of Business, University of Michigan, and author of *The Model Thinker*.

Gentner contends that using analogies enables us to identify commonalities in relationships between two sets of different objects. This can uncover new insights, and is at the heart of scientific discovery and, more broadly, areas based on a search for knowledge and understanding. It is crucial in helping us make sense of the world's complexity by identifying hidden relationships.

In *The Model Thinker*, Page takes a broad definition of models, from the intuitive mappings we make in our minds to formal mathematical models and machine-learning algorithms. Page argues we can use this diversity to explain the multiple dimensions of complex phenomena, fully exploit the vast amounts of data at our disposal and make better decisions, in an array of business, policy, academic and human fields.

DEDRE GENTNER
THE ANALOGICAL THINKER

You have been working in this field for over three decades. How did you get into it?

Having started in maths, I ended up graduating in physics. I then discovered the field of psychology which I studied in grad school at UCSD. It was fantastic. We worked on the nature of how people represent and process knowledge. My topic was analysing verb meaning. Playing with verbs makes you realise they really are institutionalised analogies. For example, many verbs have abstract meanings as well as concrete meanings (e.g. "Fred gave Ida a vase / an idea / a hard time").

Studying the way language works, I kept running into this notion that one of the things humans do superbly well is see relational patterns across different domains. We first learn something in a concrete way, but then we map it repeatedly to other things.

I was also influenced by my undergraduate work in maths and science. For example, in abstract algebra, you can map a structure from one domain to another. And in science, I had noticed that many new discoveries are made by analogy. That is where structure-mapping came from – synthesising work on verbs with work on how scientists create new ideas, and how mathematicians map functions across domains.

In structure-mapping theory,[1] you talk about structural alignment. Can you explain this?

Structural alignment refers to our ability to match two situations based on their common relational patterns, even when the concrete details are different. For example, if I ask people what is alike between "Martha divorced George" and "Wallcorp sold off Acme Tires", they say, "they both got rid of something they no longer wanted". The fact that Martha is totally different from Wallcorp doesn't faze people; we can align two situations based on abstract relational patterns. A great thing about structural alignment is that even when people have weak or incomplete models of both topics, when we compare them the common relational pattern will often leap out. This is what frequently happens in scientific discovery. Analogical comparison can uncover an idea you didn't have before, which might change the way you think about both notions.

What are the dangers of analogical thinking?

All analogies break down at some point, so if you want to reason with analogies, you should think about the differences as well as the commonalities. The more you articulate what matches and what doesn't, the better you can use the analogy for explaining and making predictions.

How should we use them to think about relational structures?

If we say, "tigers are like lions", it is useful, but when there are so many commonalities the relational pattern will not emerge. In contrast, when I say, "lawyers are like sharks", they do not share anything superficially, so the only thing you can infer is something like ferocious predators.

That has some big advantages. First, it allows you to understand something you have nothing familiar to compare it with. Second, even if you do, it is better to compare it to something different, because that will let you inspect the relational pattern in a way that is very hard if things share all kinds of other commonalities.

Does your work give a steer on whether it is better to be a specialist or generalist?

There's a role for both specialists and generalists, but I would say it's best to combine these two extremes. It's great to know some area well enough to go deep; but it's also good to have knowledge and curiosity about lots of other areas. Creative analogies very often come from seeing patterns across different domains, and this requires curiosity beyond just one specialised domain.

In the world we live in, we constantly face new issues. What we already know is not good enough to rely on for all the situations that come up. You have to be sensitive to recurring relational patterns.

How can individuals and organisations get better at tapping into analogical thinking?

For individuals, I would say learn all you can, not just in your own domain but in other areas as well. For organisations, I would say make sure teams include people with knowledge from different areas – you will not get as many interesting analogies if everyone has the same background.

For both individuals and organisations, I would suggest a two-stage process. First, encourage analogies and be open to playing with them, but in the second stage, apply your critical thinking; articulate the common principle and pay attention to differences. If something doesn't fit, say, "Wait a minute. We predicted that. What is going on?" You don't want to immediately shoot an analogy down, but eventually they all have to account for themselves.

ANALOGIES AND MODELS
continued

An analogy I like to use is that most mutations are lethal, and so are most analogies. As long as you are critical, it shouldn't be an issue, so in addition to being open to analogies, you also need to think them through. What are the inferences? Are there critical differences? Do they make nonsensical predictions? It's a bit of an art-form, really. Every kind of creative thinking has to involve critical thinking as well as generative thinking.

What is the next frontier of your focus?

There are quite a few. I am working on whether analogical processes occur in young infants (the answer seems to be yes); and on whether learning language changes the kinds of analogies we can process. I am also working on how to help children be better at relational thinking. There is a big difference here between children who succeed academically and those who fail; I think we can help all children be better at analogical thinking.

I'm also interested in how analogical processes influence the history of language and culture. With my colleague, Kensy Cooperrider, I just wrote a paper on "the career of measurement". Historically, people used to measure dimensions in context-specific ways – for example, measuring the length of a field in ox lengths but the depth of water in rope lengths. Over the centuries, through comparing and aligning units, we gradually formed abstract systems where the same terms (such as metres or miles) can be used regardless of context.

This is another case where we first learn things in a concrete way and make them less concrete by comparing them. In general, we start with concrete knowledge; then we make ourselves smarter by the comparisons we make and the language we apply to them ●

SCOTT E. PAGE
THE MODEL THINKER

How do models help us understand the world around us?

Let me give an example, on Amazon's recent decision to relocate.[2] Amazon could think about minimising shipping costs, but also labour-market geography, long-term potential growth areas… Amazon looked at it six ways to Sunday. Yet it forgot to look at a simple model of the potential political response, and the decision backfired. That's an example of coming up one model too short.

Can you briefly explain the REDCAPE uses of models?

There are seven core reasons to model. The first is to *reason*, to nail down the logic of a phenomenon. Similarly, we use models to *explain* phenomena or patterns. We can also use them to *design* things, take *action*, *predict* and *explore*. The final reason is to *communicate*, and this is what makes models so powerful. Models are of tremendous value because they allow us to articulate what we mean.

In a recent Harvard Business Review article, you mention using models to "spread attention broadly, boost predictions and seek conflict".

I wrote the article in the context of using artificial intelligence for hiring decisions. Some firms get hundreds of thousands of applicants for maybe 5,000 to 10,000 positions. One way to deal with it is to train a model to predict simple metrics like the first-year job rating or long-term success rate.

An approach to boost those predictions is the "random forest". Starting with one model of many decision trees, you test it to find which cases it would get wrong. You then create another model that only focuses on those blind spots.

Another possibility is to take a different approach entirely. Imagine that out of 70,000 employees, 100 are superstars. Could you predict those? You wouldn't want to hire everyone based on this, but if one candidate falls just short of other criteria yet is the most likely out of a million to be a superstar, you would be crazy not to hire her.

Effective analogies and model thinking require breadth and diversity

Using a single criterion will give you very similar people, while using many models will focus on different dimensions. And once all the data is coded in, it is not that expensive to construct additional models. Once you have the data, you want to array it on a lattice of models.

In The Model Thinker, you wrote: "Policy choices made on the basis of single models may ignore important features such as income disparity, identity, diversity and external interdependencies." Is this what we are doing with the Paris Agreement target to reduce CO2 emissions rather than taking on a broader, more complex view?

Something I talk about in the book is Campbell's Law, which says that as soon as you try to base policy on a metric it will no longer work because people figure out workarounds. It is obviously better to have CO2 restrictions than not, but will companies find other ways of polluting – that don't emit CO2 but maybe produce something else with just as bad an effect? If there are other ways to produce energy or create production processes, will that compensating behaviour negate the effect of the CO2 restriction?

On the other hand – and potentially this is another model – once you place large costs on CO2 or other greenhouse gases, you create huge incentives for innovation. Once incandescent bulbs became illegal, all of a sudden there was this amazing level of innovation. Previously, lightbulbs were so cheap it made no sense to try and innovate.

You advocate the use of multiple models to get the "diversity bonus" out of them. Can you give us a brief introduction to this concept?

Two people with the same training and experience will think about the world in similar ways and their predictions will be correlated. Here is where diversity delivers this big bonus. If we add someone whose predictions are not as good but are negatively correlated to the others, the collective prediction will be much better.

With models, the key question is figuring out the right ensemble. What you want is models that get different things wrong differently.

How can the use of multiple models bridge gaps between different points of view?

As an example, no one knows what will happen to the economy 30 years out. Any one person will likely be horribly wrong, so, in addition to using many models to make an average, you can use many models to define a set of bounds, to get a sense of worst and best case. There is a real robustness advantage. Ideally, you would like to use the models with the best measurements of facts but maintain the diversity of conjectures.

What about the availability of quality data?

If Big Data is what can be gathered from the web, there is also richer, thick description data from observing and interviewing people, which shouldn't be overlooked now that Big Data is so cheap. If anything, qualitative data is now far more valuable.

Going back to where we began, think about how job interviews have changed. Typical questions used to be, "Where did you go to college? What's your grade-point average?" That is now a waste of time because an algorithm has already taken it into account. That frees interviewers to focus on different things, like the ability to think on one's feet ●

AIQ SAYS

Thinking about thinking is hard work. However, analogies and models are tools that help us every day. Given that investing is about understanding the world and making sense of where things may be headed, any improvements we can make are worthwhile.

The power of analogies lies in the nature of language. They enable complex information to be communicated more easily and help us reach new levels of understanding. By making creative connections, they allow us to see things anew, to uncover patterns and new relationships.

Models are more formal and systematic. Multiple and diverse models allow complex data sets and problems to be analysed from a broader array of perspectives, thereby improving procedural rigour and – hopefully – leading to more intelligent decisions.

In this sense, it is no coincidence that effective analogies and model thinking require breadth and diverse thinking, both at the individual and group level. In an uncertain world where complexity abounds, we cannot afford to ignore their significance ●

1 The basic idea of Gentner's structure-mapping theory is that an analogy is a mapping of knowledge from one domain (the base) into another (the target) which conveys that a system of relations which holds among the base objects also holds among the target objects. Thus an analogy is a way of noticing relational commonalities independently of the objects in which those relations are embedded. Source: Northwestern University; see also Gentner, "Structure-mapping: A theoretical framework for analogy," Cognitive Science, 7, 155-170, 1983.

2 Amazon's initial decision to locate its second headquarters in Queens, New York received a huge political backlash. It eventually settled on Bellevue, Washington.

THE MORAL PHILOSOPHER'S CURSE

Marte Borhaug explores the ethical dilemmas and unintended consequences that can result from trying to do the right thing.

> *At times I feel as if I need a degree in moral philosophy*

A package arrives in the post. A surge of dopamine courses through me: my expectations for this delivery are high. It should be a source of delight and pride, the result of endless hours researching the sustainability of straws. Aware I should get out more, I am nevertheless proud of having trawled through the maze of information regarding suppliers and materials in the weeks leading up to this moment. I feel confident no stone has been left unturned.

My confidence is misguided. I open the package and stare in disbelief. To my horror I find the plastic-free straws are wrapped in – yes, you guessed it – plastic! Worse still, despite assurances to the contrary, I find they have travelled thousands of miles, crossing continents to reach my door. Their carbon footprint alone is akin to that of the average citizen of a small country for a whole year.

This story is not meant to garner pity. It is merely another example to add to the moral scrapheap of decisions I have made; another example of the complexity involved in trying to do the right thing. I could have easily picked another, like the challenges I faced trying to go vegan.

My job requires me to think deeply about such matters. It can be overwhelming. At times I feel as if I need a degree in moral philosophy – or at least a sturdy handbook – to ensure I stay within the tramlines of good behaviour. But it is these moral dilemmas that should anchor our professional conduct; we should not shy away from them. Checking personal values at the office door will not end well. If we do, there are deeper issues at play – we should seriously question whether we have found the right match.

The rabbit holes of misinformation, cognitive overload and unintended consequences

Part of the problem is we have never had to measure the consequences of our actions as a species until now, because there have never been so many of us. Had the first million humans invented plastic, they would not have had to deal with the same fallout as 7.7 billion.[1] Everything we now do can add to our footprint and we have to think hard about our choices. While in theory the right information and data exist to help us make sensible choices, all too often our view is obscured by reams of irrelevant and distracting diversions.

This is one of the challenges of living in a complex world. As soon as we look a fraction harder, it seems almost every action we take to reduce our impact trails a host of unintended consequences in its wake. A combination of two forces are at work: some of our actions can lead to unintended harm, while in other cases it is a question of choosing between two goods – or the lesser of two evils – like meat versus avocados.

When it comes to the environment, worrying about the big picture of climate change can make us lose sight of smaller, closer effects, such as the loss of local wildlife that is happening irrespective of climate change and which can wreak havoc with our ecosystems in the long run, as Jonathan Franzen argues with passion in a much-discussed *New Yorker* article.[2]

This is not just a personal battle. Staying with the theme of plastics, companies now need to ensure the supply chain of paper

Marte Borhaug
Global Head of ESG Investment Solutions, Aviva Investors

straws is itself sustainable and there is adequate infrastructure to recycle them. The push to ban plastic straws has become emblematic of our concerns around environmental damage, yet recent articles in *Wired* and *The Atlantic* both demonstrate the move needs careful consideration.[3,4]

There has always existed a delicate interplay between manufacturers and consumers. Ultimately, the former are subservient to the latter, as we can vote with our respective wallets and make our feelings known through the corporate balance sheet. We all need to take more responsibility and technology will undoubtedly provide us with some wayfinding tools, like CoGo, an app that helps me choose companies, coffee places and restaurants that align with my values.

In search of the moral high ground

On a larger scale, Kenneth Rogoff recently lamented the World Bank's decision to stop funding new fossil-fuel plants, including natural gas.[5] The issue, even for emerging economies that are investing heavily in renewables, is that doing away with fossil fuels altogether will not allow them to meet their growing energy consumption. Cutting their funding for coal and gas plants would help reduce global greenhouse gas emissions but could restrict many countries' economic growth and affect the welfare of millions.

The big trade-off here is should the 'E' in ESG trump the 'S'? Even if it does, to what end should developed markets be made to pay for their previous plundering of the planet's precious resources? Even the most seemingly straightforward of questions can be riddled with ethical complexity.

Indeed, how you balance economic development and job creation with environmental protection was a question that stared our business in the face recently. We were considering a loan to a major state-owned company in Ivory Coast to fund improvements to an existing oil refinery. On the face of it, lending money to a country with a high risk of corruption, and to finance fossil fuels, sounds mad. Yet after extremely careful consideration, we went ahead with the loan.

First, there were robust guarantees, and Ivory Coast has been making real progress in tackling corruption. Second, the refinery already existed, and the improvements would help reduce its carbon footprint. But, more importantly, the project would create local jobs, and it was a key part of Ivory Coast's National Development Plan to improve the domestic economy and reduce its reliance on energy imports. As such, it aligned extremely well with the UN's Sustainable Development Goals.[6]

Economics yields another example. Following the global financial crisis, central banks in developed countries kept interest rates low in a bid to support jobs and growth. Yet while easy monetary policy allowed us to avoid a second Great Depression, an unintended consequence is that it has contributed significantly to income inequality by inflating the prices of assets (thus benefiting the richest) while wages have stagnated.

CEO pay, a source of visceral consternation among shareholders and the responsible investment community, provides yet another. Increased transparency on executive pay has turned out to be counterproductive. Comparisons between CEO compensation packages have driven up executive pay for years as CEOs have capitalised on the competition to attract talent.[7]

> *Even the most seemingly straightforward of questions can be riddled with ethical complexity*

THE MORAL PHILOSOPHER'S CURSE
continued

> *Being responsible should never be about creating an ethical straitjacket*

When you scratch below the surface, some 'no-brainer' notions become questionable.

Don't give up: Lessons from Thunberg, Pareto and Keynes

Frighteningly, some studies show that using "green" products encourages people to adopt less altruistic attitudes elsewhere.[8] This is the moral equivalent of going for a run and then consuming a tub of ice cream. And, whether conscious or unconscious, the implications of our collective behaviour for society are huge.

Other statistics are equally discouraging. Even if we stopped emitting greenhouse gases today, oceans would continue warming and rising for years.[9] Meanwhile, the energy we are adding to Earth's atmosphere in excess of what it can radiate out to space is equivalent to 400,000 Hiroshima atomic bombs a day, every day of the year.[10] If every action we take is likely to backfire in some way, it makes it even harder to turn the situation around.

But we shouldn't give up. It is precisely because these statistics are so alarming that even the smallest of our decisions becomes more important. We need to fight the paralysis that accompanies the sense of being overwhelmed.

Hearteningly, we already have a blueprint in the UN's Sustainable Development Goals. These have been carefully thought through to be mutually beneficial to all participants, and to support the planet and its inhabitants equally.

In my experience, issues tend to arise when governments, companies and investors think that things are simple and can be solved in a siloed way; for example, only tackling plastic waste, taxing sugar and the like alone, rather than thinking about them in their broader context. In a world obsessed with specialisation, we need more fox-like thinkers. As David Epstein argues elsewhere in *AIQ* (see page 27), we need people capable of seeing the bigger picture of how things interrelate and connect. Design thinking and systems can help. As an example, under the leadership of Jacinda Ardern, ministers in New Zealand had to show how their budget initiatives would achieve the government's wellbeing priorities, meaning all parts of the cabinet had to work far more closely together.[11] More of these simple-but-effective initiatives are needed.

Being responsible – in both life and investing – should never be about creating an ethical straitjacket, but there are a few guiding principles and rules of thumb that can help.

First, we can all make a difference. If we ever needed reminding that our individual actions count for something, Greta Thunberg's stance on climate change provides us with strong proof.

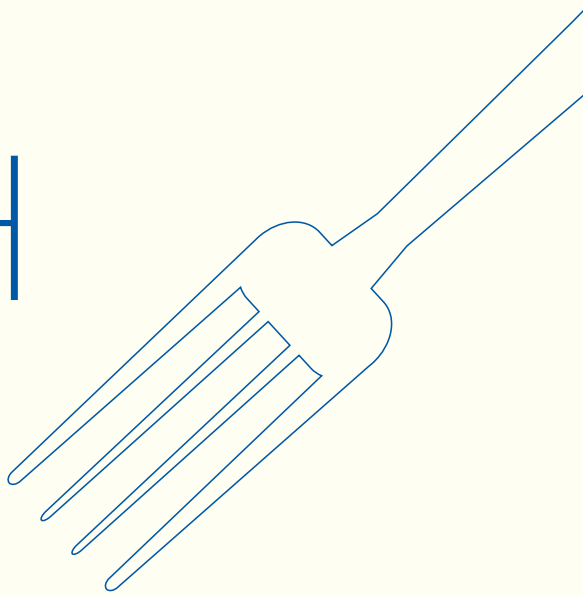
Second, harness Pareto's Principle. Pareto taught us that 20 per cent of our efforts account for 80 per cent of our results, or impact. Along with our core values, this should guide our behaviour and where we prioritise our time. We can identify the areas that will drive the most impact and focus our attention there. By doing this, daunting problems can become less so. Similarly, breaking down challenges, as the seven stabilisation wedges do for climate change, can help make the impossible seem more manageable.

Third, "*It is better to be roughly right now, than perfectly right when it is too late.*" Riffing on a famous John Maynard Keynes quote, Sarah Breeden from the Bank of England aptly highlighted the dangers of over-analysing the minutiae.[12]

The complexity of sustainability is not insurmountable. As we develop various coping strategies, and despite some inevitable and unintended hiccups like my plastic straw faux pas, we should remember that while we can't be perfect, we can be better ●

1 Worldometers based on UN estimates, August 2019.
2 Jonathan Franzen, 'Carbon Capture - Has climate change made it harder for people to care about conservation?', New Yorker, 6 April 2015.
3 Will Bedingfield, 'Why the hell can't McDonald's recycle its paper straws? It's complicated', Wired, 6 August 2019.
4 Annie Lowrey, ' The Case Against Paper Straws', The Atlantic, 20 August 2019.
5 Kenneth Rogoff, 'The Case for a World Carbon Bank', Project Syndicate, July 2019.
6 Sustainable Development Goals website.
7 Sarah O'Connor, 'Executive pay transparency will push workers to demand more money', Financial Times, September 2017.
8 Nina Mazar and Chen-Bo Zhong, 'Do Green Products Make Us Better People?', University of Toronto.
9 'Climate change is a remorseless threat to the world's coasts', The Economist – Briefing: The rising oceans, August 2019.
10 James Hansen, 'Why I must speak out about climate change', TED, February 2012.
11 'The Wellbeing Budget', The New Zealand Treasury, 2019.
12 Sarah Breeden, 'Avoiding the storm: Climate change and the financial system', Bank of England, 15 April 2019.

IN SEARCH OF A FREE LUNCH



Correlations between and within asset classes have changed in unexpected ways thanks to a decade of easy monetary policy. Our portfolio managers tell us what impact this has had on the way they manage money.

Nobel Prize winner Harry Markowitz is widely credited with claiming diversification offers "the only free lunch in investing". The founder of Modern Portfolio Theory (MPT) coined the phrase to highlight his idea that by diversifying, an investor gets the benefit of reduced risk while sacrificing little in expected returns over the long run.

Markowitz used a mathematical framework to explain that while all investors face a trade-off between risk and return, they could make use of the fact returns offered by individual assets are less than perfectly correlated to one another. He proved that for any given level of risk, it was possible to construct a series of optimal portfolios that maximised expected returns.

For the past 50 years or so his arguments formed a key component of many investment processes. That was especially true within the world of multi-asset funds, where it led to the adoption of strategic asset allocation (SAA) and tactical asset allocation (TAA). The idea was that if future returns and cross-asset correlations could be predicted with a degree of confidence, an optimal SAA could be set to capture medium and long-term investment trends. This maximises the chance of an investor meeting their return objectives while taking as little risk as possible. Meanwhile, TAA could be employed – dynamically adjusting those allocations when prices deviate from long-term values due to short-term market fluctuations – to augment returns or reduce risk.

However, for this process to work an investor needs to be able to forecast changes in asset prices with a reasonable level of accuracy. An arguably even harder task, yet no less important, is to be able to predict the way in which those price changes will be correlated with one another.

The impact of globalisation

In general, correlations have been rising across many asset classes for at least 40 years. For example, if we regress the monthly returns delivered by emerging market stocks on the S&P 500, we find the level of correlation between the two has risen by around 60 per cent since the early 1990s, as shown in Figure 1 (overleaf).

IN SEARCH OF A FREE LUNCH

continued

Since this period has coincided with rising globalisation, there are good reasons why the degree of inter-relationship between international asset markets should have strengthened. Not only have the world's economies become ever more interconnected via trade, most companies have become far less reliant on their home market. At the same time, financial markets have become increasingly intertwined as countries around the world eased capital constraints – with growing numbers of companies taking out dual listings – and price-sensitive information was transmitted faster and more cheaply.

Correlations, which hit record levels during the global financial crisis, have in some cases remained high since thanks to the unprecedented degree of monetary easing carried out by the world's leading central banks.

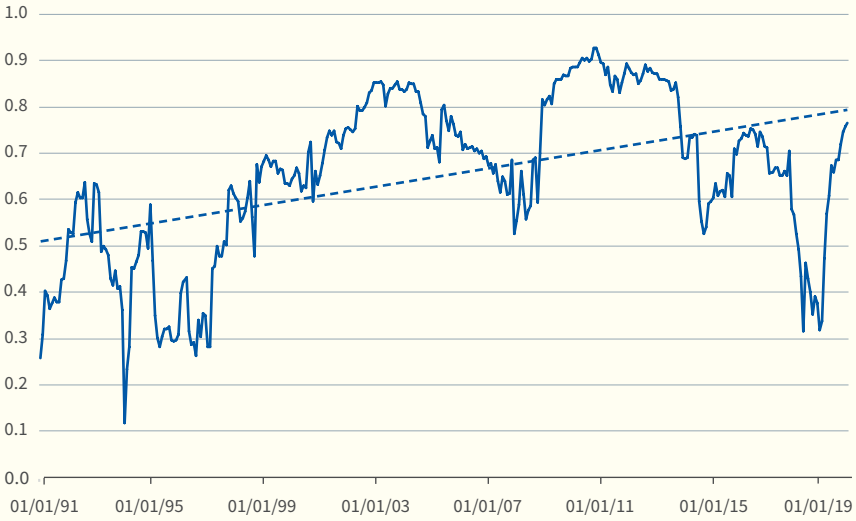
Cross-border spillovers becoming more obvious

According to Sunil Krishnan, Aviva Investors' head of multi-asset funds, that is especially true of developed government bond markets. He says negative yields in Japan and Europe have resulted in "much stronger and more consistent appetite" for investors in both regions for US bonds.

"Prior to the financial crisis, it is unlikely people would have attributed the strength of US bonds to demand from international investors, or other central banks' policy stance. Cross-border spillovers are becoming more obvious, even in the world's largest bond market," he says.

The picture in other markets is less straightforward, however. As Figures 2 and 3 show, the average absolute value of correlations between an array of assets climbed by around a third between 2008 and 2012 compared with the previous four years, jumping to 0.42, from 0.31. The bulk of assets became more positively correlated. For example, the average correlation between the four major equity indices shown rose to 0.71 from 0.55 prior to the crisis. Meanwhile, US Treasury bonds and the US dollar became increasingly effective diversifiers of risk.

Figure 1: **Rising correlation between US and emerging equities (Corr A/C)**



Shows correlation of weekly returns (from 9/1/1989 to 02/09/2019) over rolling two-year periods between S&P 500 and MSCI emerging markets US$ index.
Blue dotted line shows simple linear regression.
Source: Refinitiv Datastream, Aviva Investors.

Figure 2: **Pre-crisis correlations (2004-2007)**

	S&P 500	Eurostoxx	Nikkei 225	MSCI EM	Oil	Gold	High Yield	Global Agg Bonds	US 10-yr
S&P 500									
Eurostoxx	0.797809								
Nikkei 225	0.282845	0.259462							
MSCI EM	0.824329	0.722159	0.40951						
Oil price	0.060828	0.013337	0.24288	0.224076					
Gold	0.258228	0.167962	0.54472	0.44192	0.379849				
High yield	0.551822	0.422449	0.24989	0.589381	0.115862	0.3663866			
Global Agg	0.095002	-0.13791	0.21283	0.168358	0.129102	0.3585963	0.485678		
US 10-year	-0.07101	-0.20546	-0.0925	-0.10934	-0.07584	0.0199231	0.224869	0.6661667	
USD	-0.15346	0.057527	-0.3144	-0.2889	-0.2423	-0.471521	-0.49244	-0.8176424	-0.28316

Shows average correlation of weekly returns (from 20/09/2004 to 31/12/2007) over rolling 52-week periods.
Source: Bloomberg, Aviva Investors.

Figure 3: **Correlations in the wake of the financial crisis (2008-2012)**

	S&P 500	Eurostoxx	Nikkei 225	MSCI EM	Oil	Gold	High Yield	Global Agg Bonds	US 10-yr
S&P 500									
Eurostoxx	0.848365								
Nikkei 225	0.563616	0.580458							
MSCI EM	0.882132	0.788309	0.606737						
Oil price	0.5442	0.453277	0.563206	0.594749					
Gold	0.108347	0.043834	0.163447	0.26007	0.240911				
High yield	0.578244	0.549452	0.429044	0.572382	0.377436	0.129818			
Global Agg	0.146732	0.187929	0.192754	0.249288	0.140312	0.334356	0.391636		
US 10-year	-0.52677	-0.53406	-0.3791	-0.48949	-0.3924	0.11559	-0.29632	0.384403	
USD	-0.50351	-0.52575	-0.47509	-0.59901	-0.46565	-0.32115	-0.51659	-0.75123	0.174671

Shows average correlation of weekly returns (from 01/01/2008 to 31/12/2012) over rolling 52-week periods.
Source: Bloomberg, Aviva Investors.

Figure 4: **Correlations 2012-present**

	S&P 500	Eurostoxx	Nikkei 225	MSCI EM	Oil	Gold	High Yield	Global Agg Bonds	US 10-yr
S&P 500									
Eurostoxx	0.705525								
Nikkei 225	0.273036	0.223468							
MSCI EM	0.682884	0.59838	0.36401						
Oil price	0.302037	0.228562	0.27482	0.317852					
Gold	-0.0954	-0.17493	0.17352	0.192542	0.10796				
High yield	0.563124	0.50804	0.29193	0.632733	0.354218	0.2140391			
Global Agg	-0.10951	-0.18942	0.07731	0.177819	0.021391	0.6207769	0.348477		
US 10-year	-0.30599	-0.27803	-0.149	-0.07096	-0.17718	0.4101082	-0.00427	0.66445424	
USD	0.010422	0.137989	-0.2033	-0.22145	-0.1314	-0.511673	-0.38337	-0.7491546	-0.15533

Shows average correlation of weekly returns (from 01/01/2013 to 09/09/2019) over rolling 52-week periods.
Source: Bloomberg, Aviva Investors.

However, contrary to popular belief, since 2012 the strength of correlations between assets – both positive and negative – has declined. Figure 4 shows the average correlation over this period has fallen to 0.30 in absolute terms, close to its pre-crisis level, while the average correlation between the four equity indices has tumbled to 0.47.

While this fall in correlations may at first glance seem beneficial to an investor looking to boost the diversification of their portfolio, this is not necessarily the reality. For a start, while correlations may have fallen since 2012, they have tended to rise quite sharply during episodes of market stress – precisely those moments when diversification is most needed.

Are correlations getting more unpredictable?

Moreover, in order to profit from them, investors need to be able to predict future correlations with a reasonable degree of confidence. While this has always been fraught with difficulty, in recent years it has arguably got even harder. As Figure 5 (overleaf) shows, although the correlation between the US and UK stock markets has fluctuated wildly for the past three decades, the gyrations have been especially pronounced since 2013. It plunged in 2017 as a surge in US equity prices failed to translate into significantly higher UK prices, before rebounding just as sharply in 2018.

From a multi-asset investor's perspective, Krishnan says the divergence in performance between the US and other equity markets highlights the perils of focusing too narrowly on correlations in an effort to try to boost risk-adjusted performance.

"Correlations data only provide you with so much information. Even where they have been implying a high degree of convergence between markets, the call on which equity markets to own has been the critical factor explaining performance over the last three or four years," he says.

He believes the performance differential between the US and most other equity

IN SEARCH OF A FREE LUNCH

continued

markets has been so stark that multi-asset investors would have been better off having had exposure to equities solely through the US, or better still sub-sections of it, and looking for diversification via other asset classes.

One obvious asset class that has been a fairly reliable diversifier of risk is government bonds. As Figure 6 shows, the correlation between US equities and US government bonds has been negative for the bulk of the past two decades, having been on a declining trend since at least 1991.

Given that both Treasuries and US equities have generated solid returns for investors since the financial crisis, it may seem strange that government bonds have helped diversify a portfolio of shares and other 'risky' assets. However, the apparent incongruity of an increasingly inverse relationship between the price of two assets that have simultaneously risen is explained by the fact that, while exceptionally loose monetary policy has driven a wide variety of financial asset prices higher in recent years, they have not always risen simultaneously.

Wild gyrations

During this period, market sentiment has gyrated wildly with optimism interspersed with bouts of extreme pessimism as investors questioned central banks' ability to first reignite, and then sustain, economic growth. The result, in market parlance, has been a pronounced 'risk on: risk off' environment, with investors often behaving in a herd-like manner, at times clamouring for 'safe havens' such as government bonds only to suddenly switch back into risky assets once the panic has subsided.

Peter Fitzgerald, Aviva Investors' chief investment officer, multi-asset and macro, says while MPT, and in particular the concept of an 'efficient frontier', have always provided a handy framework for investment decisions, the inherent instability of asset price correlations limits its usefulness.

Figure 5: **Correlation between US and UK equities (Corr A/B)**

Shows correlation of weekly returns (from 9/1/1989 to 02/09/2019) over rolling two-year periods between S&P 500 and FTSE 100 index.
Source: Refinitiv Datastream, Aviva Investors.

"Correlation assumptions are important, but they are just that: assumptions. The danger is that a high number of positions leads to a false sense of security that a portfolio is more diversified than it actually is," he says.

A scenario-based approach

Partly for this reason, Fitzgerald, like Krishnan, believes it makes more sense to adopt a scenario-based approach to constructing portfolios, stressing them to see what could happen both in worst-case scenarios and assuming correlations were to change, either abruptly or for a sustained period.

As Krishnan explains, while one portfolio may look superior to another from a risk-return perspective, focusing on the worst five per cent of historical experiences may tell a different story.

"Whenever people use correlation matrices they are looking at history. But we're concerned with looking at particular periods in history. We try to be more specific and granular than just taking a 20-year average, which is not going to help you understand how sensitive the portfolio is to a re-run of 1998 or 2008," he says.

Although the degree of negative correlation between US government bonds and equities has once again weakened since 2012, it seems likely Treasuries and other 'safe-haven' assets will continue to lure investors looking to diversify their exposure to riskier asset classes.

However, Aviva Investors' head of rates James McAlevey warns that even if the relationship seems likely to persist for a while longer, there is no guarantee bonds and equities will remain negatively correlated with one another indefinitely.

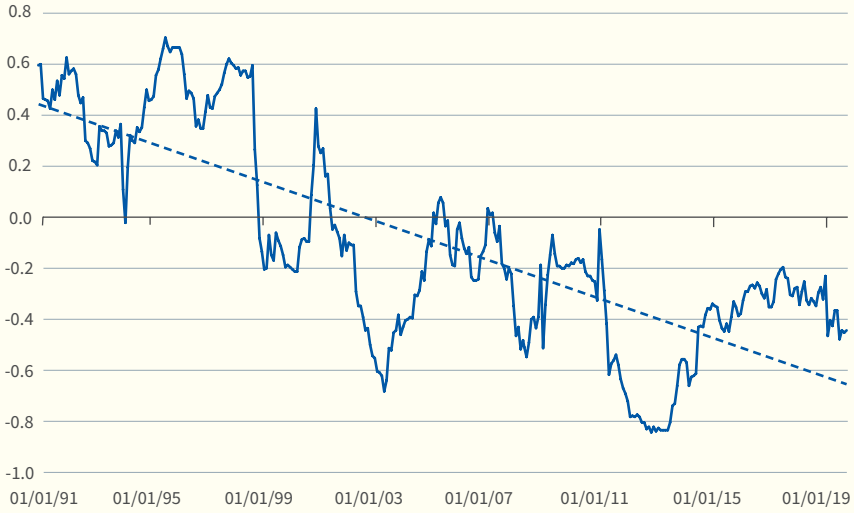
With more than U$17 trillion of debt offering negative yields as of September 22, McAlevey argues investors should worry about bonds' long-term ability to continue cushioning portfolios against losses on their equity holdings.[1]

The Holy Grail

"We've had a 30-year bull market in bonds, equities have made money and the two have had a negative correlation for much of that time. That's the Holy Grail. It doesn't get any better than that. How much longer it can go on for is another matter," says McAlevey.

The danger of relying on bonds as a diversifier became all too apparent, albeit briefly, in the final three months of 2018

Figure 6: **Government bonds have been a reliable diversifier of risk (Corr A/D)**



Shows correlation of weekly returns (from 9/1/1989 to 02/09/2019) over rolling two-year periods between S&P 500 and US 10-year total return index.
Source: Refinitiv Datastream, Aviva Investors.

Just because two variables appear to be related does not imply causation

when a sharp rise in US bond yields triggered a steep decline in equity prices. Whereas previously a 'long' position in Treasuries would have provided downside protection to a portfolio of risky assets, suddenly at the end of last year the opposite happened. Investors were instead left nursing losses on their holdings of both risk and risk-free assets, until central banks came to their rescue.

McAlevey believes that so long as worries over the global economic outlook persist, bonds will continue to help to diversify multi-asset portfolios. But if economic conditions were to improve, investors will need to find more creative ways of ensuring their portfolios are sufficiently diversified and protected against the threat of rising bond yields triggering steep declines in equity prices.

"Duration has been the traditional way for multi-asset investors to hedge their exposure to equities. But even if you're wary of owning bonds at such low yields, there are other ways bonds can hedge your risks," he says.

Trades that look to profit from changes in the shape of yield curves; shifts in credit spreads or the relative outperformance of one type of corporate debt relative to another; foreign exchange movements; and

CORRELATION DEFINITION

Correlation is a statistical technique designed to show the extent to which pairs of variables are related. It is measured by a correlation coefficient, denoted by r, which ranges from -1.0 to +1.0.

The closer r is to +1 or -1, the more closely the two variables are related. If r is positive, it means that as one variable gets larger the other gets larger. If r is negative, it means that as one gets larger, the other gets smaller. If r is 0, it means there is no relationship between the variables.

Correlations are useful because they can indicate a predictive relationship that can be exploited in practice. In the world of finance, if investors can combine two assets whose expected returns are the same, but are expected to be negatively correlated to one another, in theory it is possible to reduce risk without sacrificing return.

However, users of statistical data need to be aware that just because two variables appear to be related does not imply causation. Since some variables may be related by chance, further statistical tests can be carried out to determine how meaningful different correlations are

IN SEARCH OF A FREE LUNCH

continued

> *There are still plenty of ways of limiting risk beyond piling into government bonds*

new volatility and inflation environments are just some of the methods investors can use to hedge against a multitude of risks. If they have the ability to adopt both 'long' and 'short' positions, so much the better.

McAlevey says one way to try to ensure portfolios are sufficiently diverse is to think of trades in terms of pairs, the aim being to guard against specific risks. For example, for the past 18 months he has been running a long position in emerging market debt offset by a short position in the Australian dollar. While he believes both strategies should make money through time, the added benefit is they have a well-established negative correlation.

"While you might like emerging market debt, you may be worried about the impact of the trade war. Being short the Australian dollar can be a pretty effective hedge against that risk," he explains.

As for Krishnan, he says absolute return strategies are beginning to look more attractive in the current low-yield environment given that return streams are usually designed to be relatively uncorrelated to both equities and bonds.

An underrated asset

He also describes cash as an "underrated" asset. "Yes you don't earn much in the way of returns, but there is a great deal of optionality there as it allows you to buy assets that become undervalued or distressed, using a currency that has not become distressed."

As for equity portfolios, Giles Parkinson, global equities fund manager at Aviva Investors, says it is important to be aware of correlations to the extent they can inform you of hidden risks.

"The worst thing is to have a portfolio of the cheapest stocks in the world but to get stopped out because you've had a bad run. You need to know how much risk you're able to tolerate and where those risks might come from," he says.

The rise of exchange-traded funds is widely believed to have led to less dispersion within individual equity markets, at least over shorter periods of time. Parkinson says that can present a challenge for controlling risk. But at the same time, high correlations within an equity market, or sectors of it, can also present opportunities.

Don't throw the baby out with the bathwater

"It is precisely when correlations are highest you have the most chance of adding value, as you tend to find babies are getting thrown out with the bath water. While over shorter intervals stocks are dragged around as much as anything by changes in their (price-earnings) multiple, changes in earnings and cash flow are what really matter over the long run," he says.

Citing a January 2017 study, Parkinson says over longer time horizons there is little correlation between the multi-year returns of an individual stock and the market. Most stocks underperform the index while a select band of winners outperform massively.[2]

For now, with global interest rates seemingly set to remain lower for longer, many investors may not see it as a priority to ensure their portfolios are sufficiently diversified. After all, so long as the actions of the world's central banks succeed in pushing a wide variety of asset prices higher, it is probably more important to choose those that deliver the highest returns.

This does not, however, lessen the importance of investors preparing for the unexpected. While diversification may not seem so important in a world of rising asset prices, its virtues are likely to become all too apparent when the market turns. Investors need to beware of the risks of relying too heavily on historic correlations that are prone to change. Instead, they are better off trying to assess how financial markets would likely respond to a range of hypothetical scenarios and building portfolios that at least stand a chance of coping with the most extreme of them.

To the extent there ever was a free lunch available to investors, it probably disappeared some time ago. But while it may be getting ever harder to ensure portfolios are sufficiently diverse, for those looking to dine out cheaply there are still plenty of ways of limiting risk beyond piling into government bonds

1 Marc Jones, 'Acceptance of negative interest rates 'vaguely troubling': BIS,' Reuters, 22 September 2019.
2 Hendrik Bessembinder, 'Do Stocks Outperform Treasury Bills?', February 2017

LINK

EMBRACING THE POWER OF CONNECTED THINKING

In an increasingly complex world, understanding the connections between people and ideas is crucial. *AIQ* looks at how organisations can put connected thinking into practice.

LINK: EMBRACING THE POWER OF CONNECTED THINKING

continued

The next time you pick up your smartphone – or switch on your television, take a digital photograph, or send an email – spare a thought for Bell Labs.

Based in a campus of glass-fronted buildings in New Jersey, surrounded by lawns kept neat by grazing deer, Bell Labs was the brains trust that lay behind the success of the American Telephone and Telegraph Company (AT&T), the US conglomerate that dominated the telecommunications industry for much of the 20th century.

A series of revolutionary innovations, from radar to lasers, solar cells to communications satellites, started here. Microsoft founder Bill Gates once said that if he had access to a time machine, his first stop would be "Bell Labs in December 1947", so he could witness the invention of the transistor, building block of every electrical gadget in the modern world.[1]

What was the company's secret? The answer can be summed up in two words: connected thinking. Bell Labs was in the business of connections – its first task was to develop a transcontinental phone line – but it also grasped the importance of the more intangible links between people and concepts. With its interdisciplinary approach and free-form organisational structures, Bell Labs was able to mint new ideas at the rate other companies churn out widgets.

"What grew out of the research department was a sort of internal energy, with people combining their ideas," says Jon Gertner, author of *The Idea Factory*, a bestselling history of Bell Labs. "The silicon solar cell was created by a few people who came together serendipitously. It was a case of the right people, in the right place, in the right environment, working on the right problem."

Spotting connections

Bell Labs' influence waned in the 1980s, when AT&T's monopoly ended and its research teams were broken up. But its half-century period of collaborative innovation contains valuable lessons for companies today. In an increasingly complex and specialised economy, connected thinking has never been more important.

One indication of this is that individual experts are no longer able to dominate their chosen field as they once did. Consider science, technology, engineering and mathematics. In the 1960s, it was common for a STEM paper authored by a single academic to rack up citations. Nowadays, single-author papers are more-or-less unheard of; the most influential research tends to come from research teams that work across disciplines to survey problems from different angles.[2]

The same is true for other technical fields, including finance, where spotting the relationships between assets, markets and economic data is a critical skill. How will ageing demographics affect European property valuations? What will be the impact of the US-China trade war on Vietnam's GDP? How will Amazon's move into prescription medication affect the share prices of health insurance companies? Answering these questions requires teams of experts that are able to work together to understand how each moving piece interacts with the others.

"Connected thinking is absolutely at the heart of what it means to be a macro investment manager," says Euan Munro, CEO of Aviva Investors. "You would have to be a megalomaniac to believe you alone have the best insight into all the possible investment opportunities around the world. You need to listen to experts throughout your organisation and understand what they're seeing. Bringing together those observations to identify opportunities and risks is the key."

While the benefits are clear, connected thinking can be hard to get right. Academic research has proved investors routinely fail to notice connections between companies, even when those connections are economically simple – the relationship between a customer and a supplier, for instance – and publicly disclosed. Lucrative opportunities are being missed.[3]

In this article we explore how companies can put connected thinking into practice, drawing on examples from finance, technology, architecture and sport. As we will see, connected thinking is not just an organisational imperative – it may present solutions to some of the most serious challenges facing the world today.

We'll use Bell Labs' four-step principle as our guide. For connected thinking to work, you need the right people, in the right place, in the right environment, working on the right problem.

PART

1 PEOPLE

- **Organisations need both generalists and specialists**
- **Analogies from other disciplines can spark ideas**
- **Taking the "outside view" can mitigate the risks of siloed thinking**

Where do new ideas come from? Perhaps you are picturing the lone genius poring over a notebook or a petri dish. In fact, great ideas are more often the result of networks and collaboration than an individual's eureka moment.

Take Charles Darwin, whose theory of evolution reshaped humanity's understanding of itself. Although his famous voyage on the HMS Beagle in the 1830s yielded crucial discoveries, Darwin did surprisingly little experimental research himself. But he had an ace up his sleeve: a network of pen pals.

A prolific letter writer, Darwin combined his own insights with the knowledge he gained from hundreds of correspondents across the world: geologists, ornithologists, amateur botanists. He would cut out passages from these letters and paste them into his notebooks to develop his ideas. His great theory of the interconnectedness of life was itself a classic example of connected thinking.[4]

In his book *Range*, author David Epstein identifies Darwin as a generalist, as opposed to a specialist. Once an aspiring clergyman, Darwin took up science relatively late and distinguished himself as a "lateral-thinking integrator", whose genius derived from his curiosity and talent for synthesising existing ideas.

Epstein argues Darwin's success contains a lesson for modern business, where hiring policies tend to favour focused experts rather than applicants with broader CVs. Such policies persist despite evidence high-performing executives usually have a breadth of professional experience. In a recent study of 459,000 members, social media company LinkedIn found individuals who had worked across a range of job functions were more likely to rise through the ranks to the C-suite.[5]

This is not to say companies should do away with specialists. Depth of knowledge remains important, especially in technical industries. The point is that organisations need generalists too: people who are adept at spotting overlooked parallels and unexpected continuities. Demis Hassabis, founder and CEO of technology company DeepMind, refers to these individuals as "glue people", arguing their interdisciplinary abilities are vital in making sure teams work collaboratively.[6]

Such individuals are of particular value in large and complex organisations where individual experts may find themselves toiling at cross-purposes, unaware of each other's work –"digging parallel trenches", as one influential scientist put it.[7] Former Hewlett-Packard CEO Lew Platt wryly summed up how this problem can affect a company's bottom line: "If HP knew what HP knows," he said, "we would be three times more profitable."

By moving fluidly across departments, generalists can spot connections and help avoid the parallel trench problem. When he founded manufacturing firm W.L. Gore & Associates in 1958, Bill Gore drew on his experience that organisations do their most creative work during crises, when traditional hierarchies and silos break down. He devised a flat, porous organisational structure known as a "lattice", in which individuals are empowered to rove across different teams to accomplish their tasks without having to report to conventional chains of command. This approach yielded breakthrough inventions such as the waterproof fabric Gore-Tex.[8]

Taking the outside view

Dedre Gentner, professor of psychology at Northwestern University, points out another advantage of the generalist: the ability to spot structural similarities between concepts and scenarios. Simply put, the generalist can use analogies to identify solutions to problems.

Analogies can come from unexpected places. Studying philosophy at university in the 1930s to fulfil a course requirement, a budding engineer named Claude Shannon

LINK: EMBRACING THE POWER OF CONNECTED THINKING

continued

came across the work of George Boole, an obscure 19th century English logician who had assigned a numeric value to true statements (1) and false statements (0). Later, while working at Bell Labs, Shannon realised Boole's logic could be applied to the workings of electronic circuits. Drawing on this insight, he and his team devised a system whereby any piece of information could be transmitted electronically – and laid the foundation for all modern computing.[9]

Scientists and engineers have found the natural world to be fertile ground for analogies. The self-healing properties of skin and bone have inspired "biomimetic" suspension bridges that automatically repair themselves when damaged. Velcro is modelled on the seed burrs of the Burdock plant. The porous walls of termite mounds have taught architects how to keep their buildings cool.

Analogical thinking can also be useful in finance. Aviva Investors' Munro brought this approach to his investment process after learning of the collaborative methods employed by surgical teams in hospitals.

"The inspiration was a conversation I had with a colleague, who came from a medical family. He was describing the process on the morning of an operation: The chief surgeon, the anaesthetist, the physician and the chief nurse meet to review the patient's charts and discuss how the day is going to go. You have all these different disciplines working together on a common problem. I realised the investment world was bad at that sort of connected thinking," he says.

Munro took this analogy and used it to build a multi-strategy approach to macro investing that brought together asset-class specialists who customarily operated separately. He subsequently applied the same principle in other areas – at Aviva Investors, infrastructure and real estate specialists work side by side in an integrated real assets business, while equities professionals collaborate with credit experts to identify well-run companies and flag potential risks.

"Consulting with different asset-class specialists helps us identify potential opportunities," says Stephanie Niven, a fund manager on the global equities team at Aviva Investors. "For example, we learnt from conversations with analysts in the real assets team that battery technology improvements were being made that expanded the opportunity set of data centres. We combined this with our own insight that battery technology was likely to improve further thanks to the investments being made elsewhere by the likes of electric vehicle companies and mobile phone developers.

"Equity markets appeared to be overlooking the benefits these more-efficient batteries will bring to companies across other industries, notably in wind and solar power and data management. We subsequently invested in renewable energy company NextEra Energy and data-centre operator CoreSite," Niven adds.

Another key benefit of connected thinking in finance is it can enable teams to adopt what's known in psychology as "the outside view", mitigating the hazards associated with a tunnel-vision focus on a single discipline.

Consider a 2012 study in which private equity investors were asked to estimate the return on a project they were currently involved in. After submitting the figure, the investors then had to identify similar investment propositions and evaluate the potential return on those alternatives. On average, the investors estimated the return on their own project to be 50 per cent higher than the other examples; when they became aware of the discrepancy, they quickly revised their original estimates downwards. Familiarity with the details of their own projects had led them to overrate the chances of success – taking the outside view provided much-needed perspective.[10]

PART

2 PLACE

- **Physical location can help or hinder connected thinking**
- **Technology can improve connections among global companies**
- **Connected thinking is becoming more important within and across cities**

There is little point in hiring adaptable, generalist professionals if they are shut away in offices in remote locations, unable to communicate. Organisations can improve connected thinking by paying attention to the physical layout of their workspaces.

The executives at Bell Labs were keenly aware of the importance of place in facilitating innovation. At the centre of the physics wing at the company's New Jersey campus was a 700-foot long corridor that ran past the doorways to laboratories and offices. It was deliberately designed so that "travelling its length without encountering a number of acquaintances, problems, diversions and ideas would be almost impossible", as Gertner writes in *The Idea Factory*. A scientist walking down the corridor on their way to lunch at the cafeteria "was like a magnet rolling past iron filings".

Modern technology companies have identified other ways to bring about coincidental meetings between experts and ignite the creative spark. In 2013, as Google managers surveyed the canteens at the company's plush San Francisco offices, they noticed staff in long queues were more likely to speak to those around them. So they devised an experiment to find out the optimal length of time baristas should spend making a coffee: long enough to promote serendipitous conversation, but not so long as to irritate employees thirsty for a caffeine hit. (The answer was four minutes.)

In a similar vein, studies show that tweaking workspaces – or "optimising spatial management" to use the technical phrase – can make a big difference to productivity by putting high-performing individuals into close proximity with their peers. The Kellogg School of Management found evidence of a positive spillover from the most productive individuals to colleagues sitting in a 25-foot radius around them, boosting team-wide performance by as much as 15 per cent – the kind of result usually associated with expensive training and recruitment initiatives.[11]

When physical proximity is impossible, as may be the case across global organisations, technology can bridge the gap. Research shows process and networking tools improve productivity by 20-30 per cent among global software development teams.[12] Communications software such as Skype or Slack can enable the sharing of ideas and the assignment of tasks. The right software might be not be the obvious choice: Aviva Investors has repurposed a system called Confluence – traditionally deployed as an IT workflow tool – to compile and circulate research, aiding international collaboration.

Connected thinking and the city

There is an important relationship between connected thinking and place on a macro scale, too. As economies continue to shift away from heavy manufacturing towards service-based sectors, knowledge networks are becoming more important than physical supply chains. Increasingly, connected thinking is distinguishing the leading cities from the laggards.

The recent economic tilt towards "intangible" investments in design and creative talent is contributing to this trend. As the academics Jonathan Haskel and Stian Westlake observe in their book *Capitalism Without Capital*, intangible assets gain in value due to synergies and spillovers between innovative firms. As intangible-focused companies form clusters in the same areas, they tend to hoover up the best talent from elsewhere, reshaping property market dynamics.

LINK: EMBRACING THE POWER OF CONNECTED THINKING

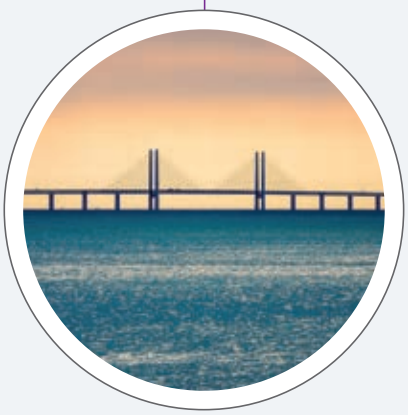
continued

"Today, a city's success is driven by its ability to facilitate knowledge exchange and information sharing to nurture idea creation," says Vivienne Bolla, real assets research analyst at Aviva Investors. "Being part of a cluster provides companies with easier access to information and technology, while generating efficiencies in sourcing inputs such as labour."

Understanding the value of such clusters is important for companies searching for the best location for their headquarters, as well as for investors who want to allocate capital to locations that will grow sustainably over the longer term. In Europe, Aviva Investors' real assets team identifies Stockholm, Berlin, Amsterdam and Copenhagen as cities with particularly productive clusters in digital and biotech fields; London and Paris also score highly for their scale and ability to attract talent.

Grasping the connections between cities, knowledge networks and economic growth is also imperative for governments, especially as clusters can deprive less-dynamic areas of talent and investment. Building infrastructure to physically link clusters with these regions is one solution to this problem, according to Oxford economist Carl Benedikt Frey, an expert on the interplay between labour markets and technology.

Frey cites as evidence the Öresund Bridge linking post-industrial Malmö in Sweden and bustling Copenhagen. Built in 1999, the bridge revitalised the Swedish city's economy by enabling residents to commute to higher-paying jobs in the Danish capital.



PART

3 ENVIRONMENT

- **Inclusive meetings can facilitate a culture of participation**
- **A safe environment can foster debate**
- **Diverse teams outperform on complex tasks**

Just as important as the physical layout of an office or the cluster of buildings in a city is the more intangible surrounding environment, or organisational culture. What does it feel like to work in a company? Are fresh ideas encouraged or shot down? Are new colleagues enthusiastically welcomed into the fold, or frostily left to their own devices?

In an exclusive culture, powerful senior staff are likely to dominate discussions, with junior individuals left without an opportunity to contribute. This is short-sighted. As venture capitalist Paul Graham has observed, there are two kinds of work schedule: that of the maker, whose day is free of mandatory engagements, freeing up periods in which they can think creatively; and the manager, whose day is divided into a series of hour-long blocks dedicated to various appointments. If managers don't listen to the makers, they are closing themselves off from these creative energies.

A good yardstick of a healthy working culture is whether meetings feel inclusive. Tabitha Alwyn, a consultant at Alliance Coaching, says creating a sense of "psychological safety" is important if everyone is to pitch in. One way of doing this is to outlaw interruptions – psychologists have observed that when a speaker is interrupted their brain goes into fight-or-flight mode, in the same way it would respond to a physical threat. Another option is to formalise the procedure for contributions so that everyone is given an equal opportunity to speak.

> *Diverse teams are better at predicting the outcome of complex systems*

"We have found that opening a meeting by inviting everyone present to speak in turn – even on a relatively routine matter such as recent portfolio activity – can loosen up the group," says Sunil Krishnan, head of multi-asset funds at Aviva Investors. "In more substantive debate it's important to have the senior leaders speak last, so they don't influence others."

These inclusive principles can be carried beyond meetings into everyday conversations. The global equities team follows a principle known as "vulnerable sharing". Derived from the work of author Brené Brown, this technique is about encouraging individuals to open up to colleagues about their strengths and weaknesses. Such dialogue tends to facilitate an open environment that is conducive to debate. It also allows teams to more efficiently assign tasks and match the right people with the right problem, without cleaving to narrow sector specialisms.

"Teams can't flourish together unless they have a safe environment to share," says Niven. "In a culture based on trust, you are free to ask questions whose answers might be assumed to be obvious – for example, a member of the team might ask why Alphabet is a good investment. It means we can rigorously test ideas and challenge conventional wisdom.

"Much has been written about behavioural economics at a market level, but much less has been written about behaviour as it applies to investor culture within organisations. Culture is extremely significant and how decisions are made and committed to is as important, if not more important, than the decisions that are made," she adds.

The diversity bonus

As Niven makes clear, asking questions and challenging received wisdom are key to connected thinking. The desire for harmony can lead to a fuzzy consensus, overriding the inclination to correct bad decisions. The result is groupthink: the dangerous tendency to follow the crowd.

One of the best ways to avoid groupthink is to ensure teams are diverse, as groupthink is more likely to arise in an environment that lacks diversity of gender, ethnicity, sexual orientation and social class.

In his recent book *Rebel Ideas: The Power of Diverse Thinking*, Matthew Syed argues that one of the reasons the Central Intelligence Agency (CIA) failed to prevent the 9/11 attacks was that the organisation was overwhelmingly white and male, and as a result did not grasp the potent religious symbolism of Osama Bin Laden's propaganda. A more diverse group, with more Muslim members of staff, would have better understood the threat posed by al-Qaeda.[13]

Diversity can also bring commercial benefits. In a recent talk at the World Economic Forum, Victoria Plaut, professor of law and social science at the University of California, Berkeley, showcased a dizzying array of research that indicates diverse teams outperform more homogenous ones in business and finance. One study looked at companies in the S&P 500 Index and found gender diversity among top management predicted a US$42 million increase in firm value. A similar study of 177 US national banks found firms with more racial diversity showed enhanced performance (the effect was particularly significant among banks working on new innovations).[14]

As social scientist Scott E. Page argues in his book *The Diversity Bonus*, diverse teams have a specific advantage in that they are better at predicting the outcome of complex systems such as markets. This effect is by now so well documented as to be a mathematical principle.

"Two people with the same training and experience will think about the world in similar ways and their predictions will be correlated. Here is where diversity delivers this big bonus. If we add someone whose predictions are not as good but are negatively correlated to the others, the collective prediction will be much better," says Page.

Page cites the outcome of the Netflix Prize, a competition to find the most accurate algorithm to predict user ratings for films on the streaming service. Teams from across the world entered the contest over a period of three years between 2006 and 2009, and it accrued a prestige worth far more than the nominal US$1 million prize money. The decisive progress came in the final days of the competition, when teams that had looked to be also-rans decided to team up to beat the frontrunner. The hybrid team won handily despite the tight time-frame, submitting the winning algorithm 24 minutes before the deadline. The result proved that combining diverse models to a problem can be the most effective approach.

Charlie Munger, vice chairman of US conglomerate Berkshire Hathaway and partner to Warren Buffett, is one of the most prominent proponents of the "multiple model" framework in finance. When considering an investment, Munger applies what he calls a "latticework" of different models to ensure every dimension has been considered.

"Most people are trained in one model – economics, for example – and try to solve all the problems in one way," as Munger once put it, in his trademark folksy style. "You know the old saying: 'To the man with a hammer, the world looks like a nail.' This is a dumb way of handling problems."[15]

LINK: EMBRACING THE POWER OF CONNECTED THINKING

continued

PART 4

PROBLEMS

- **The investment industry remains poor at spotting connections**
- **Connected thinking can yield promising investment ideas**
- **Solutions to bigger challenges rely on appreciating connectedness**

Bringing together all of these aspects of connected thinking – the right people, in the right place, in the right environment – can help organisations solve problems. In asset management, for example, marshalling global expertise to spot overlooked connections across companies and sectors holds the key to identifying opportunities.

"Connected thinking allows you to build an information infrastructure that maximises the ability to capture valuable insights wherever they originate from, and to deliver that intelligence to the place where it is most valuable," says Mikhail Zverev, head of global equities at Aviva Investors.

This might sound like common sense, but research shows many investors are poor at managing and responding to information in this way. The efficient markets hypothesis – which holds that market pricing always incorporates all of the relevant available information, rendering the hunt for undervalued stocks futile – has long since been debunked by behavioural economists such as Daniel Kahneman and Richard Thaler, who have proved investors are prone to various cognitive biases that hinder rational decision making. But the industry has yet to fully appreciate the extent to which important data goes overlooked, especially as it pertains to the connections between firms.

In 2008, the academics Lauren Cohen and Andrea Frazzini conducted a study that found a high degree of "investor inattention" surrounding the links between companies and their suppliers. They highlighted an example centring on the long-standing relationship between Coastcast, a manufacturer of golf club heads, and its major customer Calloway, a retailer of golf equipment.

In June 2001, Calloway was downgraded by analysts and slashed its earnings projections by US$50 million; its share price fell by 30 per cent in two days. But these developments did not affect Coastcast's share price at all, even though Calloway accounted for half of its sales. In fact, Coastcast's shares only began to adjust in response to the Calloway information two months after it became public knowledge.

The study found this pattern repeated across other firms in the US stock market. The effect was predictable, such that the authors found a long-short equity strategy based on responding quickly to information of this kind could yield monthly alpha in excess of 150 basis points.[16]

In their conclusion, Cohen and Frazzini speculated that "if it is true investors ignore even these blatant links, then the informational efficiency of prices to reflect more complex pieces of information is potentially less likely". Subsequent research has borne this out. A 2014 study from the University of California Davis and the Federal Reserve Board of Governors found less-defined links between companies, discoverable through statistical analysis, are also being ignored by investors.[17]

Connected thinking in investment

Connections are even more likely to be ignored when their relevance depends on future developments. Consider telecommunications, a sphere that has changed profoundly since AT&T and Bell Labs dominated the field. Nowadays the industry is a complex ecosystem, with giant conglomerates competing on new technological fronts with upstart players. In this global matrix, innovations seamlessly cross borders, affecting multiple industries.

The next big change could be transformational: 5G. This new network technology is set to influence not just telecoms firms, but companies that manufacture telecoms equipment and indeed any industry that relies on intensive

data processing and transfer, from media to healthcare. One particularly interesting shift is set to occur among smartphone makers and their own suppliers, according to Zverev.

"After conversations with companies and analysts and consultations across global investment teams, we took the view 5G could boost the smartphone industry, which has been struggling with underwhelming sales over the past two years. This, in turn, could benefit companies such as semiconductor manufacturer Skyworks, which looks to be undervalued by the market," Zverev adds.

In an industry that is increasingly adopting AI-driven algorithms to spot correlations and make instantaneous trading decisions, this kind of connected thinking – patiently piecing together the puzzle to build a picture of how technological developments will ripple across multiple industries into the future – could give human investors an edge.

Niven describes connected thinking as "subjective but repeatable"; human investors are better placed than algorithms to draw conclusions based on informational inputs, not just market outputs, and to bring proven approaches to bear on unfamiliar problems. She argues this is the best defence against passive and algorithm-driven investing.

"Quant models work on the assumption the past is the best predictor we have of the future," says Munro. "But while you can take lessons from something that's worked well over the last 20 years, that might have been because interest rates were going down over that period. How is the situation going to change when interest rates rise? What we're always trying to do is to identify the impact of new trends – that's where humans can offer value over machines."

The greatest challenge

Another example of the role of connected thinking in investment is the rising importance of environmental, social and governance (ESG) factors. Once considered a niche pursuit, ESG is now understood to be a vital part of the investment decision-making process across all asset classes. It can help deliver long-term value, offer insight into key risks and improve corporate performance on sustainability issues. On a wider scale, connected thinking on ESG is likely to play a major role in the global effort to tackle climate change.

After publishing his study of Bell Labs, Jon Gertner's next project was *The Ice at the End of the World*, a book that tells the stories of generations of explorers who mounted expeditions across Greenland. In recent years, these heroic treks have yielded vital data: braving the Arctic winds to drill deep into isolated glaciers, scientists have recovered air pockets that tell us about the rise in temperatures over centuries – and help build a case for action.

> *Connected thinking on ESG is likely to play a major role in the effort to tackle climate change*

LINK: EMBRACING THE POWER OF CONNECTED THINKING

continued

Connected thinking may yet pave the way for transformational climate-related technologies

"All these [scientists] who have collaborated over the years have put in our laps a wealth of information that we now need to know what do to with. In this case, it's a matter of politics and policy and creating new technologies to address this challenge," Gertner says.

Connected thinking may yet pave the way for transformational climate-related technologies. History provides grounds for hope. In the early 20th century, while looking for new sources of nitrogen to create crop fertiliser, a pair of German chemists literally pulled the solution out of thin air, devising the Haber process that converts nitrogen to ammonia by combining it with hydrogen. Drawing the analogy with the problems we face today, contemporary scientists have developed carbon-capture technologies that can remove harmful carbon dioxide from the atmosphere.

While such technological solutions hold promise, carbon emissions will also need to be drastically curtailed at source if climate breakdown is to be avoided. This will require a coordinated effort between governments, markets and individuals. Appreciating our position in the network – and how our behaviour affects the other links in the chain – is a good starting point.

"You might sit in New York or London and think, 'why should I care about Greenland or the Arctic – these places are thousands of miles away, they don't necessarily affect my day.' That's kind of true at the moment, but it will become less and less true as we understand that interconnectivity of the environment," Gertner says.

Throughout history, from the deck of the *Beagle* to the innovation hub at Bell Labs, from the trading desk to the sports field, connected thinking has played a crucial role in bringing people together to solve problems. As we face up to climate change – the greatest challenge of all – it might just help save the world ●

1 Jon Gertner, *The Idea Factory: Bell Labs and the Great Age of American Innovation* (Penguin, 2012).
2 'The science behind the growing importance of collaboration,' Kellogg School of Management, September 2017.
3 See Lauren Cohen and Andrea Frazzini, 'Economic links and predictable returns,' The Journal of Finance, Vol LXIII, No 4, August 2008.
4 David Epstein, *Range: How Generalists Triumph in a Specialised World* (Macmillan, 2019).
5 'What really fuels creative genius: It's about breadth, not depth,' David Epstein, LinkedIn post, May 2019.
6 'Inside DeepMind's epic mission to solve science's trickiest problem,' Wired, July 2019.
7 The scientist is biologist Arturo Casadevall, who has sought to 'de-specialise' graduate training to give students a broader range of expertise. See Epstein, *Range*.
8 'Everyone a team leader: shared influence at W.L. Gore & Associates,' Organizational Dynamics, Vol. 38, No.3, July 2009.
9 See Gertner, *The Idea Factory*, and Epstein, *Range*.
10 See Epstein, *Range*.
11 'Sitting near a high performer can make you better at your job,' Kellogg School of Management, July 2018.
12 'Advanced social technologies and the future of collaboration,' McKinsey Quarterly, July 2017.
13 See the extract from Syed's book on BBC website: 'Was CIA 'too white' to spot 9/11 clues?', September 2019.
14 See Victoria Plaut, 'Diversity is good for your brain,' available at the WEF's YouTube channel.
15 See *Poor Charlie's Almanack: The Wit and Wisdom of Charles* T. Munger (Walsworth Publishing, 2005).
16 Cohen and Frazzini, 'Economic links and predictable returns'.
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FINDING RANGE:

AN INTERVIEW WITH DAVID EPSTEIN

AIQ speaks to author David Epstein about his new book, _Range_, which explores how generalists succeed in a specialised world.

In his book *Outliers*, Malcolm Gladwell popularised research that indicates world-class expertise in any field requires 10,000 hours of dedicated practice. It follows that highly successful people will find their vocation early and ruthlessly specialise.

Or does it? A recent study has cast doubt on the 10,000 hours premise. And in his new book, *Range: How Generalists Triumph in a Specialised World*, author David Epstein argues that breadth, rather than narrow specialisation, is the key to success. Generalists are more adaptable and more likely to notice productive connections. In a fast-changing and devilishly complex world, these are key advantages.

> *Society has tended to overvalue specialists and undervalue generalists*

Epstein cites examples from across business, culture and sport. Tiger Woods might have become a world-beating golfer by starting at an early age – but another great, Roger Federer, spent years sampling different sports before bringing what he learned into tennis. Nobel Prize-winning scientists are much more likely to have an artistic hobby than their less-successful peers. Broadway plays that combine different genres are more likely to be hits at the box office.

In this interview, Epstein introduces *AIQ* to his findings and offers some tips on how individuals can find their own range.

What would you say is the key message of Range?

The obvious message is that society has tended to overvalue specialists and undervalue generalists. However, another message is that sometimes the things you can do to cause the most rapid short-term improvements can actually undermine long-term development.

FINDING RANGE
continued

What are the methods individuals, companies and policymakers can use to "embrace the potential that lies on the interface of domains and disciplines", as you put it in the book?

One has to do with the way we hire. I have been to conferences where people talk about trying to automate human resources, because there is so much résumé information online you can find people who have a direct line of experience to whatever you are looking for. But the work of Abbie Griffin, who studies so-called serial innovators, shows this approach will screen out the potential serial innovators, because these people tend to have "zigzag" paths, where they have worked and have networks across multiple domains.

One of the experiences that led me to this project was working with the Pat Tillman Foundation, named after a former professional American football player who left in the middle of his career to join the army. He was killed in Afghanistan. The foundation gives scholarships to military veterans to aid career changes. I was on the selection committee and the first thing I noticed was the résumés often look a little disjointed. But when you start to learn more about the applicants, you understand there is actually a narrative of individual growth, and they have taken left turns in response to things they have learned, opportunities they did not know existed before, or skills they have uncovered. Then it makes a tonne of sense.

Organisations need to understand these journeys of personal growth. That is how you get people with breadth – what I would call *range* – and serial innovators.

Beyond hiring policies, are there any other lessons organisations can take from Range?

One thing companies can do to expand their internal range is to make their teams porous. Bill Gore founded the company that created Gore-Tex based on his notion that a company did its most innovative work when in crisis, because suddenly domain boundaries go out the window and everybody starts figuring out what everyone else's capabilities are and work together. He wanted to make that process systematic in a way that did not require a crisis, so there was a lot of moving people between teams.

Networks that give rise to creative breakthroughs have porous boundaries between teams; networks that do not give rise to breakthroughs are those in which the same people collaborate with the same people, over and over again. That turns out to be the case whether for Broadway plays or scientific research. That is not to say you have to shuffle everyone all the time, but there should be some flow between teams of people to bring in new ideas. In the process, people familiarise themselves with other areas of the business.

What are the risks of overspecialising? Do you have any examples of the negative consequences of an overly narrow focus?

When I was doing investigative reporting on the medical industry, I started noticing the perverse outcomes that resulted from increasing specialisation in medicine.

For example, specialised surgeons have fewer complications – but there is also evidence specialised surgeons are more likely to do procedures on people who do not need it, so it is a double-edged sword. Take partial meniscus repairs, which may be the most common orthopaedic surgery in the world. Someone has knee pain, comes in to get imaging of their knee; the surgeon finds a little tear in their meniscus – a crescent-shaped piece of fibre in the knee – and fixes it. This has been going on routinely for years.

Finally, a team in Finland decided to study this on a large scale and used a control group, in which some people had "sham" surgery, meaning they would have an incision in their knee, the surgeons would act as if they were performing surgery, sew them up and send them home. Those people did just as well as, and sometimes better than, the people who had real surgery. It turns out that maybe the most common orthopaedic surgery in the world does not work, and yet specialists continue to do it because it is what they are trained to do. One of the many reasons healthcare costs have gone completely out of control is the epidemic of unnecessary treatment that, in some ways, is an outgrowth of increasing specialisation.

What are the implications of these findings for training and development?

In the US, our education system was built for the industrial economy and came out of Taylorism, which is basically the science of management efficiency. People were trained to have the basic knowledge needed for an industrial economy, where they could expect work next year to look like work last year. They could do the same things over and over.

Now we live in a knowledge economy where work next year might not look like work last year. Many people are stuck with a specialised set of skills, unable to adapt. That has caused tremendous social turmoil in a lot of countries that have switched rapidly from an industrialised to a knowledge economy, faster than workers could adjust.

Workers will have to reinvent themselves more frequently, multiple times over their career, in a way they did not have to in the past. We will need to set up systems that support people's reinvention, unless we want what we have now: which is a lot of people losing manufacturing jobs and unable to find another job.

> *We should think of social tools as a way to expand our intellectual tendrils*

Will school-level education need to change as well?

The typical way teaching works, and certainly the way I learned maths, is by "using procedures", where you essentially teach someone the way to execute procedures, algorithms or sometimes tricks.

That works well in getting people to make rapid progress in what they are doing, but the problem is it does not impart the conceptual knowledge that allows what psychologists call "transfer". We often lose sight of the fact that transfer is ultimately what you want from a lot of education. It is the term psychologists use to mean your ability to take skills and knowledge and apply them to a problem you have not exactly practised before. That is what you ultimately want, but it requires you to form broader conceptual models that allow you to bend your knowledge to a new situation.

How could this different type of teaching work?

A study just came out in which a bunch of seventh-grade maths classrooms were randomised to different types of maths learning. Some got "blocked practice", which means the teacher teaches them a type of problem, like problem type A. They practise, practise, practise, then move on to problem B and problem C, and so on. They get really good at executing whatever procedure they have to. The kids rate their learning as high. They feel they are learning a lot, because they are getting better in front of their eyes. They rate their teacher as good, because they are making progress so quickly.

Other classrooms were randomised to what is called "interleaved training", where, instead of getting A, A, A, B, B, B, they get A, C, B, D. It is as if you have all the problem types in a hat and you draw from it at random. In that situation, the kids get frustrated, rank their learning as lower and rate their teacher worse, because they are not making progress as rapidly. But, instead of learning how to execute procedures, they are learning how to match a strategy to a type of problem.

When test time came around, the students with interleaved practice blew the blocked practice groups away. They were learning the same problems; it was just that these were arranged in a way that made initial progress slower and more frustrating, but which forced the learners to build a conceptual model from matching strategies to problem types, instead of just executing procedures they had memorised.

Can these insights be applied to everyday life?

Once I started learning about this research, I used interleaving any time I possibly could, in anything I wanted to study, and also things like spacing – another so-called "desirable difficulty". If you want to retain knowledge, study it, wait until you have just about forgotten it, and then study it again.

In a classic study, two groups were taught some Spanish vocabulary: one group got eight hours of practice on one day and then a test; the other group got four hours on one day, then four hours a month later and then a test. The group with eight hours did better on their test. Then, when both groups were brought back eight years later, with no study in the interim, the spaced practice group remembered 250 per cent more, with no study in the intervening time. One of the ways you move knowledge to your long-term memory is by essentially waiting until it has just been buried, and then drag it back up.

Can technology help people form connections and find range?

Absolutely. A Massachusetts Institute of Technology (MIT) study looked at how business professionals use their social media accounts. On Twitter, for example, the rough pattern was that most people used their social media to follow people who were already in their domain or social sphere, or who entertained them.

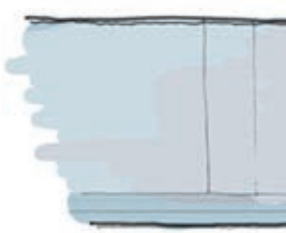
But a smaller number of professionals constantly curated their Twitter networks. They looked for people outside of their domain. They were constantly taking people off and adding others on, cycling through different industries. The study found project proposals from people who used their social media networks in this way to make connections in different domains were systematically rated higher by their bosses. We should think of those social tools as a way to expand our intellectual tendrils, as opposed to just sharing memes.

You begin the book with a comparison between two sporting greats: Tiger Woods, who specialised in golf from the age of three, and Roger Federer, who was more of a generalist. What does this teach us about range?

After I wrote my previous book, *The Sports Gene*, I was invited to a debate with Malcolm Gladwell at MIT, co-founded by the general manager of [basketball team] the Houston Rockets. Gladwell and I had never met, and he had written about the importance of early specialisation in sports as an insurmountable advantage. I was the science writer for *Sports Illustrated* at the time, so I said, "Okay, but that's just hypothesis: I am going to look at the data." I saw that, in fact, in almost all sports, when scientists track athletes who eventually become elite, they see a so-called sampling period, when they play a wide variety of sports and play in lightly structured or non-structured activities. They learn about their interests and abilities, and delay specialising until later than their peers. I picked Roger Federer because he is representative of what the science says is the norm ●

CONNECTIONS AND COMMUNITIES

Today, a handful of urban centres are pulling away from their rivals – creating more innovation, more growth and more jobs. Those changes have deep implications; understanding them and what they mean for local communities takes joined-up thinking.



The Industrial Revolution changed how cities worked and how they looked

Every era has dreamers setting out their utopias. For Sidewalk Labs, the Alphabet subsidiary tasked with bringing smart city technologies to Quayside Toronto, that involves redeveloping the dockland area "from the internet up".[1] Its vision includes creating an innovation hub where residents move between energy- efficient buildings in self-driving cars and old-school bicycles. Streets without curbs and heated pavements are designed to make life more comfortable for pedestrians; meanwhile, deep underground, a network of tunnels is planned for robots to service the buildings, silently removing waste.

The project has generated a disproportionate amount of attention – positive and negative. Planners have broadly welcomed the suggestion to use engineered wood buildings and let the space evolve flexibly, as advocated by the legendary urbanist Jane Jacobs. "One of the mistakes that previous cities have made is the idea that you can plan something from the top," says Dan Doctoroff, former mayor of New York and Sidewalk Labs' CEO. "That is not how cities work – they evolve organically."

But some of the most interesting ideas – like the ability to change land use to introduce rush-hour cycle lanes or pop-up shops – sit alongside others that have unsettled Toronto's residents. They have expressed fears of a corporate land grab, as Sidewalk Labs intends to harvest residents' digital data from multiple sites.[2]

Bricks-and-mortar: Mirroring socioeconomic change

Quayside demonstrates how the factors shaping the built environment can change. In the 19th century, the steam engine and the railway left a distinctive stamp on the landscape, before the internal combustion engine and electricity fundamentally altered the logistics of transport and production. The Industrial Revolution changed how cities worked and how they looked.

Now the environment is morphing again, with the fallout from the arrival of the microprocessor and the internet. In communications, distribution and logistics, as a marketplace, library and computing platform, these technologies have enormous power to disrupt.

"There has never been a commercial technology like this in the history of the world," said Robert Hormats, deputy chairman of Goldman Sachs back in 1999. Data centres the size of multiple football pitches, warehouses for 24-hour deliveries and the hollowing out of the local high street: all this became part of the new reality.

The next wave of change might be around a response to climate emergency. Regenerative communities, where the outputs of one system deliver the inputs of another, could be a way forward: densely packed green buildings powered by

Close connections are increasingly important, with people clustering around key hubs

Sidewalk Labs is using underground space for low-impact waste and services

Source: Sidewalk Labs 2019

renewable energy, food produced using aquaponics by cultivating plants in water, perhaps underground, and extensive use of 'waste-to-resource' systems.[4]

Further out, there is potential disruption from new transport technologies, such as the drone. "They will fundamentally change how we relate to each other, across space, across territory, across the city," says architect and think-tank founder Liam Young.[5] He believes flexible transport infrastructure will reshape urban skylines, allowing access at multiple levels in a building, many floors above the street. Front of mind for the award-winning designer Norman Foster is how to service those drones. His prototype droneport – a simple arched structure made of compressed earth blocks – could be a foretaste of what is to come.[6]

Understanding real-world dynamics

So why does this matter? Understanding the dynamics of societies is particularly important for those selecting real assets, because their physical properties have worth that, if not properly managed, could easily erode.

It means asking what will fuel tomorrow's world, what kind of buildings will populate it and what trade-offs will be made in the process, as well as assessing how desirable these assets will be in the long term. The best of them can be stores of value that are largely immune to the vagaries of the financial cycle.

"After the 2008 global financial crisis, buildings in the centres of global cities increasingly functioned as proxy currencies, providing security in uncertain conditions," says Richard Williams, a professor at the University of Edinburgh and expert in visual culture.

Beyond crises, understanding the environment means looking behind the façade to the forces driving infrastructure, the skeleton of the built environment, and the buildings that make up the upper skin. Sensitivity to value destruction in carbon-heavy assets, how the tenant mix might change the nature of a building or how to harvest premia from green buildings – these are the subtleties that need to be understood.

While the built environment inevitably ages and deteriorates, there is enormous potential to re-invigorate too. Wealth is created and destroyed as spaces evolve, but people drive the dynamism. This means it is not always easy to anticipate what happens next.

The death of distance?

One example of this is how economists misjudged what digital communications might mean around the millennium. At this point, e-communication was becoming increasingly important. As the cost of transmitting data began to fall, books like *The Death of Distance: How the Communications Revolution Is Changing Our Lives*[7] began contemplating the future.

"If you go back 20 years, people talked about the death of distance a lot, due to innovations like the fax machine and email," says Chris Urwin, Aviva Investors' director of real assets research. "Supposedly people could work anywhere, so people talked about the death of distance or the death of geography. It didn't happen. In fact, the opposite has happened."

Instead, close connections are increasingly important, with people clustering around key hubs. "We live in an age where it is effortless to telecommute across the planet, where we can all dial-in from whatever sylvan spot appeals to our biophilia – the innate tendency we have to connect to nature – and forgo all the conveniences that come with city life," says Harvard University professor and urban economist Ed Glaeser. "But in so many ways and in so many places, we still choose to be around other people. We still chose cities.

"There is a reason for this. New technologies and globalisation are not enemies of the city. They are its friends. New technologies have increased the returns to being smart, and we are fundamentally a social species that gets smart by being around other smart people," he adds.

CONNECTIONS AND COMMUNITIES

continued

Increasingly, agglomerations of highly skilled people have become critical to an area's prospects. Put it another way: talent, clusters and scale drive success. Cities with clusters of excellence attract human talent, which in turn leads them to grow.

There are many processes at work. First, as the world has become more complex and the balance has shifted towards services rather than manufacturing in developed economies, face-to-face human contact has become more critical. Significantly, interaction between knowledge workers can spur the development of new ideas. A recent working paper titled *The Geography of Unconventional Innovation,* by economists Enrico Berkes of Northwestern University and Ruben Gaetani of the University of Toronto, suggests innovation is not limited to densely populated areas, but they are more likely to produce unconventional combinations of knowledge.[8] This is hugely relevant: the unconventional can differentiate.

Second, scale is advantageous from a labour-market perspective. Larger centres are more likely to host the universities, research facilities and other educational institutions needed to develop a highly skilled workforce and keep them actively employed.

"Large labour markets improve the quality of matches between workers with rare skills and the firms that need them, and cut the cost of economic disruptions," according to a recent review in *The Economist*. Why? Someone who has just lost their job is more likely to find a new position in a place with thousands of potential employers than one with a handful.[9]

Third, technology has enhanced the wage premium for the highly skilled. The pay of those at the top of the wage scale in knowledge businesses tends to be significantly higher than others. This is because digital technology can amplify – successful applications created by the few can potentially reach the many. The outcome is quite distinctive: small but growing numbers of the highly paid, and a larger number on low pay or minimum wage, for those servicing people in high-skill enclaves.[10] These trends are spilling into real estate markets on the ground; values in sought-after areas are rising faster than average, locking out those on lower wages.

The result: "winner-takes-most" urbanism.[11] A landscape where talent is clustered in densely networked superstar cities that generate a disproportionate amount of economic growth.[12] In these cities, the urban form reveals demand for space – more skyscrapers, more intensity. Below them, regional superstars also carry disproportionate weight, and the health of surrounding communities depends on how well they can leverage that success.

In Europe, for example, Stockholm, Berlin, Amsterdam and Copenhagen have become cities with world-renowned clusters in the digital and biotech sectors. Berlin is said to launch one start-up every 20 minutes.[13] Munich, Frankfurt and Dublin also compete globally, with vibrant clusters in financial, automotive, engineering, ICT and creative industries. In a crowded field, cities are striving to become talent hubs, competing aggressively for corporate headquarters and the like with tax breaks and incentives. But some less successful locations have capital drifting away, with high streets in decline and life being squeezed out of the urban core.

"We are seeing polarisation in economic outcomes between the larger cities and the rest," says Urwin. "This makes it essential for investors to have exposure to the right places. Being in larger cities with the best talent and cluster credentials is important. Smaller cities, meanwhile, need to adapt to that economic and geographic reality and tap into the ecosystem of larger cities, so connectivity is essential."

Creating value in an intellectual-property hub

The power of established intellectual-property hubs is illustrated neatly by Cambridge in the UK, home to one of the leading universities in the world. Since the university was founded in 1209, it has grown to attract 25,000 students, and the city has swollen too. It now houses a cluster of over 4,700 knowledge-intensive firms in tech, biotech and the life sciences, including nine valued at more than a billion dollars.[14] Together, they make up Europe's largest technology cluster.

Amazon, Microsoft, Apple, Google and AstraZeneca are among those attracted to Silicon Fen, and the city continues to evolve with a new enterprise zone on its periphery. By any measure, Cambridge is an innovation hub: it registers 341 patents per 100,000 residents – more than the UK's next four cities combined.[15]

"Does this area have a sense of place?" is an important question for those making long-term investments, according to Urwin. "Making a location a 'somewhere' rather than an 'anywhere' is difficult – you certainly can't flick a switch to make that happen," he says. Cambridge is a 'somewhere', with its 'cityness'[16] based around a long-established intellectual tradition.

For long-term investors, the question is how that can be harnessed for durable cash flows. There is strong demand for office and laboratory space but tight constraints on development, as no less than 17 conservation areas exist.[17] Recent

> *Cities have a lifecycle; they can fade and be re-invigorated*

efforts to step up the intensity of land use near the railway station with new housing (including lower-cost homes), shops, luxury offices and leisure facilities have been met with strong interest. The plan is to maximise every inch of space and work hard to deliver a high-quality experience for tenants, with ultra-fast connectivity, gyms, concierge services, baristas and bicycle storage on tap.

"As more jobs become automated, real estate investment decisions will be increasingly driven by the sustainability of cities' labour markets. Cambridge's knowledge-intensive industries and supply-constrained development mean there is more scope for durable rental growth than many other centres outside London," says Jonathan Bayfield, senior research analyst at Aviva Investors.

"Designing a dream city is easy; rebuilding a living one takes imagination." Jane Jacobs

Cities have a lifecycle; they can fade and be re-invigorated. In urban design, the question is how those process can be directed to create quality environments that enhance the lives of those who live and work there.

Manchester is a case in point. Once an archetypal city of the Industrial Revolution and a UK textiles powerhouse, it produced and exported goods all over the world. Both the railway and canal played a part in making it an important international commercial centre. But the city's industrial heritage was checked by globalisation, as labour costs made the city's outputs increasingly uncompetitive. By the 1970s and '80s, a hive of mills, factories and commercial buildings had fallen into disrepair, although the city's cultural life was very much alive.

Today, Manchester is in the process of reinventing itself. It is hoped the "triple helix" – university, industry, government[18] – will deliver the elusive mix that generates long-term growth. So far, the evidence is encouraging. Manchester has invested heavily in its public spaces and its cultural life has exploded. It has become the fastest-growing city in the UK, adding more than 19,000 residents aged between 16 and 21 from 2009 to 2017.

A key factor in Manchester's appeal lies in its educational profile. One of its four universities – the University of Manchester – has an annual turnover of more than £1 billion.[19] Together, higher educational facilities pull in talent, and the city has strong record of holding onto its qualified leavers.

"Student retention is among the best in the UK," according to Giles York, a director in Aviva Investors' core regional office team. "More than half of the students from Manchester's universities stay on after they graduate. Lots of graduates from Manchester who study elsewhere choose to return as well."

This has caused the population in central Manchester to increase dramatically (although it is still lower than in parts of its history, when residents lived cheek-by-jowl). Among the ranks of researchers and other professionals are UGGs – urban grannies and grandads – who have chosen to live out their retirement close to amenities.

Keeping the spirit of the community alive

There is complexity in revitalisation, however. With no little irony given the importance of graduates to Manchester's revival, university newspaper *The Mancunion* asked in 2018: "Is gentrification ripping the soul out of the former Cottonopolis?"[20] Manchester's character, woven from warehouses and mills and laced with iconic buildings, is part of what makes it special. Could large-scale development destroy it, as wealthy professionals change the chaotic and vibrant mix?

That fundamental tension is explored by professor Richard Florida from the University of Toronto in his book *The New Urban Crisis*. In a recent policy discussion with Glaeser, he summed it up like this: "On the one side, the clustering of urban activity drives innovation, drives economic growth, and is the main source of productivity. But on the other side, it also creates the divides in our society. The old urban crisis was one of decline—the middle class was moving out, poverty had moved in, crime, the urban core was falling apart. That old urban crisis is still with us in some places. But now we have a New Urban Crisis, which is in many ways a crisis of success."[21]

High demand for space in small parts of cities is pushing out the lower-paid to disadvantaged spots or poorly connected suburbs. This is a life of low or uncertain wages and long commutes. What does it do to city-centre communities, if only the advantaged can be there?

"We are often asked, 'What's wrong with gentrification?'" says Aviva Investors' ESG analyst Stanley Kwong. "Gentrification brings lots of positives – investment, jobs and so on – but it can also change people's lives in negative ways, affecting their cultural identity, sense of community and how they live. We need to be aware of these factors, as the pressures sometimes reveal themselves unexpectedly, and that can undermine a development's purpose. We need to break away from these displacement cycles and focus on real long-term positive impact."

CONNECTIONS AND COMMUNITIES
continued

Concentrating on inclusive prosperity

Florida believes one answer is to target "inclusive prosperity": stepping up investment in infrastructure, seeking to deliver more high-intensity, low-cost housing close to city centres and ensuring any jobs created deliver a fair wage. His response is part of a larger wave of analysis of the disenchantment that has been generated in recent decades as 'haves' have visibly flourished, while many others have not.

Professor Thomas Picketty from the Paris School of Economics points to the way in which assets tend to appreciate faster than the economic growth rate, which he distilled into the equation $r > g$.[22] His analysis of how wealth tends to accumulate in the hands of asset holders sparked intense debates on inequality.[23]

Analysis by professor Raghuram Rajan, former chief economist at the International Monetary Fund and former governor of the Reserve Bank of India, draws a slightly different conclusion. "Capitalism has stopped working" in some locations, he believes, due to disequilibria between the pillars of market, state, and community that underpin society.[24] Neglecting community has meant cohorts of people neither identify with those around them or feel supported. This leaves them feeling locked out of the positive changes underway in other parts of society, fuelling extremism and a backlash against liberal democracy and globalisation.

"Society suffers when any of the pillars weakens or strengthens overly relative to others," wrote Rajan in his recent book, *The Third Pillar*. "Too much market and society becomes inequitable; too much community and society becomes static, and too much state and society becomes authoritarian. A balance is essential!"[25]

Calculating the social return on capital: Seeking consensus[28]

The mix of factors fuelling today's debates is unique, but unease about gentrification and hyper-gentrification (state-supported gentrification) is not new. Think of the changes instigated by Napoléon III and Georges-Eugène Haussmann in Paris in the 1850s. Clearing densely packed neighbourhoods for wide boulevards, parks and squares created the centre of the city as it now is. Where many saw beauty, outspoken critic Jules Ferry could only rue what had been lost.[26]

Can investment deliver inclusive prosperity?

So what might 'inclusive prosperity' mean for investors? Growing assets and generating income is a core priority, but contributing to a thriving society is fundamental too.

In infrastructure, economists working on 'value' have concentrated on aggregates, like the infrastructure multiplier. These attempt to show how much growth might flow from each dollar invested in essential services. For example, a study of more than 40 countries at different stages of development by Ethan Ilzetzki, Enrique Mendoza and Carlos Vegh estimated the long-run infrastructure multiplier at 1.5 for developed countries, or 1.6 for developing countries.[27] (Each dollar invested would be expected to generate – on average – one dollar and 50 cents, although the precise 'bang for buck' would depend on local factors.) These studies suggest investing in transport and social infrastructure can be a win-win, particularly where outcomes are widely shared.

When it comes to assessing returns from individual assets, however, the issues are tricky. There is currently no consensus on how to calculate social value, although progress is being made, as the simplified illustration above shows. It involves trying to capture the value generated but not fully reflected in market prices, using quantitative and qualitative measures.

"The social value of a building is particularly hard to measure," says Laurence Monnier, head of quantitative research, real assets at Aviva Investors. "One of the best ways to do

> *The hubs where communities meet, work, create and relax will be fundamental to their lives*

it is in the creation of jobs and the regeneration impact. These are features we are paying increasing attention to. Prior to now, the industry has tended to focus on the environmental aspects of a building – building efficiency, energy efficiency, water consumption, supplier management and so on – these are much easier to get a handle on."

But even metrics like 'jobs created' can be quite crude, so a commitment to 'inclusive prosperity' needs a highly detailed view. The Enterprise City development in Manchester on the site of the former Granada Television studios is a prime example. The project aims to re-model several 1960s office buildings into a hub promoting start-ups and smaller companies, drawing on Manchester's creative history. Office space, a bonded warehouse, space for film and TV production, a cinema, gym, events space and hotel rooms will all be included.

Assessing the investment case in the round might include public engagement and checking whether the development will bring benefits for Mancunians as they meet and engage, as well as creatives and exporters. Then, from an asset management perspective, there might be checks on prospective tenants to ensure they are reputable, committed to fair employment practices and paying a living wage.

Channelling capital has real-world impacts. Despite the hurdles to measurement, assessing those effects is likely to become even more critical for those investing in real assets. What is clear is that as some spaces become largely devoid of people (data centres, automated ports and warehouses and so on), the hubs where communities meet, work, create and relax will be fundamental to their lives. Ensuring people's needs are being met is an essential part of the process. To paraphrase Jane Jacobs, success is likely to mean concentrating efforts on lively, diverse, outward-looking clusters, which have the vitality to address problems outside themselves

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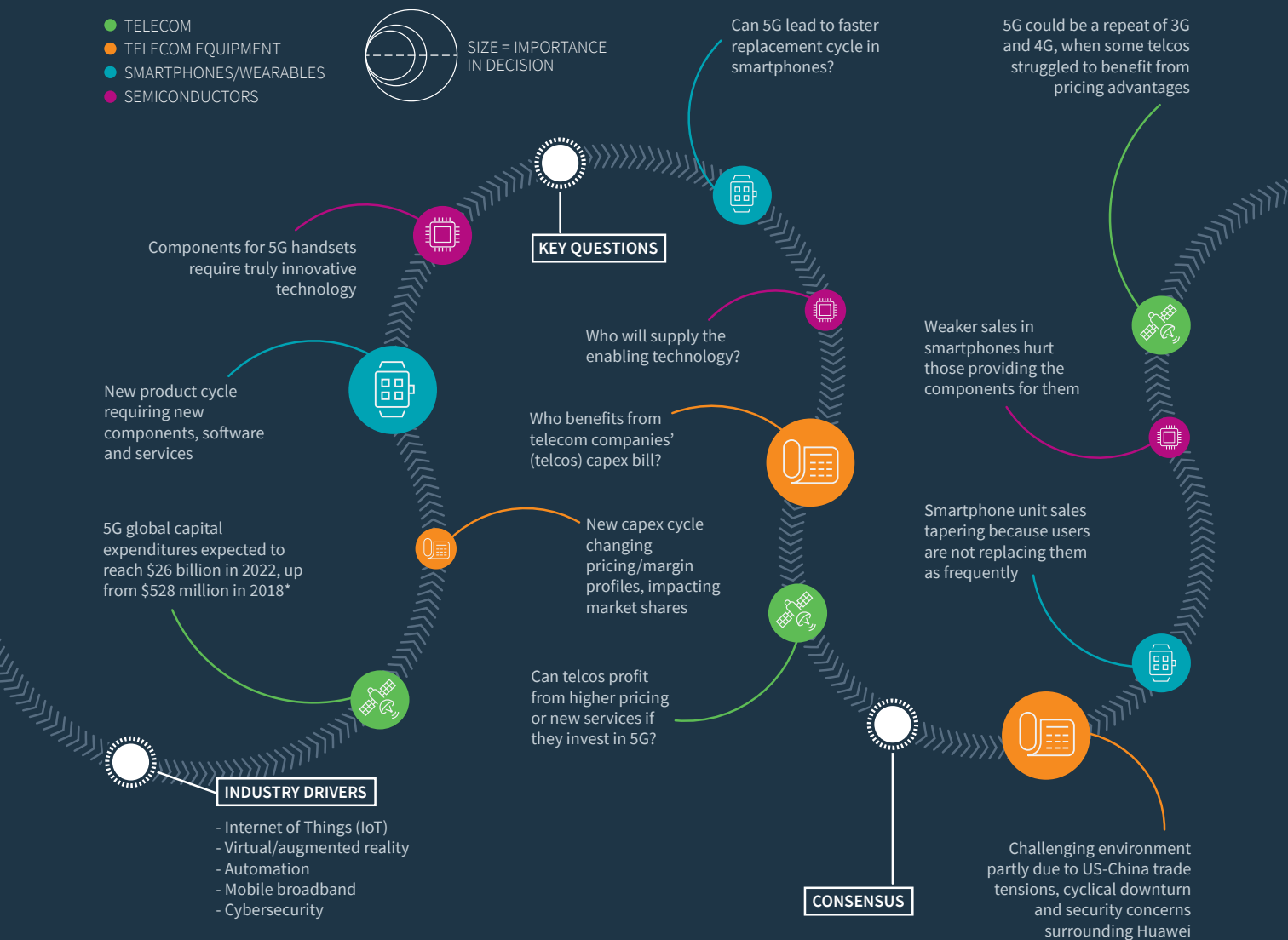
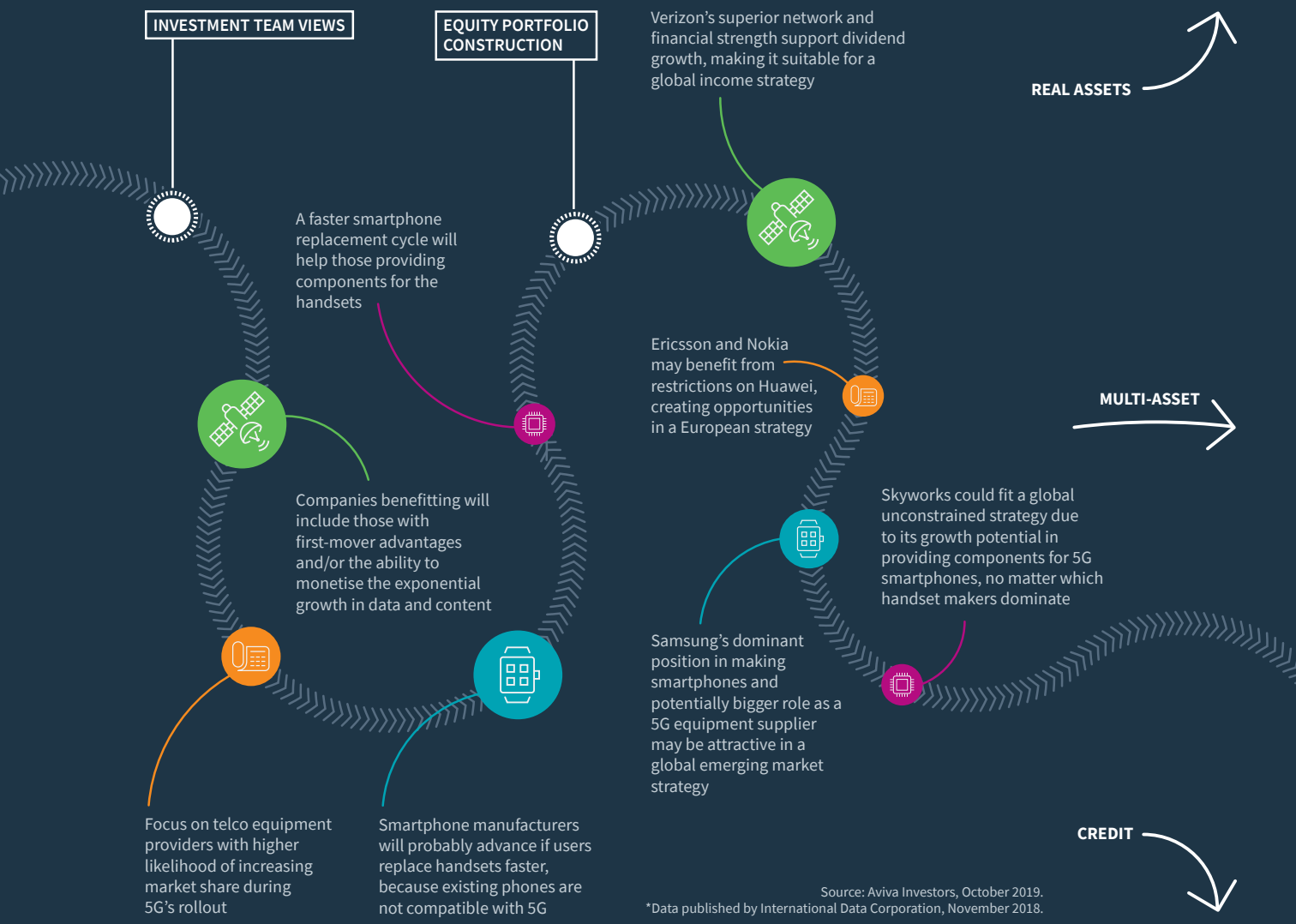
ANATOMY OF AN INVESTMENT IDEA



The evolution of wireless technology has fuelled a host of new mobile applications and helped propel companies such as Netflix. 5G, its next iteration, promises speeds up to 20 times faster than the current 4G. But to think only in terms of speed severely underestimates 5G's potential to fundamentally transform the business landscape – though not without tremendous risk. We consider a route for investors to explore 5G's opportunities in the following diagram.



Source: Aviva Investors, October 2019.
*Data published by International Data Corporation, November 2018.

RAGE AGAINST

A new wave of tech-driven automation promises improved productivity and economic growth. But as humans are replaced by robots, a political backlash is building.

> *Today's economies are on the brink of a new age of automation that could rival the Industrial Revolution for its disruptive impact*

In the late 18th century, Ned Ludd, a weaver from Leicestershire, was whipped by his bosses as punishment for being idle. Overcome with rage, he grabbed a hammer and smashed his knitting machine into pieces.

At least, that's the story. There is little evidence Ludd existed – he may have been a folk invention, like Robin Hood – but the movement that took his name was real. When textiles bosses introduced automated factory equipment in the early 19th century, a group of displaced handloom weavers banded together. Calling themselves the Luddites, they set about destroying the machines that had taken their jobs.

The Luddites have gone down in history as short-sighted reactionaries who failed to grasp the economic benefits of new technology. Before 1750, global per-capita income doubled every 6,000 years; since then, it has doubled every 50 years.[1] Without the labour-saving innovations of the Industrial Revolution, such rapid progress in living standards would have been impossible.

But, in another sense, the Luddites' actions were perfectly logical. Most of them did not live to see automation bring any tangible gains. All they knew was that those new-fangled looms had robbed them of their livelihoods.

The Luddites' fate contains important lessons for modern societies. As advances in robotics and artificial intelligence shake up industries from long-distance trucking to journalism and law, today's economies are on the brink of a new age of automation that could rival the Industrial Revolution for its disruptive impact. In 2016, Parisian taxi drivers who felt threatened by the rise of automated-driving technology overturned empty Uber cars and set them on fire, in an echo of the Luddite riots.[2]

So what are the implications of AI-powered automation for economies, companies and individuals? And how can we learn to embrace the improvements in productivity while mitigating the negative impact on the workforce?

White light, white heat

In his new book, *The Technology Trap*, Oxford economist Carl Benedikt Frey shows that, until the Industrial Revolution, technological innovations were frequently and deliberately blocked by the governing classes for fear of stoking discontent among laid-off workers.

From Roman Emperor Vespasian, who refused to adopt machinery for transporting heavy goods – "You must allow my poor hauliers to earn their bread," he remarked – to Elizabeth I, who refused to grant William Lee a patent for a stocking-frame knitting machine due to employment concerns, rulers repeatedly sacrificed economic growth to maintain stability.

THE MACHINE

"A simple explanation for this is that craft guilds had strong political influence and wouldn't put up with anything that threatened their jobs," says Frey. "Monarchs sided with the guilds rather than pioneers of industry and innovators. What changed in Britain during the Industrial Revolution was that the government for the first time began to side with merchant manufacturers and innovators rather than the people doing the rioting."

Technology and labour enjoyed a more harmonious relationship during the latter half of the 20th century, when companies used machines to augment, rather than replace, the work of humans. Wages rose strongly, with hourly compensation keeping pace with labour productivity from 1870-1980.[3] Workers gained access to new consumer goods, including household gadgets that significantly eased the burden of domestic chores. Jobs were plentiful.

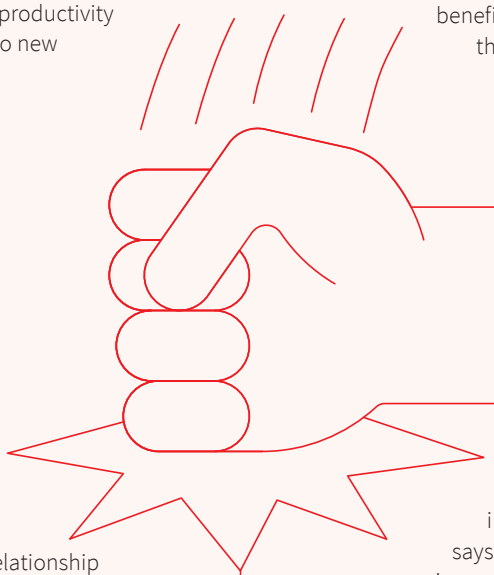
"If you look at Europe in the 1950s and '60s, trend growth ran at five to six per cent partly because you had higher productivity, driven by what UK Prime Minister Harold Wilson called the 'white heat' of technology," says Stewart Robertson, senior economist at Aviva Investors. "Productivity growth, coupled with a growing labour force, will tend to push trend GDP growth higher."

In recent decades, however, this happy relationship between labour and capital has broken down. Manufacturers have automated production lines, while developments in information and communications technology have facilitated the restructuring of supply chains and the outsourcing of labour to emerging economies.

The share of the US workforce employed in manufacturing has fallen from 25 per cent in 1950 to under ten per cent today, even as the sector's share of GDP has remained constant thanks to productivity improvements.[4] And now, advances in artificial intelligence pose a fresh danger to labour markets, threatening to displace a host of service-industry jobs. Frey's fear is that, taken together, these trends could culminate in a modern version of the technology trap, whereby so many people's lives are disrupted that governments feel compelled to clamp down on technological innovation.

The return of the challenges of the 19th century is evident in the textiles industry, where advances in AI have enabled the end-to-end automation of garment sewing for the first time (until now, robots in clothes factories were confounded by stretches and bunches in fabric, requiring a human to tend the machine). A company called SoftWear Automation has created a robot that can make as many T-shirts per hour as 17 human workers – workers who may now find themselves as redundant as the Luddites two centuries ago.[5]

Investment implications



For companies in the industrials sector, the benefits of automation are clear enough: the cost efficiencies from labour-saving technologies immediately show up on their bottom line. And, unlike human workers, AI-driven processes never need a rest and are ever-vigilant to potential problems.

"Discrete automation drives higher productivity, better quality and uniformity, flexibility and safety in the manufacturing process. Robots don't call in sick and don't require health benefits, so the payback on the initial capital investment required to automate an industrial process can be quite short," says Max Burns, portfolio manager and senior research analyst at Aviva Investors.

"Boeing is a great example of a company that is automating a historically manual manufacturing process. Three years ago, Boeing began to automate the riveting process on the 777. It takes over 60,000 rivets to assemble a 777, and the manual work is gruelling, fraught with repetitive-stress injuries. A robotic system can perform repetitive tasks better and in a safer manner than a manual process," Burns adds.

ABB Group, a Swedish-Swiss technology multinational, is another company that has introduced automation in manufacturing; the firm has developed an AI algorithm that can detect when electric motors on a production line start vibrating. Learning from the data it has already collected, the programme can decide autonomously whether the motor needs to be replaced, and how quickly. Solutions of this kind

RAGE AGAINST THE MACHINE

continued

> *The gap between winners and losers could be stark*

are being implemented by other large industrial companies that can afford to roll out AI-driven automation at scale, including Schneider Electric and Siemens.

Just as some industrial companies begin to develop their own in-house AI software to facilitate streamlined automation, tech giants such as Google and Intel are using AI to move towards the production of physical devices, including autonomous vehicles. IBM, another major player, has spotted opportunities to supply AI technology to companies in service sectors seeking to automate their operations, from call centres to insurance.

From an investment perspective, identifying sectors that will benefit from AI-powered automation seems relatively straightforward. The reams of data produced by internet-connected machinery will require manipulation, favouring data centre operators and tech analytics firms; tech giants in the US and China will attract new customers as their proprietary algorithms become ever more powerful.

Nevertheless, identifying individual companies that stand to do well out of these trends can be tricky. Automation can introduce new problems. While robots have made Boeing's manufacturing process safer and more efficient, automated stabilisation systems designed to help pilots in the air may have played a role in recent 737 crashes.[6]

As tech-driven automation spreads across economies, competing firms are likely to copy each other in introducing cost-saving innovations, quickly flattening out any first-mover advantage. Consider a relatively low-tech precedent: self-service till kiosks in supermarkets.

"The first supermarkets to automate checkouts in this way gained an advantage and were able to cut costs, but others copied them and the gains were soon competed away," says Giles Parkinson, global equities fund manager at Aviva Investors. "We could see something similar in the service sectors that begin to use AI. Whether incumbents gain an advantage, however, will depend on the specifics of the industry."

Investors must also consider the risk governments will fall into a modern version of the technology trap by outlawing job-replacing hardware. New regulations designed to protect jobs could disrupt the companies rolling out automation, wrongfooting investors that had been anticipating a fall in costs and a leap in share prices.

Automation and the economy

In a famous 2013 study, Frey and his colleague Michael Osborne explored the susceptibility to computerisation of a variety of jobs. Conducting detailed surveys of 702 distinct occupations, they concluded 47 per cent of total US employment was vulnerable over the next two decades. Jobs based on routine and repeatable tasks – including office-based telesales and secretarial roles – were most at risk.[7]

In the legal sector, some firms are already using AI to identify precedents, reducing the need to employ squads of frazzled paralegals to sift through voluminous case histories. Others are introducing contract-reviewing robots.

"AI can be used to review rental agreements, for example," says Parkinson. "The right machine can quickly pick up the presence of unusual clauses in contracts, or normal clauses that should be there but aren't. It needs an element of human oversight, but the interesting thing is that it can learn by itself what is contractually normal and what isn't."

The advent of technologies of this kind is not necessarily bad news for job numbers overall. Economists warn against what's known as the "lump of labour fallacy", which assumes there is a set amount of labour in an economy that must be shunted between jobs. After all, new roles will be created, especially in technology-intensive industries. And productivity improvements will boost living standards and overall economic growth. Oxford Economics estimates robotic installations in factories could improve global GDP by 5.3 per cent by 2030; or to put it another way, robots could make the global economy US$4.9 trillion richer.[8]

This sunny outlook chimes with the findings of a McKinsey report from 2017, which found automation could raise annual global productivity growth by between 0.8 per cent and 1.4 per cent. These gains could be particularly important in compensating for the negative impact of ageing demographics in advanced economies, the authors argue.[9]

But the economic benefits of automation will not be evenly spread, and the gap between winners and losers both within and between economies could be stark. Lower-income regions in developed nations are set to be hit disproportionately. Research shows that installing one industrial robot in lower-income areas displaces twice as many manufacturing jobs as in higher-income ones, even where manufacturing accounts for the same amount of economic activity. (This is probably because workers in higher-income areas are better trained and more productive.)[10]

What is more, lower-income regions are less likely to reap the economic gains from advances in robotics and AI, as new jobs created by automation tend to appear in

the kind of affluent urban areas where technology firms cluster.

To get a better sense of what this means for labour markets as a whole, compare Detroit, once the dynamic hub of US industry, with Silicon Valley today. In 1990, Detroit's three largest companies had a market capitalisation of US$36 billion, while collectively employing 1.2 million workers. Today, Apple, Alphabet and Facebook have a combined market capitalisation of nearly $2.5 trillion, while employing only around 260,000 people.[11]

Impact on emerging markets

The biggest impact on jobs could yet come in emerging markets, which have posted impressive growth over recent decades thanks in part to their involvement in global value chains. Global companies invested heavily in emerging economies to take advantage of labour-market arbitrage, but as manufacturing technology becomes more sophisticated, many of these firms are reshoring their operations.

At the same time, richer emerging economies are starting to automate their own installed manufacturing bases. China, for example, is responsible for one in every three manufacturing robots installed globally. A recent study from Oxford Economics and Cisco estimated 6.6 million jobs will become redundant across the Association of Southeast Asian Nations by 2028 as a result of tech-powered automation.[12]

Poorer countries are already undergoing a process the Harvard economist Dani Rodrik has termed "premature deindustrialisation", partly as a consequence of technological developments. Rodrik's data shows Latin America and sub-Saharan Africa are beginning to deindustrialise at much lower levels of income than advanced economies did.

"Developing countries are turning into service economies without having gone through a proper experience of industrialisation," wrote Rodrik in his landmark 2015 paper on the topic.

Because service industries are more skills intensive (and less labour intensive) than manufacturing, huge numbers of low-skilled workers are being left without the opportunities for advancement enjoyed by their historic counterparts in fully industrialised economies. "Early deindustrialisation could well remove the main channel through which rapid growth has taken place in the past," according to Rodrik.[13]

These economies may be able to take advantage of technology to boost development in new ways. Farmers in Kenya are using the ubiquitous mobile-payments app, M-Pesa, to become more productive. Kenya also hosts innovative companies such as Samasource, which offers a high-tech equivalent of industrial production lines; it specialises in training AI algorithms through image tagging, with low-skilled workers using computer terminals to manually input information.[14]

But this kind of work is a double-edged sword, economically speaking. Better AI will threaten the very office-based roles – such as those in outsourced call centres – that have furnished millions of middle-class jobs in emerging economies in recent years.[15]

The cumulative result of these trends in automation is that the very factor that once gave emerging economies a comparative advantage – large amounts of low-skilled, working-age labour – could prove politically hazardous in the event these people are deprived of jobs to lift them out of poverty. In his 2015 paper, before the rise of controversial emerging market "strongmen" such as the Philippines' Rodrigo Duterte,

RAGE AGAINST THE MACHINE
continued

85% of Americans support measures to restrict workforce automation

Rodrik presciently warned premature deindustrialisation "is likely to foster different paths of political development, not necessarily friendly to liberal democracy". He also foresaw the advent of leaders who would whip up new divisions based on identity and ethnicity.

Politics and connectedness

In advanced economies, too, deindustrialisation has been linked to populist political outcomes. Frey points to a correlation between the US states with the highest robot density and those more likely to vote for Donald Trump, whose trade war with China is ostensibly being waged to protect US manufacturing. Frey argues Michigan, Pennsylvania and Wisconsin would almost certainly have voted in favour of Trump's opponent Hillary Clinton – and given the Democratic Party an overall majority in 2016 – had the number of robots in America's factories not increased since the 2012 election.[16]

The politics around the issue are becoming ever more fraught: a recent study from the Pew Research Center found 85 per cent of Americans support measures to restrict workforce automation. Meanwhile, Andrew Yang claims he is running to become the Democratic presidential candidate in 2020 to protect jobs from robots.[17]

What seems clear is that sophisticated measures will be needed to mitigate the effects of automation on jobs and wages and assuage popular discontent. Some economists have argued for a universal basic income (UBI) that gives workers a guaranteed standard of living amid the convulsions of a tech-driven economy (the economic feasibility of these proposals is a topic of much debate).

Frey argues instead for a package of less ambitious but more-targeted policies, such as tax credits, new forms of wage insurance for workers who lose jobs to robots, and more affordable housing in cities. Improving connectivity between high- and low-performing regions and sectors – which can improve what's known in economic parlance as "diffusion" of productivity – would also help.

Connectedness will be important for emerging economies facing disruption, too. Rodrik argues poorer countries need to focus on bringing public and private sectors together, implementing "proactive policies of government-business collaboration targeted at strengthening the connection between the highly productive global firms, potential local suppliers, and the domestic labour force."[18]

Under Rodrik's proposals, companies should be encouraged to develop plans of action that are in line with public objectives, such as expanding employment. In return, the government would work to unblock private-sector constraints while remaining accountable to the electorate. Such an approach has proved effective in Peru, where company representatives meet policymakers at regular sectoral roundtables.[19]

Skills and training

Most economists agree investment in education and retraining will be vital to give workers the skills they need to adapt to new roles in an automated economy; even if they retain their jobs, most people will have to respond to fresh demands as automation takes hold.

"Improvements in infrastructure and measures to make the business environment more fluid and efficient will bring benefits," says Robertson. "But you also need to provide people with the necessary education and training to be able to adapt to new technologies and do their jobs better."

Take long-distance trucking, which is often cited as one of the most vulnerable jobs in modern societies due to the rapid progress of autonomous-driving technology. In fact, a recent study of the industry by academics at Michigan State University found the impact of automation on trucking jobs is not likely to be significant until the late 2020s and, even then, fewer jobs are at risk than is commonly supposed. But the role of the "driver" will be utterly transformed.[20]

"The participants in our study saw there would still need to be people in the trucks, but they might not be driving – most likely, towards the end of the next decade, they would be doing logistical and troubleshooting activities," says MSU professor Shelia Cotten, one of the authors of the report. "They may not need to be able to use a stick-shift, but they may need to know more about the technical operations of automated vehicles."

The study found most haulage companies would want to keep a human in the driver's cab for security and trouble-shooting reasons, even in a truck able to drive itself. As the job changes into a more

technical, software-operator role – effectively putting a person at the console of a massive, internet-connected computer – trucking may even begin to appeal to a younger, tech-savvy demographic. But whoever is sitting in the driver's seat will need to be comprehensively trained.

"Policymakers, educational organisations and local government organisations will need to work together with the auto companies developing these new vehicles if we're going to adequately prepare the workforce for the future," adds Cotten, who emphasises the need for transferrable skills that drivers can use across different forms of technology.

This pattern, in which technology changes the nature of labour, has been repeated many times through history. The introduction of the automatic teller machine, for example, did not replace human bank tellers; instead, it forced them to take on a range of new tasks: from customer services to financial advice to marketing. Like them, workers in the automated economy will require a breadth of capabilities they can apply across disciplines.

Policymakers and companies need to keep this in mind as they navigate the fast-changing landscape of the automated world. If Ned Ludd's ancestors are given access to life-long education and retraining programmes, perhaps they can be persuaded against taking their cudgels to the job-stealing machines. If not, the transition to a fully automated society could prove to be a bumpy ride

Workers in the automated economy will require a breadth of capabilities

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THE TECHNOLOGY TRAP: AN INTERVIEW WITH CARL BENEDIKT FREY

AIQ speaks to Oxford economist Carl Benedikt Frey about his pioneering research into labour markets and automation.

> *During periods of rapid technological change, a lot of people can be left behind*

> *We are in a period in which middle-income jobs have disappeared*

When Oxford University economists Carl Benedikt Frey and Michael Osborne published *The Future of Employment* (2013), a study of technological automation, they could scarcely have imagined the response.

The paper has become one of the most-cited in history. Its key finding – that 47 per cent of all US jobs are vulnerable to computerisation – remains a staple of news reports on technology. The study's methodology has been replicated by Barack Obama's Council of Economic Advisors, the Bank of England and the World Bank. It has even been the subject of a segment on the satirical news programme *Last Week Tonight With John Oliver*.

In 2019, Frey – who currently directs a programme on technology and employment at the Oxford Martin School – followed up this study with a book, *The Technology Trap: Capital, Labour and Power in the Age of Automation*. Ranging through history, from ancient Rome to the Industrial Revolution to the advent of AI, Frey explores how societies can gain from technological progress while limiting the negative effects. He spoke to *AIQ* about his findings.

Could you explain the title of your book?

The "technology trap" refers to the period up until the Industrial Revolution, when the political economy of technological change was such that it was frequently blocked and banned by the ruling class. This slowed down the pace of technology adoption and led to slow economic growth as a consequence. A simple explanation for this is that the craft guilds had strong political influence and wouldn't put up with anything that threatened their jobs. Monarchs sided with the guilds rather than pioneers of industry and innovators. What changed in Britain during the Industrial Revolution was that the government for the first time began to side with merchant manufacturers and innovators rather than the people doing the rioting.

What does Britain's experience during the Industrial Revolution teach us about tech-fuelled automation today?

What that period shows is that during periods of rapid technological change, a lot of people can be left behind. The Luddites are often portrayed as irrational enemies of progress, but they were not the ones who stood to benefit from mechanisation, so their opposition to it made sense. These were middle-income craftsmen whose jobs were effectively replaced by children working in factories; while they might have benefited from cheaper textiles, that wasn't nearly enough to make up for the loss in income.

The Industrial Revolution shows the ruling classes were right to fear technological progress for so long, because it brought a lot of social unrest. The era that began with the mechanisation of factory production and ended with the construction of the railroads also paved the way for [Karl Marx and Friedrich Engels'] *The Communist Manifesto*.

Clearly we are not undergoing a re-run of the Industrial Revolution, but we are in a period in which middle-income jobs have disappeared and we are seeing growing economic inequality as a result. This is translating into political polarisation. The people whose manufacturing jobs are drying up due to globalisation and automation are the most discontented with their lives. They are more likely to vote for populist policies.

You write that for most of the 20th century, labour and technology enjoyed a more harmonious relationship. Is that because technologies in this period enabled labour rather than replaced it?

In the 20th century you still saw lamplighters being replaced, elevator operators disappearing and so on. But a couple of things changed in the early 20th century. People had the experience of rising wages after the Industrial Revolution, and for the first time they saw that technology can work in their interests. Even most economists during the Industrial Revolution didn't believe technology could improve the human lot.

There were also a lot of product innovations during this time which gave people access to things they couldn't have dreamed of before: personalised transportation in the form of automobiles, the electrification of the home. Gadgets that relieved people from tedious work in the household were available very cheaply. And while mass production involved machines, it required a lot of labour and complemented people's skills. From the early 20th century in the US to the manufacturing peak (in terms of absolute employment) in 1979, the working class were doing so well that many of them became firmly middle class.

What has happened since then is that industrial robots, and automation more broadly, has cut down the number of jobs for machine operators and replaced many of those middle-income jobs that provided an elevated middle-class status for people without a college education. It is a period of reversal.

You wrote a famous piece of research about the potential effect of new AI-driven technologies on jobs. Which kinds of roles are most vulnerable?

Before artificial intelligence and machine-learning technology became more pervasive, automation was very much confined to routine, rule-based tasks that could be easily specified in computer code.

THE TECHNOLOGY TRAP: AN INTERVIEW WITH CARL BENEDIKT FREY

continued

> *A lot of low-skilled jobs that had been safe havens for workers are now exposed*

When my colleague Michael Osborne and I started to look at this in late 2011, we realised there were a lot of examples of automation that had started to go beyond routine rule-based activities: translation work, driving a car, writing short news stories, medical diagnosis. We tried to think about how the division of labour between humans and computers had evolved and decided to ask the question the other way around: In which domains do computers still perform very poorly? The answer was things like complex social interactions, creativity, the manipulation of irregular objects. Jobs that involve these types of tasks are relatively safe from automation; those could be everyone from artists to software engineers to nurses.

On the other hand, a lot of low-skilled jobs that had been safe havens for workers before – such as truck driving, working in a call centre or warehouse – are now exposed.

Most commentators have attributed the rise of populism to a backlash against globalisation rather than automation. What is the connection between globalisation and automation and are the two trends affecting the same kinds of communities?

Both globalisation and automation are driven by technology – without computers, companies wouldn't have been able to restructure supply chains to take advantage of cheap labour in places like China. Outsourcing was made possible with ICT. And Chinese import competition and robot adoption affect the same geographic areas, which are more likely to opt for Trump, in the US case. The far-right Swedish Democrats have also done better among voters whose jobs are at risk of automation. But automation and Chinese import competition are distinct phenomena and automation is more broad-based; in the US the output share of manufacturing has been constant over the last 50 years, even as the employment share has fallen.

What steps can governments take to help those affected by automation?

There is a tendency to think that because we are facing this big challenge we need a big solution. But what it comes down to is a lot of small things that make a big difference. If you look at the automation dilemma, it's very much a dilemma of geography. Jobs have been disappearing in places like the rustbelt, and those manufacturing jobs supported lots of other jobs in the local service economy. New jobs are emerging, but in different places, as tech industries tend to be highly clustered in cities. That has driven up house prices in those prime locations, which has made it more difficult for people on lower incomes to move into those markets. Building more houses in those cities, or creating better connections to declining places through smart infrastructure investment, is a very important part of the story.

I grew up in southern Sweden, near Malmö, which used to specialise in building ships. But the shipyards closed down in the early 1990s and Malmö did very poorly for a long time. The revival came with the construction of the bridge to Copenhagen, which meant people could live in Malmö, where housing was cheap, and commute to Copenhagen, where there were better-paid jobs. But they were still spending money locally, which gave a boost to the service economy and created this virtuous cycle. Now it's one of the most dynamic labour markets in Europe.

How about training and education?

Early childhood education matters hugely. We know that children who do poorly in math and reading early in life, perhaps because their parents don't spend much time with them, do worse in further learning. By investing in early childhood education you are giving people from deprived communities the opportunity to get better grades at school and go to college later on. So that needs to be part of it. Income tax credits at the bottom end of the income distribution, to ensure that low-skilled work still pays, could be important; I also discuss measures such as wage insurance for people who are forced out of middle-income jobs and have to take lower-paying jobs.

Who pays for these measures? Should we tax the big tech companies that are rolling out AI?

I'm all for getting these companies to pay more tax. What I don't think is a good way forward is to say: tax the robots, tax the algorithms, tax the things that make societies more productive. While clearly we need to tax corporations, and maybe we need to tax capital and housing more broadly, the point is that many of these policies will easily pay for themselves.

If you think about the huge distortions that occur in the economy, most people don't have the ability to live where most jobs and growth happen, and that has been a huge drag on economic growth. But if you give relocation vouchers to someone who is unemployed, enabling them to move somewhere else to get a job, that means that person will no longer require unemployment benefits.

Similarly, if you look at the economic returns on childhood education, it runs at between seven and ten per cent. Most of these policy proposals are not very expensive. And, at a time of negative interest rates, they are a no-brainer. Sooner or later, policymakers will have to come up with credible solutions to these problems if they want to win elections. I am reasonably optimistic the right policies will come, but I have no idea how long that is going to take ●

THE SUPPLY CHAIN WARS: A COMPLEX UNRAVELLING

With the US and China locking horns, we take a deeper look at the tangled and complex web of multinational relationships in the global economic ecosystem.

"Trade wars are good, and easy to win," US President Donald Trump boasted in March 2018. One year in to his trade spat with China, it is clear they are anything but.

While trade representatives came close to reaching an agreement in May, the 11th round of talks ultimately broke down amid bitter recriminations. According to reports, China balked at the idea of the US policing its compliance with the new deal.

Part of Trump's problem is that having broadcast his vow to shrink the deficit with China, as a way of repatriating lost industrial jobs, so loudly ahead of the 2016 election, he has so far got little to show for his efforts. Far from shrinking, the bilateral deficit has expanded to new records, as Figure 1 (overleaf) shows. In the year to the end of June 2019 it totalled US$401 billion, compared with US$350 billion in the 12 months before he entered office.

Can outsourcing be reversed?

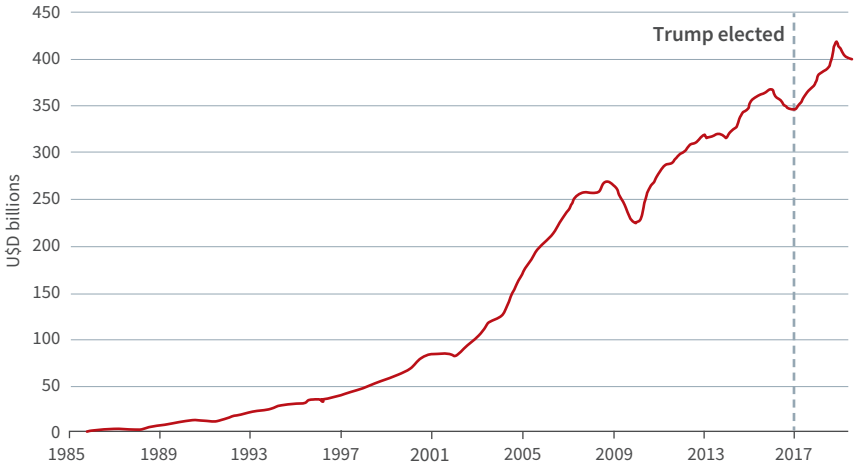
In terms of halting and even reversing the shift of manufacturing production to China, as Trump looks to win back some of the five million jobs lost in the two decades up to 2017, there is some, albeit patchy, evidence of success. For instance, Stanley Black & Decker in May said it planned to move production of its Craftsman wrenches back to the US from China, citing the raised cost of imports.[1]

However, with a tight US labour market having led to widespread skills shortages, Aviva Investors' head of global equities Mikhail Zverev believes there is limited scope for other companies to follow suit.

The process of 'insourcing' production actually predates Trump's presidency. GE, for example, brought much of its appliance-manufacturing operations back

THE SUPPLY CHAIN WARS
continued

Figure 1: **US trade in goods deficit with China, rolling 12 months**



Source: US Census Bureau

to its Appliance Park site in Louisville, Kentucky, in February 2012.[2] Decisions such as these are partly explained by the increased use of robots and artificial intelligence. Unfortunately for Trump, that suggests insourcing is unlikely to create as many jobs as he would like. This probably helps explain why job creation in US manufacturing has lagged that of the broader economy since he came to power.

It is certainly true an ever-expanding list of companies have been rejigging supply chains in order to evade tariffs. The American Chamber of Commerce in South China in October 2018 said more than 70 per cent of US companies operating in southern China were considering delaying investment or moving their manufacturing facilities.[3] However, other Southeast Asian countries were the most likely destination.

"Steady wage inflation meant China ceased to be cheapest supplier in a number of manufacturing categories some time ago. Countries such as Vietnam and Bangladesh have been the main beneficiaries," Zverev says.

Apple has reportedly asked its major suppliers to assess the cost implications of moving as much as 30 per cent of their production capacity from China to Southeast Asia and India as it prepares for a restructuring of its supply chain.[4] PC makers HP and Dell are likewise thinking of re-locating up to 30 per cent of their notebook production in China to Southeast Asia and elsewhere.[5]

However, Aviva Investors' head of emerging market equities Alistair Way says margins in some supply chains are so low the end result will almost certainly be higher prices for US consumers.

It is not only US firms that are being forced into restructuring their supply chains. According to a July 18 report in *Nikkei Asian Review*, more than 50 multinationals have announced, or are considering, plans to move production out of China.[6] Japan's Nintendo is to shift a portion of its Switch game-system production from China to Vietnam, while Panasonic in 2018 said it would transfer production of in-car stereos from China to Thailand and Malaysia, as well as Mexico.[7,8]

The reconfiguring of supply chains does not solely consist of companies moving out of China. After all, it is not just tariffs imposed by the US they are having to skirt. German automaker BMW in June 2018 said it would ramp up Chinese production of its X3 SUV to avoid Chinese tariffs.[9] This was another unintended consequence of Trump's policies, since ironically the X3 had been made exclusively in South Carolina.

In April, a survey of 600 multinational corporations by US law firm Baker McKenzie found nearly half were considering "major" changes to their supply chains, and over ten per cent a complete overhaul.[10]

Zverev says that for less-complicated businesses, such as those operating within the textiles industry, it is relatively easy to shift supply chains from one country to another. For others, however, where customers and manufacturers have invested in tooling and training specific to the product, it is much harder to shift production. Most will want to hold off for as long as possible to see how the trade war develops before moving supply chains out of China. And once they have moved, they are unlikely to shift back even if trade tensions were to subside.

Shortening supply chains

Way says the recent trend has been for companies to shorten their supply chains, where possible looking for new domestic suppliers of components. He expects this to continue. Citing Samsung as an example, he argues that while the South Korean conglomerate has in the past been happy to rely on Japanese and American suppliers, this is changing. "Faced with so much uncertainty over the outlook for global trade, companies like Samsung are being forced to get much more control of their supply chains," he says.

He points to Japan restricting exports to South Korea of three chemicals crucial for producing memory chips and displays for consumer electronic devices, citing national security concerns.[11]

Reconfiguring supply chains is taking a toll on multinational companies' bottom lines and has injected an element of uncertainty into business planning. As Stanley Black & Decker's chief executive James Loree said in 2018, finding new suppliers and altering supply chains is costly and risky. "We don't know what the lifespan of these tariffs is going to be, a couple of months, a couple of years, for ever, who knows?"[12]

Dutch health technology company Royal Philips revealed in October last year that the trade war could shave €60 million from its

> *There are signs Trump's actions are hurting American producers*

annual profit as it was forced into redesigning some of its supply chains by creating regional manufacturing hubs.[13] The same month, Panasonic said Trump's threat of additional tariffs on China could hit its annual profits by ten billion yen (US$89 million).

While most firms will lose out as a result of rising protectionism, some are likely to benefit. Wonik IPS, a small-cap company based in South Korea, could be one such example. It makes machines that manufacture semiconductors and has been picking up orders from both Samsung Electronics and Hynix, another Korean technology company. Way believes even from Samsung's perspective the long-term advantages of switching supplier could outweigh the short-run costs. "Having suppliers on your doorstep means they can be more responsive and might help to lower costs in the long run," he says.

US companies in China

On August 23, Trump called on US companies to "immediately start looking for an alternative" to China or face the threat of being forced to cut ties. Once again, his calls threaten to have unintended consequences.

With the US being a relatively closed economy, China accounting for less than ten per cent of its total exports, and the large bilateral trade deficit, Trump appears to reckon China has far more to lose from an all-out trade war. That could be a miscalculation. After all, the trade deficit fails to account for the fact that, according to one estimate, US companies based in China sell nine times more to Chinese customers than Chinese companies operating in the US sell to Americans.[14]

Interestingly, despite the worsening trade war, investments by US companies in China actually grew in the first half of 2019 as firms looked to tap into the country's fast-growing retail market, which, according to one recent report, will overtake the US as the world's biggest this year. In total, US companies invested US$6.8 billion in the first half, up 1.5 per cent from the average during the same period over the past two years, according to the Rhodium Group, a consultancy.[15]

Somewhat ironically, there are also signs China is starting to open up its economy to foreign competition. For instance, BMW in October 2018 became the first automaker to take control of its main joint venture in the country as Beijing started to relax ownership rules for the world's biggest auto market.[16]

US rival Tesla is building a plant near Shanghai – its first outside the US – where it plans to start making its top-selling Model 3 electric car later this year. The company has had significant support from China, securing as much as US$521 million in loans from local banks. On August 29, China said Tesla's cars will be exempted from a ten per cent purchase tax, something typically reserved for domestic makers of electric vehicles. The news helped propel Tesla's shares up as much as 4.8 per cent.[17]

With Rhodium Group reckoning 70,000 US companies invested US$256 billion in developing operations in China between 1990 and 2017, it is difficult to see the logic in Trump trying to force them to pull out of the country. After all, foreign competitors would almost certainly try to step in to fill the void.

Already there are signs Trump's actions are hurting American producers. US goods exports to China totalled US$52 billion in the first half of 2019, a 19 per cent drop on the corresponding period a year earlier.[18] While the fall has been driven by a sharp decline in US exports of agricultural products as well as petrochemicals, manufacturers have also been affected. For example, exports of automobiles reportedly dropped 20 per cent over the same period.

Chinese hostility

There are signs Trump's policies are backfiring in a more dangerous way for other US companies. For them, China is becoming a more hostile place to do business. Take Boeing, the world's largest aircraft maker. China is threatening to single it out as a result of the trade dispute. In March, it became the first country to ground its 737 Max jet after the plane's second fatal crash in just five months. Two months later, Hu Xijin, editor-in-chief of the *Global Times*, a state-affiliated publication, tweeted China may "reduce Boeing orders" as one of its retaliatory tactics.[19]

Although the problems with the 737 Max may go a long way towards explaining why Chinese airlines have placed virtually no orders for Boeing jets this year, intriguingly the drop in orders preceded the crashes. Chinese airlines in 2018 placed no new orders for Boeing jets for the first time in 16 years.

Any embargo would be costly for Boeing. Although China may have placed no orders for its planes in 2018, deliveries still generated US$13.8 billion, 13.6 per cent of global revenues.[20] That made it the company's second biggest market. Furthermore, ongoing rapid growth means China is expected to boast the world's biggest aviation market within a decade. Boeing itself forecasts Chinese airlines will buy 7,690 new aircraft, valued at US$1.2 trillion, by 2038.

While China is developing its own airliner, the C919, to compete with Boeing and Airbus, the programme is well behind schedule. For now, Boeing's loss could be Airbus's gain. In March, French President Emmanuel Macron landed a €30 billion contract for the European aircraft maker during a state visit to France by Chinese President Xi Jinping. China said it would buy 300 aircraft, twice what had been touted.[21]

THE SUPPLY CHAIN WARS
continued

Although it may be the most prominent example, Boeing is far from alone in being caught in the crosshairs of the trade dispute. On June 5, China fined Ford Motor Co.'s main joint venture in the country 162.8 million yuan (US$23.6 million) for antitrust violations. The country is the automaker's second-most important market, accounting for around 30 per cent of revenues.[22]

While Beijing did not link the fine to rising trade tensions, the suspicion is the two are related, not least since just four days before it said it was investigating FedEx Corp for the "wrongful delivery" of parcels. The logistics group allegedly diverted two Huawei Technologies packages, intended to go from Tokyo to China, to its global headquarters in Memphis, without notifying the Chinese company. China's state-run broadcaster CCTV said the investigation "will be a warning to other foreign companies, organisations and individuals violating China's rules and regulations".[23]

According to most commentators, the battle over trade is just part of a much broader question: how the US responds to the rapid emergence of China as an economic superpower – moreover one with a very different ideology and competing strategic interests.

Technological Cold War

This helps explains why the trade war has already begun to morph into a conflict over technology, encompassing issues such as China's forced transfer of technologies, who builds the world's 5G networks, and artificial intelligence.

"The US sees China's global ambitions, especially to be the global leader in a number of advanced technology sectors, as a threat. But China is not going to abandon those ambitions. The tensions created by that are going to be very difficult to resolve," says Mary Rosenbaum of macroeconomic policy advisory Observatory Group.

According to Peter Fitzgerald, chief investment officer, multi-asset and macro, at Aviva Investors, the 'Technology Cold War' threatens to present companies with even bigger challenges than tariffs, and heap further damage on the world's economies.

"Trade is the battle, but the real war is over technology. It's going to be much more disruptive than tariffs," he says.

The Trump administration has blacklisted more than 140 Chinese companies, severely limiting their access to US components they rely on. Most prominent among them is Huawei, the world's largest telecom provider and second-largest smartphone seller. Accused of being a threat to national security, violating US sanctions and being a vehicle for espionage, it has been barred from buying from key American suppliers. The sanctions also prevent Huawei's US subsidiary from transferring technology abroad.

Zverev says this has highlighted how dominant some US companies are in terms of producing some of the key components in many supply chains. He expects China to invest heavily in building up its domestic capability in some of these areas since it realises this is a strategic weakness.

"There are listed Chinese companies that are domestic champions and likely to be given every advantage under the sun to catch up and overtake. Other Asian companies will be eager to equip China as well," says Zverev.

In the meantime, China is retaliating. It says it will compile a list of so-called unreliable entities that damage the interests of domestic companies. It will single out companies that have stopped supplying to Chinese partners for non-commercial reasons and limit their business transactions.

Shares in Qualcomm fell sharply on August 1 after the US chipmaker warned "continued weakness in China", where it earns 65 per cent of its revenues, was set to push earnings to a seven-year low.[24] Two weeks later, shares in Cisco Systems plunged almost nine per cent after the US computer networking equipment company issued a profit warning, citing decisions by Chinese government-controlled enterprises to work with local vendors.

"We certainly saw an impact (of the trade war) on our business in China this quarter," said Cisco chief executive Chuck Robbins.[25]

Rare earths becoming rarer

China is fighting back in other ways. With the country controlling more than 90 per cent of the global output of rare earths, the threat to block off supplies of these 17 metallic elements is one of the most strategic weapons in its arsenal.

A recent editorial in the *Global Times* warned Washington not to push "too hard" if it wanted to retain access to supplies. "China is in no hurry to ban rare-earths exports and the best choice is to maintain a deterrent force on the US in the long run by using rare earths as leverage," the newspaper said.[26]

Rare earths have been deemed critical by the US Geological Survey for multiple sectors, including the country's defence industry. They are used in military jet engines, satellites and laser-guided missiles, as well as a wide range of consumer products, from smartphones to car batteries.

However, while an embargo could be problematic for many companies in the short run, rare earths are more abundant than their name suggests. Although China is currently the world's dominant producer, it only controls about one-third of the world's deposits.

Its near monopoly of production is largely explained by its lax labour and environmental regulations. Since the process of refining rare earths is laborious

China controls

90%

of the world's output of rare earths

and generates large amounts of toxic and radioactive waste, countries such as the US have until now been happy to cede production to it. That looks set to change. On July 22 Trump ordered the Pentagon to support domestic production, labelling rare earths critical for national defence.[27]

Bad vibrations: Europe caught in the middle

The impact on supply chains from the trade war goes far beyond China and the US. In some cases, other countries and their producers could benefit. For instance, according to a recent report from the Peterson Institute, while China has increased tariffs on US exports to an average 20.7 percent, it has simultaneously reduced tariffs on competing products imported from everyone else to an average of only 6.7 per cent.[28]

As recently as early 2018, the report said, firms in both the United States and the rest of the world competed in China with each other on a level playing field, facing an average tariff of eight per cent.

With China widely expected to overtake the US as the world's biggest economy within

CHINESE PLOY: THE CURRENCY BATTLEGROUND

On August 5, China's currency, the renminbi, fell below 7.00 per US dollar for the first time in a decade. Almost inevitably, its breaching of such a psychologically important level led to speculation the move was a deliberate act. After all, it happened just days after Trump's August 1 tariff announcement.

"Since they could have defended the currency aggressively had they so wished, it could be they were firing a warning shot across Trump's bow, telling him this is a tool at their disposal should he decide to intensify the trade war," explains Joubeen Hurren, fixed income portfolio manager at Aviva investors.

At the same time, Hurren says it is important to recognise the renminbi has been depreciating for the past 18 months.

Yet rather than being driven by government policy, the renminbi's decline has largely been the result of Trump's trade policy as investors responded to softer Chinese economic data, itself partly a function of the trade backdrop. Hurren believes Beijing ultimately does not want to see a big drop in the value of the renminbi, since it wishes to open up its economy to foreign investment and is eager to promote it as an alternative reserve currency to the dollar. Both objectives require a free-floating and relatively stable exchange rate.

The decline in the renminbi led to an almost immediate riposte, with Washington labelling China a 'currency manipulator'. According to Aviva Investors' head of investment strategy and chief economist Michael Grady, while the US can, in theory, use the tag to begin a process of trade sanctions, since it is already well down that path anyway it is largely a symbolic gesture. Although the US Treasury could intervene to weaken the dollar, it will be extremely hesitant to do so. Unlike past dollar interventions, which were coordinated with other authorities, such a move would be likely to destabilise financial markets.

As for speculation, China – the biggest foreign owner of US government bonds – could offload large quantities of its holdings as retaliation and force US interest rates higher. That also seems unlikely.

"Not only is there a shortage of alternative assets in which to park such a large amount of money, it would be counterproductive to inflict big losses on itself. If it wants to diversify away from the dollar, it would be far more sensible to do it gradually by allowing maturing debt to run off," Hurren says ●

THE SUPPLY CHAIN WARS
continued

the next two decades, non-US companies could benefit if Beijing embargoes their US rivals' goods.

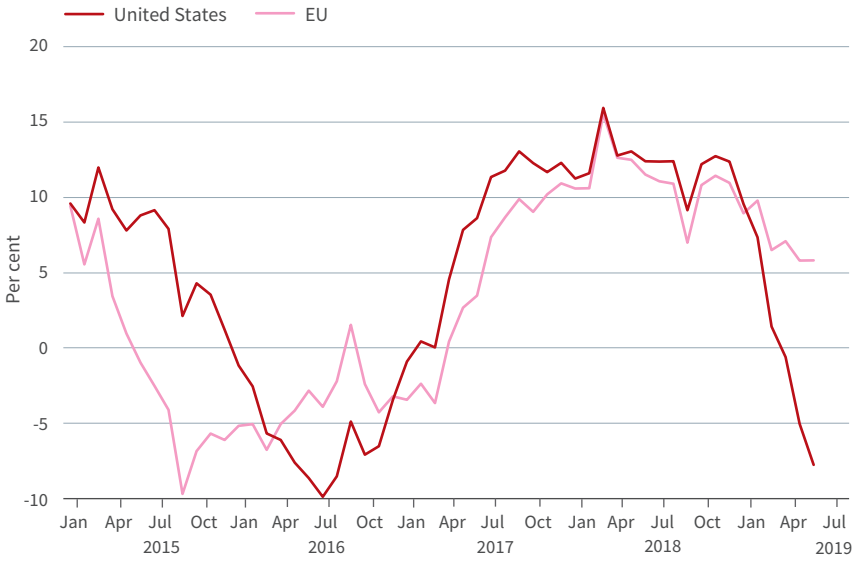
In the majority of instances, however, the consequences seem more likely to be negative. Germany, for instance, is on the brink of recession as industrial production contracts at its fastest pace in nine years. Sales of machine parts and cars to China, an engine of the country's economic growth in recent years, have been falling sharply.

Not only has Chinese demand for European exports been hurt by the trade war, it seems China may also be trying to divert exports intended for the US to Europe. As Figure 2 shows, until this year China's exports to the US and Europe had moved largely in lockstep. That is no longer the case. While the rate of growth of exports to the US has decelerated, exports to Europe have continued to grow at a healthy rate. That is despite much of the region teetering on the brink of recession. The European Commission in January imposed anti-dumping measures against imports of a number of items from China, including electric bicycles, arguing Chinese exporters were benefiting from state subsidies. Two months later, it labelled China an "economic competitor" and "a systemic rival", a seismic shift in its stance.[29]

In March, French President Emmanuel Macron declared the "time of European naïveté" towards China had ended and called for a robust and co-ordinated response by the EU towards Beijing.[30] At the same time, both he and other European leaders have been urging the US and China to pull back from their conflict. So far, their calls appear to be falling on deaf ears.

Observers say Europe, caught in the middle of the unfolding US-China rivalry, will become an important battlefield in the two nations' geopolitical ambitions. For instance, the US is pressuring European allies to exclude Huawei from their 5G networks on security grounds. Spain, Germany, and the Netherlands have refused, but Britain has said a provisional decision to allow Huawei to take part in some non-core parts of its network is under review.

Figure 2: **Is China diverting exports to EU from US?**



Exports, 6 month moving average, annual change, USD. Source: Macrobond.

Pressure to choose sides is not limited to Europe. Brazil, Mexico and Argentina – Latin America's three largest economies – are due to decide this year or in early 2020 whether they will allow Huawei to participate in the rollout of 5G mobile infrastructure in their countries. The Trump administration has been pressing for it to be excluded. For now, the signs are the countries are likely to resist, not least because faltering economic growth makes Chinese investment and financing especially attractive.

Trump's trade war is colliding with global politics in other ways. Eager to secure a trade deal with the US as it exits the EU, Britain is under pressure from Washington to drop plans to tax big US tech firms, as well as to adopt a tougher stance on the Iranian regime. Elsewhere in Europe, Italy caused consternation in Washington when in March it became the first G7 nation to endorse China's controversial Belt and Road Initiative. The US has voiced concern about China using the initiative to gain influence or control over strategically important assets across the world. However, as with the three Latin American nations, Italy is desperate for help in financing investment in its ailing infrastructure.

Reading the runes

According to some, the current conflict between the US and China was an inevitable consequence of China's emergence as an economic superpower, which has put it in a position to challenge US hegemony.

Fitzgerald says it is hard to remember a time when investing was more about geopolitics.

"Not only has the trade war laid bare the intricate ways in which the world's economies have become intertwined over the past quarter of a century or so, we've now got a technology war that is forcing countries to choose sides. It all threatens to upend global political alliances, the consequence of which is hard to calculate," he says.

That financial markets are finding it difficult to work out the full implications of what is occurring is apparent when one considers that US$17 trillion worth of government bonds carried negative yields in September, a sure sign markets are fearful the trade war is about to plunge the world into recession. But strangely, while other safe-haven assets such as gold have surged as well, riskier asset classes such as equities are also close to record highs.

Fitzgerald believes the disconnect cannot persist. "We believe equity markets will ultimately have to follow bonds. If you accept the enmeshment of the Chinese and

US economies has led to favourable investment conditions for the past 25 years, you have to believe if we're now entering a new Cold War there are going to be some fairly major adverse consequences," he says.

It always seemed as if Trump's claim that trade wars are good and easy to win was little more than hyperbole, said largely for dramatic effect. But if he did think there was a grain of truth to the boast, there are signs he is having second thoughts.

Apple has complained tariffs are hurting it more than its rival Samsung because so much of the iPhone's supply chain is in China. Following a dinner with the technology giant's chief executive Tim Cook on August 17, Trump said he was "thinking about" a remedy.[31] As the unintended consequences of his actions become ever more apparent, Cook is unlikely to be alone in hoping Trump can find a way to close Pandora's Box – and soon

> *If we're now entering a new Cold War there are going to be some fairly major adverse consequences*

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PRIVATE WANTS, PUBLIC NEEDS:

CREATING BETTER INCENTIVES FOR TECHNOLOGY, PHARMA AND INFRASTRUCTURE

With society facing many urgent and complex challenges, deciding who is best-placed to deliver solutions has become an emotive and often political subject. We assess whether there is a better way to utilise the skills and resources of the public, private and third sectors for the greater good.

$1.5 billion
average cost of a NASA shuttle launch

Blasting a shuttle into space is a costly business. With the National Aeronautics and Space Agency (NASA) at the controls, a single shuttle could burn US$1.5 billion taking matter into low Earth orbit.[1]

But NASA's approach seems anathema today. Who would plan such a costly, complex operation and jettison parts after a single use? Today, US commercial operator SpaceX partners NASA in transporting cargo to the International Space Station over 400 kilometres above the earth, but it has a different vision, based around simplifying and re-using as quickly as possible.

By using new approaches – like a floating platform to land a rocket booster as it returns to land, or a ship armed with nets to 'catch' jettisoned parts – the economics of space travel can be transformed. Targeting rapid parts turnaround means cost equations change entirely.

"Reusability is only relevant if it is rapid and complete," explains SpaceX CEO Elon Musk. "You do not send your aircraft into Boeing in between flights."[2]

Of course, the reality is complicated, and only small parts of the 're-use and re-cycle' vision have been achieved. An insulated rocket nose cone could be larger than a bus, weighing in at around 800 kilos, and, even when slowed by a parachute, getting an ocean landing area cleared and a recovery boat in the right spot to 'catch' it will be challenging.

Costing progress

Taking 1kg into Low Earth Orbit[3]	
NASA	US$54,000
SpaceX	US$2,720

Figure 1: **The movement from broad challenges to specific missions**

Source: Mission-Oriented Research and Innovation in the European Union. Professor Mariana Mazzucato. 22 February 2018.

Which of today's problems need cutting-edge science, and who should deliver the solutions?

1. WHO NEEDS INNOVATION 'MOONSHOTS'?

It is a nice anecdote, but it is reasonable to question why this is relevant in understanding who is best placed to solve complex challenges in the long-standing public/private debate.

It could be argued no-one 'needed' President Kennedy's 'moonshot' in the 1960s, but the US justified an enormous national investment as the Soviet Union was sabre-rattling. The space programme served a clear political objective – a direct challenge to USSR – and led to innovation in multiple fields simultaneously: defence, robotics, satellite technology, nutritional science, water purification and textile design.[4]

Since then, private companies have actively capitalised on those ideas. New communications technologies, drought warning systems, specialist fabrics for extreme climates, dehydrated foods, comfort foam beds… the list goes on. The value created from the original research drive has been immense, and whole new areas of commercial activity have emerged. A world monitored from space has few places to hide, but may have the infrastructure to deliver cheap, universal WiFi.[5]

This raises several questions. Which of today's problems need cutting-edge science, and who should deliver the solutions? Specifically, what should the role of the state be when resources are short but society's wants and to-do lists are so long? And, if delivering solutions means pulling in capital and market discipline from the private sector, how can incentives be structured in ways that will genuinely benefit the wider community?

Setting the compass

An approach gaining traction involves re-imagining the role of the state, not as a sluggish Leviathan, but an important player directing growth. Professor Mariana Mazzucato, from the Institute of Innovation and Public Purpose at University College London, believes innovation has two elements – pace and direction – and governments can influence both. In her view, an unfettered free market has benefits but is unlikely to deliver complex technical or social goals without at least some direction from the state. She argues it is naïve to think achievements that are often claimed by the private sector – like the development of the smartphone – came about without any government involvement.

PRIVATE WANTS, PUBLIC NEEDS

continued

"If you take apart the iPhone, every little bit of it is actually funded by the state," she said in a speech at the University of Sussex in 2012. "The state has not just funded the schools that have educated the workers that have done the research behind the iPhone. The state directly funded the internet, GPS, the touchscreen display and the communication technology behind the phone."

This conviction in the state's ability to make and shape underpins the mission-led innovation policy Mazzucato is actively promoting around the world. By setting targets and providing explicit incentives – like providing capital to the institutions that underpin research, offering tax breaks, income-contingent loans and credit guarantees – state involvement can be transformative.

Time for more mission-oriented moonshots?

This line of thinking has put some ambitious moonshots on the European political agenda, including how to achieve 100 carbon-neutral cities by 2030, how to collect more than half the unwanted plastics in the marine environment by 2025, and how to decrease the burden of dementia through personalised health.[6] They are ambitious goals, and it is too soon to judge how respective public and private roles will play out.

Significantly, Mazzucato says that without significant public infrastructure and established funding pathways in place, the private sector would likely struggle to make progress. Science is a collaborative endeavour, but ultra-long term or speculative research and investment might never be made by listed companies whose decisions may be overly influenced by the confines of a quarterly reporting cycle.

Instead, active providers of risk capital should step forward. Examples include Finnish innovation fund SITRA, or state investment banks like such as BNDES in Brazil and Germany's Kreditanstalt für Wiederaufbau Bankengruppe. They have capacity to provide early-stage capital and 'pump prime' directional technologies, and may be particularly helpful for backing innovative projects without proven financing or funding models.

Ultimately, though, the private sector may still capture the bulk of the gains from government-funded breakthroughs. "Because innovation is so cumulative, think of it as a curve, depending on where you position yourself along the curve, you can in theory 'win' the whole space underneath the curve, not just your marginal contribution," Mazzucato said in her 2012 lecture.

From this flows the idea an entrepreneurial state might be alive to capturing a larger share of the advantages that result from higher risk investments, beyond any tax receipts from successful ventures, particularly through equity stakes. Consider, for example, how SITRA's decision to hold a stake in mobile-phone provider Nokia paid off in the company's glory days. Conversely, the users of the UK's National Health Service will not benefit directly from royalties from the blockbuster cancer drug Keytruda, an immunotherapy treatment developed from the Medical Research Council's intellectual property. These were recently acquired by the Canada Pension Plan Investment Board for US$1.3 billion.[7] Users may, of course, be beneficiaries of other bioscience breakthroughs.

MONITORING DELIVERY

One of the key questions for public-service providers is how to ensure the quality of service to the taxpayers funding them. Today, cities like Barcelona are trialling citizen-led data-collection models, which will allow them to collect granular data to be used for the common good.

DEcentralised Citizen-owned Data Ecosystems, or DECODE, will allow individuals to decide which applications, platforms and tools can access their personal information, and allow government and the private sector to use it.[22] It is a vision of a data commons Francesca Bria, Barcelona's chief technology and digital innovation officer, believes should be pursued so that the people paying for services can also shape them.

The key advantages are the democratic approach – people can be consulted directly about what they wish to prioritise – and the fact the city will build a data pool to give it an integrated approach without any unwanted tie-ins.

"You end up outsourcing critical urban services to big providers without being able to shift from one provider to another and without being able to be in control of the data, and even knowing who owns what," Bria explains.

The plan is to undertake data gathering for administrative purposes, including better healthcare provision, with anonymous verification to minimise the risks of sharing sensitive data with city authorities ●

2. DESIGNING A HEALTHCARE REMEDY

Beyond technology and innovation, how should we approach areas where society clearly has needs, but the private sector seems reluctant to engage?

The pharmaceutical sector is a case in point. As the use of antibiotics has become ubiquitous, the number of resistant microbes or 'superbugs' has grown.

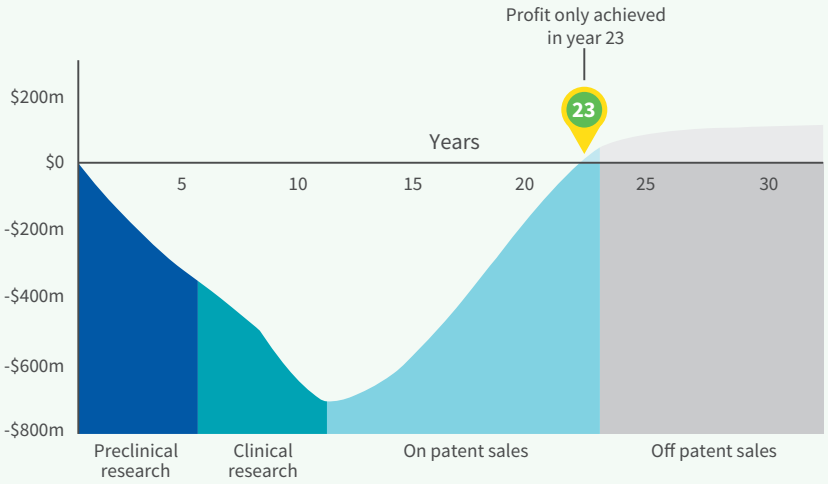
"We need new drugs to replace the ones that are not working anymore because of resistance," wrote leading economist Lord Jim O'Neil in his review of the UK pharmaceutical industry in 2015.[8] "We have not seen a truly new class of antibiotics for decades."

A world without effective antibiotics is alarming, as the accounts of drug-resistant MRSA-sufferers attest.[9] Chills, sweats, burning, itching, extreme tiredness: the symptoms of persistent bacterial infection are diverse. There were more than one million deaths caused by superbugs worldwide in 2018,[10] and scientists at the University of Melbourne, Australia, have flagged the presence of *staphylococcus epidermidis*, a bacterium resistant to all known antibiotics, in ten countries around the world.[11] If resistance grows, ten million people could die annually by 2050[12] and even common surgery may be threatened.

Nevertheless, some large pharma companies seem to be edging away from developing anti-infectives. Recently, both Sanofi and Novartis have chosen to focus their research efforts elsewhere, as have AstraZeneca and Allergan. That leaves a narrow field of big pharma companies active in this field, including Merck, Roche, GlaxoSmithKline and Pfizer.

As for why, the structure of incentives is driving activity away from areas of the greatest health need. Bear in mind that it might take more than 20 years for a private company to shift from initiating research to achieving a profitable, marketable drug (shown in Figure 2). There is pressure for modest pricing for treatments that might be used in high volume, but 'last-line' antibiotics are needed too. These are the drugs to be kept at the back of the medical tool kit, used rarely or not at all.

Figure 2: **Cumulative profits from antibiotic research**



Source: Tackling Drug-resistant infections globally: Final report and recommendations. The Review on Antimicrobial resistance chaired by Jim O'Neil, May 2016.

Cumulative profits from antibacterial research

"Society and markets are telling companies to prioritise sale volume over value," says Sora Utzinger, responsible investment analyst at Aviva Investors. "But you need a completely different model for antibiotics. The biggest barrier for companies is the regulatory burden. The costs of trials are so high, and society is not willing to pay the high price for antibiotics. That is the paradox."

New antibiotics are likely to be tightly controlled to limit the risk of resistance emerging. On average, they cost no more than US$1,000 a day, and treatment times tend to be short, amounting to a total of around US$10,000 for a course. Cancer treatments might cost ten times more.[13] So, the financial rewards for successful anti-infectives tend to be quite modest; only five of the 16 antibiotics introduced in the US between 2000 and 2015 achieved sales of over US$100 million.[14] It is no surprise there has been more of a commercial impetus for developing treatments in oncology.

Creating the right incentives

There are now several potential solutions being aired to tackle these issues, and they all share the same challenge: incentive design. The 'carrot-type' approaches include tax credits for research and development into anti-infectives, 'golden payments' for significant intellectual property and early-stage funding guarantees backed by government and non-commercial sources.

Significantly, a role for charities or the third sector is now an important part of the mix.

"There are fledgling initiatives – for example CARB-X – that fund the initial phase of research for promising projects, using philanthropic donations and government subsidies," says Utzinger. "The Wellcome Trust and the Bill & Melinda Gates Foundation are partners for CARB-X.[15] They will fund research up

PRIVATE WANTS, PUBLIC NEEDS

continued

to a point where the drug candidate is ready to be commercialised. At that point, if you have a government entity ready to step in and say: 'Well, ok, we are going to promise X over a certain amount of time as a guarantee', you would calculate the discount and agree the net present value for the drug. But that intervention is not necessarily from a private company. So, you already have an existing cross-sectoral public/private model, but it's the funding guarantee that is missing."

Other possibilities include scaling up success payments, perhaps to around US$1-£1.5 billion per drug, to be funded by multiple countries collaboratively. There is also a new subscription model being mooted in the US and trialled by the UK's National Health Service, which would involve antibiotic users paying to access to certain drugs.

"A subscription-based model could see a hospital paying a flat fee for access to a certain number of doses of an important new anti-microbial," explains former Food and Drug Administration Commissioner Scott Gottlieb. "These fees could be priced at a level to create a sufficient return for the investment made in a drug with the appropriate profile. This should have the effect of creating a natural market for drugs that meet certain important specifications."

Other options include sharing the private sector's intellectual property more widely. "Pharmaceutical companies are under constant pressure to launch the next blockbuster drug and justify the billions of shareholder funds being ploughed into research and development. Consequently, the risk-reward trade-off with antibiotics often fails to meet strict investment criteria," says Mirza Baig, global head of governance at Aviva Investors.

"One possible option is for pharmaceutical companies to actively explore joint ventures with government agencies and development banks to house the development of antibiotics and treatment for neglected diseases," he adds. "The joint-venture structure would enable companies to offset the financial impact of developing lower-margin drugs through risk-sharing development costs and enhanced distribution opportunities."

Such risk-sharing arrangements are common in the energy sector and, ultimately, it seems collaborative arrangements involving multiple parties, perhaps sharing intellectual property through content hubs, may work better in the search for complex solutions.

"The problem with antibiotic drug discovery is that it is not a single problem to solve," says Erin Duffy, chief scientific officer of US biopharmaceutical firm Melinta Therapeutics. "We like to think of the antibiotic problem in simple terms in terms of the Rubik's cube, where you have multiple faces to figure out. You are not going to solve them all. It's not impossible, but certainly not likely that just by randomly changing different pieces you will come up with the solution."

Phages to the rescue?

True to form, the issues are morphing again, with microbiologists boldly talking of a post-antibiotic era, and showing greater interest in how viral bacteriophages might challenge superbugs (see Figure 3).[16] More than 100 years after they were first discovered, using viruses to destroy bacteria is moving back up the research agenda, but the ideas are not widely commercialised.

"Phages land on their host bacterium, infect it, then propagate themselves inside it until there are so many phage particles inside that it bursts," explains Lorenzo Corsini, chief executive officer and head of research at emerging Austrian biotech company PhagoMed. "They can destroy or sterilise a whole bacterial population."

This behaviour helps regulate the level of bacteria that occur naturally in the environment. Corsini believes it might be used directly in the treatment of persistent infections, supplementing or even replacing conventional antibiotics.

Currently, there are a limited number of phage treatments approved for human use, but the area is coming back into vogue as the cost of failing anti-infectives is becoming too large to ignore. One European Commission estimate puts the figure at €1.5 billion annually from healthcare costs and productivity losses, potentially rising to trillions across the OECD by 2050.[17]

The first European clinical, randomised-control trials into phage therapy were EU funded, involving the French Ministry of Defence and French small and medium-sized entities, including Pherecydes Pharma and Clean Cells.[18] They ended in 2017. Since then, PhagoMed has received funding from FFG, the body promoting research and development in Austria, and the development bank Austria Wirtschaftsservice Gesellschaft (aws) to explore further pathways for commercialisation.

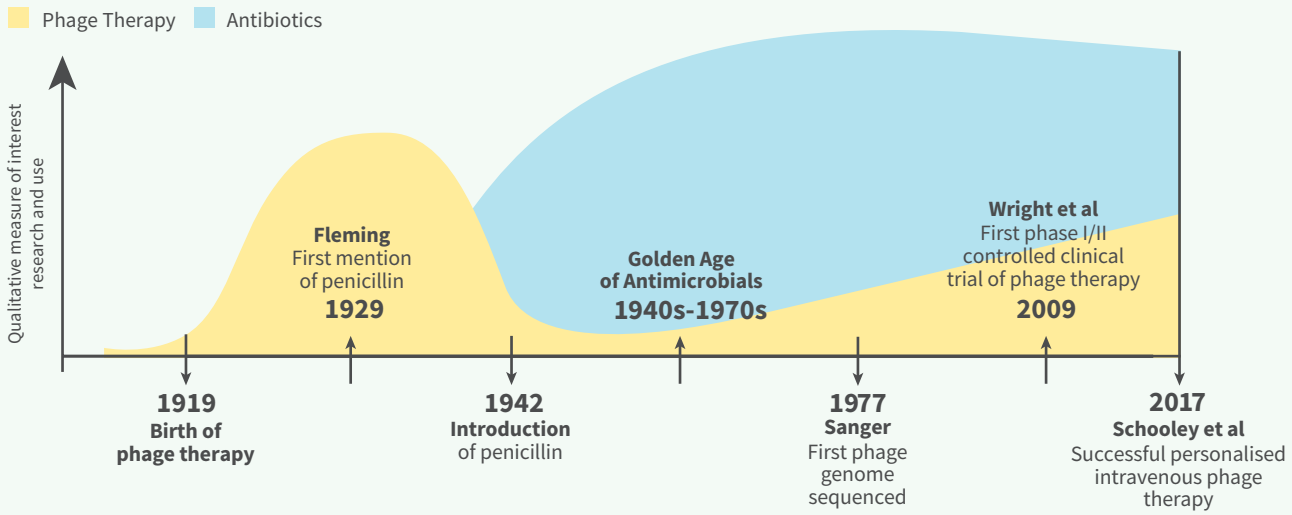
Meanwhile, the US Food and Drug Administration has accepted its first application for an intravenous phage therapy, run by AmpliPhi Biosciences.[19] And corporate positioning continues elsewhere, for example, with Johnson & Johnson recently announcing partnerships with Locus Biosciences and the Israeli company, BiomX.[20]

Researchers in the field point out the mind-boggling number of naturally occurring phages to explore (1031 to 1032; that's 10 to the power of 31 – 10,000,000,000,000,000,000,000,000,000,000 or more!), in addition to options from bioengineering.[21]

Significantly, these emerging therapies are highly specific and cannot be used in the way antibiotics are for mass or blanket applications. "Part of the reason phages have not been widely used to treat bacterial infections is because you need to know exactly what the pathogen is," Corsini explains.

That suggests there is revenue potential in quite selective areas, such as the deep-seated infections that can set in after joint replacement surgery. In these cases, bacteria can form a film on new implants that inhibit the effectiveness of antibiotics. Any treatment that could break down the biofilm and address lingering drug-resistant bacteria could have significant commercial value. But there is a major operational challenge in creating a diagnostic environment that is efficient and can be scaled up.

Figure 3: **Research interest in antibiotics and phage therapy**



Source: Fernando L. Gardillo Altamirano and Jeremy J. Barr, Phage Therapy in the Postantibiotic Era, American Society for Microbiology 2019.

3. DOWN TO EARTH: BALANCING PUBLIC AND PRIVATE INCENTIVES

Moonshots are also required closer to home. To keep pace with the changing world, providing infrastructure and other social goods will require governments around the world to muster some major resources. Whether to meet basic needs, improve resilience to climate change or provide new transport, power and data infrastructure, a large part of the capital required for building and maintaining public-service infrastructure is expected to flow from the private sector. (See Figure 4, overleaf, for the estimated gap between investment need and what is being achieved. It shows how far meeting the UN's Sustainable Development Goals raises the bar.)

Global infrastructure funding gap

But a key part of the challenge is that the solutions are not yet agreed upon or proven at scale – for example, in energy battery storage, carbon capture and storage or nuclear power. There are also few commercial models to provide long-term stable revenue to support financing and investment.

Government has the option to support in any or all of three key ways: by providing clearly stated policy outcomes, intervening to support funding models and providing capital. The right mix might vary, depending on the nature of the conundrum. But only when the measures and incentives are properly aligned is it likely that a true public-private solution can be delivered.

Cost, quality, risk

For public-private collaborations to work, they need to address the sensitive areas of cost, quality and risk sharing.

When it comes to cost, any private-sector pathway is likely to have an initially higher cost of capital (as governments can simply borrow more cheaply). However, this could be offset by efficiencies achieved down the track – fewer cost over-runs, better risk management or achieving better asset quality overall.

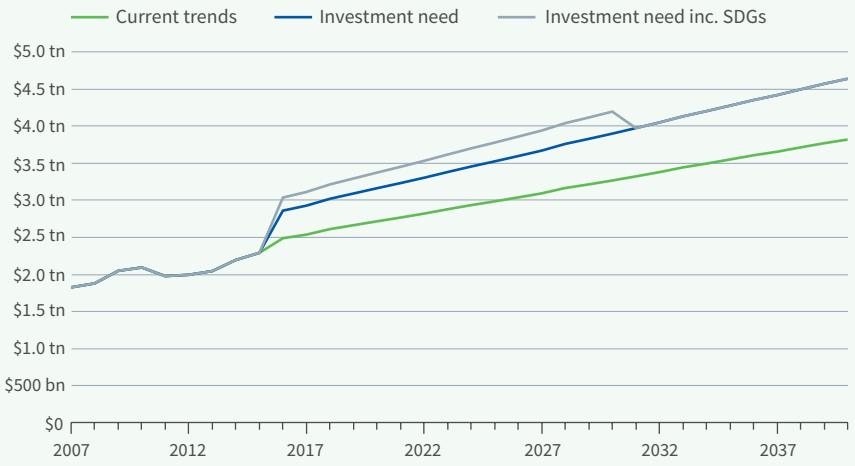
The quality issue is contentious, as in the past the needs of service users – the general public – have not always been kept front of mind.

"In many cases the private sector has simply failed to provide tangible evidence of value," says Darryl Murphy, head of infrastructure debt at Aviva Investors. "A lot of the dialogue around these issues has been focused on the public sector, rather than engagement with local users and communities. The industry needs to provide hard evidence, backed up by data, and focus on delivering better outcomes to the public."

PRIVATE WANTS, PUBLIC NEEDS

continued

Figure 4: **Infrastructure investment at current trends and need**



Source: G20 Global Infrastructure Outlook, 2018.

Perhaps this failure to involve the public and limited monitoring of outcomes explain why enthusiasm for collaboration has waned.

In terms of risk, the key is sharing. The general idea has been the party best qualified to manage the risk should be the one to take it on. But, significantly, the next generation of infrastructure challenges look quite different from the past. For example, the risks of financing data infrastructure with high obsolescence risk or nuclear-power projects costing in excess of £20 billion per plant to smooth the transition to a low-carbon economy are clearly of a different scale to small water projects.

Many new projects on the drawing board are large, do not have proven financing or funding models, nor will they generate stable, predictable cashflows from the outset – all features that appeal to institutional investors. The major question then is how the private sector can be encouraged to step forward if governments do not have the appetite.

"These projects could really benefit from credit enhancement through flexible guarantees to address specific risks, like complex construction or counterparty-credit risk," says Murphy. "In our experience, institutional debt investors mainly have appetite for investment-grade projects, particularly those investing to fund pensioners' annuities. Using credit enhancement where there might be material illiquidity premia – say in single-A to BBB rated credits – could mobilise significant capital."

He also highlights the potential for co-investing, to help take early-stage projects out of the starting blocks to the point where institutional investors, and even the wider community, want to be involved.

"It's really important to move away from the idea of a zero-sum game between private capital and public-interest projects," Murphy says. "There's a need to collaborate and lots to gain; for the government in delivering on its commitments, for private sector stakeholders, who could make a genuine contribution to enhancing assets and services, and for the public, the users. But for that to materialise, there needs to be greater clarity around what 'success' is."

This helps explain the interest in 'people-first' public-private partnerships, to ensure citizens' needs are properly met, as well as using new, direct methods of data gathering to monitor public preferences and service outcomes (see boxed text p.56). In a similar vein, Carlo Ratti, Massachusetts Institute of Technology professor and director of the Senseable City Lab, talks of PPPPs – 'public-private partnerships with people'.

Alternative ways to risk-share

In terms of future-model design, appetite for the old public-private partnership (PPP) model is lacking, but it appears the regulatory asset base (RAB) model – used for financing the Thames Tideway Tunnel, London's super sewer – could play a more prominent role.

There are important differences between the PPP and RAB models in terms of risk transfer. Most importantly, the latter introduces the idea costs and risks borne by stakeholders and investors should be shared and monitored. By allocating risk more broadly, and guaranteeing an upfront, regulated return on investment for projects in development, the overall cost of capital can be reduced.

Ultimately, the model could be rolled out widely for large-scale projects where it is difficult to be certain on costs. Developing automated signalling and train controls on live railways, carbon capture and storage, nuclear power, and wider digital infrastructure are obvious examples.

A parting thought

While we were putting the final touches on this article, a headline flashed across social media. It referenced a partnership between Amazon and US police departments to leverage Amazon Ring's doorbell camera for neighbourhood security purposes. Regardless of your view of whether this is intrusive, the inevitable privacy concerns and/or fears over the degree to which tech giants are infiltrating our day-to-day lives, it provides a timely reminder of just how wide the public and private collaboration debate extends. It demands our urgent attention.

Creating effective partnerships is not going to be easy. There is no standard template to cut-and-paste from; no one-size-fits-all approach that can be read across

It is time to harness one of the most powerful forces in behavioural psychology: incentives

industries and sectors. Designing the right frameworks for public and private enterprise to operate and, more importantly, thrive in is something generations have tried and failed to do. It will require significant investment, rigorous governance, new definitions of what constitutes value and, in some cases, a complete rethink on the role of market forces in driving optimal outcomes.

However, the costs and risks associated with not figuring this out do not bear thinking about. Problems like climate change and inequality are not going to be resolved without serious intervention and changes in behaviour. It is time to harness one of the most powerful forces in behavioural psychology and, arguably, economics: incentives.

It will take close collaboration between stakeholders – in the public, private and third sectors – to find answers. But, as governance specialists John Donahue and Richard Zeckhauser point out, maximising the benefits of collaboration is a bit like riding a unicycle: there are multiple ways to fail. But for governments bold enough to set the direction and for collaborators that understand risk, a sustained effort could bring some real 'win-win' scenarios ●

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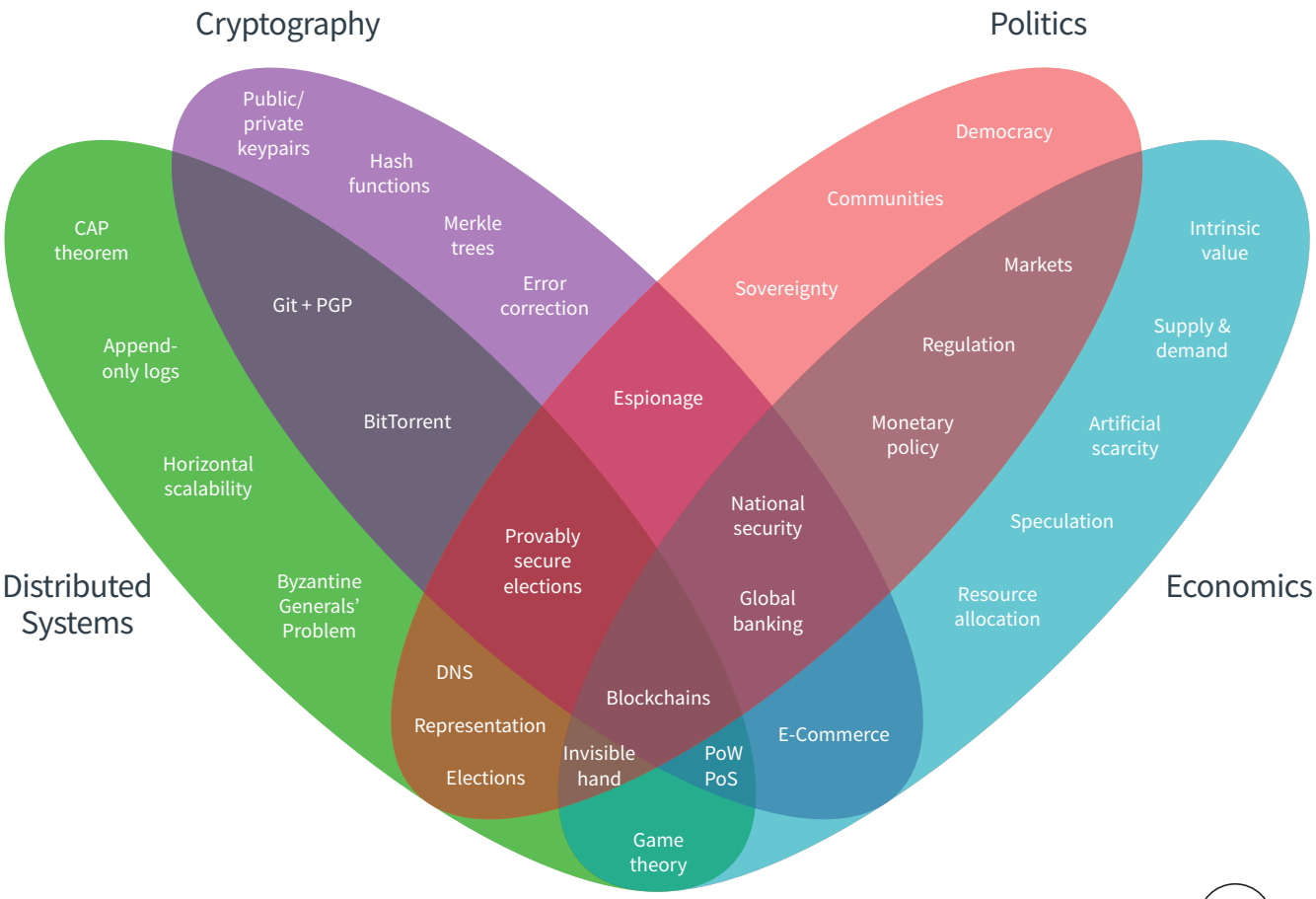
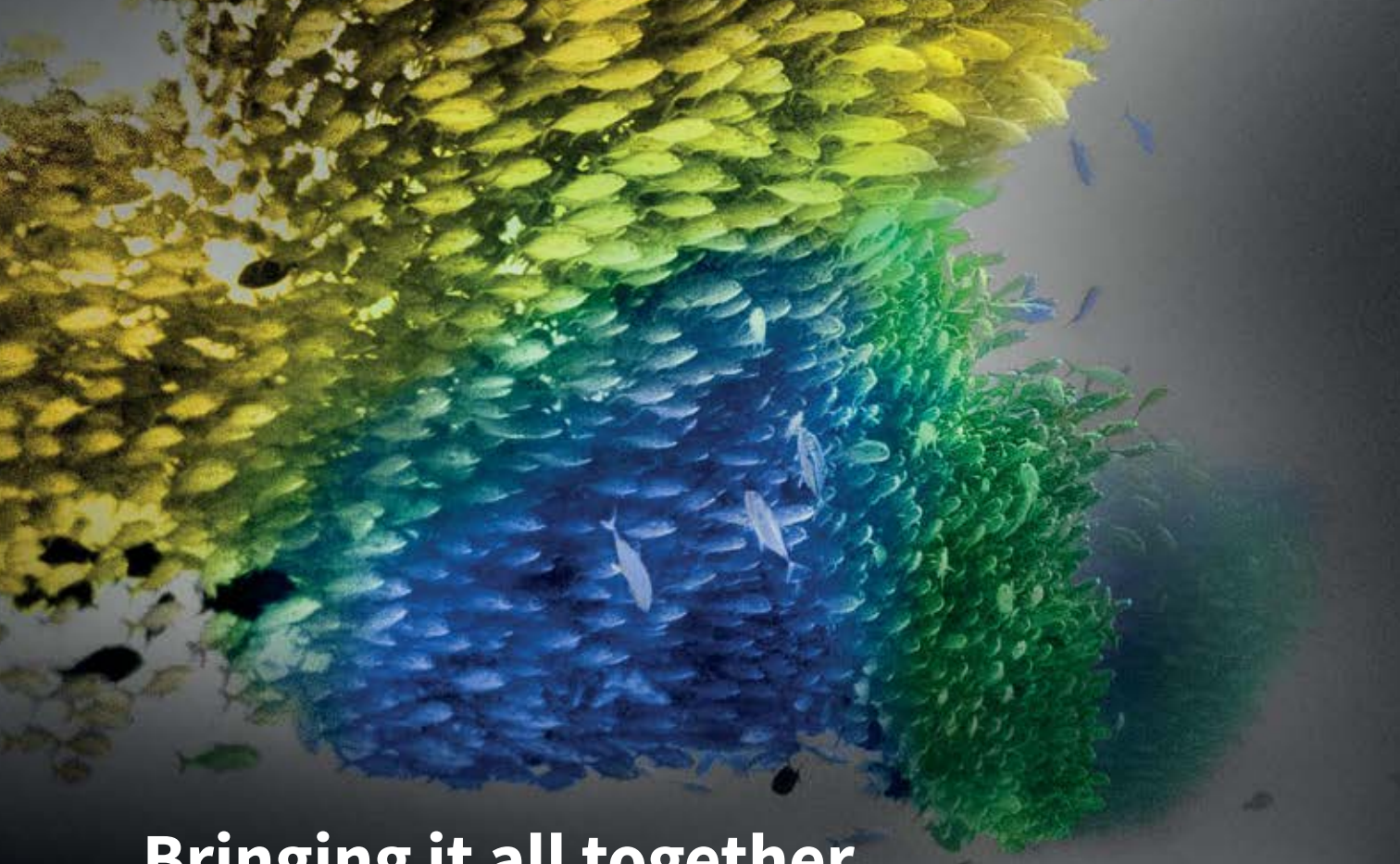
A QUESTION OF TRUST: WHAT'S BEHIND BLOCKCHAIN TECHNOLOGY?

Tech-enabled trends such as social networking, the sharing economy and crowdfunding all rest on three basic levels of trust: trust in the idea; trust in the platform; and trust in other users. Blockchain – the world's first distributed trustless consensus algorithm behind cryptocurrencies – reduces that convention of building and managing trust a step further.

Users still need to trust the idea and the platform, but they no longer need to trust other users. The process making this possible is far too complex to detail here, but essentially connects existing and new concepts in both technical and social disciplines, as shown in the Venn diagram below.

Whether society is ready for such a change remains to be seen. If you believe the anarchists, decentralising trust is the answer. However, the battle over where we place our trust is intensely political, as indicated by the global attempts to regulate – and even co-opt – cryptocurrency exchanges, chipping away at one of Blockchain's main advantages around decentralisation. Don't give up on our innate reliance on institutions and norms to create our trust frameworks just yet





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