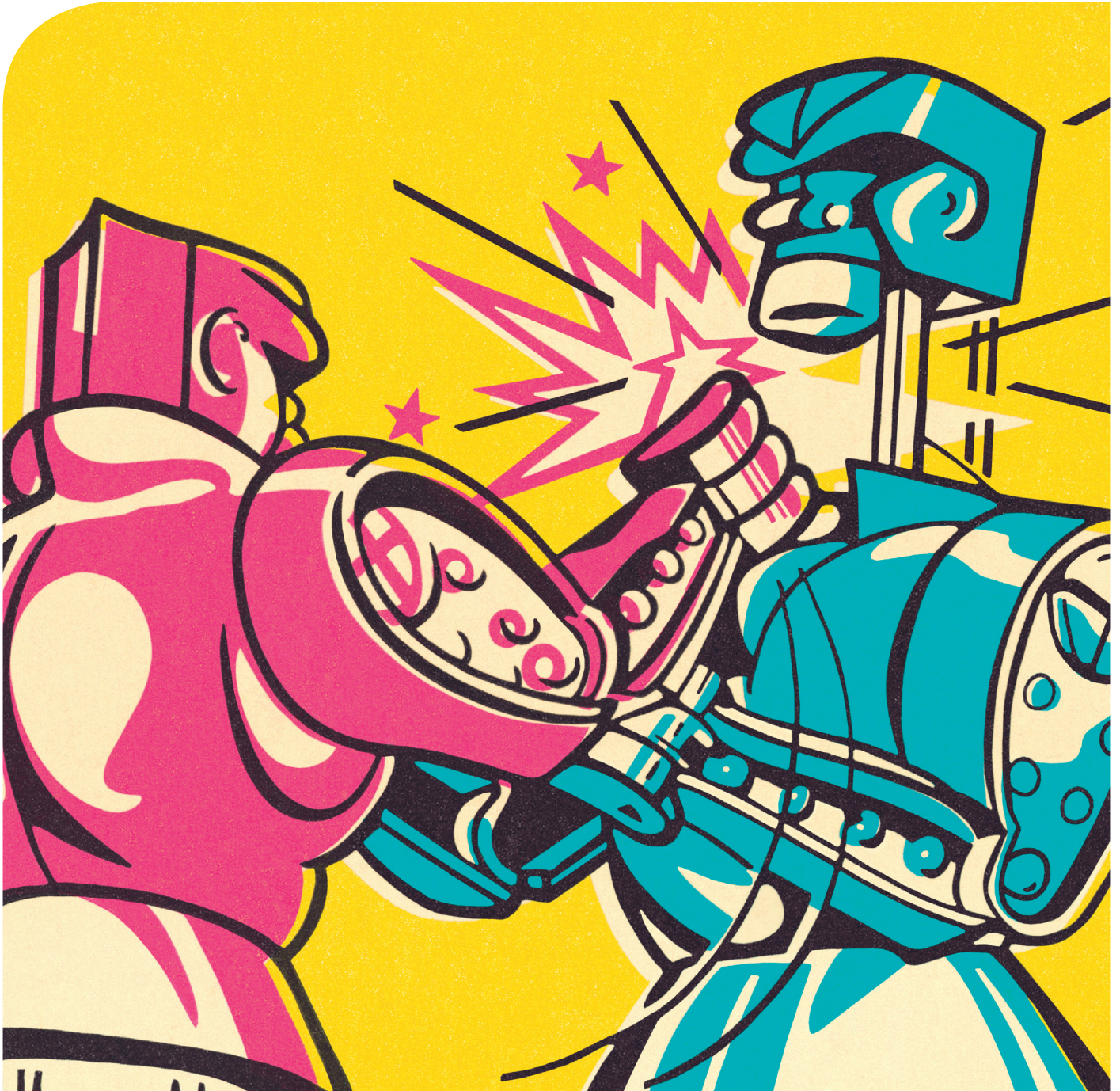


How soon is now?

The investment impact of disruptive technologies



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Foreword

It is claimed that technology is changing the world at an unprecedented pace. Whether the rate of change now is greater than in the 1840s with the railways and wider Industrial Revolution is debatable, but it is certainly true that a wide range of technological developments – some incremental and some radical – are fast changing how we live.

Such changes have profound investment implications. In the next few years, some companies will go out of business as their technology is rendered obsolete – these are the canal companies of their day. Others will survive by adopting and adapting new technologies. But even for those companies at the forefront of technological change, investment success is not guaranteed as rival technologies compete and development capital is eaten up. Investing in today's railway companies will be no guarantee of success – it will be necessary to avoid the hype and invest in the companies with business models *that can make money from the new technology*.

The primary purpose of our investment reports is to guide our investment managers, so they can make informed investment decisions on behalf of their clients. The success of these reports is determined by their scope. Technological innovation is fascinating, but we have tried to focus on the investment implications of 'disruptive technology'.

While nearly all sectors of the economy will experience change, we have focused on four areas where there is a real prospect of disruption to the status quo. This list is by no means exhaustive, but we feel these could be the areas that experience the most substantial investment impact:

- **personalised medicine:** Mona Shah examines how the healthcare sector is vulnerable to the widely predicted shift to designer drugs.
- **automation and the impact on labour markets:** Edward Smith looks at the threat to jobs from intelligent robots. Will capitalism self-destruct as swathes of white collar jobs are lost to machines?
- **alternative energy:** Sanjiv Tumkur considers the potential impact of solar and wind energy generation and energy storage technology on the utilities sectors, as well as the outlook for electric and driverless vehicles.
- **blockchain:** ignoring the over-hyped bitcoin digital currency, Jakov Agbaba looks at the technologies that underpin much of the financial system to see how much impact blockchain could have on transactions and the current financial ecosystem.

Our writers consider the short (0–3 years), medium (4–8 years) and long term (9–15 years) – beyond that, this report would be too speculative to be useful. That said, in thinking through the primary and secondary effects of disruption, we have encountered questions that cannot be answered definitively at present. Given the scale of the potential technological changes, being aware of the risks and open-minded about the potential outcomes is the best way to protect our clients.

The opportunities and challenges of disruptive technologies



In June 2014, we held an in-house investment conference on disruptive technologies. With insight from external speakers from technology companies, investment strategists and specialist fund managers, we considered how technology will change how we live and how these changes might affect investors. It was a fascinating day.

Three years on, the terminology and buzzwords that were used at the conference are far more commonplace and some of the technology is already impacting on the behaviour of companies and consumers.

For example, cloud storage, 3D printing and solar energy are now more or less mainstream; the 'internet of things', big data and electric vehicles are shifting from development to the everyday; while other technologies, such as intelligent robots, designer medicine and nanotechnology, remain further away.

The sheer scale and speed of change that we face render any report on this revolution a daunting challenge. However, as professional investors, it is imperative that we understand how technology is changing the world and anticipate how investments may be affected, positively or negatively.

What is disruptive technology?

In this report we have focused on the investment impact of 'disruptive technology', rather than make airy futurology-style projections. The term – used interchangeably with disruptive innovation – was first coined back in 1995 by Harvard Business School professors Clayton M Christensen and Joseph Bower. It applies not so much to the initial invention as to the point at which it is widely adopted and changes the market.

The invention of the motor car was not disruptive, for example, because early models were luxury items that barely affected the market for horse-drawn vehicles. It took Henry Ford's

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innovative use of mass production and the launch of his affordable Model T in 1908 to cause a seismic shift in the market. Affordability is a key driver in the widespread adoption of new technology.

While innovation is a facet of such disruption, they're not the same thing. Market leaders can innovate and introduce new technology, but the existing model survives. Professor Christensen subsequently described such innovation as 'sustaining' – this can be evolutionary or revolutionary, but the market survives and participants aren't radically affected. For example, while the introduction of cash machines (ATMs) meant we no longer had to go inside a branch to withdraw money, instantly altering how a bank could interact with its customers, it didn't lead to the instant emergence of new ATM-only banks.

Instead, we have focused on markets and sectors where the status quo could change radically. As an example, internet file sharing and the emergence of MP3 players, such as Apple's iPod, killed CD sales almost overnight, causing specialist retailers to close and significant disruption to the music industry.

Without fixating on the current academic discourse, there are several key points about disruptive technologies: – they tend to be developed by outsiders and entrepreneurs rather than market leaders as they are not sufficiently profitable at first and could detract from sustaining innovation: as a result, disruptive technologies can take longer to develop and be higher risk, yet achieve much faster penetration when they finally impact on the market. – large companies know their markets,

stay close to their customers and develop existing technology – in contrast, they often fail to capitalise on disruptive technology, which can initially lack refinement or have performance problems.

- disruption affects processes as well as products – in other words, changing how we do something is just as

important as the new technology that enables us to do it. It is rare that a technology is inherently disruptive – disruption usually occurs when a low-margin technology (or combination of technologies) is applied to a new market at a lower price.

- there can be multiple disruptive technologies across an industry, some

of which are competing.

- despite the apparent chaotic nature of change, some developments are to some extent predictable – this is particularly the case where technological progress is contingent on a previous development (see Box 1: Six ages of the internet).

Box 1: Six ages of the internet

In some ways, the IT revolution is following clear stages. The invention of the internet (first age) and world wide web (second age) started the process, making possible applications such as email, but the development of search engines such as Yahoo! and Google as well as the mobile internet and devices such as smart phones and tablets (third age) enabled the real transformation in how we apply this technology. Crucially, each stage had to occur before the next was possible.

The cloud (fourth age), which enables the remote storage of data and software, is already with us, but the benefits are still to be maximised, particularly by big companies. Small- and medium-sized enterprises have been attracted by how cost-effective it can be to use the cloud, but many larger companies, which may be more worried about security or are otherwise less nimble, are still to exploit its potential.

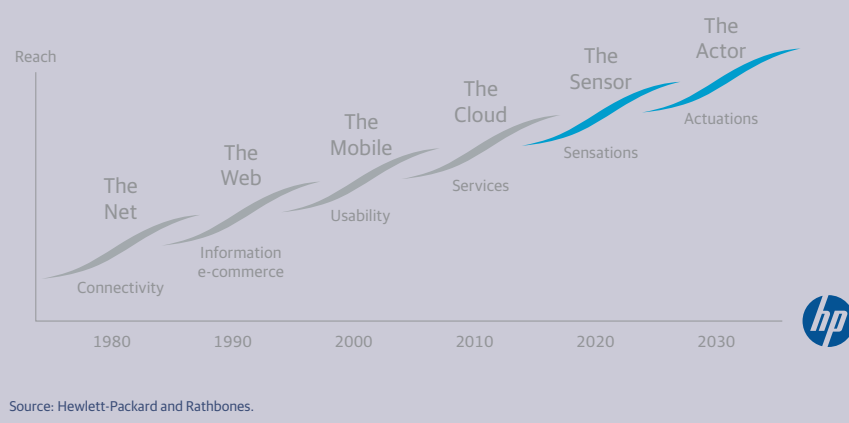
Next the so-called ‘internet of things’ (fifth age), based on the widespread application of wireless sensors, will have a substantial impact on our lives and the economy. Smart technology will be embedded in our homes, offices, cars and urban environment, helping us to manage our lives more efficiently. From monitoring traffic flow, to measuring the moisture in a field of crops, to tracking the flow of water through utility pipes, the internet of things will allow consumers, businesses and governments to cut costs.

The world’s largest technology companies are driving this transformation. From a global network of trillions of sensors to measure, study and communicate, the much-hyped concept of ‘big data’ will become a reality.

Beyond this, perhaps 10 years away, robotic devices will use this data to make decisions and act, just as humans do today (sixth age) – this is known as actuation.

Figure 1: The ages of the internet

Hewlett-Packard describes the development of the internet in terms of progressive stages. This model suggests the “sensor” stage is the next development but it is likely to take a few years to achieve its true potential and global reach.



Beware the hype

Technology is fascinating, but experience shows it can be a sure-fire way to destroy wealth – many an investor has rued the day they listened to a persuasive analyst talk about a fascinating new innovation. You may be right about the potential of a particular technology (although many do not work out as predicted and are quickly superseded by even better – or cheaper – technology), but you also need to identify how it will be adopted and which companies will profit.

The dotcom crash of 2000 serves as an enduring reminder of the risks of believing the hype without appreciating how to extract value from the business model. From 1997, analysts and investors became increasingly credulous about the impact that the internet would have and how companies might make money from it. Many of these companies were start-ups and years from making profits; in some cases, they didn't yet have any revenues.

The ability to value a company properly was superseded by the ability to imagine a future in which a company used technology to create a new market or displace existing providers. Yet, when the stock market fell, many of these start-ups went bust as their capital was used up in development or through costly advertising campaigns – that is to say, by normal costs of doing business.

While companies from the dotcom boom and bust era show the problem of ‘buying the story’, they present investors with a challenge. Some of the companies from that period have gone on to change how we live and to disrupt the market radically, whereas other apparent winners have in turn been overtaken by their competition.

Amazon was one of the early IPOs, coming to market in May 1997 – it survived both the boom and bust and has since revolutionised retailing globally. Yahoo! came to the market in April 1996

and quickly became the most popular internet search engine. Its share price skyrocketed, closing at \$118.75 in January 2000; in September 2001, after the bubble had burst, it fell to \$8.11. Subsequently, Google (whose IPO was delayed until 2004) has gone on to usurp Yahoo! and more or less drive it out of business.

As with the dotcom boom, there is so much hype about developments like the 'internet of things' and big data that it can be difficult to identify if, when and how they will actually happen, and how best to invest in their potential. As Peter Berezin (Senior Vice President, Global Investment Strategy at BCA Research) said at our 2014 conference, the challenge for investors is that technological shifts may not be obvious for 20 or 30 years and often depend on marketing and adaption to reach a critical tipping point. We need to be aware of this in devising an investment strategy.

How to invest?

Notwithstanding these challenges, the opportunity cost of not investing in technology could be huge. But is it better to invest directly in smaller technology companies by trying to spot the next Amazon or Google that is truly transformative and can profit from its innovation? Or do technology funds, managed by specialists, offer diversification against the inevitable business failures in such a high-risk area? History is littered with companies that went bust before their technology reached critical mass. Alongside valuation, commercial viability, barriers to entry and market penetration are all key considerations for investors.

The current tech giants could be the answer. This may seem surprising given their exponential growth to date, but companies such as Google and Amazon are using the huge cash flow from their current businesses to buy up smaller companies to augment their offering (and, arguably, to neuter the threat from rival technologies).

Alternatively, the forthcoming developments could be so far-reaching that companies in every sector will benefit from falling costs as technology 'commoditises' the world. The financial benefits may accrue to the consumers

rather than the innovators – if business costs fall sharply, the winners may be retailers, insurance or engineering companies, while the technology companies may destroy shareholder value through price wars or other bad financial decisions.

Whichever approach investors take, disruptive technologies could have a disastrous effect on investment portfolios as whole sectors are at risk of obsolescence. Active investing is arguably better suited to this challenge as technologically-vulnerable behemoths can be avoided in favour of smaller 'new tech' companies. In simple terms, passive investors run the risk of holding a portfolio of canal operators just as the railway companies are about to take off. While this is not the place to rerun the active vs. passive debate, active portfolios can more easily invest in the leaders of tomorrow.

Conclusion

Technology transcends national and industry boundaries, so as investors we must consider it on a global basis across all sectors. Although governments are generally poor at creativity and innovation, they can influence how technology is developed and adopted, with important implications for intelligence, policy and taxation. However, implementing regulatory or governance structures that serve all stakeholders equally may be a challenge for national governments.

The UK is well positioned to benefit from technological changes. Tech City in London is now the second-largest technology start-up cluster in the world after California's Silicon Valley. While we have an excellent history of innovation, we have historically lagged the US in exploiting the commercial benefits. This is changing, however, and many UK businesses are now world leaders in the digital economy, enjoying strong intellectual property rights and a dynamic marketing culture.

Despite our national tendency to play down success, the UK is a major player in the technological revolution. Significant changes are coming, but we should embrace the future with optimism.

As with the dotcom boom, there is so much hype about developments like the 'internet of things' and big data that it can be difficult to identify if, when and how they will actually happen, and how best to invest in their potential.

Personalised medicine is coming soon to a clinic near you



Mona Shah is head of collectives, generating fund ideas and undertaking quantitative, qualitative and operational due diligence. She also sits on the strategic asset allocation and collectives research committees. She joined Rathbones in 2007 after graduating from the University of Bristol with a first-class degree in Economics and Politics. Mona is also a CFA charterholder.

In brief

Personalised medicine will disrupt every part of the healthcare sector, from R&D and clinical trials, through diagnostic testing to regulation and healthcare provision (whether insurance-based or through national systems, such as the NHS). This will be driven by economics and improved medical outcomes. A key challenge will be the storage and analysis of huge quantities of patient data.

Risk of disruption = high

In the late 1990s, advances in research and development (R&D) promised to revolutionise the pharmaceuticals industry. Scientists were on the cusp of mapping the human genome, which is the DNA 'genetic barcode' containing the information to build, repair and run our bodies. It also contains clues about things that might go wrong as we age and which medicines might work best for us.

It was believed this would enable us to take a big step towards personalised medicine (also known as precision medicine) and away from the existing 'one-size-fits-all' model. A 2001 study showed that only 40% of patients benefitted from commonly used drugs for asthma and diabetes (FDA, 2013). Similarly, fewer than half of migraine sufferers find their tablets to be effective.

Surely by designing medicine based on an individual's genetic map, science could markedly improve our quality of life. Nearly 20 years later, is personalised medicine a reality or was it just hype and wishful thinking?

What is personalised medicine?

The EU describes personalised medicine as "providing the right treatment to the right patient, at the right dose at

the right time". By taking into account genetic factors, doctors will be able to recognise at diagnosis which patients are more likely to benefit from a particular treatment. The outcome of this is wide-ranging – increased wellbeing, fewer side effects and lower costs. In contrast, the current model is essentially based on trial and error.

For example, a patient with high blood pressure could be prescribed one of many drugs, based on their height, age, weight and lifestyle. If the patient's blood pressure reading does not fall, an alternative drug will be prescribed and the process repeated until the result is positive. For premature babies, a hospital needs to provide intensive care as it works out which drugs will work best. This could cost up to \$20,000 a day; running a genomics panel would result in more efficient treatment and a shorter stay in hospital (Shobert, 2017).

In light of the above statistics, an improvement in the efficacy of the drugs we take (how effective they are) would have a huge impact. The annual NHS drugs budget is £12 billion: if just 25% of that is wasted on ineffective drugs, these cost savings alone make personalised medicine an attractive prospect.

Box 2: Beating cancer through our own immune system

Scientists have known for decades that immune systems are relevant to treating cancer, but have only recently identified how tumours evade attacks on the immune system.

T cells are a key part of our immune system. They multiply when germs are identified to defend us from disease. They can over-multiply, so we have immune checkpoints in order to prevent autoimmune attacks on the body's own cells. Tumours, which arise from cancer, are problematic because they pressure the immune system to stop attacking the cancer cells. By blocking the immune checkpoints from interference, patients can fight the cancer; this is immunotherapy. The attraction of immunotherapy is the patient's own immune system does the work, so there are far fewer side effects than with chemotherapy.

Not all patients respond to immunotherapy, however, as it only recognises pure expressions of the PD-1 protein on T cells. In humans, it is encoded by the PDCD1 gene. By testing for this, oncologists can identify whether patients will respond to immunotherapy or other treatments will be necessary.

Why is personalised medicine on the agenda now?

The cost of gene mapping has fallen exponentially, making 'designer medicine' possible for all. Furthermore, it is now rarely necessary to map the whole genome: a panel test for a smaller sequence is possible, as is a test for one or two genes using a handheld device.

In 2013, Angelina Jolie underwent a double mastectomy after having a genetic test that showed she had a mutation in the BRCA1 gene increasing her likelihood of breast and ovarian cancers to 87% and 50% respectively. After the mastectomy, her breast cancer risk dropped to 5%.

The first human genome to be mapped cost approximately \$3 billion; by 2007, this had decreased to \$2 million; Ms Jolie's test was estimated to cost \$10,000 in 2013; and today it costs just \$1,000. BGI, a Shenzhen-based company at the forefront of nano-chip technology, believes it can drive the cost down to \$200 (Shobert, 2017).

The impact of predictive testing varies for different inherited cancer conditions. For example, ovarian cancer is still relatively hard to screen and treat, yet keyhole surgery is relatively straightforward. As a result, after having

their families, surgery is taken up by over 80% of those identified as at risk. In contrast, because the screening and treatment for breast cancer are better, yet surgery is far more severe, take-up is only around 33%.

As well as prevention, personalised medicine is also already used in treatment with positive results. Genetic testing has transformed the treatment of lung cancer: there is much faster testing for far more people, and it is now almost routine. A study by the M.D. Andersen Cancer Center showed that patients who received targeted therapy had a much higher response rate of 27% compared with only 5% for a non-targeted approach (Tsimberidou & Kurzrock, 2011).

A question of cost

Immunotherapy (see box 2 on page 7) shows how important genetic mapping is to ensure patients get the right treatment. Such applications will surely increase given testing costs haven't fallen so rapidly.

But what about the cost of drugs? At present, through R&D, pharmaceuticals companies identify potential drugs and conduct a series of expensive clinical trials that test efficacy and safety. Eventually, if the data are sufficiently

The cost of gene mapping has fallen exponentially, making 'designer medicine' possible for all.

compelling, they seek approval from the appropriate regulator, such as the US Food and Drug Administration (FDA) or the Medicines and Healthcare products Regulatory Agency (MHRA) in the UK.

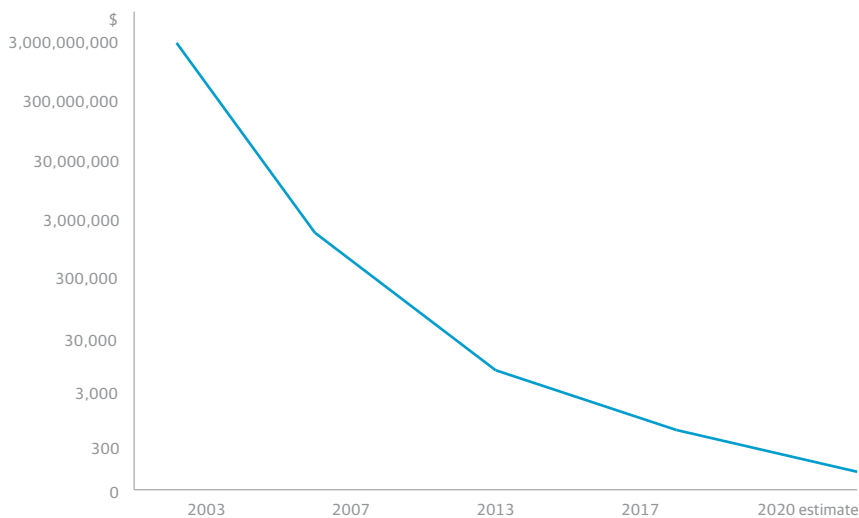
If approved, they can be manufactured exclusively by that company until its patent expires. Then generics companies can apply to produce them, often driving down the price dramatically as the cost is in R&D, not manufacture. Patents usually extend for 20 years, but R&D and the approval process can eat up the first 12 to 15 years, leaving the drug company with only a few years to ramp up sales by convincing doctors and patients of the product's superior efficacy.

As a result, only one in five approved drugs recoups its development costs (and many aren't approved, resulting in lost R&D expenditure). Many pharmaceuticals companies survive on the supranormal profits from 'blockbuster' drugs and even these have proved more elusive in recent years.

As we have seen, however, a key element of personalised medicine is that the use of drugs will be reduced to those patients for whom they will be efficacious. Pharmaceuticals companies could view genetic testing as the enemy as it is low cost and is likely to reduce the addressable population for a specific drug. They fear being squeezed at both ends by high R&D costs and lower revenues.

Genetic sequencing could result in the end of blockbuster drugs as new medicines drive higher efficacy rates, but for smaller groups of patients. If unit sales fall materially, drug companies would have to increase their prices accordingly, offsetting the cost savings of personalised medicine to the healthcare provider. To avoid this, they must be incentivised to invest in R&D without increasing their prices – one solution would require a radical change in the regulatory model.

Figure 2: Unlocking the human genome
The cost of mapping the human genome has fallen rapidly.



Source: Rathbones

If regulators can bring down the cost of developing drugs, pharmaceutical companies will be more likely to embrace bespoke medicines.

Regulate to cultivate: the role of the regulator

If regulators can bring down the cost of developing drugs, pharmaceutical companies will be more likely to embrace bespoke medicines. For example, regulators currently require large populations to be tested in expensive clinical trials to ensure that any safety issues show up in the data. By trialling drugs only on those that have specific genetic or other attributes, clinical trials could be smaller and more targeted, and would therefore be far more efficient.

The FDA has historically believed the greater the number of subjects in a trial, the greater its confidence in the results. For example, a recent cervical cancer vaccine called Cervarix was tested on 30,000 young women (CDC, 2016). Such trials are extremely expensive. The FDA's 2013 paper on personalised medicine seems to be aware of the challenges of this approach.

Smaller studies can be accurate if the tested population is very similar – genetic testing is the key to this. The FDA has set up a genomic reference library for regulatory agencies to compare results from different sequencing platforms. This is a step towards overcoming the limitations of smaller drug trials. There is an interesting link to blockchain (discussed on pages 22–25) here because it could facilitate the secure sharing of patient data. If smaller trials could be conducted more quickly, pharmaceuticals companies would also enjoy a longer period of patent-protected sales. Equally, an increase in patent length to 22 years or more could offset the decrease in unit sales.

Improved safety is an important factor in personalised medicine. From the regulators' focus on safety, it would be reasonable to imagine that all approved drugs are safe today. However, in 2015, 6.5% of all NHS hospital admissions were from adverse drug

reactions. With a median stay of eight days, this accounted for 8,000 NHS beds at a cost of £1 billion.

Pharmacogenetics is a new field of medicine that has important implications for healthcare providers. It relates to how our genes affect our response to certain drugs. Scientists believe that 30–50% of this may be genetically determined, but that it could be up to 100% for some drugs. Where kidney function tests to monitor dosage levels are currently routine, genetic tests are not. In future, such tests may allow doctors to tailor doses for maximum efficacy and minimum side effects. For example, abacavir, an HIV drug, causes serious side effects that may cause death in 7% of patients – testing has greatly reduced such reactions.

Ironically, this highlights a disruptive challenge of moving to personalised medicine – much of the value generated comes from patients not taking a certain drug, which saves money for the healthcare provider (whether it's a national health service or insurance company), avoids adverse reactions and stops time being wasted while taking ineffective drugs. Yet diagnostic tests are now very cheap, while drugs remain expensive.

The regulator could alter its current practise by approving a screening test and corresponding treatment at the same time. This would align the interests of the drug developer, diagnostic developer and the healthcare provider. Our view is that partnerships will develop between drug and diagnostic developers. Although the potential profits from such a partnership are higher for the drug developer, for pharmaceuticals companies to maximise their profits they must embrace genetic testers.

To insure is to cure

As we have shown, the biggest disruption from personalised medicine is in healthcare economics. Can the obvious health and financial benefits be realised within the current system or will there be big winners and losers?

In the US, we believe change will be driven by the healthcare insurance sector as it will be the beneficiary from greater efficacy at a lower cost. Within reason, it is also incentivised to benefit from

Box 3: Blue-sky thinking: healthcare in 3D

Imagine if you walked into Boots with your prescription and, instead of the pharmacist selecting from aisles of drugs, a 3D printer was used to print your bespoke tablets.

The use of 3D printing is already common in the production of prosthetics, particularly in arms and implants, and customised hearing aids. Researchers at Harvard University have just printed live cells, which include different types of tissues, such as skin, liver and cartilage, and can use them to test medicines. In the future, it may be possible to print new organs using a patient's own cells.

The idea of a 3D printing pharmacy is not farfetched if genetic sequencing becomes commonplace. Your doctor would prescribe bespoke medicine in the form of a chemical recipe for the 3D printer to make a tablet.

expenditure today to achieve future cost savings. If different treatment options are available, insurance companies will pay for a test to identify the best course given a particular patient's genetic make-up. They could therefore play an important role in selecting the most cost-effective tests. On this basis, they are a bridge between the diagnostics and the pharmaceuticals companies.

Under the new regime of personalised medicine, however, will the concept of 'shared risk' become irrelevant? This is the traditional foundation of insurance, but if affordable tests are able to give us more accurate predictions on the likelihood of contracting life-threatening conditions, this could feed through to insurance premiums. Those with 'healthy' genes could pay far less – the opposite would also apply.

How would insurance companies view rare diseases or those where personalised medicine is not available? There are many questions here we cannot answer, but it would be a mistake to think that healthcare insurance companies are less relevant in a world of

bespoke medicine. We believe they will be instrumental in driving the transition to the new system and may well remain central to its delivery.

The same ought to be true of national healthcare systems, such as the NHS. The cost benefits from better treatment outcomes, lower spending on ineffective drugs and a great reduction in adverse drug reactions ought to make personalised medicine a 'no brainer', but centralised healthcare systems are very cumbersome and slow to adapt. For example, the NHS works on annual budgets: it isn't designed to 'invest' this year to achieve cost savings that might accrue in the future. While thousands of women have now benefitted from preventative treatment like Ms Jolie, could the NHS cope if this approach was applied across all diseases?

It is also 'siloed' – that is to say, different parts of the NHS find it difficult to communicate, let alone collaborate in order to derive future economic benefits. At present, for example, tests can only be ordered through a clinical geneticist, even if the data is required by a cardiologist to benefit his or her patients.

The data challenges

Other than the economics, the biggest challenge for healthcare systems will involve data. The capacity of organisations such as the NHS to handle huge quantities of data is a concern. A file containing genetic data for just one of us is almost a terabyte in size. Cloud computing will take a key role in genetic sequencing, but the computing power required to process this data will be huge. Technologists may argue that the era of 'big data' is fast approaching, but organisations have to be resourced with staff and technology to store and analyse these data, and direct their resources accordingly.

There are also huge questions about data usage and protection. The US Genetic Information Nondiscrimination Act was passed in 2008 to stop genetic information from being sold on to other businesses and insurers. Nevertheless, in future will patients have the right not to disclose particular personal health information to insurance companies?

Again, there is a possible link to blockchain because the secure storage of genetic information is central to patient privacy. Although patients' genetic information must remain secure, there are strong positives to the data being shared among healthcare professionals. The cryptography within blockchain can ensure data is secure, yet easily accessible.

Governments and insurance companies need to start thinking about solutions because personalised medicine is not far away. In 2012, the UK established the 100,000 genome project, making it the first country to sequence 100,000 complete genomes and start to link it to long-term health and hospital data. An impressive start, but can this high-profile research project become part of everyday medicine and healthcare management?

Conclusion: striking the genetic jackpot

Statistics MRC claims that personalised medicine accounted for \$94 billion of sales in 2015 and will rise to \$178 billion by 2022. How these drugs are used, what they cost and how they are regulated are all questions that must be resolved for them to become mainstream. We believe it will be insurance companies in the US and, to a lesser extent, national healthcare systems in Europe that play the pivotal role in eventually making bespoke medicine ordinary.

There are currently 2,500 clinical trials taking place for immunotherapy alone. On this basis, it is timely to look at personalised medicine. However, it is still early days for this investment theme. Pharmaceutical companies that have strong pipelines in immunotherapy or other areas of personalised medicine look well placed. In contrast, those with weaker pipelines and large sales forces may struggle in the short term as they restructure.

It may be that the biggest winners from personalised medicine are the healthcare insurance companies. However, to maximise their profitability they need to transform their business away from the concept of 'shared risk'. There will be winners and losers; some insurance companies may shrink in order to become more profitable.

Although there are many obstacles to its adoption, scientific breakthroughs and exponentially increasing computing power mean that personalised medicine is coming soon to a clinic near you.

The cost benefits from better treatment outcomes, lower spending on ineffective drugs and a great reduction in adverse drug reactions ought to make personalised medicine a 'no brainer', but centralised healthcare systems are very cumbersome and slow to adapt.

If the machines aren't coming for your jobs, are they coming for your investment returns?



Edward Smith supports Rathbones' investment process with proprietary macro-based, multi-asset research and is a member of the strategic asset allocation committee. Starting his career at BlackRock, Edward joined Rathbones in 2014 from Canaccord Genuity, where he was global strategist and co-lead manager of their Risk Enhanced Multi-Asset Portfolio service.

He is a CFA charterholder and a member of the Continuing Education committee for CFA UK, helping to set the educational agenda for the investment analyst profession. Edward has completed a course in Quantitative Economic Methods at Birkbeck, University of London and received an MA from the University of Oxford.

In brief

Despite alarmist media reports, the risk to most jobs from automation is low for the foreseeable future – we tend to an optimistic view of mankind's ability to respond to technological disruption. Nonetheless, certain segments of mid-skill workers may be vulnerable and politicians will need to address the impact on standards of living.

Risk of disruption = medium

Technophobia is a recurrent theme in the political history of economic progress. Pericles spent huge sums on major public works to occupy those feared unemployable by new technology; Elizabeth I denied a patent to a knitting machine, convinced it would turn her subjects into beggars; and in 1964 a group of Nobel prize-winning economists organised to alert President Johnson to the dangers of "the automated self-regulating machine". Time and again, predictions of widespread technological unemployment were wrong. Is the latest wave of technology – robotics and artificial intelligence – any different?

A trip to London's Science Museum would provide some welcome relief to the technophobic. Its curators have assembled a collection of some of the world's most advanced robots, but on the second weekend of the exhibition most appeared to have fallen into a state of technological catatonia. Baxter, a robot adept at sorting and packing, is even programmed to show emotions to help him interact with human colleagues. When we first met he was confused. When I checked on him 20 minutes later... still confused.

Yet in a survey of 1,896 experts from a variety of disciplines, 48% expected technology to displace more jobs than it creates by 2025 (Pew, 2014). Most of the doomsayers are techies, while most of the optimists are economists and historians. One can't help but see some hubris in the techies' forecasts, and we fall into the more optimistic camp, at least as far as the next 10 to 20 years are concerned. Mass unemployment is unlikely, but optimists and pessimists agree on one thing: that the change is going to be more rapid and the impact on the economy more rattling than we've seen before.

We start by setting out the debate around the impact on jobs, but we want to move the discussion on. We end by asking how the machines might impact real interest rates, which set the benchmark for all investment returns.

The discourse may seem esoteric, but it is pertinent to all of our clients.

Always consider the net effect

The optimists' argument has it that increasingly cheap robots will displace labour, but with an important corollary: the goods and services produced by the robots will become cheaper, thus stimulating demand. Technological progress also leads to product innovation, thus creating entirely new sectors. The labour displaced by the robots then switches roles to meet this new demand. As ever, we shouldn't consider whether individual jobs are being replaced by machines without considering the net effect of all changes in employment that result over time.

The counterargument is usually structured along three broad lines of attack: (i) that we have invented all of the products we are ever likely to consume; (ii) that robots will soon be able to perform the majority of tasks that humans do, so there will be no roles into which labour can switch; or (iii) that robots will cause such a dramatic redistribution of wealth and income in favour of their owners and architects that the total demand for goods and services will fall.

Use your imagination

The first counterargument is easy to dismiss. Theorists have always missed the capacity for human ingenuity to create entirely new ways to spend money. No less a mind than John Maynard Keynes wrongly predicted that we would be working 15-hour weeks by now because he assumed that the gains to our productivity would accrue more to free time than consumption. In short, discussions of how technology may affect the demand for labour too often focus on existing jobs and neglect the emergence of the yet-to-be-imagined jobs of the future.

The machines are here to help...

The second counterargument – that robots will become so advanced that they will take all of today's jobs and tomorrow's (both the cognitive and the routine) – is not so farfetched, but is unlikely to be a concern for most of our lifetimes. And, as we shall see, ignores some fundamental principles of economics.

This fear has been fuelled by a frequently cited (and miscited) study conducted by two Oxford professors, Frey and Osborne (figure 3), which estimated the susceptibility of employment to automation. It concluded that 47% of US jobs are at risk. However, the citations invariably take this statistic out of context. A job could register as susceptible to automation within the next two decades, even if the probability of that potential being realised was very small. Indeed, Frey qualified his position in a later paper: "Although we cannot exclude the possibility that technology may reduce the overall demand for jobs in the future, this is seemingly not an immediate concern... [and] concerns over automation causing mass unemployment seem exaggerated, at least for now." (Frey & Rahbari, 2016)

They also ignore that jobs invariably involve a multitude of tasks. If a machine could perform every task performed by a certain profession, then automation necessarily reduces employment in that

profession. But if a profession is only partially automated, employment could well increase (so long as demand for their combined output increases as prices fall). Today in the US there are more cashpoints than human tellers, but there are still twice as many tellers today as there were in the 1970s when cashpoints were first introduced (Bessen, 2015). Cashpoints drove down branch costs and improved the productivity of tellers after they were relieved of the mundane task of counting out money. This allowed banks to open more branches.

Automation is usually aimed at specific tasks rather than whole occupations. The evidence so far suggests that most of the adjustment to automation to date has occurred through changing task structures within occupations, rather than through workers being forced to switch occupations (Spitz-Oener, 2006). Economists at the Organization for Economic Cooperation and Development (OECD) used detailed analysis of the tasks associated with our jobs to re-estimate the risk of occupational automation projected by Frey and Osborne. On the assumption that a job could disappear entirely if more than 70% of its associated tasks have the potential to be automated, the study found that only 9% of US and 11% of UK jobs are at risk (Arntz et al, 2016). The jobs most at risk are not just those currently requiring skilled hands, but also those related to exchanging information and selling products.

We are still a long way from Artificial General Intelligence (AGI) – machines able to turn their hand to pretty much any task without being programmed specifically to do so. Computers have long since been able to defeat the best human chess players, but they still can't look at a five-year-old's picture book and tell us what's going on. We may be less than 10 years from the day when \$1,000 buys us the equivalent processing power of the human brain (Rachel & Smith, 2015), but we have only just been able to emulate the neurological complexity of a flatworm (Techradar, 2015). Humans are likely to have long-lasting comparative advantages when it comes to reacting to unexpectedly complex situations, spontaneous

failures and tasks employing social and emotional intelligence quotients. Indeed, occupations that are relatively social-skill intensive have accounted for nearly all new jobs in the US since 1980. The wages of those employed in jobs requiring limited social skills have fared poorly, even if that job requires high maths skills (Deming, 2015).

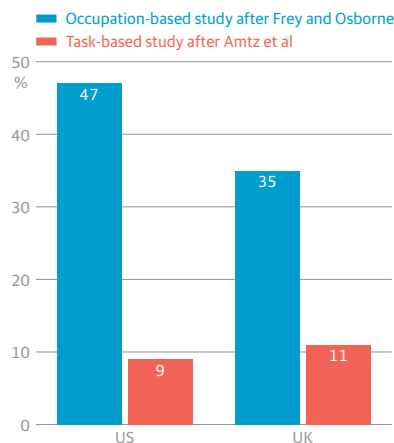
For sure, machines will cause more and more disruption, but are likely to be more our complement than our substitute. Even if we are on the brink of a technological onslaught, major disruptors still require complementary investment. People need to come up with ways to integrate them. MIT professors Erik Brynjolfsson and Andrew McAfee in their book *The Second Machine Age* show how this has been the case with most disruptive technologies since steam power. In other research, Brynjolfsson has shown that for each dollar of capital invested in computers, firms tend to make \$10 of complementary investments in 'organisation capital' (such as business processes, repurposing roles and tasks, and training). That's a big multiplier.

What's more, new technologies often have to wait for another technology to come along before they are truly game-changing. The computer did not revolutionise consumer markets until the internet brought new ways to work, shop and play into every home. One new technology begets another; one new industry begets a second. Evidence of these second-round effects was another reason why Frey issued the qualification of his original work with Osborne.

"Labour is not dead wood to be carved up between tasks. It is a tree whose trunk and branches have lengthened and thickened with time," says Andy Haldane, with a poetic flourish unusual for a Bank of England Chief Economist (Haldane, 2015).

The substitution of automatable jobs will also depend on the wage level, of course. If intelligent machines do leave a lot of people looking for a job, wages will fall relative to the price of machines (though not necessarily in absolute terms as long as new roles and new products are created), thereby improving employment prospects again. The

Figure 3: Jobs at risk from automation
Jobs tend to be an amalgamation of tasks, most of which cannot be automated.



Source: Frey & Osborne (2013, 2015), Arntz et al (2016).

market clears. Furthermore, economic expansion occurs where inputs are in abundance. If labour becomes cheaper relative to other factors, that influences the range of tasks allocated to it. It also influences the direction of technological change itself by incentivising firms to introduce technologies that allow firms to harness labour and its comparative advantage in certain tasks more intensively (Acemoglu & Restrepo, 2016).

...but that help won't come for free

But how great an impact could machines have on wages? Could they skew the distribution of income to such an extent that it would result in a decline in the aggregate demand for goods and services? Remember that the highest earners have the highest propensity to save extra income. Businesses also have a high propensity to save. Therefore if machines compete more with low- and mid-earners, pushing down their wages, and more and more income accrues to the highest earners and firms, less of the overall pot will be spent or invested in the economy.

We know that the only way for societies to become wealthier – to improve the standard of living and raise real wages – is to keep getting more output relative to the number of inputs (Krugman, 1994). This is called productivity growth and it happens

through innovation and technology. But, in theory, technological progress could be so biased towards the newly intelligent machines, their owners and the few high-skilled people they need to work with that average real wages decline, even if comparative advantage keeps people in a job.

An analogy might help. Imagine everyone is a fisherman, bar one capitalist who supplies nets. Everyone is employed and they fish in a small lake. The wages of fishermen would be determined by how many extra fish an additional fisherman could pull out of the lake for a given number of nets. Now imagine the capitalist supplies better nets (technological change). This would result in more fish per fisherman, and would improve the extra catch one new fisherman could provide, so their wages would rise.

But now imagine not a better net, but something really game-changing – a fantastical fish magnet, perhaps. This magnet would dramatically increase the catch to the point where the fishermen could catch a surfeit of fish without requiring any new labour. This would change the impact of adding new fishermen. Put another way, the gains from the fish magnet are much larger at lower levels of employment, but the incremental benefit of adding new fishermen is now diminished and real wages wouldn't increase (and could move

lower). The fish magnet is a substitute for much of the fisherman's role, while the better net is complementary. This technological change is what we call 'capital-biased'. The share of total income will accrue more to the magnet man than the fishermen.

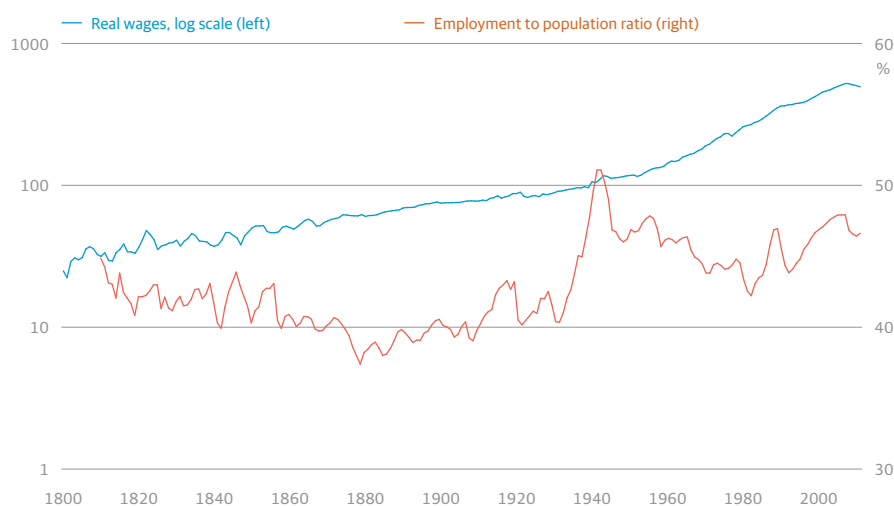
In practice, the evidence does suggest rising real wages, albeit with more inequality. Or, more crudely, the poor gain, but not as much as the rich. How much inequality rises from here depends on how substitutable machines become for labour. As we have discussed, it seems we are decades away from perfect substitutability in most professions. If machines are not perfect substitutes, humans' unique talents become increasingly valuable and productive as they combine with the accumulating, newly intelligent machines. This increase in labour productivity outweighs the fact that the machines are replacing some humans, and wages rise with output. But as we have seen, harnessing the true productive potential can take time.

Using a theoretical model, economists at the IMF suggest a baseline of 20 years for the productivity effect to outweigh the substitution effect and drive up wages. This lag corresponds with the evidence from the last 200 years of disruptive innovation, as figure 4 shows (Haldane, 2015).

Historic and contemporary evidence suggests that mid-skill workers are most affected by the initial disruption. Today's mid-skill jobs are the ones that haven't come back after each of the last three recessions (Siu & Jaimovich, 2012). While over time, new mid-skill jobs will emerge, they may come too late for the displaced individuals – state-provided retraining is very unsuccessful. These workers tend to add to the supply of low-skill workers, placing downward pressure on wages as income inequality rises.

Complex economic simulations, depending on their parameters, suggest a wide variety of outcomes in the race between man and machine, but they almost universally conclude that the average worker will likely end up taking home a decreasing share of total income (cf. Benzell et al, 2014) as humans become more

Figure 4: Real wages and employment
Technology has not proved a problem over the past 200 years in the UK



Source: Bank of England and Rathbones.

reliant on machines for the continued improvement of their productivity.

Automation versus ageing

It is imperative, however, to join the automation debate with another great conundrum of our era: ageing. Ageing workforces are close to transitioning to shrinking workforces. Machines may take some jobs, but there will be fewer workers to apply for them anyway. Furthermore, as we age, we tend to consume more services than goods (think healthcare). Services tend to be more labour intensive, and it is in the provision of services – particularly those requiring human interaction – where machines are likely to be least substitutable for humans. This should further alleviate concerns that machines will decimate workers’ pay.

Will the robots eat my interest rate?

Ageing is frequently blamed for lower rates of growth and lower rates of returns. Certainly it is partly culpable, but there are a number of other factors and we now ask how intelligent machines could alter the outlook.

Contrary to popular belief, real interest rates are not driven by central bankers, but by the ‘neutral real rate’. The neutral real rate is often described as the ‘Goldilocks’ rate of interest; the rate

consistent with stable economic growth that does not cause inflation to overheat. It is linked to two factors.

First, it is linked to the potential growth rate of the economy (potential, meaning an economy operating without any slack caused by a downturn in the business cycle). If you think of growth as a proxy for the return on investment, lower returns leads to less demand for capital and that pushes down on real rates. Years of ultra-low central bank policy rates have not caused the economy to overheat because trend growth and the neutral rate have fallen, and so policy is not nearly as expansionary as many pundits make it out to be. Central bankers are slaves to the neutral rate.

It is also linked to the desire to save or invest. At a global level, savings and investment must be equal – all investment must be funded. If you’re wondering how debt works here, a loan is accounted for simultaneously as an investment the lender makes in the borrowers’ debt and as money (savings) deposited in the borrowers’ bank account. The neutral rate of interest is what balances the two. Desired saving will tend to rise as real rates increase, because higher rates generate higher returns on saving; desired investment will tend to fall as real rates increase

because the real rate is a key component of the cost of capital, so as real rates rise it becomes more costly to invest.

The neutral real rate has declined by approximately 4.5% since the 1980s. Studies attribute about a third of the decline in the neutral rate over the past few decades to lower potential growth, and most of the remainder to changes in the preference for savings and investments (Rachel & Smith, 2015; Laubach & Williams, 2003). Below we set out the key drivers behind these moves and ask how intelligent machines may influence them. We summarise the impact on real interest rates in figure 5.

Potential growth

Potential growth is a function of more workers, more invested capital and higher productivity. Machines can’t make more workers, and in the short term could lead to fewer eligible workers participating in the job market if older workers find it more difficult to acquire the skills needed to work with new machines (Fujita and Fujiwara, 2014). We discussed how new technology often begets more investment, but offsetting that are the observed trends of corporate capital hoarding, constrained banking and the falling cost of machines. If the new technology is truly disruptive it will likely require the scrapping of old capital and a new wave of investment. Productivity growth has stalled, but remember that there is often a lag after the initial technological change.

In short, if we are on the cusp of a new era of intelligent machines, we would be likely to see an improvement in growth as a result of investment and productivity – and therefore slightly higher real rates – but there are still other structural forces blowing in the opposite direction.

Ageing and saving

An eight percentage point increase in the number of people of working age relative to the total population has increased desired savings to such an extent that it may have lowered real rates by almost 1% (Rachel & Smith, 2015). People in the second half of their working lives save the most, while older people tend to draw on their savings. On current trends,

Figure 5: Robots and rates

Factors driving down neutral rates over the past 30 years.

Factors that have driven down rates	Impact of automation on rates	Reasons
Potential growth	↑	Some uplift to productivity likely
Ageing and saving	↑	Initial decline in older workers’ participation
Inequality	↓↓	Greater share to capital, with a higher propensity to save
Emerging markets savings glut	—	Highly dependent on response by government and firms
Falling capital goods prices	↑	The impact is a trade off dependent on returns to capital
Falling public investment	↑	Louder and louder calls from policymaking circles to appease popular unrest
Higher net returns	—	Lots of scenarios in which returns increase by more than rates and vice versa

Source: Rathbones.

this will reverse from about 2020. If automation causes older workers to drop out of the workforce rather than retrain, it could lead to a faster drop in savings. On the other hand, a technology-driven healthcare revolution (as described in the article on personalised medicine on pages 7–10) could increase life expectancy and this could cause retirees to consume less each year from their savings and people in work to save even more.

Inequality

Firms and the wealthy have a higher propensity to save. So if they take a larger slice of the pie, desired savings increase. One of the few things that everyone seems to agree on in the man versus machine debate is that income and wealth inequality will increase, especially in the initial stages of disruption when skills and retraining opportunities are deficient.

Emerging market savings glut

Rising commodity prices and decisions to increase reserves after the Asian crisis saw the desired savings of emerging markets (EM) rise more than investment. If machines are less complements and more substitutes for EM workers, then machines could cause EM household savings to decline. EM governments may also increase investment in education and infrastructure to boost their comparative advantages in order to offset some of the impact of machines. Moreover, if EMs are equally as good at coding and managing the machines, then firms may choose to increase investment there too. That said, if automation in manufacturing leads to Western firms withdrawing their production, capital could flow out of EM economies. The effect of automation on EM savings is uncertain.

Falling capital goods prices

The prices of investment goods (such as computers) have fallen. When this happens, a given project requires less investment expenditure, but more projects can be undertaken. The net effect across the economy depends on substitutability again – whether investment displaces consumers so requiring fewer projects to meet future demand. As we have discussed the next generation of intelligent machines are

not likely to be perfect substitutes for most occupations, but the gains are likely to be somewhat biased towards capital owners. New opportunities should alleviate some of the downward pressure falling investment prices place on rates.

Falling public investment

The global government investment to GDP ratio has declined by about one percentage point, for reasons more to do with politics than economics. If technology causes higher inequality, it may necessitate greater public investment in order to compensate the working classes for the increase in inequality. On the other hand, capital is taxed at a lower rate than labour and if automation leads to a rising capital share, tax receipts will be lower making infrastructure spending difficult, particularly at a time of high debt.

Higher net returns

Investment decisions are based on the difference between return on capital and cost of capital. The IMF estimates that the global return on capital has risen relative to rates, meaning that fewer investments need to be made in order to deliver required returns to investors, thereby pushing down on real interest rates. In so far as machines are productivity enhancing, the return on capital should rise. Whether or not it rises faster than the cost of capital depends upon all of the factors above.

So on balance, machines are likely to exert some upward pressure on real interest rates. This is good news for holders of cash. Higher real interest rates would hurt bond holders as yields normalise in accordance with a higher neutral real rate. But as yields rise it increases the ability for bonds to satisfy the required returns of new investors, thereby decreasing the incentive to move into credit or equities.

Conclusion

The relationship between jobs and technology is far more nuanced than many commentators appreciate. Hopefully, this will provide some reassurance to clients who might have feared that their children or grandchildren face a life of robot-induced

penury. Given my interaction with Baxter at the Science Museum, any such dystopia is decades away; but we still take a more optimistic view of mankind's ingenuity and believe that technology will unleash as many new employment opportunities as threats.

Given many workers may not have the right skills to work alongside new technologies – and that retraining programmes are poor (Card et al, 2010) – machines are likely to disrupt many working lives. History suggests this trend is likely to affect particular groups of mid-skill workers, possibly concentrated in particular regions. As a result, greater income inequality and a decline in the average worker's share of total income could exacerbate social and political tensions.

If the initial analysis is right about last year's EU independence referendum decision and the election of President Trump being the product of working- and middle-class anger about declining standards of living, technology could create further political populism. Like globalisation, it is a perfect faceless enemy for demagogues, appearing to line the pockets of the global elite. The challenge for politicians is to find better ways to ameliorate the impact of change on specific groups and communities and to articulate better the wider social and economic benefits of technological progress. Investors should take note: our research last year uncovered a new relationship between policy uncertainty and investment valuations, unprecedented for at least 25 years.

On the other hand investors concerned about secular stagnation or the impotence of monetary policy to deal with the next recession when interest rates are near zero should welcome the age of automation, for it appears that it is likely to exert a net upward pressure on the structural rate of interest appropriate for the economy. As ever, we must consider the net effects.

PERSONALISED MEDICINE

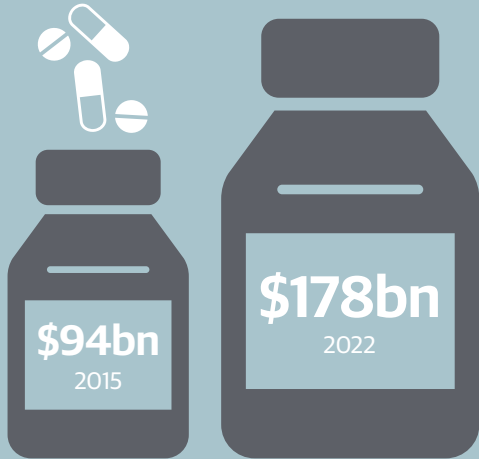
Only 40% of patients benefit from common asthma and diabetes drugs



6.5% of NHS hospital admissions in 2015 were from adverse drug reactions, accounting for 8,000 beds and costing £1 billion



£12bn Annual NHS drugs budget



Predicted personalised medicine sales

Women identified at risk of ovarian cancer who accept the offer of simple keyhole surgery



Women identified at risk of breast cancer who accept the offer of surgery – far lower as surgery is much more severe

\$3bn
2003

\$2m
2007

THE FALLING COST TO MAP A HUMAN GENOME

\$1,000
2017

\$200(?)
2020



Amazon are already trialling a Prime Air drone delivery service



CHARGING FORWARD

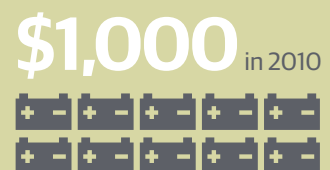


1880s renewable energy first developed in the form of windmills, dams and solar cells



1 in 3 automobiles at the start of the 20th Century were electric

Average electric vehicle battery price per kW



2-3 million

electric cars to be produced by Volkswagen per year by 2025



68%

average fall in cost of utility-scale solar systems from 2009-2015



28%

of global electricity generated in 2021 will be renewable energy

2.28 secs

fastest ever 0-60mph set by a production vehicle, the electric Tesla Roadster S P100D



ROBOTICS AND ARTIFICIAL INTELLIGENCE



8%
increase in the number of people of working age relative to the total population since 1980s

Opinion is divided on how many US jobs are at risk from automation



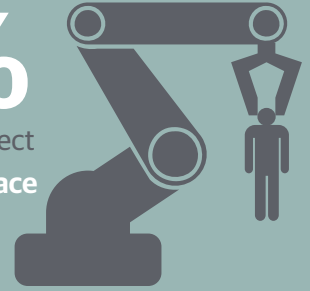
According to the OECD



According to Oxford professors Frey and Osborne

48%

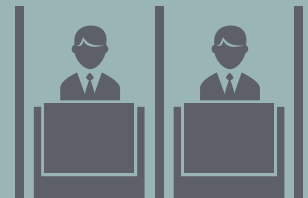
of 1,896 experts expect technology to displace more jobs than it creates by 2025



After last year's EU referendum and election of President Trump, technology could create greater social and political tensions

There are **more cashpoints than human tellers** in the US today but there are still

2x

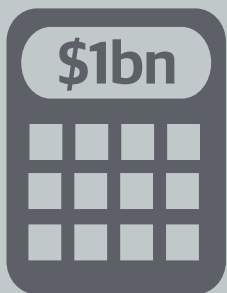


as many tellers now than in the 70s

Each dollar of capital invested in computers leads to \$10 of investment in 'organisation capital'



BLOCKCHAIN



investment by venture capitalists of blockchain development in 2015 and 2016

740+

cryptocurrencies in the world today of which Bitcoin is one example



\$40m

average spend per year by banks on 'Know Your Customer' checks



25%

saving of banks operational costs from the use of blockchain in customer onboarding and transaction monitoring

\$15-20bn

estimated savings per year in cross-border payments by 2022

\$11-12bn

estimated cost savings in the financial industry by the automation of custodial services



\$400m

expected spend by banks on blockchain by 2019



\$80-110bn

estimated value that blockchain could generate in financial services

Charging forward: how the revolution in battery technology could transform our world



Sanjiv Tumkur is Head of Equity Research. He started his career at Morgan Grenfell Asset Management (later Deutsche Asset Management) in 1996 where he was an investment manager and equity research analyst. In 2006 he joined Alliance Bernstein to focus on equity research for mid-cap companies and later moved to Investec Wealth & Investment. Sanjiv graduated from Oxford University with a degree in Philosophy, Politics and Economics and has passed the Institute of Investment Management and Research (IIMR) exams.

In brief

Through advances in battery storage technology, we are on the cusp of major changes for electric vehicles and alternative energy. These are likely to be disruptive to utilities – with the ability for homes to go ‘off grid’ – and car manufacturers. Less reliance on fossil fuel consumption could have significant geopolitical implications.

Risk of disruption = high

A revolution in battery technology could reshape the way we live, radically alter the economics of some markets and potentially shift the balance of world power. This is not speculation for the distant future. The start of your day 15 years from now may be very different from this morning:

As you head to your bathroom, you note that you are making money again from your solar panels, even as they instantaneously power your piping hot shower. And you see from the indicator that the store of energy in your small solar-powered home battery has only dipped to 80% of capacity despite weeks of poor weather.

After breakfast, your electric car slides silently to a halt outside the front door. Usually you catch up on emails during your 30-minute commute. But yesterday was a particularly successful day at work and this morning you feel like a treat. So, as you have grown confident enough in your self-driving car over the last year not even to keep half an eye on the road, you switch on the immersive virtual reality player and play the latest episode of ‘Robot Wars’.

The minutes pass only too quickly before you stride into the office full of optimism – helped by checking the price of your investment in BBC stock – the British Battery Corporation, of course, not the recently privatised broadcaster...

What seemed like science fiction just a few years ago is now a reality and will likely be a part of daily life for many of us within the next decade or two. But haven’t we heard all of this before?

Indeed, alternative or renewable energy, in the form of windmills, hydroelectric dams and solar cells being used to produce electric power, was first developed in the 1880s. Windmills and dams had been a source of non-electric power for grinding flour and irrigation for millennia before this.

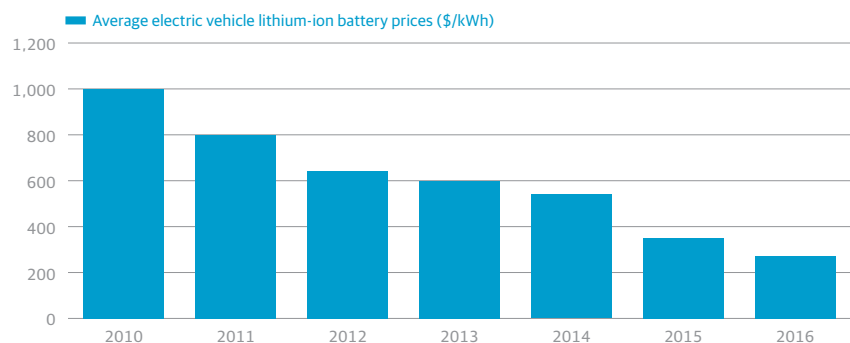
Electric vehicles were first devised in the 1830s and used to be far more prevalent. At the beginning of the 20th century they represented around a third of all automobiles. Henry Ford’s introduction of the Model T led to the dominance of the petrol-powered internal combustion engine that persists to this day, as it offered higher speeds and reaped the benefits of lower cost through mass production.

Why are these technologies not mainstream today?

In most cases, renewable energy sources have simply not been cost-effective compared with the fossil fuels of oil, gas and coal. These have been readily available, albeit that their supply is ultimately finite. And where alternative

Figure 6: Battery costs are falling

This chart shows the average prices of battery electric vehicle and plug-in hybrid electric vehicle batteries, including both cell and battery pack costs.



Source: ‘2016 Lithium-ion battery price survey’ – Claire Curry, Bloomberg New Energy Finance, December 2016, and Rathbones.

energies have been cost competitive, such as hydroelectric, geothermal and biomass power (using wood, crops or manure), they have faced significant limitations. Hydroelectric power works best in areas with steep mountains and building new dams creates huge social and environmental upheaval, as in the Three Gorges in China. Geothermal power works best in areas around tectonic plate boundaries. Biomass tends to produce air pollution, while using scarce agricultural land and water resources.

Wind and solar energy have suffered from their unpredictability – what happens if the wind doesn't blow or the sun doesn't shine? This 'intermittency' has made it difficult to rely on them as sources of energy, whether for an individual home or for a country, and has limited their ability to contribute to energy generation.

Even if alternative energy had been more cost effective and reliable, for a long time battery technology was too rudimentary to enable it to be effectively harnessed. Electric vehicles lost out to the internal combustion engine a hundred years ago in large part because battery technology at that stage was too basic to allow higher speeds.

So what is changing now?

Essentially two things: the significant advances in battery technology that ameliorate the problems of intermittency and improve cost efficiency; and government commitments to tackle climate change, which are encouraging a change in taxation, subsidy and pricing to account for the negative 'external costs' of fossil fuels, such as pollution and global warming.

Battery technology has advanced significantly over the last decade, making solar and wind power and electric vehicles far more attractive than ever before. The rechargeable lithium-ion battery, commercialised by Sony in 1991, has made possible the revolution in portable mobile devices. Since 1991, the battery's energy density (the amount of energy it holds) has more than doubled, helping reduce the weight of the battery within an electric car, while its cost has fallen by more than 90%. And, since 2010, average electric vehicle battery prices have fallen from \$1,000 per kWh

Box 4: An autonomous world

In the long term, once autonomous driving is conclusively shown to be safe, it could be adopted relatively quickly. Generations who have seen driving as the passport to adulthood, and a car as a key possession to aspire to, will probably be among the last to adopt autonomous driving. However, there is significant evidence that millennials, especially those who live in cities, are driving less and those who do drive often use car clubs rather than own their own car. While partly explained by economic factors, this indifference to driving has been boosted by the rise of instantly available and relatively affordable ride-sourcing services, such as Uber and Lyft.

At the extreme, one could envisage a future in some decades' time in which society has moved to 100% autonomous driving, which theoretically should make roads much safer as human error causes an

estimated 90% of car crashes (5) – this will have implications for the insurance and healthcare sectors. In this scenario, private car ownership would probably be minimal, with most cars produced for large fleets owned by corporations to rent to consumers on a journey-by-journey basis. This would impact on car manufacturers, as they would no longer target consumers with aspirational brands, but adopt a similar business model to the aircraft manufacturers Boeing and Airbus – seeking to appeal to fleet owners by emphasising their efficiency and utilisation credentials. There would be little need for parking spaces in urban city centres and one could imagine a radical restructuring of the cityscape, with wider pavements and potentially more pedestrianised roads. Car passengers, in particular commuters, would have more time to work or to 'consume' entertainment.

to \$273 (see figure 6), and are predicted to fall to \$109 by 2025. Cheaper, lighter and more powerful batteries are crucial for electric vehicles to be cost effective and fast, and in giving alternative energy a greater role in the economy.

Electric cars offer energy efficiency, converting around 60% of electrical energy from the grid to power at the wheels, compared to internal combustion engine vehicles which only convert 20% of the energy stored in gasoline to power at the wheels.

Alternative energy and electric vehicles have long been seen as necessary for the world to meet climate change and carbon emission targets without sacrificing economic development and standards of living. Climate change has become an increasingly important concern, exemplified most recently by the ratification of the Paris Agreement in 2016, which seeks to hold the increase in global average temperatures to well below 2 degrees centigrade higher than pre-industrial levels, and to try to limit the increase to 1.5 degrees. In addition geopolitical instability in key oil and gas

producing areas, such as the Middle East and Russia, has made greater energy independence a growing priority.

Government policy has focused particularly on wind and solar energy, which are the 'cleanest' alternative energies with the widest global applications. They are seen as helpful to fill the gap left by the phasing out of nuclear power, following Japan's Fukushima disaster, in countries such as Germany and Spain. Government tax credits, subsidies and power purchase agreements have enabled wind and solar energy to grow to a scale whereby they are now nearing commercial parity with conventional energy, even without subsidies. The average cost of utility-scale solar systems fell 68% from the end of 2009 to the start of 2016.

If one takes into account construction costs as well as ongoing input and operating costs, on a unit cost basis solar power is already cheaper than conventional gas-fired power plants in sunnier areas, such as South Africa and the Middle East, while onshore wind turbines are more cost effective in countries with stronger winds like

Denmark and parts of North America. As manufacturing volumes increase and further push down unit costs, solar and wind will ultimately become cost effective in most geographies.

Where are the early transitions to mass markets already evident?

Taking the car industry first, rapid advances are imminent. The renaissance in electric vehicles, such as the Nissan Leaf and the Chevrolet Volt, was championed by environmentally conscious early adopters who were happy to put up with limitations such as a maximum range of 100 miles on a single charge, which in most drivers would produce 'range anxiety' or the fear of the battery running out during a long journey.

Manufacturers are now, however, already offering a more aspirational range of cars which do not require any sacrifice in terms of performance. For example, Tesla's Roadster launched in 2008 and Model S in 2012 boasted a range of more than 200 miles and 0–60 miles per hour acceleration in 3.7 seconds. A recent software update enabled the newer Model S P100D in its 'Ludicrous+' mode to accelerate from 0–60 in 2.28 seconds, making it the fastest accelerating production vehicle ever (as measured by 'Motor Trend'), benefiting from the electric motor's instant 'torque' or turning force at zero speed. However these cars were aimed at the luxury end of the market with launch prices of \$109,000 for the

Roadster and \$95,000 for the Model S, owing to the high cost of the battery.

Tesla's long-awaited Model 3, due for release in 2017, is targeted at the mainstream market with a starting price of \$35,000 (£28,000), the average cost of a new American car. With forthcoming electric models announced by Chevrolet (the Bolt) and BMW (the new i3) for 2017 and Volkswagen announcing its ambition to produce 2–3 million electric cars a year by 2025, there will be a wide range of aspirational electric cars offering high performance and long range (200 miles+) at an affordable price point – this should increase penetration of the total car market. Developments in battery charging – making it faster and expanding charging infrastructure, perhaps at petrol stations – would further help the adoption of electric cars.

The rise of the electric car is likely to be accompanied by autonomous or driverless technology, spearheaded by the likes of Google with its 'Waymo' technology and also its artificial intelligence work. The drive-by-wire and brake-by-wire systems in electric vehicles are better structured for autonomous driving than the mechanical control systems found in conventional cars. Once fully matured, autonomous driving will enable passengers to spend their time focusing on other things than the road – reading, relaxing, working or sleeping. In time, this is likely to have wider economic and social impacts than on just the car market, including where people choose to live in relation to work.

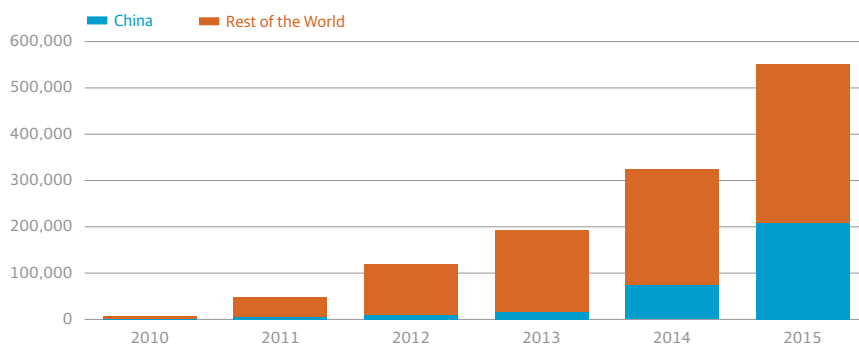
The battery is currently by far the most expensive component in electric cars, so the shift to electric cars will depend on how quickly the cost of batteries can be reduced. For example, the key to Tesla's ambitions is its battery strategy, centred on its \$5 billion 'Gigafactory' in the Nevada desert. In partnership with Panasonic, it aims to substantially reduce the unit costs of lithium-ion batteries through scale manufacture and improvements in chemistry, enabling them to offer more power at lower cost. There is some scepticism, however, about how much further battery costs can be reduced.

The reduction in the unit cost of batteries is also key to a potential transformation of energy production – not least the development of a mass market in home energy production. Batteries can store electricity generated in favourable conditions to be used at other times of the day or week; lower battery costs make this more financially viable. This offers the tantalising prospect of home owners becoming self-sufficient and going 'off-grid', or even being able to generate extra money by selling surplus electricity back to utility companies. As with the car market, the early signs of this emerging mass market are already evident. Examples include the wall-mounted Powerwall domestic battery from Tesla, which stores energy from solar panels for subsequent use.

Future developments in battery technology and chemistry will drive the penetration of electric vehicles and alternative energy. Much research is going into battery materials, with nickel content increasing on lithium oxide cathodes (the positive electrode) and silicon content increasing on the graphite anodes (the negative electrode) in order to improve battery performance and capacity. Longer-term opportunities could lie in 'solid state' batteries, where the liquid electrolyte is replaced with a solid polymer for improved energy density and safety, and in 'lithium air' which uses oxygen and could potentially increase battery capacity fourfold.

Figure 7: China is driving the transition to electric vehicles

New registrations of electric vehicles in China and the rest of the world (2010–15).



Source: International Energy Agency 'Global EV outlook 2016: Beyond one million cars' and Rathbones.

What are the implications for industries and countries?

Improvements in cost-effective battery storage will allow national grids to manage inflows of solar or wind power and continue to provide electricity on demand even as more reliable fossil fuel generation is phased out. This will enable renewable energy to become a much more important part of the energy mix.

This potential could be enhanced through 'flow batteries', where energy is stored in the liquid electrolyte and which could be recharged many more times than lithium-ion batteries. Grid-level storage could also utilise second-hand batteries from electric vehicles for a much cheaper storage solution.

Increased adoption of alternative energy will change how we define energy-rich countries and alter the dependence of countries with poor fossil fuel reserves on those rich in such resources. We should note and plan for the long-term implications of this - but these changes will be slower than the potential changes in markets such as the car industry or home energy production.

Fossil fuels will diminish in importance as solar and wind power become cheaper and a bigger proportion of power generation. This could lead to a virtuous or vicious circle (depending upon one's point of view) whereby falling capacity utilisation for fossil fuel plants leads to rising unit costs for fossil fuel energy, making renewables seem even cheaper. This could incentivise greater investment in renewables, pushing down their costs even further.

The International Energy Agency only sees renewable energy rising from 23% of global electricity generation in 2015 to 28% by 2021. Energy demand will continue to grow, with emerging market demand more than offsetting fuel efficiency in the developed world, so even though there will be competing sources of energy supply, oil will continue to have an important role for the foreseeable future. Its price may be effectively capped, however, which will have implications for oil-producing economies such as Russia and the Middle East.

It is interesting to note that much of the investment in alternative energy comes from the Middle East, as it seeks to reduce its dependence on oil. China is also spearheading clean energy investment as it seeks to make its economy cleaner, more efficient and more energy independent, and is likely to be a technology leader in this area (see figure 7 on page 20). More generally, the growth of 'distributed power', where many consumers generate their own power and do not need a grid connection, could be a boon for the development of emerging markets as it would reduce the need for investment in expensive centralised grids.

The revolution in battery technology and an increasing role for alternative energy and electric vehicles could potentially be much quicker than the market currently expects. The private sector will need to respond. Firstly, companies which are wholly focused on old technology - whether car companies wedded to the internal combustion engine or fossil fuel-reliant power generation companies - will face significant challenges. Electric cars will require significantly less maintenance as an electric motor has around half a dozen moving parts, compared to the hundreds in an internal combustion engine.

Also, the role of centralised utility companies could be undermined by the growth of self-sufficient homes and businesses with solar power fulfilling most or all of their power needs. Utilities may need to retain their relevance by offering management and maintenance solutions, or investing in charging stations in order to profit from the adoption of electric cars.

Companies which make or supply materials for batteries, solar cells or wind turbines might in theory do well, but rapidly growing markets often see sharp unit price falls that cause a lot of players to go out of business, as was seen in the solar panel market.

The battery revolution is under way and we will be monitoring developments in order to identify the winners - and, perhaps more numerous, the losers.

Box 5: Drones

Advances in battery technology also expand the range and opportunities for unmanned aerial vehicles or 'drones'. Lighter, cheaper and more powerful batteries will enable drones to fly further and for longer, opening up the number of applications.

That drones have been used for military operations for several years is well known. They are now being trialled by the likes of Amazon, UPS and DHL for delivery of goods to customers' homes, in particular for time-sensitive orders or to remote locations. Amazon is trialling a Prime Air drone delivery service, which at its fastest took just 13 minutes from online order click to delivery (admittedly for a customer who lived close to a delivery depot). Drones will be particularly useful in performing tasks that are difficult or dangerous for humans, such as scanning the underside of oil rigs.

One of the most significant applications for drones is in precision agriculture, whereby drones will be able to monitor large tracts of farmland, scanning and using infrared cameras to identify areas which need more intensive inputs and then delivering tailored crop treatments, fertilisers, seed packages or watering. This could have a dramatic impact on agricultural yields and help the world to feed itself better as populations grow. Drones could also expand the amount of land that can be cultivated, as they can treat hilly or remote areas which cannot currently be accessed by tractors. A US company, Biocarbon Engineering, has announced a bold plan to plant 1 billion trees a year using drones, which will drop pre-germinated seeds and high-quality soil and then water and monitor the growing saplings, in order to combat deforestation and desertification.

The internet of value



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This article has been co-authored with our Chief Investment Officer Julian Chillingworth.

In brief

Blockchain offers an alternative to many record-based transactions, from money transfers and asset custody to 'know your client' checks, healthcare records and music downloading. It would release huge cost savings and create additional value, but could negatively impact employment levels. Otherwise, transaction times are likely to be reduced.

Risk of disruption = medium/high

You might have read or heard about it; 'blockchain' is the financial disruption buzzword of the moment. Intended initially as the platform for storing and transferring the Bitcoin currency, blockchain has become the building template for what is referred to by some as the biggest change since the internet.

Blockchain is promising to do for value what the internet has done for information: decentralise control, remove asymmetries, and change the way we transact and interact with everything. From money transfers and asset trading, through healthcare provision and music downloading to collaborating and sharing of resources, blockchain promises to enable, empower and revolutionise. And disrupt.

A huge public ledger of transactions

Blockchain is a platform for transacting without an intermediary, from one individual or peer directly to another. In electronic payment terms this means that one person can make a payment to another person without using a bank or any other intermediary. All aspects of the transaction are performed by a computer or, as is actually the case, by a database. Figure 8 shows how this differs from current intermediated transactions.

The first defining feature of this new and nascent technology is that it is distributed or shared. Rather than located on one computer, blockchain is a database spread across multiple machines. Everyone can access blockchain, view its contents and add new transactions.

Another defining feature of blockchain is that it is decentralised. In the context of databases, this simply means that no single party has control. The update and maintenance of blockchain database is carried out by many parties. In Bitcoin blockchain, these parties are known as miners. Their job is to validate transactions and keep the database up to date.

Cross-border payments

Recent estimates from McKinsey & Co suggest that blockchain could generate \$80 to \$110 billion of value in the financial services industry alone (McKinsey, 2017). Most of this impact, McKinsey says, would be felt in the payments segment, where cross-border business-to-business payments could see new value creation of \$50 to \$60 billion. This would be created from additional activity, cost reduction, and capital release from the current cumbersome process.

A report published in 2015 by Santander InnoVentures claimed that blockchain could generate cost savings in cross-border payments of \$15–20 billion per year by 2022 (Santander InnoVentures, 2015). The report went on to say that the immediate impact would be felt by the cross-border payments segment of the financial sector. Blockchain would achieve those savings, the authors argued, by bypassing the existing international payment networks, which are slow and expensive.

The disruption of cross-border payments has already started. Transferring money from one country to another today costs significantly less than it used to. There are many online providers of this service, which has put significant competitive pressure on the traditional providers, such as banks and money transfer companies.

Chris Mager of BNY Mellon describes the current state of affairs in banking as an "unprecedented period of change and transformation" and goes on to say that there is a potential role for blockchain in payments (Fintech Network, 2017).

Cryptocurrency is digital money. Just like physical money, cryptocurrency can be transferred from one party to another. There are believed to be over 740 cryptocurrencies in the world today.

Existing payment systems are outdated, slow and inefficient; they were not designed for the world we live in today. Blockchain could help by eliminating these inefficiencies and, through this, reducing banks' costs and their charges to the consumer.

Blockchain technology has the potential to make the cost of transferring £1 equivalent to the cost of transferring £10,000. At present, the costs associated with processing a transaction make the £1 transfer disproportionately costly. The human effort required to process both transactions is identical, yet the value of each is vastly different. Remove human involvement and replace it with a machine and the cost falls to the point where both transactions are viable.

Application of blockchain technology to payments would also deal with the disproportionate amount of time it takes to process cross-border transactions: between four and seven days. Blockchain could enable the almost instantaneous execution of payments, both domestically and globally (Fintech Network, 2017). The delay between sending and receiving the payment would be equal to the amount of time it took for the sender to sign off the transaction, the recipient to confirm and the miner to validate it. On average, this is somewhere between 10 minutes and an hour (Dr. Joseph Bonneau, 2015).

It is important to note the impact of these changes is not limited to the cost

savings and convenience for consumers. The changes can have a significant impact on global trade too. Exporters and importers are heavily burdened by the cost and time it takes to pay for goods and services. As an aside, global shipping companies can experience significant delays when crucial customs paperwork gets lost, delaying the loading or unloading of containers. Blockchain could allow such paperwork to be seen by all necessary parties in real time without the risk of it becoming lost. The cost-savings could be huge.

Bitcoin is a cryptocurrency. It is also *raison d'être* for blockchain. The supply of bitcoins is limited to 21 million, which makes it a deflationary currency.

Know your client

The impact of this technology on the financial sector is not limited to payments. Blockchain database could be used to store other data. In its recent white paper, the Fintech Network (a blockchain consortium of about 70 banks) cites four potential areas of banking where blockchain could reduce inefficiencies, generate savings, increase security and reduce fraud (Fintech Network, 2017).

Know your customer (KYC) is a procedure mandated by regulators through which banks and other financial institutions carry out checks on customers in order to prevent fraud, particularly money-laundering. According to a recent survey by Thomson Reuters, banks on average spend \$60 million per year to carry out these checks. For the largest banks, however, expenditure on KYC and due diligence can be closer to \$500 million (Thomson Reuters, 2016).

KYC procedures can be costly, demanding and cumbersome for both the financial institution and their customers. Although there are attempts to centralise KYC information and make it available to participating banks, 84% of banks in the SWIFT network still do not participate in information sharing (Fintech Network, 2017).

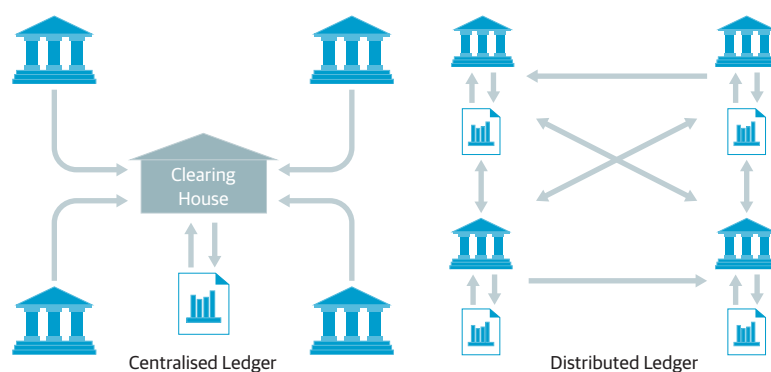
Each time a customer – retail or corporate – switches banks or approaches another bank for additional services, a new KYC procedure must be carried out. The information the new bank is required to gather is already there, but just isn't shared. So the task is duplicated, the cost replicated, the customer inconvenienced by having to once again prove their identity and cover at least a part of the cost of this repeated activity. If the information were held on a blockchain, it could be readily used by other financial institutions.

It is important to make clear that this or any other information does not need to be shared with the whole of blockchain. Using private blockchains, the information can be secured and distributed only to those who need to view it. These can be either private sections of a public blockchain or separate and closely-held blockchains.

Miners are computer 'farms'. There are many of them, they are independent and based in different parts of the world. Their job is to validate transactions and add them to blockchain. They compete for this task and are paid in bitcoin.

Figure 8: Embedding distributed ledger technology

A distributed ledger is a network that records ownership through a shared registry.



In contrast to today's networks, distributed ledgers eliminate the need for central authorities to certify ownership and clear transactions. They can be open, verifying anonymous actors in the network, or they can be closed and require actors in the network to be identified. The best known existing use for the distributed ledger is the cryptocurrency Bitcoin.

Source: Santander InnoVentures.

Box 6: Blockchain: how it works

Blockchain is a digital public ledger of all transactions that have ever been executed. Each block in the chain represents a group of transactions.

A new transaction is carried out using a private key. Using a public digital signature, the same transaction is then signed by the sender at one end and the recipient at the other. Once the transactions in a block have been validated (by so-called 'miners' in the case of Bitcoin), the block is added to the chain and forms a permanent part of the database.

Think of it as pages in a book. A book is a chain of pages. Each page in this blockchain book is a mini-statement of transactions. The entire blockchain book represents all the transactions ever executed. Every time a block is filled and added to the chain, a new block is generated. Blocks are linked to each other in a clear linear and chronological order, with every block containing a hash or link to the previous one. The entire chain is akin to a chronologically ordered book of all transactions that can be read and added to by everyone – an open book for all.

Unless it has been disputed, which normally happens very early on, the transaction cannot be erased or altered retroactively. This is the third key feature of blockchain: it is protected from revision and tampering. Once entered, a transaction is permanent.

The database is secured using complex and powerful cryptography. There are private keys we mentioned earlier, but there are also public keys. Owners are linked to their cryptocurrency using private keys. Provided they are stored securely, these private keys are not accessible to anybody else. The public and private keys are then linked together, so that the information necessary for a transaction to take place can be relayed publicly. All other information remains accessible to the holder of the private key only. Giving your private key to somebody else means giving them access to your cryptocurrency – losing your private key means losing your cryptocurrency forever.

Hacking into and taking control of the database would be prohibitively expensive. It is said that the power behind the bitcoin blockchain is equal to 500 of the world's most powerful supercomputers multiplied by 13,000 (The Economist Explains, 2015).

These are like an intranet; it is similar to the internet, except accessible only to the employees of a particular organisation.

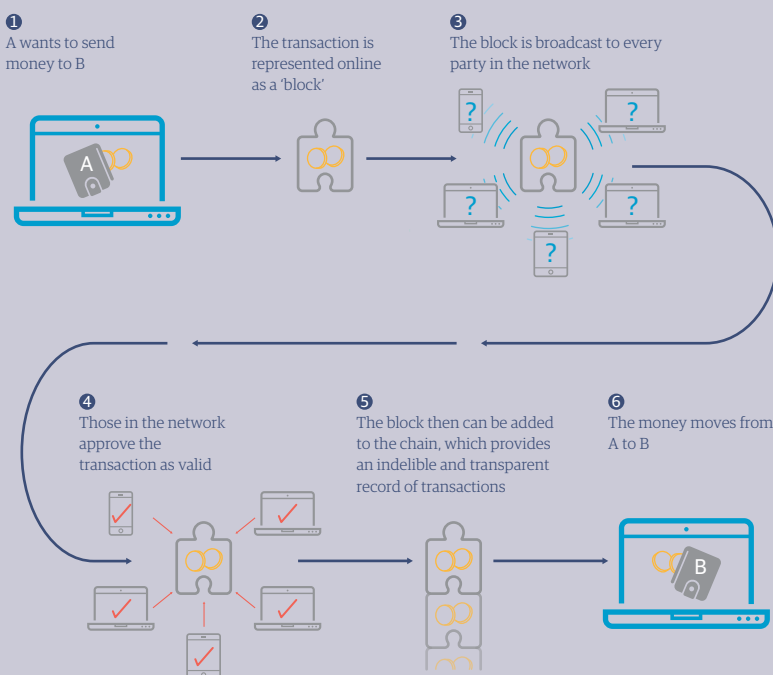
Chris Huls, a blockchain specialist at Rabobank who investigates different types of blockchain and the opportunities they offer to the financial sector, has proposed that KYC data be stored on the blockchain (Fintech Network, 2017). Once a bank has carried out its KYC process on a customer, it could confirm this with a statement on the blockchain and a summary of the documentation that has been collected from the customer. This information could then be used by other banks, insurance companies and other financial institutions – after all, much of the underlying information belongs to the customer, not the bank.

In a recent report, Goldman Sachs estimated that application of blockchain in customer onboarding and transaction monitoring, as well as the technology and training required for these functions, would generate \$2.5 billion of cost savings for banks, or 25% of the overall operational costs. Key savings would be seen in transaction monitoring (that is, the monitoring of existing clients), where blockchain would lead to a 30% reduction in headcount or cost savings of \$1.4 billion (Goldman Sachs, 2016).

Cryptocurrencies and cryptosecurities

Global custody is another key area of potential disruption. Custodians are the safe-keepers of assets. Their role is to safeguard the financial assets of individuals and financial institutions. Custodians hold stocks, bonds and commodities; they handle settlements of asset purchases and sales, recording changes in ownership; they collect and store information on assets, record and monitor dividends as well as coupon payments on bonds; administer corporate actions; manage bank accounts and handle foreign exchange transactions.

All of these roles could be performed automatically through blockchain. They can be written into what is known as a smart contract. This is an automated and self-executing agreement stored on blockchain in the form of computer code or a program consisting of pre-written logic in the form a statement: "if this happens, then do that". The



Source: Financial Times.

execution of a smart contract is performed by a computer. It can be viewed by everybody, replicated and used as a template for new contracts and arrangements (Antony Lewis, 2015).

Blockchain's recording and data storing capability will deal with the register of ownership, while smart contracts will facilitate everything that needs to happen in the life of an asset, such as dividend and coupon payments, corporate actions and so on. Goldman Sachs estimates that the automation of custodial services will save the financial industry \$11 billion to \$12 billion per year in overhead costs (Goldman Sachs, 2016). It will also speed the settlement of assets from the current period of three days to potentially one hour, which is inconceivable in the current labour-intensive systems of settlements and custody (Fintech Network, 2017).

Blockchain can allow parties to enter into any transaction, irrespective of size, without drawing up a new contract every time this transaction occurs. For example, a musician might decide to post his or her music on a blockchain music platform, including, for example, one free play of the song. But, if another party wanted to download the song for future listening, use it as a ring tone or put it into a movie, the artist could stipulate the costs and terms governing such use.

This same contract could be applied to an infinite number of transactions. The artist wouldn't need an agent to sell his or her music, neither would a new legal contract be needed for each transaction. The artist would be able to keep a larger proportion of the value they have created and the consumer would benefit from lower costs.

Smart bonds

Such an automated world could sound like pie in the sky to anyone who is familiar with the labyrinthine workings of financial institutions' middle and back offices, as well as the global settlements and custodian processes for every asset, but the future is surprisingly near.

In 2015, UBS reported it was working on smart contracts in the form of self-servicing bonds (Sarah Jenn, 2015). These instruments, also known as smart bonds, are automated contracts in which all

aspects of servicing are executed by a computer. UBS has created a blockchain-based application that can deal with a bond's issuance, interest calculation, coupon payments and maturation process. There is no need for pre- or post-trade intermediaries, usually the back and middle offices in an organisation.

Other uses of blockchain

Although the initial wave of significant blockchain innovation and disruption is likely to happen in the financial industry, the technology has potential to change other areas of life.

Imagine a healthcare system with the data and other tools required to make treatment fully targeted, less expensive, more effective and, above all, make certain conditions preventable. From clinical trials and patient records to patient compliance with treatment, blockchain could be the first medium of healthcare collaboration between patients, physicians, medical researchers and regulators.

At present, medicine still largely has a 'one-size-fits-all' approach, which means that adverse drug reactions are commonplace. Often, a simple test and immediate access to a patient's records, could prevent such reactions. Sharing patient data between physicians using one secure database source could mean that treatment could be given more effectively, at a lower cost, and without sometimes fatal errors.

Data from clinical trials is rarely shared between different medical researchers. Sometimes, this cannot be done for competitive reasons, but there are situations and stages of medical development which would warrant greater collaboration between medical researchers. While looking for one particular molecule, researchers will often come across other molecules that do not fall into their area of research or expertise. These molecules are usually not shared, but sharing them with other researchers, the World Health Organisation and other organisations could potentially lead to ground-breaking discoveries (Deloitte, 2017; Tierion, 2016; and Helen Disney, 2017).

We have mentioned the effect blockchain may have on healthcare, but there are other industries as well

as parts of our daily lives that could be significantly changed with the advent of this technology. We discussed custodial services earlier, but similar effect could be seen in the land registry. Some countries are already transferring their land registries to blockchain. Other areas of innovation and disruption include:

- instantaneous smart card payments
- corporate supply chains
- tracking of government finances
- online voting
- cloud storage
- music payment and licensing
- further decentralisation of the sharing economy.

Conclusion: disruption or innovation?

In 2015 and 2016, venture capitalists invested around \$1 billion in the development of blockchain (McKinsey, 2017). The banking industry is expected to spend around \$400 million by 2019 (McKinsey, 2017). Wide-ranging uses of blockchain are being developed and tested in many other industries.

Blockchain is coming, that's for sure. What is not certain is what shape it will take, the kind of change it will eventually lead to and when this will happen. It will be some time before these questions can be answered.

Proponents of blockchain argue that the technology is not as much about disruption as it is about innovation. And to some extent they are right. For example, with cross-border payments, blockchain might offer banks a get-out-of-jail-free card – a way to compete against their online counterparts and ultimately hold on to their market share. In terms of healthcare, blockchain may offer a less costly, more effective and secure way of collecting, storing, sharing and analysing data. It could lead to significant improvements in healthcare provision.

But some companies will inevitably suffer disruption. In these cases, blockchain may prove impossible to adopt, conflicting with every part of their service offering and presenting a threat rather than opportunity. Those businesses will either have to readjust and change, which can take both time and resources, or face closure when other providers gain critical mass and offer similar services at far lower cost.

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