HUAWEI

Intelligent Economy

Enabling Sustainable Growth

CONTENTS

Executive Summary

Definition of the Intelligent Economy

The Intelligent Economy generates value through the seamless integration of next-generation technologies including but not limited to 5G+, Artificial Intelligence (AI), and the Internet of Things (IoT) to progress single-point intelligence systems working in isolation towards multiple intelligence systems that operate in tandem, that have the strong potential to create new and innovative solutions to enhance productivity gains, social well-being, and benefits to the environment.

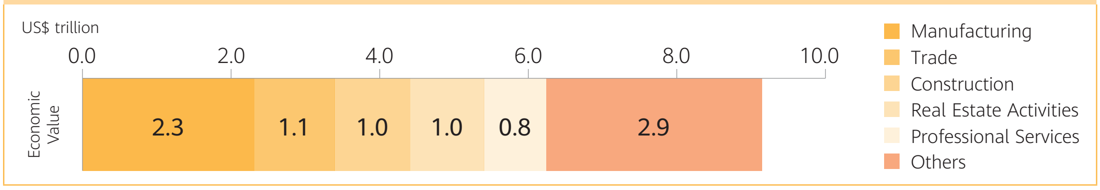
Key Characteristics of the Intelligent Economy

Labour value increased from greater access to new skills and opportunities	Capital enhances the boundaries of human creativity	A greater integration of technologies, revolutionising production processes

Value of the Intelligent Economy in 2030

Total: **US$18.8 trillion** = Productivity: **US$9.1 trillion** + Social: **US$5.2 trillion** + Environmental: **US$4.5 trillion**

Productivity Impacts of the Intelligent Economy



Social Impacts of the Intelligent Economy

Consumer Time Savings:

+US$ 1.5 trillion

Examples
- Future Retail
- Autonomous Vehicles
- Citizen Services

Health and Safety:

+US$ 3.2 trillion

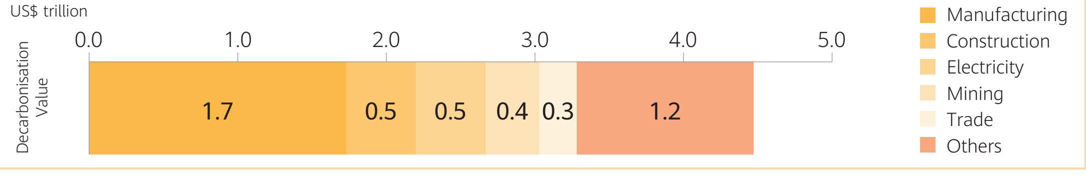
Examples
- Workplace Safety
- Crime Prevention
- Emergency Response Time

Social Inclusion:

+US$ 0.4 trillion

Examples
- Access to Credit
- More Inclusive Workforces

Environmental Impacts of the Intelligent Economy



Numbers may not sum due to rounding

Chapter 01

The global economy will be impacted by several megatrends

From advancements in space exploration to the need to build health systems resilient to future pandemics, the world we live in faces an unprecedented number of trends that are likely to have profound impacts on how we live, work, and play. This chapter highlights four trends that are likely to have major implications on the future landscape of the global economy: i) the structural decline in labour productivity; ii) the rising risks of climate change; iii) the need to redefine business valuations due to digitalisation; and iv) a fundamental shift in consumer and worker expectations.

Labour productivity growth has been on a decline since the Great Financial Crisis

After many years of economic growth which saw 1.3 billion people lifted out of poverty between 1990 and 2018,[1] the world is now going through a structural decline in labour productivity growth which is dragging growth. Many governments have attempted to reverse this trend through initiatives such as labour force upskilling programmes. However, these efforts have yielded limited results so far in solving the productivity puzzle. The average growth rate of labour productivity in advanced economies has decreased from 1.3% per annum in the period 2002-2007 to 0.8% per annum in the period 2013-2018. This slowdown in labour productivity is not unique to advanced economies, as the average growth rate of labour productivity in emerging markets and developing economies (EMDEs) has also decreased from 4.9% per annum in the period 2002-2007 to 3.5% per annum in the period 2013-2018.[2]

The average growth rate of labour productivity in emerging markets economies has **decreased to 3.5%** per annum between 2013 and 2018 – **down from 4.9%** between 2002 and 2007.

[1] The World Bank (2018). Piecing Together the Poverty Puzzle. Available at: https://www.worldbank.org/en/publication/poverty-and-shared-prosperity-2018#:~:text=and%20shared%20prosperity.-,The%202018%20edition%20%E2%80%94%20Piecing%20Together%20the%20Poverty%20Puzzle%20%E2%80%94broadens%20the,differences%20in%20needs%20across%20countries.

[2] The World Bank (2021). Global Productivity, Trends, Drivers, and Policies. Available at: https://www.worldbank.org/en/research/publication/global-productivity

The negative economic implications of a slowdown in labour productivity growth are compounded by the fact that the global demographic dividend is coming towards its tail-end. According to the World Health Organisation (WHO), the percentage of total people aged 60 years and older will rise from 13% today to 17% and 22% in 2030 and 2050 respectively.[3] The global average fertility rate has declined from 5.0 in 1960 to 2.4 in 2020,[4] a figure just above the 2.1 replacement level fertility needed to maintain population sizes.[5] In 2019, more than 40% of the world's population lived in countries that were at of below the replacement rate of 2.1 children per woman, and this share has climbed to nearly 60% in 2021.[6] One of the major risks of slower economic growth in the developed world is a widening wealth gap that increases inequality in society.[7] This has already contributed to the growing social and political divergence seen in many countries, as well as increasingly protectionist policies in trade and the labour markets.

Climate change poses a significant challenge for future economic growth

Climate change refers to long-term shifts in temperatures and weather patterns. These shifts may be natural, such as through variations in the solar cycle, but since the 1800s, human activities have been the main driver of climate change due primarily to the burning of fossil fuels. Greenhouse gas concentrations are currently at their highest levels in two million years and emissions continue to be on the rise. Global carbon emissions have risen to a historically high level of 36.3 billion tonnes in 2021 as estimated by the International Energy Agency (IEA).[8] As a result, the Earth is now about 1.1 degrees Celsius warmer than it was in the late 1800s, with the last decade being the warmest on record. The environmental consequences of climate change include intense droughts, water scarcity, fires, rising sea levels, flooding, and declining biodiversity, resulting in severe economic destruction.

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[3] WHO (2021), "Ageing and health", Available at: https://www.who.int/news-room/fact-sheets/detail/ageing-and-health

[4] World Bank (2022), Fertility rate, total (births per woman, Available at: https://data.worldbank.org/indicator/SP.DYN.TFRT.IN

[5] J. Craig (1994). Replacement level fertility and future population growth. Available at: https://pubmed.ncbi.nlm.nih.gov/7834459/#:~:text=In%20developed%20countries%2C%20replacement%20level,need%20to%20be%20much%20higher.

[6] United Nations (2022). "The Global Population Will Soon Reach 8 Billion—Then What?". Available at: https://www.un.org/en/un-chronicle/global-population-will-soon-reach-8-billion-then-what

[7] T. Piketty, (2013). Capital in the Twenty-First Century, Available at: https://dowbor.org/wp-content/uploads/2014/06/14Thomas-Piketty.pdf

[8] IEA (2021). Global Energy Review: CO2 Emissions in 2021. Available at: https://iea.blob.core.windows.net/assets/c3086240-732b-4f6a-89d7-db01be018f5e/GlobalEnergyReviewCO2Emissionsin2021.pdf

A recent study shows that in the severe scenario where temperatures rise by 3.2 degrees Celsius due to no mitigating actions being taken, up to 18% of global GDP could be wiped out. Under this severe scenario, Asian economies are estimated to be hit worst, with up 26% of their GDP under threat.[9] The main risks to the economy as a result of climate change comes from property damage, disruption to trade due to climate shocks, and further loss in productivity. Moreover, over 80% of the calories consumed globally come from just 10 crops including wheat, rice, and maize.[10] This is alarming considering the fact that global rice and wheat yields have been declining by 0.3% and 0.9% on average each year as a result of climate change.[11] Another study also estimates that maize crop yields could decline 24% as early as 2030 under a high greenhouse gas emissions scenario.[12]

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While the estimated amount of investment required to combat climate change varies widely, they are all very significant. For example, the International Renewable Energy Agency forecasts that US$750 billion annually is needed just for renewables,[13] while Morgan Stanley suggests that US$50 trillion of investment is required across renewables, electric vehicles, carbon capture and storage, biofuels, and hydrogen by 2050 to cut emissions sufficiently to meet the Paris Agreement's goal of halting global warming.[14] Unfortunately, the Intergovernmental Panel on Climate Change's (IPCC) latest report concludes that global efforts have fallen short of what is needed to combat climate change, with investment in the shift to a low-carbon world almost six times lower than what is required.[15] It is clear that the risks to food security, productivity and economic growth are not purely physical, but also include transitional risks. Tackling climate change will require a reassessment of asset values, a reduction in our dependency on assets such as fossil fuel deposits or coal reserves, and will bring systemic devaluation risks to the global financial sector.[16]

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9 Swiss Re Institute (2021). The economics of climate change. Available at: https://www.swissre.com/dam/jcr:e73ee7c3-7f83-4c17-a2b8-8ef23a8d3312/swiss-re-institute-expertise-publication-economics-of-climate-change.pdf

10 D. Tilman (2011). Global food demand and the sustainable intensification of agriculture. Available at: https://www.pnas.org/doi/full/10.1073/pnas.1116437108

11 The Conversation (2019). "Climate change is affecting crop yields and reducing global food supplies". Available at: https://theconversation.com/climate-change-is-affecting-crop-yields-and-reducing-global-food-supplies-118897

12 J. Jägermeyr (2021). Climate impacts on global agriculture emerge earlier in new generation of climate and crop models. Available at: https://www.nature.com/articles/s43016-021-00400-y

13 RIA (2020). " Investing in Green Bonds: How "Green" is Green?" Available at: https://www.riacanada.ca/magazine/investing-in-green-bonds-how-green-is-green/

14 Bloomberg (2019). "Morgan Stanley Says These Firms Will Profit From Climate Change". Available at: https://www.bloomberg.com/news/articles/2019-10-24/-50-trillion-is-needed-to-stop-global-warming-morgan-stanley

15 IPCC (2022). Climate Change 2022, Mitigation of Climate Change. Available at: https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/

16 Swiss Re Institute (2021). The economics of climate change. Available at: https://www.swissre.com/dam/jcr:e73ee7c3-7f83-4c17-a2b8-8ef23a8d3312/swiss-re-institute-expertise-publication-economics-of-climate-change.pdf

Digital disruption is redefining the way businesses are valued

The rate of technological adoption and data creation is rising exponentially. Overall enterprise Internet of Things (IoT) spending grew by 22% in 2021 and is expected to continue growing at a rate of over 20% to more than US$520 billion by 2027.[17] It is estimated that 90% of the world's data was created in the last two years, with 2.5 quintillion bytes (18 zeroes long) of data being created each day.[18] In 2018, the total amount of data created, captured, copied, and consumed in the world was 33 trillion gigabytes. This grew to 59 trillion gigabytes in 2020 and is predicted to almost triple by 2025.[19]

90% of the world's data was created in the last two years, with **2.5 quintillion bytes** of data created daily

A 2022 global survey has shown that 35% of companies today report using some form of AI in their business, with an additional 42% reporting that they are currently in the midst of exploring the future use of AI.[20] These firms are increasingly using AI to transform the customer experience from producing targeted product recommendations that increase customer loyalty to providing consumers with their very own electronic personal assistant (such as Amazon Echo and Google Home) that can act as the central hub that connects various devices throughout one's household. By 2025, 20 billion smart home devices are estimated to be in operation, with 14% of families worldwide having a smart domestic robot at home, and 90% of people using personal assistants on their smart devices.[21] Furthermore, it is predicted that by 2030, every 10,000 employees will be supported by 390 robots.[22]

Technology is not only improving people's lives, but is also changing the way people, governments, and businesses interact. At the height of the COVID-19 pandemic, many companies that had digital capabilities, particularly those in the service sector, fared much better than those without. This has served as a catalyst for digital adoption in both the private and public sectors. Digital transformations will be necessary for companies to keep up with emerging customer demands and survive in the face of the future. With the ongoing rise in prominence of technologies such as Big Data, AI, IoT, Cloud Services, and Scalable Platforms, companies that do not digitalise are at risk of falling behind.

[17] IoT Analytics (2022). "Global IoT market size grew 22% in 2021 — these 16 factors affect the growth trajectory to 2027". Available at: https://iot-analytics.com/iot-market-size/

[18] Forbes (2018). "How Much Data Do We Create Every Day? The Mind-Blowing Stats Everyone Should Read". https://www.forbes.com/sites/bernardmarr/2018/05/21/how-much-data-do-we-create-every-day-the-mind-blowing-stats-everyone-should-read/?sh=510491b660ba

[19] IDC (2020). DataSphere and StorageSphere forecasts. Available at: https://www.idc.com/getdoc.jsp?containerId=US47509621

[20] IBM (2022). IBM Global AI Adoption Index 2022. Available at: https://www.ibm.com/downloads/cas/GVAGA3JP

[21] Huawei (2021). "The Future of the Digital Economy: Built on the Cloud, Fuelled by Data, and Driven by AI". Available at: https://e.huawei.com/tr/eblog/industries/insights/2021/digital-economy-built-cloud-fueled-data-driven-ai

[22] Huawei (2021). Intelligent World 2030. Available at: https://www-file.huawei.com/-/media/CORP2020/pdf/giv/Intelligent_World_2030_en.pdf

As companies continue to digitalise, new methodologies are needed to analyse and value these companies. This would entail looking into other avenues to understand where the future of each company lies as judging how long a company will grow rapidly, the effectiveness of their barriers to entry, and identifying which companies will be able to gain long-term market power, will become increasingly challenging. While still important, the traditional way of valuing a business by measuring the worth of their physical assets (cash, machines, and land etc.) would need to be complemented with an increasing need to accurately value other intangibles such as internet traffic, data created and analysed, total number of subscribers, the number of daily active users (DAU), its social impact and so on. A transition into this new form of capital will likely come with its own set of challenges including the need to apply monetary values to these measurement areas to more comprehensively understand its overall value.

Changing worker and consumer expectations are forcing businesses to adapt

With rapid technological adoption, the expectations of workers and consumers are currently undergoing rapid changes.

i. **For workers**, technology has made it more feasible to work remotely and have flexible working hours, and Covid-19 has accelerated this trend. Although workers reported having worked longer hours, they also described higher levels of happiness and productivity.[23] In addition, Covid-19 also jumpstarted the so-called "Great Resignation", which saw the rate of monthly voluntary quits rise to its highest level this century. Many workers have taken the pandemic as an opportune time to regain control over their time and lives, forcing firms to innovate on ways to address the issue of job dissatisfaction in the labour market, including the use of advanced technologies such as the potential of metaverse applications to reshape the way organisations work in the future.

ii. **For consumers**, the definition of what consumers consider "fast" has drastically changed due to social media and the smartphone. Social media has allowed users to connect to an instant feed of breaking news, live updates of people, and messages. This 24/7 and "always on" culture will require businesses to adapt their services to match consumer needs. The requirements to succeed in today's consumer business landscape is more competitive than ever due to the availability of the internet. Customers are becoming more sophisticated due to the internet increasing the availability of public reviews on products and providing consumers with the ability to find the products of

[23] The Economist (2021). The rise of working from home. Available at: https://www.economist.com/special-report/2021/04/08/the-rise-of-working-from-home

alternative brands that prioritize sustainability. This increasingly challenging requirements will require businesses to transform the way in which they operated previously to ensure that their products will are able to thrive in today's competitive landscape.

These fundamental changes in workers and consumers have implications on the way businesses have to react and adapt, leading to the development of new types of business models. For example, the sharing and gig economies have grown drastically in recent years alongside the rise of platform business models. These include companies such as Uber - the world's largest taxi company that owns no vehicles; and Airbnb - the world's largest accommodation provider that owns no real estate.[24] These new business models not only create new markets, but they also accelerated the contraction of companies lagging behind in innovation. For example, the continual rise of online shopping and food delivery services is expected to lead to the closure of an estimated 25% of America's malls over the next three to five years.[25]

Transitioning into the Intelligent Economy can help us overcome these challenges

While these trends appear to create new social, policy, and business challenges, the good news is that there are levers available to address these challenges. These are well covered in the literature and public discourse, and are not the focus of this study. Rather, the objective of this research is to introduce a new concept to highlight how the world is already beginning a transition onto a new trajectory of digital development - one underlined by the widespread adoption of frontier technologies that help create smart solutions for the emerging social, policy and business challenges in the world today. This concept is that of an Intelligent Economy – the next stage of the Digital Economy and the key to unlocking its full potential. This study further aims to show how a transition towards the Intelligent Economy will herald new possibilities and also yield socioeconomic and environmental benefits.

Currently, the value of these intelligent applications are limited to isolated case studies and not understood holistically. Using a combination of computational general equilibrium (CGE) modelling and bottom-up estimations, this study attempts to quantify the potential global value of the continued adoption of these technologies across various industries. The hope is to fuel optimism and excitement in the private sector and amongst regulators to embrace and enable the full Intelligent Economy transition. The Appendix section provides more details of the CGE model used in this study.

[24] T. Goodwin (2018). Digital Darwinism: Survival of the Fittest in the Age of Business Disruption. Available at: https://www.amazon.com/Digital-Darwinism-Survival-Business-Disruption/dp/0749482281

[25] CNBC (2020). "25% of U.S. malls are expected to shut within 5 years. Giving them a new life won't be easy". Available at: https://www.cnbc.com/2020/08/27/25percent-of-us-malls-are-set-to-shut-within-5-years-what-comes-next.html

Chapter 02

Introducing the Intelligent Economy

The average growth rate of global GDP between 2015-2030 is expected to be 2.7%.[26] Based on a past study done by Huawei, the Digital Economy is defined as the total economic return and impact that technological investments have on GDP.[27] In that study, it was noted that the Digital Economy for several of the world's advanced economies have already reached a level of more than 30% of GDP, and that roughly 55% of global economic growth between 2015-2025 is expected to come from the Digital Economy. While the Digital Economy's contributing share to overall GDP is still rising, the overall growth rate of the Digital Economy is currently on a downward trend (Exhibit 1). The growth rate of the Digital Economy is expected to slow from 14.0% in 2017 to 4.9% in 2030. With the Non-Digital Economy's growth rate expected to average 1.6% throughout the period 2015-2030, this implies a likely deceleration in global growth. Chapter 1 has already highlighted some of the potential risks of a global economic slowdown. Therefore, in order to mitigate these risks, there is a need to look for the next stage of digital growth: the Intelligent Economy.

The Digital Economy's growth rate is likely to decline to under **5%** between now till 2030

[26] Oxford Economics (2022). Oxford Economics Database. Available at: https://www.oxfordeconomics.com/

[27] Oxford Economics (2017). Digital Spillover. https://www.huawei.com/minisite/gci/en/digital-spillover/files/gci_digital_spillover.pdf

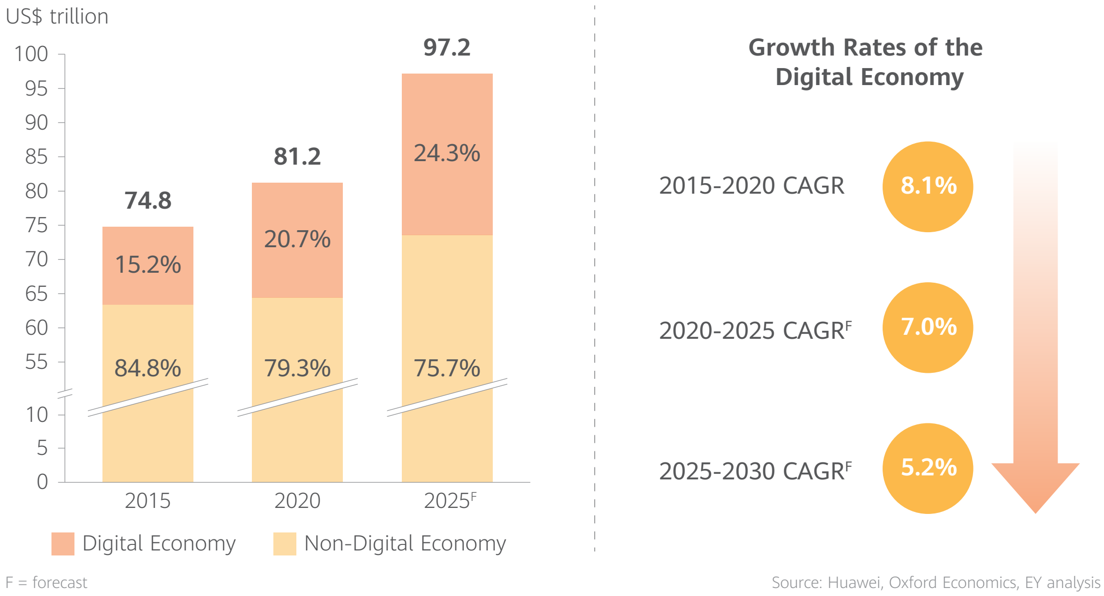

Exhibit 1: The Digital Economy's has been a key driver of the global economy, however, its growth rate is projected to slow over the next decade

What is the Intelligent Economy and how does it differ from the Digital Economy?

This study attempts to highlight a subtle but important distinction in our understanding of the Digital Economy, its purpose, and its possibilities. Seen as the next iteration of the Digital Economy, the Intelligent Economy generates value through the seamless integration of next-generation technologies including but not limited to 5G+, Artificial Intelligence (AI), and the Internet of Things (IoT) to progress single-point intelligence systems working in isolation towards multiple intelligence systems that operate in tandem, that have the strong potential to create new and innovative solutions to enhance productivity gains, social well-being, and benefits to the environment.

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While the end goal in the Digital Economy is centred around maximising the reach of existing product and service offerings by firms, allowing them to engage with a greater number of consumers, the scope and objectives of the

Intelligent Economy could be viewed as wider – and concerns tackling longstanding market failures (e.g., information asymmetry) and promoting overall social and environmental well-being.

For example, blockchain technology was created to ensure digital records cannot be altered or destroyed, leading to an improvement in the security and transparency of transactions, while its applications, such as cryptocurrency, has provided a payment system that is free of central government control. Technology in the Intelligent Economy enables the creation of entirely new products and asset classes (e.g., NFTs and cryptocurrency) whose full potential are constantly evolving and developing.

To be sure, the Intelligent Economy relies on technologies that could already be available in the Digital Economy. Hence, while it is not possible to completely delineate the two concepts, this study proposes three key traits that are different between the two. These differences are enabled by technical and cost breakthroughs in technologies (hence, greater adoption and experimentation of applications) such as telecommunications (5G+), Artificial Intelligence (AI), Internet of Things (IoT), blockchain, next-generation interactive tech (AR/VR), and even other non-ICT enablers such as nanotechnology (nanotech), biotechnology (biotech), and green technology (green tech). Exhibit 2 summarises these traits.

First, the Intelligent Economy provides incremental benefits to labour by providing a more efficient and greater access to skills, leading to an increase in overall labour mobility. Second, capital in the Intelligent Economy is now complementing labour to push the boundaries of human creativity, allowing for the creation of new ideas to meet rapidly changing market demands. Third, the Intelligent Economy also features a greater integration of technologies, leading to the creation of new service offerings and enhanced production processes (such as flexible manufacturing) that delivers greater economies of scope and reduces production risks such as overcapacity issues.

	1. Increase in value of labour	2. Capital to enhance the boundaries of human creativity	3. Greater Integration of frontier technologies to revolutionise production processes
Digital Economy	• Many new job opportunities created but did not lead to significant increase in wages	• Creative process largely performed by humans • Digital platforms created more distribution channels but no change to underlying products	• No or nascent integration of technologies • Production processes less flexible
Intelligent Economy	• Smart training and more efficient skills development methods • Safer and cheaper access to new skills training • Further increase in labour mobility, especially across industries and towards higher paying jobs	• Capital (i.e., technology) complements and/or takes over labour in the creative generation of ideas • Trial and error and productisation costs drastically reduced	• High levels of technological integration (e.g., AI, Blockchain, and IoT) working in tandem • Highly flexible production processes

Source: EY analysis

Exhibit 2: There are three key characteristics that differentiate the Intelligent Economy from the Digital Economy

The Intelligent Economy increases the value of labour by enabling greater access to new skills and an increase in labour mobility

In the Digital Economy, many new opportunities for labour were created including ride-hailing and food delivery services. In essence, one could say that the scope of available opportunities in the economy faced a major expansion, each with its own set of requirements. However, even though there has been an increase in the types of roles for labour, wages in these new roles have largely remained stagnant relative to existing roles. For instance, the average monthly wage of a factory worker in China is US$1,035 per month[28] while the average monthly wage of a takeaway rider is US$1,125 (CNY7,750) per

[28] SCMP (2019). "What is it like inside Foxconn: the world's largest iPhone assembly plant in China". Available at: https://www.scmp.com/economy/china-economy/article/2188162/foxconn-tale-slashed-salaries-disappearing-benefits-and-mass

month.[29] Part of the reason for this is workers in these new business models have not necessarily acquired new skills that the market perceives as 'high-value'. Conversely, the Intelligent Economy has the potential to change this by enhancing the capabilities of labour through smart training and skills development methods, which could go a long way in helping redistribute the rewards to labour instead of its traditional accumulation with capital-owners.

In the Intelligent Economy, technologies such as next-generation interactivity (e.g., metaverses, AR, VR) could provide workers with better and cheaper access to acquire new skills more quickly in order to increase their market value. Skills training in the Intelligent Economy has been shown to be both safer and less costly. For example, companies utilise next-generation interactive technology to train individuals in welding, claim to achieve an 84% reduction in the numbers of accidents with a 68% reduction in training costs.[30] Training labour in roles such as surgery, piloting, and operating advanced machinery has become more effective which allows for labour to shift into completely new industries that was not possible without the interventions made possible by applications of the Intelligent Economy. With the increased ease in the ability for labour to upskill, their production value has a higher likelihood of increasing, leading to a greater amount of the benefits of technology being transferred to the labour force.

The Intelligent Economy can enhance the boundaries of human creativity to meet rapidly changing consumer demands

In the Digital Economy, capital (i.e., technology, machines) was primarily used to reduce acquisition costs: both for the consumer in acquiring products, and enterprises in acquiring consumers. For example, with the advent of e-commerce, the cost of browsing through hundreds of products in a single day and comparing their prices has been greatly reduced for consumers. Additionally, the prices of goods were able to decrease from economies of scale as enterprises reduced costs by streamlining supply chains, payment systems, and downstream logistics. For an enterprise acquiring customers, e-commerce platforms and social media enabled them to reach customers far beyond what the physical store could. Eventhough digital platforms help to increase the access and reach of firms, their underlying products, content such as music and film, were not different. The creative process largely remains the function of workers.

Whereas in the Intelligent Economy, capital

[29] TechNode (2019). "Tough deadlines and lower wages push China's delivery drivers to take risks." Available at: https://technode.com/2019/11/04/tough-deadlines-and-lower-wages-push-chinas-delivery-drivers-to-take-risks/

[30] Soldmatic (2022). "Welding Simulator Augmented Training Vs Traditional". Available at: https://www.soldamatic.com/

and technology could begin to take on and complement labour's role, particularly in pushing the boundaries of human creativity, allowing for the creation of new ideas that lead to the development of entirely new products, markets, and production processes. The technological enablers of the Intelligent Economy will assist labour in the creative generation of ideas, reducing trial and error and productisation costs drastically. For example, one of the fast fashion e-commerce company utilises AI throughout its entire supply chain to standout from its competitors. Its AI engine is capable of picking up changes in consumer demand or interest in new fashion trends in real-time. The AI engine then produces forecasts for its technology-driven and connected supply chain to create an entire collection and deliver it to the market within three days - more than five times faster than most other major fashion brands.[31] It is estimated that this fashion company is capable of producing an average of 10,000 new designs per day[32] with a design team of only 200 people because of its AI engine.[33]

We have also seen companies developing software that allows users to generate a freeform digital sketch from a text prompt and to create animations from sketches respectively, whilst AIVA (Artificial Intelligence Virtual Artist) is an electronic composer that is said to have passed the Turing test for the music it has composed. As machines continue to acquire cognitive abilities and make decisions and perform tasks independent of human workers, the result is a reinterpretation of what constitutes as "labour" in classical economic theory (see Box 1 for a further discussion). Furthermore, the previous definition of "capital" can also be expanded to include data. The upshot is that allowing machines to support or takeover tasks previously reserved for human labour will free up capacity and time for humans to partake in more strategic and high-value tasks themselves, including having more leisure time.

[31] PSFK (2022). "Shein's AI Program Matches Local Demand at Scale". Available at: https://www.psfk.com/2022/06/sheins-consumer-to-manufacturer-ai-program-matches-local-demand-at-scale.html

[32] The Guardian (2022). "Shein: the unacceptable face of throwaway fast fashion". Available at: https://www.theguardian.com/fashion/2022/apr/10/shein-the-unacceptable-face-of-throwaway-fast-fashion

[33] BBC (2022). "Shein: The secretive Chinese brand dressing Gen Z". Available at: https://www.bbc.com/news/business-59163278

Box 1

The Intelligent Economy blurs the line between capital and labour

The Cobb-Douglas production function is a model which describes the relationship between the production output and the production inputs of capital (K) and labour (L), especially in the manufacturing industry.[1] The function is described as follows:

$$Y = AL^{(\alpha)}K^{(1-\alpha)}$$

In this formula, Y is the overall output produced from the inputs L and K, whilst A represents Total Factor Productivity (TFP), a parameter which captures the change in output not attributable to the level of inputs, e.g., technological advancements.

Traditionally, labour as a factor of production was defined strictly as the number of human workers. For nations, this meant that the factor of production, L, depended largely on the demographic trends of the country. On the other hand, capital in the Non-Digital Economy was traditionally used to refer to only real-world tangible and physical assets, such as machines. However, during the advent of the Digital Economy, the definition of capital was forced to be transformed as it could no longer be strictly used for physical assets due to the rise of software and internet having very real economic values. Labour, in conjunction with intangibles such as software, were able to generate economic value not thought of when the Cobb-Douglas equation was first introduced in the 1920s.

As the world transitions into the Intelligent Economy, we are seeing yet another fundamental shift in the way we need to think about labour and capital in the global economy. This is because of the increasing encroachment of machines and capital into traditionally labour roles. It used to simply be a matter of a trade-off for a factory owner deciding between whether to increase the number of machines or the number of workers. But in the Intelligent Economy, with capital now being able to simulate natural intelligence such as conducting schedule planning, forming recommendations, reading texts, and understanding speech, labour and capital are now more blended than ever. The old structure and model equation of how goods are produced no longer holds because with capital now taking on the role of labour, the two now serve to augment each other in a dynamic not previously possible. Whilst AI is capable of generating insights and analyses for labour to use, it is up to labour to in turn coach and train AI to provide results that more closely matches what labour needs. The role of capital and technology in the Intelligent Economy serves to augment the capabilities of labour by either taking on the burden of laborious tasks, allowing them to transition to higher value roles, or providing them with the tools necessary to raise their productivity to new heights. The classic dichotomy of labour and capital of the past no longer holds, due to the definition of labour needing constant redefining and the increasing reliance of both labour and capital with one another to produce economic value for society.

Sources:

[1] C. Cobb and P. Douglas (1928). A Theory of Production. Available at: https://www.jstor.org/stable/1811556

The Intelligent Economy will feature a greater integration of technologies, revolutionising production processes

Although some of the key technologies enabling the Intelligent Economy have been around for some time, they were mostly used in silos. In other words, there is a nascent (or no) degree of integration between technologies. As the world transits towards the Intelligent Economy, the level of integration between these technologies increases significantly, leading to a wider spectrum of production capabilities (Exhibit 3).

For example, adopting AI as a single-point of intelligence in the Intelligent Economy will become less costly as a result of technological developments. In addition to that, there is also an emerging trend of integrating multiple intelligence systems to achieve new solutions, and this could potentially result in an exponential increase in productive efficiency. In other words, the increased adoption and integration of intelligent technologies could mirror the results of Metcalfe's law, which states that the value of a network is proportional to the square of the number of connected users of the system (n2).[34]

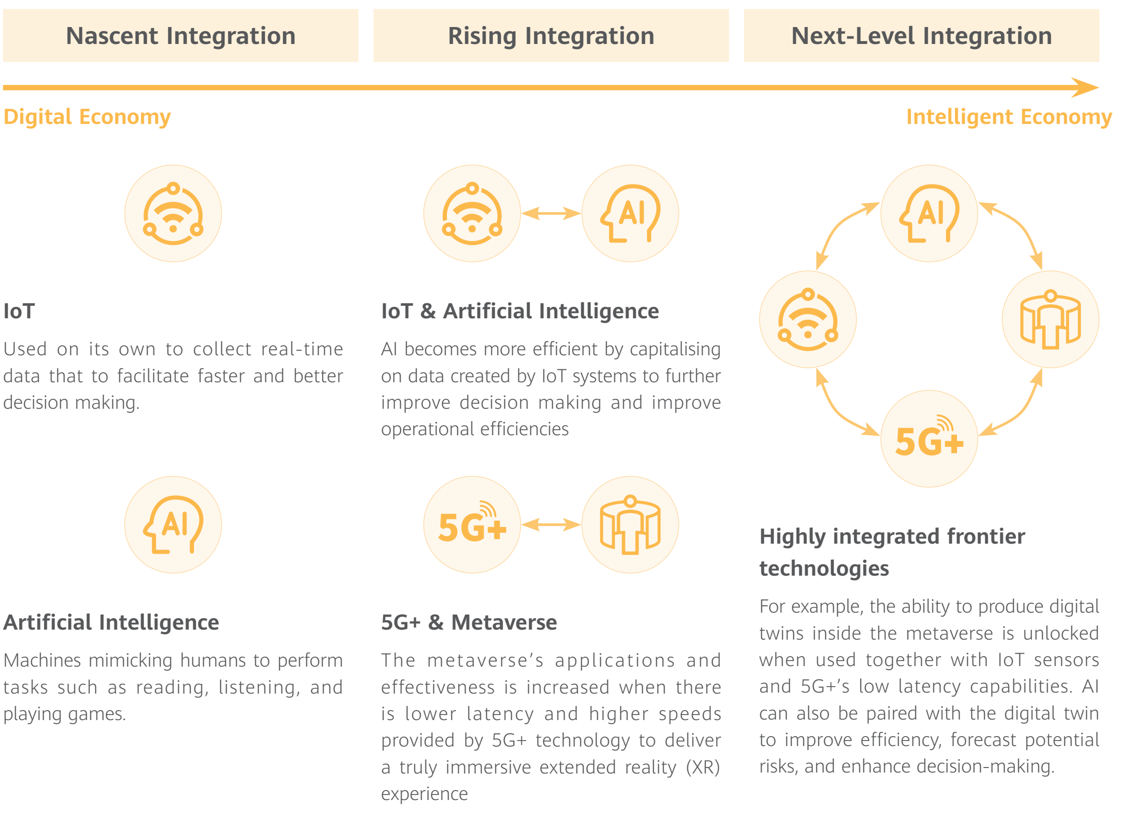


Exhibit 3: The increased integration of frontier technologies is a key characteristic of the Intelligent Economy

[34] C. Shapiro and H. Varian (1999). Information Rules: A Strategic Guide to The Network Economy. Available at: https://www.researchgate.net/publication/200167344_Information_Rules_A_Strategic_Guide_to_The_Network_Economy

A common challenge in manufacturing is the need to accurately forecast market demand and economic forces in order to adapt the production line to avoid issues of overcapacity and inventory shortage/buildup. To address this, the integration of technologies in the Intelligent Economy could enable solutions, such as e-manufacturing, that will reduce the time to market (TTM) of ideas. A firm that has a manufacturing process that is high on technological integration will allow them to realise a quick and low-cost adaptation to small orders and new products. Cross-enterprise capacity collaboration to enable quick capacity matching will also become increasingly possible as more firms in the Intelligent Economy adopt e-manufacturing. All of this will aggregate to a significant reduction in the time taken between conceptualisation and the end product, and allow more companies to reap the benefits of economies of scope.

Production capacity pooling is a key enabler of flexible manufacturing and demonstrates how the value of capital in the Intelligent Economy increases drastically from the integration of technologies. Collaborative robots (cobots) in itself can be viewed as a single intelligence system that incorporates multiple next-generation technologies such as IoT and AI.[35] Multiple cobots interacting with each other through the support of 5G+ is a prime example of multiple intelligence systems operating in tandem with one another. One of the China's leading manufacturer of bathroom accessories and auto parts, has installed 64 cobots to upgrade the efficiency of its production processes.[36]

Through the use of cobots and their integration with one another, this manufacturer is able to reduce the production line time for new projects from 6 months to 1 week by adjusting the cobots' functions and layout. The company has witnessed a sharp increase in its product yield ever since the deployment of cobots, while the redeployment of staff positions effectively has helped reduce the company's employee turnover rate.[37] Box 2 provides another example of how the integration of technologies can contribute to unique solutions, such as an autonomous car, that delivers positive benefits to society.

[35] Universal Robots (2022). "About Universal Robots". Available at: https://www.universal-robots.com/about-universal-robots/

[36] Equipment News (2020). "Collaborative Robots Open New Horizons In Quality Control Processes". Available at: https://www.equipment-news.com/collaborative-robots-open-new-horizons-in-quality-control-processes/

[37] Universal Robots (2022). "Xiamen Runner Industrial Corporation". Available at: https://www.universal-robots.com/case-stories/runner/

Box 2

The automobile's transition from the non-digital to the Intelligent Economy

In the non-digital economy, the automobile was the primary asset (capital), and it needed a driver (labour) to function, thus, there was a sole reliance on labour to operate the car (e.g., how to get from point A to B, how much to steer when making a turn). But as technology evolved in the digital economy, a variety of information such as vehicle health, navigation recommendations, and safety became readily available. While the driver still has ultimate control of the car, his decision-making is supported by digital data available at his disposal. The result is the ability to cut down traveling time by taking optimal routes, avoiding heavy traffic, and reducing time spent on diagnosing vehicle health.

In the Intelligent Economy, vehicles will gradually begin to perform singular tasks previously requiring the input of a human, such as staying within lanes or slowing down when the car in front gets nearer; this is what is often referred to at "Level 1: Driving Assistance" in the levels of driving automation. However, when these technologies are integrated with one another, that is when "Level 2: Partial Driving Automation" is achieved. Eventually, there will come a point when vehicles become entirely autonomous, freeing up humans to do other tasks during commutes, referred to as "Level 5: Full Automation". Commuters who spend many hours a day on the road will no longer have their minds occupied during travel and will have the time and ability to focus on other tasks that generate additional economic value or individual utility. The intelligence of capital in the Intelligent Economy is unlikely to stop merely at the point of freeing labour but will most likely include the ability to perform previously labour-centric tasks at higher efficiencies than that of humans. For example, smart vehicles will be able to communicate with each other and road infrastructure. This will lead to an integrated communication among vehicles and infrastructure, opening new opportunities for traffic management and improving commute efficiency.

Subsequently, the future of technologies communicating with one another within a city will not be limited Vehicle-to-Vehicle (V2V) or Vehicle-to-Infrastructure (V2I) communication, as there are many more avenues within a city where data may be collected. These include citizens, power plants, utilities, water supply networks, waste, crime detection, schools, libraries, hospitals, etc. By collecting data from the many components throughout the city, we will be able to optimise the efficiency of city operations and services and create smart cities. The integration of technologies is a key component of the Intelligent Economy and is what will allow us to maximise total societal benefits.

Chapter 03

Key technologies behind the Intelligent Economy

Frontier technologies refers to the technologies that are likely to scale considerably in the next decade to significantly disrupt multiple industries and create major benefits to societies and economies. Many of these technologies are considered 'smart' as they support the faster and better making of decisions in our lives. Table 1 provides a summary of these frontier technologies. While some of these technologies such as AI and IoT have already been in existence for some time, the form and scope have been continuously advancing.

Technology	Description	Examples of applications
5th Generation Plus (5G+)	5th generation plus mobile network delivering ultra-low latency and massive network capacity to virtually connect everyone and everything together including machines, objects, and devices. The development of 5G+ has already begun, with 5.5G and 6G likely to provide even more use cases as a result of its greater speed and lower latency.	» Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication » Telesurgery » Enterprise collaboration » Home entertainment » Emergency response communication » Smart cities
Artificial Intelligence	Artificial Intelligence is a constellation of technologies (such as machine learning and natural language processing) that mimics human intelligence to perform cognitive tasks such as problem-solving.	» Manufacturing robots » Self-driving cars » Predictive medicine
Next-Generation Interactive Technology	Next-generation interactive technology can be described as a network of virtual spaces which allows interaction in a 3D immersive environment. In contrast to the standard internet, users can interact with others via their avatars in the metaverse.	» Immersive tourism » Gaming » Real estate » Virtual advertising » Medical education
Internet of Things (IoT)	Internet of Things (IoT) is a network of physical objects equipped with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet.	» Smart wearables » Smart homes » Predictive maintenance
Blockchain	Blockchain is a shared, immutable ledger that facilitates the process of recording transactions and tracking assets (both tangible and intangible) in a business network.	» NFTs » Decentralised finance » Supply chain and logistics monitoring » Smart contracts
Non-digital enabling technologies	Other non-digital related technologies such as nanotech, biotech, and green tech complement digital technologies to expand the possibilities within the Intelligent Economy.	» Nanomaterials » Nanomedicine » Pharmacogenomics

Table 1: Summary of various frontier technologies enabling the Intelligent Economy

5G+

5G is the 5th generation mobile network. 5G wireless technology is meant to deliver higher multi-Gbps peak data speeds, ultra-low latency, more reliability, massive network capacity, increased availability, and a more uniform user experience to more users. 5G is designed to do a variety of things that can transform our lives, including giving us faster download speeds, low latency, and more capacity and connectivity for billions of devices—especially in the areas of virtual reality (VR), the IoT, and artificial intelligence (AI). For example, with 5G, you can access new and improved experiences including near-instant access to cloud services, multiplayer cloud gaming, shopping with augmented reality, real-time video translation, and IoT-enabled self-driving cars.[38]

The projected adoption rate for 5G differs drastically from all previous generation networks. Estimates show that 5G connections will surpass 1 billion in 2022 and 2 billion by 2025, making it the fastest generation ever to be rolled out on a global scale. For comparison, 18 months after its launch, 5G accounted for more than 5.5% of mobile connections – neither 3G nor 4G exceeded 2.2% penetration in the same time. By the end of 2025, 5G will account for over a fifth of total mobile connections, and more than two in five people globally will live within reach of a 5G network.[39] Moreover, the industry has reached a consensus that, over the next 10 years, networks will evolve from 5G to 5G+ (e.g., 5.5G and 6G),[40] improving real-time interactive experiences for users, enhancing cellular IoT capabilities and creating even more applications.

This new generation of telecommunication speed enhances the productivity of labour and capital, as well as increases the usefulness of data in our world. The capabilities of labour are augmented because of the increased speed at which people can retrieve and process information. This reduced latency will enable us to make better decisions based on real time data. 5G+ will also unlock the potential for capital to communicate with one another at speeds not previously achievable, augmenting the productivity of existing machines. Moreover, 5G+ as an enabler will lead to the creation of new capital, such as data which was previously thought unusable due to latency issues. One example is digital twins within the metaverse which can have value as a predictor of the real world.

With more and more connected devices on the factory floor, 5G+ can offer efficient and faster communication between people and machines. The higher sensor density enabled by 5G+ will optimise production schedules,

[38] Qualcomm (2022). "Everything you need to know about 5G". Available at: https://www.qualcomm.com/5g/what-is-5g

[39] GSMA, (2022). "Mobile Momentum: 5G connections to surpass 1 billion in 2022". Available at: https://www.gsma.com/futurenetworks/latest-news/mobile-momentum-5g-connections-to-surpass-1-billion-in-2022-says-gsma/#:~:text=Latest%20News%20%7C%20mmWave-,According%20to%20the%20GSMA%2C%205G%20connections%20will%20surpass%201%20billion,Report%202022%20from%20the%20GSMA.

[40] Huawei (2021). Intelligent World 2030. Available at: https://www-file.huawei.com/-/media/CORP2020/pdf/giv/Intelligent_World_2030_en.pdf

reduce maintenance costs, and enhance logistics management, lifting the productivity of existing labour and capital. Another application of 5G+ connectivity is intelligent transportation. 5G+ supported Vehicle-to-Infrastructure (V2I) and Vehicle-to-Vehicle (V2V) communication will play a key role in allowing vehicles to sense obstacles beyond the line of sight with the aid of shared video information from cars and infrastructure. This enhancement in traffic efficiency should aid in reducing collisions, in turn improving the supply of labour in the economy.

Artificial Intelligence

Artificial intelligence is the simulation of human intelligence processes by machines, especially computer systems. This means that with machines increasingly able to take on human tasks, the blending of labour and capital will increase in the intelligent economy where both labour and capital work with one another to bring productivity to new levels. This is in-line with the many new roles that will emerge as a result of AI, such as an empathy trainer, transparency analyst, and automation economist, which fall into the categories of trainers, explainers, and sustainers of AI respectively.[41] For humans, much of the difficult guesswork or uncertain aspects of their jobs can be solved through machine learning, allowing them to utilise their time more efficiently. The invention of AI can be considered a new form of capital itself as it has intrinsic value and is productive on its own. With AI being able to work alongside humans and assist them in various tasks, this should free up time for more labour to partake in other economic activities or high utility activities such as leisure and rest.

There are three forms of AI: Artificial Narrow Intelligence (ANI), Artificial General Intelligence (AGI), and Artificial Superintelligence (ASI). ANI focuses primarily on one single task and is the dominant form of AI currently. AGI technology would be a machine capable of understanding the world as well as any human, and with the same capacity to learn how to carry out a huge range of tasks. ASI refers to AI technology that will match and then surpass the human mind. To be classed as an ASI, the technology would have to be more capable than a human in every single way possible. Research to entirely model the human brain is already underway with neuromorphic computing, a method whereby computer hardware and software are modelled after systems in the human brain and nervous system.

As adoption across industries increases, AI has now penetrated all aspects of industries and human life. In particular, the COVID-19 outbreak has accelerated the use of AI in the medical industry, where the use of telemedicine, medical robots, and pathology-assisted diagnosis, have assisted clinicians to perform various functions

[41] MIT Sloan Management Review (2017). "The Jobs That Artificial Intelligence Will Create". Available at: https://sloanreview.mit.edu/article/will-ai-create-as-many-jobs-as-it-eliminates/

throughout the pandemic. For instance, during the control and prevention stage of COVID-19, machine learning algorithms that could identify "asymptomatic infections" and "super spreaders" within the population were developed.[42] Moreover, researchers are increasingly trying to merge genome sequencing with AI in order to detect potential diseases earlier, understand how a certain kind of cancer will progress in a patient, and identify disease-causing genomic variants.[43]

AI has also transformed the way goods are produced in factories. Smart factories can offer value in the planning of factory operations, whilst intelligent machines can automate production processes and reduce downtime through predictive maintenance. AI robots can use machine learning algorithms to automate certain decision-making processes and routine tasks on the factory floor.

AI also has the potential to address climate change from applications to reduce emissions to enhancing climate change adaptation efforts. AI can enable organisations to monitor their carbon footprint by analysing emissions data. They can also use predictive AI to forecast their future emissions, allowing them to set carbon footprint targets and optimise their operations. For instance, an American oil and gas corporation uses AI to sort large volumes of data collected through sensors deployed in their fields. AI can also enhance the accuracy of forest monitoring by installing sensors and processing millions of satellite images to identify illegal forest activities. Some of the innovations also include predicting deforestation and taking preventive measures in partnership with local governments and institutions. PrevisIA uses AI to analyse satellite imagery and an algorithm to find areas most prone to deforestation. With an image processing forest model, the tool can identify unofficial roads (one of the leading indicators of future deforestation) and simulate future scenarios to stop rainforest loss events, such as forest fires, before they happen. The tool has recently identified nearly 10,000 square kilometres of the Brazilian Amazon that is in imminent danger.

[42] IEEE Spectrum (2021). "AI Predicts Asymptomatic Carriers of COVID-19 Machine learning identifies superspreaders and ranks source of infection among a moving crowd". Available at: https://spectrum.ieee.org/ai-predicts-asymptomatic-carriers-of-covid19

[43] National Human Genome Research Institute (n.d.). "Artificial Intelligence, Machine Learning and Genomics". Available at: https://www.genome.gov/about-genomics/educational-resources/fact-sheets/artificial-intelligence-machine-learning-and-genomics

Next-Generation Interactive Technology

Interactive technology is divided into output technology and input technology. Output technologies include head-mounted displays, touch, pain, smell, and even direct neural information transmission and other technologies that convert electrical signals to human senses; input technologies include micro-cameras, position sensors, force sensors, and speed sensors. The composite interactive technology also includes various brain-computer interfaces, which is also the ultimate development direction of interactive technology.[44] Neuralink is a brain-machine interface company that claims to have been able to enable monkeys to play Pong, a simple computer game, using just their minds through a Bluetooth-enabled chip that is implanted into their brains. Interactive technology development is a key driver in the development of a metaverse. Defined as a virtual-reality space in which users can interact online, the metaverse is evolving into an increasingly vast and rich ecosystem that comprises metaverse gateways, platforms, digital infrastructure. Moreover, it contains a variety of service providers to enhance the customer experience with identity, social, gaming and economic services.[45] It is a new immersive version of the internet. Instead of viewing digital content on a computer, people wear virtual reality headsets to move around 3D environments.

As interactive technology continues to gain prominence, it can be seen as a new form of capital, and one that is very different from machines in the Non-Digital Economy. By creating an entirely virtual space, businesses can leverage this new form of capital to deliver value to customers. Conversely for labour, their value is increased due to the potential amount of time that gets to be saved by receiving services virtually through interactive technology, cutting out the need to travel from place to place. Using interactive technology has a strong potential to enhance the capabilities of labour, as many tasks or services previously undeliverable due to distance no longer face such barriers. In fact, via a virtual world, one could even experiment beforehand with the various options before executing it in the real world. Labour and capital will be even more blended than ever in the Intelligent Economy due to the new possibilities created with interactive technology.

Businesses have started to explore the range of possible applications of virtual spaces to their operations, and the technology's potential impact on business models and value propositions. For instance, interactive technology offers a huge transformative potential to the gaming and entertainment industry. Several metaverse concepts, such as 3D avatars and world-building, can already be found in early immersive games like Sim City, Minecraft and Second Life. Roblox, a leading metaverse player with a collection of

[44] INF (2022). "The six technical pillars BIGANT that underpin the "Metaverse"". Available at: https://inf.news/en/tech/aa014e2124875cc39dc4df026886f03a.html

[45] Real estate, advertising, retail, fashion etc.

games and metaverse experiences, saw daily active users grow from 32.6 million in 2020 to nearly 50 million in 2021.[46] Gaming companies also have the opportunity to unlock new revenue streams by hosting music concerts, monetising virtual goods and brand deals for advertising. During the pandemic, restrictions on in-person entertainment paved the way for virtual forms. For example, several artists such as Imagine Dragons, Ariana Grande and others held their first virtual reality concerts.

The benefits of next-generation interactive technology also extend to the field of healthcare. For example, companies such as Level Ex create medical video games designed to advance the clinical skills of physicians and surgeons. Level Ex is also helping NASA build a framework for future astronaut medical training. Through the metaverse, two people thousands of miles apart can jointly practice virtual surgeries. In the future, advances in everything from spatial computing technologies to video conferencing, and 5G+'s lower latency will allow virtual surgeries to take place inside an operating room at the same time as a real one. Hospitals may even use a digital twin to identify the best technique or angle a surgeon should use for an operation.[47]

Internet of Things (IoT)

IoT is a term that describes the increasingly sophisticated ecosystem of online connected devices we share with our world. Today, many of the devices we use in our homes, offices, factories, or wear on our bodies can be digitally connected, hence the term internet of "things." The number of connected things already exceeds the number of connected people. The number of connections to the IoT worldwide has grown at a rate of 10% every year for the past decade. By 2030, the number of IoT connections is expected to be growing at a rate more than 10 times faster than the growth rate of Internet users.[48]

IoT unlocks the potential for existing stocks of capital to increase their productivity by connecting to the internet. It allows their collective productivity to be augmented as a whole as they now gain the ability to trade information with one another. Simultaneously the productivity of labour is also augmented through the use of IoT. This is because they will now have access to data that was previously uncaptured. The advent of an influx of real-time data as a result of IoT will enable labour to make better decisions whilst also having a better understanding of the world around them.

Since its evolution, the concept has undergone

[46] Forbes (2022). "Five Industries That Will Be Transformed By The Metaverse". Available at: https://www.forbes.com/sites/forbestechcouncil/2022/03/22/five-industries-that-will-be-transformed-by-the-metaverse/?sh=290a56424e40

[47] The Innovator (2022). "How the Metaverse Might Change The Way Business Operates". Available at: https://theinnovator.news/how-the-metaverse-might-change-the-way-businesses-operate/

[48] Huawei (2021). Intelligent World 2030. Available at: https://www-file.huawei.com/-/media/CORP2020/pdf/giv/Intelligent_World_2030_en.pdf

dramatic transformation with connectivity moving beyond devices designed for the internet such as mobile phones and computers to objects such as vehicles, air conditioners, washing machines, wearables, and home robots. In 2019, IoT devices generated about 18 zettabytes of data, and by 2025, IDC expects that number to more than triple to over 73 zettabytes. Improvements in the last-mile connectivity, cheaper sensors, availability of low-power technology, and long-lasting batteries are making IoT solutions more relevant and affordable compared with the situation a decade ago.[49]

Wearable tech, such as smart watches, has a huge potential in the IoT space and for many businesses. Fitness and lifestyle-based businesses will especially find this trend beneficial, considering the fact that many smartwatches and wearable devices are integrated with health and fitness monitoring options. The healthcare industry is also expected to take advantage of this growing trend as wearable IoT devices could be used to prevent and monitor heart attacks, high blood pressure, and asthma. Along with AI, IoT can also be used to analyse patient data, genetic information, and blood samples to create new drugs.

IoT also has huge implications for the manufacturing industry. Smart factories and logistics plants are becoming increasingly automated, and the increasing availability of robotics and IoT infrastructure "as-a-service" means a larger number of smaller companies will be able to take advantage of the new opportunities. IoT technology includes sensors fitted to machinery in order to measure performance and enable predictive maintenance – predicting where failures and breakdowns will happen before they occur to more efficiently replace and repair faulty equipment. IoT tools also cover the emerging field of additive manufacturing techniques, such as 3D printing, which will provide increasingly innovative ways to build and create products, and allow greater levels of customisation and personalisation, while also minimising waste.

[49] Deloitte (2020). IoT: The rise of the connected world. Available at: https://www2.deloitte.com/content/dam/Deloitte/in/Documents/technology-media-telecommunications/in-tmt-IoT_Theriseoftheconnectedworld-28aug-noexp.pdf

Box 3

The Metaverse and new ways of working

With the shift to remote working during the pandemic, keeping employees engaged has become a key challenge. Meeting over videoconferencing calls has been reported to make employees feel isolated and disconnected from their team, leading companies to turn to metaverse-based platforms to improve team engagement and collaboration. With a new immersive platform designed by NextMeet, employees' digital avatars can work from virtual offices in real-time, enabling a higher quality of interaction amongst colleagues. Moreover, colleagues in the metaverse would not only comprise the avatars physical colleagues but will also include AI powered human-like bots. These robots will have the capability of working jointly with us, carrying out the more tedious and routine tasks in order to free up labour for the more value-added tasks. There are companies that focus on creating "digital humans" that can work across different roles in a wide variety of fields.

Training and skill-development will also be revolutionised within the virtual space through a reduction in the time taken to acquire new skills. AI enabled digital coaches may offer important advantages over traditional classroom-based trainings as concepts may be visually demonstrated using 3D.

The Metaverse in our daily lives

- In 2021, Gucci created The Gucci Garden Experience to sell virtual products and sold a virtual-only digital twin of a Gucci purse for a higher price than its real-world counterpart.
- In 2020, a Travis Scott Fortnite concert had 27.7 million unique attendees – far more than a typical concert venue can accommodate.
- In the last 12 months Decentraland – a user-owned Ethereum-based virtual world – saw 21,000 real estate transactions worth US$110 million.

Nike launched a virtual world called NIKELAND on Roblox in late 2021. NIKELAND contains buildings and fields inspired by the company's real-world headquarters, arenas where visitors can play games, and a digital showroom where they can outfit their avatars with Nike products. The full experience crosses into the physical world too: through the use of accelerometers on their phones, visitors can translate activity in the physical world into longer jumps or faster running speeds in NIKELAND games.

Blockchain

Blockchain, which first came into existence in 2009, is a digital ledger technology that can be used to record and store transactions. The concept first emerged from cryptocurrencies, but with technical advances, has now found applications across multiple industries, ranging from supply chain to retail to healthcare. Blockchain technology is changing the nature of doing business and helping companies redefine how they manage tangible and digital assets. Tangible assets can be tracked better using the blockchain system, whilst non-replicable digital assets, such as NFTs (see Box 4), are changing the way we need to think about capital in the real world.

The banking and finance industry leads the way in adopting blockchain technology. It is revolutionising how digital banking and commerce are conducted by enabling faster cross-border payments, greater transparency, and cost reductions. Blockchain puts all relevant parties into a common digitised infrastructure, allowing for a more efficient execution of transactions and a reduction in fraud. Storing KYC statements on a blockchain also allows a bank to access a customer's information and perform diligence checks. The unique digital identity of each participant in a blockchain network can help streamline authentication processes thus reducing operating costs.

Another area in which blockchain offers immense potential is supply chain efficiency. The availability of decentralised information enables end-to-end traceability of material supply chains by helping participants record and access relevant details such as price, date, location, quality, and certification. For example, an automaker which releases faulty vehicles bears huge costs in recalls and repairs. However, with the use of blockchain to trace the suppliers of faulty parts more efficiently, they are able to contain the issue better, reducing time and labour costs.

Another prominent service offered by blockchain are smart contracts. Smart contracts are programmes stored on a blockchain that run when predefined conditions are met. These can automate, calculate, and arrange payments by automatically carrying out their terms and conditions. When obligations are met, these contracts can be executed instantly, saving time, removing intermediaries, and allowing for multi-party consensus-based validation.

Non-digital enabling technologies

It is important to note that there are other non-ICT-related technologies within the Intelligent Economy that can assist in achieving the goals outlined in the previous chapter. Nanotech, defined as the manipulation of matter with at least one dimension sized from 1 to 100 nanometres, is capable of being utilised to fight cancer cells or create batteries that last 10 times longer.[50] Biotech, defined as the integration of natural sciences and engineering sciences, has found many use cases in the healthcare industry, such as stem cell research, and agriculture, such as genetically modified organisms.[51] Lastly, green tech, defined as the usage technology to protect the world's natural resources and mitigate the negative environmental impact of human activity, has a significant potential to address the global economy's most pressing environmental problems, as outlined in Chapter 1. Scientist used the power of AI to develop a neural operator architecture that can simulate pressure levels during carbon storage, helping scientists find optimal injection rates and sites during carbon sequestration.[52] Despite these examples not stemming strictly from the ICT's domain, it is crucial to demonstrate that how they could contribute to the Intelligent Economy when used in conjunction with digital technologies.

[50] Iberdola (2022). "Nanotechnology: a small solution to big problems". Available at: https://www.iberdrola.com/innovation/nanotechnology-applications

[51] Brittanica (2022). "Applications of biotechnology". Available at: https://www.britannica.com/technology/biotechnology/Applications-of-biotechnology

[52] Wen et. Al (2022). "U-FNO—An enhanced Fourier neural operator-based deep-learning model for multiphase flow". Available at: https://www.sciencedirect.com/science/article/abs/pii/S0309170822000562

NFT

Box 4

NFTs are grabbing the headlines

Non-fungible tokens (NFTs), or unique blockchain-backed digital assets have been all over the headlines recently thanks to their rising popularity and soaring valuations in the world of collectibles, art and sports. Sales grew from just US$41 million in 2018 to US$11 billion in 2021, growing nearly 60 times.

NFTs started grabbing mainstream attention in 2021, when Christie's Auction House hosted its first digital based NFT auction – a piece by the artist Beeple titled Everydays: The First 5000 Days. In that auction they accomplished two firsts: They sold the most expensive piece of digital art in history (the work went for US$69.3 million) and became the first auction house to accept cryptocurrency as payment. By simultaneously validating a new form of art and a digital currency to its customers, it became a leader in shaping how commerce can be done in purely digital worlds – a future they've since doubled down on. Just one year after their first auction, Christie's has now surpassed US$100 million in NFT sales.

How do NFTs work?

NFTs are unique and tamper-proof digital assets that live on the blockchain and are used to prove ownership and authenticity. They can be bought and sold online, typically with cryptocurrency. The immutability of the blockchain is what gives NFTs its value. With NFTs, every transaction, especially one involving ownership, is recorded and verified on the blockchain. This has allowed the application of NFTs in many domains such digital asset ownership in gaming and the metaverse, as well as ticket and real-world art authentication.

Domains where NFTs are currently being used:

Gaming: In 2017, a new video game CryptoKitties became popular which allowed users to collect, breed and sell NFT kittens. Games like Axie Infinity and Blankos Block Party are making waves with play-to-earn (P2E) models which allows gamers to make real money as they get a hold of potentially valuable in-game assets, e.g., skins, cards, or a specific type of cryptocurrency. With over US$3.5 billion traded on the Axie platform, it's one of the most valuable NFT projects in the world.

Metaverse: NFTs are also proving to be useful in metaverse as secure ways of proving ownership of identities and digital assets in the virtual space. Leading metaverse companies Decentraland and Sandbox are using NFTs for tokenising everything from usernames to in-game wearables to real estate.

Ticketing: The creation of tickets as NFTs gives more control over the ticket resale market, ensures a more secure storage of tickets, and presents an opportunity for tickets to be considered as digital collectibles. Kings of Leon sold NFTs that entitle buyers to lifetime front row seats at their tours. Coinbase gave out free NFTs as merchandise at the Governors Ball Music Festival in New York, granting users access to the VIP lounge.

Art and collectibles: NFTs are disrupting the art world by changing the way art is traded. By digitising their art, artists can make greater profits by authenticating their work using blockchain technology. An NFT may represent many kinds of works, such as paintings, memes, GIFs, music, videos, etc. For example, Twitter CEO Jack Dorsey sold his very first NFT, Tweet from Twitter's launch day in March 2006, for nearly US$3 million. We see many platforms emerging for the buying and selling of NFTs in recent years, such as Top Shot, an NFT marketplace for the buying, selling, and trading of videos of NBA moments, and the Bored Ape Yacht Club, which as of 2022, has generated over US$1 billion from selling pictures of cartoon apes which have been bought by the likes of Justin Bieber, Paris Hilton, and Madonna.

Chapter 04

Quantifying the value of the Intelligent Economy

The Intelligent Economy could be worth US$18.8 trillion by 2030

The Intelligent Economy has the potential to yield a wide range of benefits across many industries. These benefits are not normally valued by traditional economic accounting measures such as Gross Domestic Product (GDP) which purely measures the monetary value of goods and services in the economy but does not account for the value of broader externalities such as social and environmental benefits.[53] This study attempts to capture the value of these benefits through three sources of impact:

i. Augmented productivity gains, the incremental increase in global economic output as a result of the application and use of next-generation technologies.

ii. Improved social well-being, the positive externalities in terms of time saved, health and safety, and social inclusion generated from the use of next-generation technologies.

iii. Environmental benefits, the value of carbon tax savings that firms create through decarbonisation applications enabled by technologies

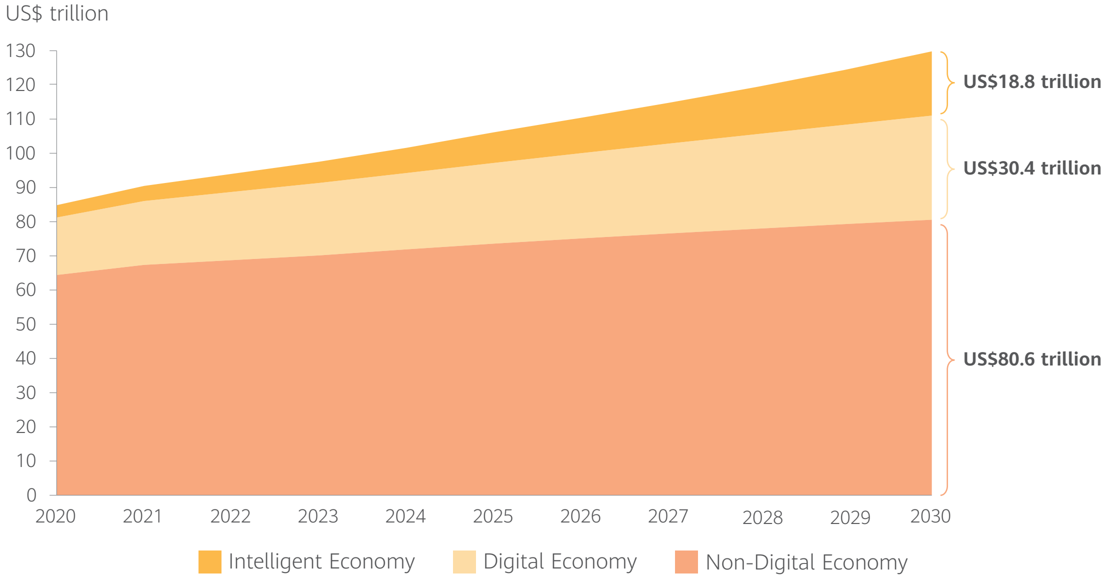
The Intelligent Economy has the potential to generate significant value for the global economy. In total, it is estimated that the Intelligent Economy could have a value of US$18.8 trillion by 2030 (Exhibits 4 and 5), representing over 16.9% of the global economy.[54] The Intelligent Economy is expected to grow at a CAGR of 18.0% between 2020 and 2030, a rate higher than the 2.3% and 6.1% CAGRs estimated for both the non-digital and digital economies respectively. In the future, the speed and extent of frontier technology adoption will determine the rate at which countries will be able to enjoy Intelligent Economy benefits. As more use cases and applications may be discovered in the future, the value of Intelligent Economy in the periods ahead could actually be larger than those estimated in this study. The route to a larger and more productive Intelligent Economy in the future would undoubtedly be an increased

[53] For example, living standards, better health services, more secure livelihoods, wider access to education, better working conditions, security against crime, more satisfying leisure time, a healthy and sustainable environment cannot be by measured by GDP alone.

[54] All figures in this report are in real terms with 2015 as the base year

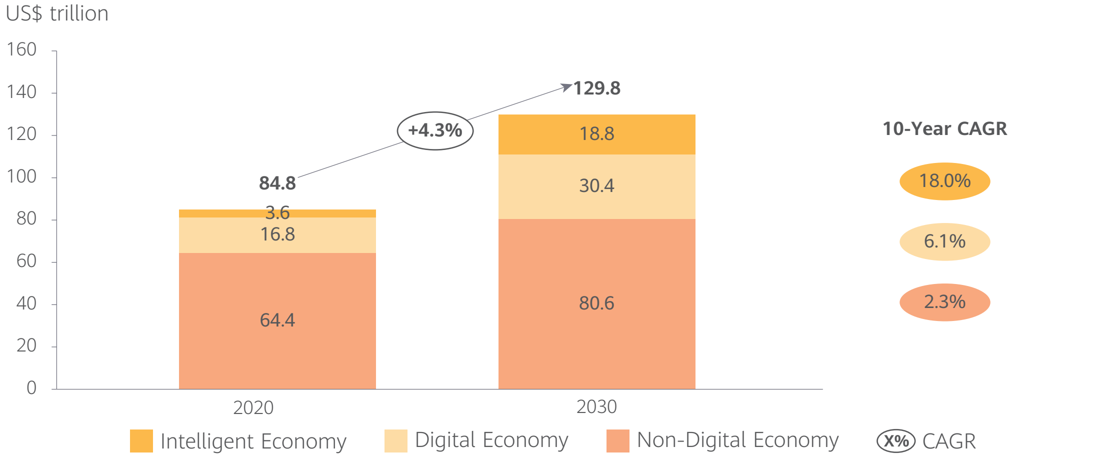
capital investment in frontier technologies across all industries globally, as well as an enabling regulatory and business environments for these technological applications to thrive.

The Intelligent Economy could be **worth US$18.8** trillion by 2030, representing **16.9%** of the global economy



Source: Huawei, Oxford Economics, EY analysis

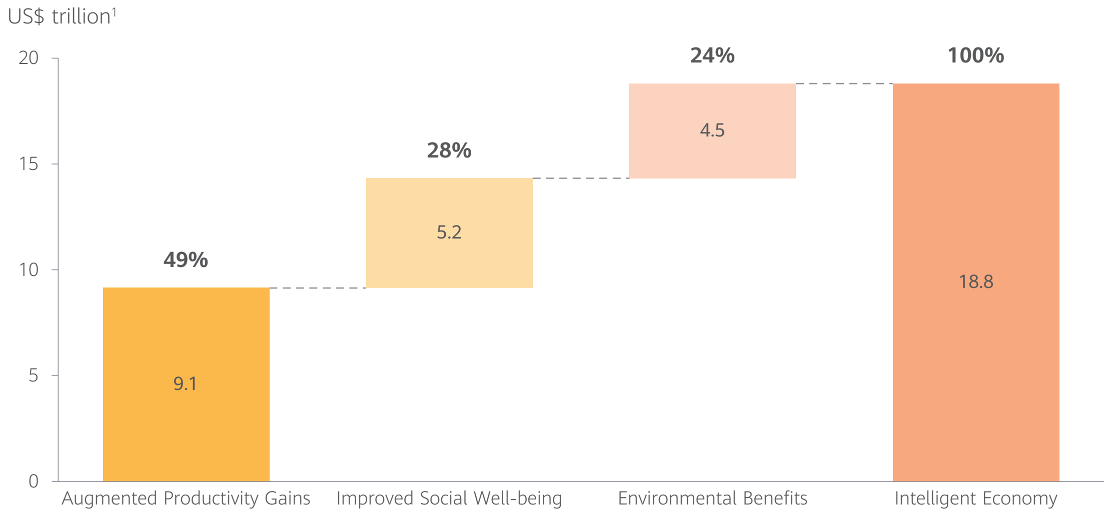
Exhibit 4: The Intelligent Economy could generate an additional US$18.8 trillion in value by 2030



Source: Huawei, Oxford Economics, EY analysis

Exhibit 5: The Intelligent Economy is estimated to grow quicker than the Digital and Non-Digital Economies

In terms of breakdown across the three sources of impact, augmented productivity gains are expected to have the highest potential impact of around US$9.1 trillion, while social well-being could generate US$5.2 trillion worth of value, followed by environmental impacts estimated to be worth around US$4.5 trillion (Exhibit 6).



[1] Numbers may not sum due to rounding

Source: Huawei, EY analysis

Exhibit 6: Productivity gains could be the largest contributor to the Intelligent Economy in 2030

Augmented productivity gains could be worth US$9.1 trillion by 2030

First, augmented productivity gains could be enjoyed across industries from the application of frontier technologies. These have positive implications on the global economy, and their cross-industrial impacts and multipliers can be estimated using a computational general equilibrium model (see Appendix for details). As mentioned earlier, there has been a broad-based slowdown in labour productivity growth in advanced economies since the late 1990s. The trend of this decline which started after the global financial crisis, has further been exacerbated by the disruptions caused by the COVID-19 pandemic.

The Intelligent Economy has the potential to help economies solve the productivity slowdown by allowing labour to focus on higher-valued skills such as creativity, problem-solving, and networking. A significant portion of these benefits will come not from replacing existing labour and capital, but by enabling them to be used much more effectively. Some examples of productivity impacts in selected industries include:

Augmented productivity gains could be worth **US$9.1** trillion by 2030 – the manufacturing industry to gain the most **(US$2.3 trillion)**

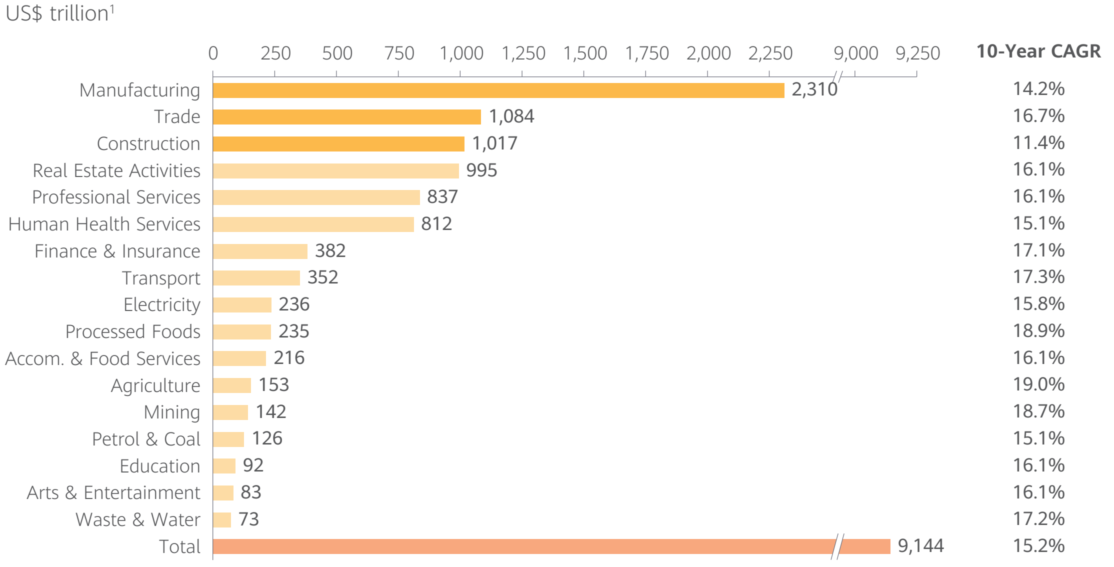
- Manufacturing: Manufacturers may use AI in the design phase of a factory to optimise the process to deliver the maximal return on investments. Moreover, IoT opens up doors for predictive maintenance, reducing machine downtime and maximising machine productivity.

- **Healthcare:** IoT, 5G+, implantable diagnostic devices, and wearables enable healthcare providers to reach both patients in the home setting, saving them costly trips to the doctor's office, and the hospital setting, enabling them to accurately assess a patient's current conditions and identify the best course of action.

- **Retail:** Retailers can combine the use of AI in cameras and RFID technology to create an entirely autonomous shopping experience where customers simply need to "grab and go", skipping queues and receiving receipts digitally on their devices. The use of this technology will also enable retailers to better understand shopping habits and improve shelf-space selection for specific items

- **Financial services:** Financial institutions can utilise quantum computing to analyse large or unstructured data sets, allowing them to make better decisions and improve customer service, such as by providing timelier or more relevant offers (e.g., a mortgage based on browsing history).

Exhibit 7 highlights the value of the potential productivity gains from the Intelligent Economy segmented by industry. The manufacturing, trade, and construction industry have the highest potential gain, with the manufacturing industry likely to capture over US$2.3 trillion in productivity gains. The reason manufacturing stands to benefit the most in terms of productivity in the Intelligent Economy is due to the vast number of use cases and applications applicable to the industry based on existing research. Many of these advanced and intelligent technological solutions have yet to be fully utilised and adopted across all manufacturing processes globally, especially in manufacturing plants in developing economies. Construction also stands to be a major benefactor from the Intelligent Economy (+US$1 trillion) with Box 5 providing further details.



[1] Numbers may not sum due to rounding

Source: Huawei, EY analysis

Exhibit 7: The manufacturing, trade, and construction industries are likely to have the largest productivity gains in the Intelligent Economy

Box 5

Construction industry can reap significant benefits by deploying frontier technologies

Construction, which encompasses real estate, infrastructure, and industrial structures, is one of the largest industry in the global economy, accounting for 13% of the world's GDP, however, the industry has been constrained by lower productivity growth. A study notes that the industry's labour productivity growth has averaged just 1% a year for the past 20 years, which is only a third of the total economy average.[1] This industry has great potential in benefitting from the application of frontier technologies to overcome challenges such as safety concerns, labour shortages and cost and schedule overruns. Currently the industry is not well known for leveraging data effectively nor using cutting-edge analytics to make informed business decisions. Technology can help add value to the construction activity in areas of design, bidding, financing, procurement, construction, operations, asset management and business model transformation.

Digital technologies are enabling better collaboration and a shift toward more data-driven decision making. As a result of this, companies are adopting 5-D building-information modelling (BIM), advanced analytics, digital-procurement and supply-chain management throughout their organisations. Some of the offerings are:

- Digital Twin: Potential savings via digital twins are huge, extending beyond product development to the entire product lifecycle. For example, it can be used for problem diagnostics and predictive maintenance, reducing costs substantially when compared to more labour-intensive processes used today. AI based tools may detect possible clashes, delays, and changes within the construction process by comparing the digital twin of the building that is present in the Building Information Modelling (BIM) cloud against the actual physical representation.

- Drone surveying: Crewless aerial and ground vehicles equipped with optical cameras can carry out monitoring activities, particularly in unsafe or inaccessible areas. Geospatial Information Systems (GIS), Drones, and Geospatial AI (GeoAI) significantly reduces the time it usually takes to gather accurate survey maps and aerial images of a job site.

- Accurate task scheduling and predictions: Through real-time collection of site data, AI can enable a more precise allocation of resources and a reduction in idle time by considering weather conditions, worker skill sets and potential interruptions.

- Autonomous construction equipment: Some companies are offering self-driving construction machinery, such as autonomous bulldozers and brick laying robots, which would enable time savings and efficiency gains.

- **Enhanced safety at construction sites:** A major cause of construction delays and cost overruns are accidents. By combining the computer vision capabilities of AI with cameras at construction sites, there is a possibility mitigating risks and reducing the number of accidents greatly.

- **Civil Information Modelling:** Instead of developing 2D drawings, projects are now being modelled using 3D software. This allows users to immerse themselves in a completed project and evaluate the model before beginning any construction.

Case study: L&T group modernised its US$10 billion construction business

Four years into the process, L&T Group's engineering and construction business is reaping the benefits of a well-implemented and comprehensive data strategy. More than 10,700 machines across 450 worksites have been connected, and employees have been trained to understand real time analytics on projects created through a variety of technologies such as AI, IoT, VR/AR, robotic process automation, and cybersecurity. Workplace safety has improved greatly from the implementation of immersive training with VR, the use of mobile apps for compliance processing, and the use of sensors and beacons. Every component of a project can now be measured, leading to improvements such as a 25% increase in equipment fuel efficiency, a 15% increase in worker productivity, and a 10% increase in plant & machinery productivity and utilisation.[2]

Sources:

[1] McKinsey & Company (2020). "The next normal in construction". Available at: https://www.mckinsey.com/business-functions/operations/our-insights/the-next-normal-in-construction-how-disruption-is-reshaping-the-worlds-largest-ecosystem

[2] Harvard Business Review (2020). "Building a Data-Driven Culture from the Ground Up". Available at: https://hbr.org/2020/02/building-a-data-driven-culture-from-the-ground-up

Improved Social Well-being could be worth US$5.2 trillion by 2030

Second, the use of these technologies to make faster decisions and more accurate predictions could produce social benefits in the form of consumer time savings, more optimal health and safety outcomes, and greater social inclusion. Case studies were used to understand and extrapolate these impacts to the global level. Social well-being was assessed through three key lenses - i) increased consumer time savings; ii) enhanced health and safety benefits; and iii) improved social inclusion.

i. Increased Time Savings

The Intelligent Economy offers numerous applications which result in time savings of individuals which they can then devote to work or leisure. For example, the adoption of driverless vehicles is expected to provide wide ranging benefits such as reducing the scale of traffic congestions, and saving time spent on commuting. In a survey-based study on the potential implications of self-driving cars, it is estimated that in the long term (through 2050), autonomous vehicles (AVs) could free as much as 50 minutes a day for drivers, who will be able to spend traveling time working, relaxing, or accessing entertainment.

ii. Enhanced Health and Safety Benefits

The use of AI applications for security purposes has been growing in recent years in the areas of innovative police services, connecting forces to citizens, and enhanced citizen surveillance services. Cities are investing in developing smart solutions, such as real-time crime mapping, crowd management, gunshot detection, and drone surveillance systems to ensure public safety. A study showed that AI could help cities reduce crime rates by 30 to 40% and reduce response times for emergency services by 20 to 35%.[55] Machine learning and big data analyses also make it possible to analyse data on crime and terrorism, enabling the identification of patterns, correlations, and trends, leading to the prediction and prevention of crimes.

iii. Improved Social Inclusion

Technologies such as machine learning and AI can make the systems of education, financial services, and hiring processes more inclusive. For example, a report, Artificial Intelligence for Job Seeking (2020), argues that correct and responsible use of information-intensive AI search has the potential to speed up services processes, customise them and mitigate biases that lead to employment discrimination.[56] With a better and more sensitive design of the tools and algorithms that match the characteristics of vacancies with the skills of candidates, AI tools for job searching could provide greater inclusion of vulnerable groups in the labour market. AI systems can also optimise job search services to ensure that everyone receives equal opportunities when considering and applying for work.

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[55] Deloitte (2021). Urban Future with a Purpose. Available at: https://www2.deloitte.com/global/en/pages/public-sector/articles/urban-future-with-a-purpose/surveillance-and-predictive-policing-through-ai.html

[56] IDB (2022). The Effects of AI on the Working Lives of Women. Publications. Available at: https://publications.iadb.org/publications/english/document/The-Effects-of-AI-on-the-Working-Lives-of-Women.pdf.

Methodology for Quantifying Social Benefits

This section focuses on quantifying the benefits of social well-being from the implementation of frontier technologies that are not captured by traditional accounting measures. Through an extensive literature review, use cases of frontier technologies with quantifiable social impacts were assessed and extrapolated to the global level. There are a number of caveats to estimating the size of social impacts. First, the literature review is not exhaustive and more/different use cases will continue to emerge as technologies and adoption rates evolve, resulting in potentially greater benefits. Second, this study only captures positive social impacts as attempting to understand net social impacts will introduce significant uncertainties and beyond the scope of this study.

Three components of social well-being (further segmented into 12 sub-areas) are assessed. The benefits captured are unpriced externalities, and any increments in productivity due to the use cases are strictly captured within the CGE model. More details on the estimation methodology can be found in the Appendix.

Component 1: Increase Time Savings

This refers to the value of time savings that consumers could enjoy through the applications of frontier technologies. Five applications are most relevant:

i. Autonomous Vehicles (AVs): The value of time saved by humans not needing to drive the car due to AVs.

ii. Traffic Control and Maintenance: The value of time saved due to the reduction in traffic congestion and waiting times arising from the use of IoT and data analytics to optimise traffic management.

iii. Autonomous Checkout: The value of time saved due to the elimination of waiting times through automated payments (without the need for cashiers) in grocery shopping with IoT and RFID technologies. This is particularly applicable through the usage of self-checkout mechanism (e.g., Amazon Go).

iv. Chore Automation: The value of time saved due to the adoption of advanced robotics to handle household chores. Additional benefits are derived from the participation of more meaningful activities for the individual.

v. Public Service Delivery: The value of time saved is derived from more efficient government services (e.g., calculation and paying of taxes, registering for public services etc.) made possible by technologies such as AI and machine learning.

Component 2: Enhanced Health and Safety Benefits

This quantifies the value of health and safety benefits derived from the application of intelligent technologies. Five key applications are most relevant:

i. Autonomous Vehicles: The value of life loss avoided through the prevention of deaths with the use of AVs.

ii. **Crime Prevention:** The value of life and property loss avoided, as well as costs incurred on criminal investigations, from using IoT and predictive analysis to improve early warning systems to prevent serious crimes.

iii. **Emergency Response Times:** The value of life loss, property damages, and healthcare costs avoided from the use of satellite-enabled technology imbedded with IoT and AI to enhance surveillance of natural disasters and improve the efficient dispatching of disaster relief services.

iv. **Enhanced Patient Monitoring:** The value of an increase in lifespans of patients (through the potential reduction in accidents, injuries, and health outcomes) from the continued advancements in patient monitoring and health tracking applications that are enabled by IoT and advanced data analytics.

v. **Workplace Injuries:** The value of life loss and injuries avoided at workplaces from the use of IoT and AI-enabled applications to predict and detect potential accidents (e.g., detect safety violations such as failure of factory workers to wear helmets and safety vests).

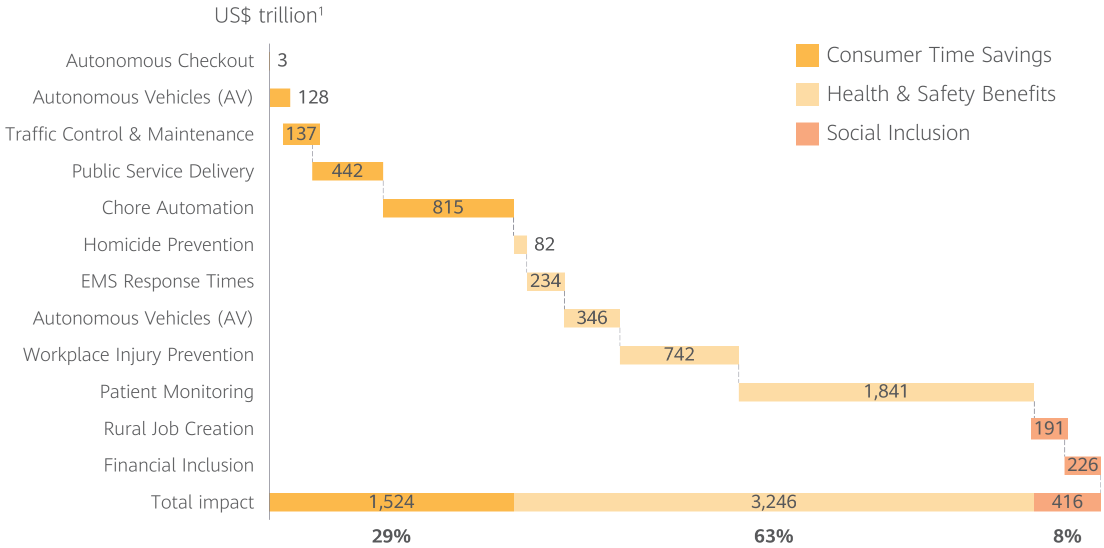
Component 3: Improved Social Inclusion

i. **Access to credit:** The predictive patterns identified by AI technology and big data analytics can help lenders widen their credit access in comparison to traditional means of relying on applicants' declared data and credit bureau information. This will help to enhance financial inclusion and provide more opportunities for availing credit to borrowers with no credit scores.

ii. **Job opportunities for rural communities:** The onset of IoT, 5G+ and AI may enable the creation of new markets in the rural healthcare and agriculture industry, creating new jobs and enriching the previously underserved communities.

Increased time savings, enhanced health and safety benefits, and improved social inclusion could be worth **US1.5 trillion, US$3.2 trillion, and US$0.4 trillion** by 2030

The quantification of these applications shows that the Intelligent Economy can potentially generate an additional US$5.2 trillion of value through improved social well-being by 2030 (Exhibit 8). Of this US$5.2 trillion, increased time savings, enhanced health and safety benefits, and improved social inclusion account for 29%, 63%, and 8% of the total value respectively.



[1] Numbers may not sum due to rounding

Source: Huawei, EY analysis

Exhibit 8: The Intelligent Economy could bring US$5.2 trillion worth of social value by 2030, with health and safety benefits the largest contributor

Box 6

Chore automation frees up time for labour

The pandemic brought a significant change in the way individuals and businesses operate. Working from home has become a viable option for many employees around the world and is becoming the new normal. This change has led the boundary between work and personal spaces to become increasingly blurred. Tasks such as cooking and cleaning act as distractions for employees and may hamper their work productivity. If these tasks are automated, employees can free a large amount of their time to focus more on more productive work.

A research study predicts that by 2040, 90% of common household tasks - including dusting, doing laundry, and cleaning dishes – may become automated through the application of AI and advance robotics.[1] This would allow people to save almost two hours a day, or the equivalent of more than 33 days a year. By combining information on the market growth rate of household robots, and forecasts on the number of households containing AI-enabled robots, this study predicts a total value of 74 billion hours being saved from the household chore automation by 2030 which can be allocated to either productive work or leisure (see Appendix for details). The study also highlights some of the applications of technology in automating the household chores:

- House robots: There have already been advancements in robots being used in industries such as manufacturing, aviation, healthcare, etc., and it is predicted that these robots will soon be able to perform household chores such as folding laundry, changing sheets and moving furniture as well.
- Laundry management: Smart machines can sense the "dirtiness" levels in different types of fabric (workwear, school uniforms, linen clothes, denim) and accordingly set the washing and drying speed. In addition, smart wardrobes and cabinets can use IoT-driven applications and RFID technology to manage clothing and outfit scheduling.
- Robotic vacuum cleaners: These would offer noise free and autonomous cleaning and use specialised mapping algorithms to detect obstacles. Such devices will be controlled by voice commands and integrated AI assistants.
- Mini drones: It is predicted that tiny drones may help in tasks such as for watering plants and monitoring security around the house. These drones would have lights, sound, cameras, microphones, sensors, and robotic arms.
- AI butlers: Imagined as extremely advanced versions of Siri or Alexa, AI Butlers will assist in routine life administrative tasks such as like paying bills, managing subscriptions, and shopping. They may also play the roles of teachers or trainers.
- Reverse microwaves: These ovens would be designed for cooling down things instantly.
- Ultra-smart fridges: These fridges will have the ability to learn what you eat and assist in reordering stocks when they are low. They will also have the ability to recommend recipes to users based on the contents of their fridge and their expiry dates. Because of built-in cameras inside these fridges, users will be able to see what they have inside from a mobile phone anywhere.

Sources:

[1] M. Dohler and I. Pearson (2020). Life More Automated Report. Available at: https://www.comparethemarket.com/globalassets/simples-lab/new-simples-lab-march-2020/001_20_CTM_Automated_Report_doc_v10_ebf086b2-9f19-4cdd-ba67-92e10208d2cb.pdf

Box 7

Amazon's "just walk-out" stores are the future of retail

Amazon opened its first Amazon Go grocery store in Seattle, Washington in 2017. The company described the original store as "a new kind of store with no checkout required". It offers ready to eat snacks, grocery, and household essentials. Shoppers do not need to wait in line whilst shopping at these kinds of stores. These stores work by using technologies similar to self-driving cars, such as computer vision, sensor fusion, and deep learning. This technology can detect when products are taken or returned to the shelves, and keeps track of them in a virtual cart. When the customer leaves the store with their goods, his or her Amazon account is charged automatically and they are sent a virtual receipt.

A research study estimates the economic impact from the self-checkout stores:[1]

- Direct Labour Savings: These stores eliminate the need for cashiers and stock inventory counters, leading to total savings of about US$412,300 in annual savings per store.

- Indirect Labour Savings: The data created by the platform indirectly allows additional optimisation of the workforce and supply chain. For example, with that data, the system knows how many picks per hour each stocker is completing and exactly when items go out of stock. This would lead to an estimated US$50,000 annual savings per store.

- Increase in gross profit: Faster checkout would also get more customer traffic in the store from competitive stores which would be translated to US$173,000 in incremental gross profit per year per store.

Thus, the total annual economic benefit from Amazon's self-check-out store comes out to be about US$645,000 per store.

Sources:

[1] Medium (2019). "Analysis of the Amazon Go Platform and Its Implications on Large Format Grocery Stores". Available at: https://medium.com/focal-systems/analysis-of-the-amazon-go-platform-and-its-implications-on-large-format-grocery-stores-727d9b25f04a

Environmental benefits could be worth US$4.5 trillion by 2030

Third, intelligent technologies could contribute to decarbonisation especially in industries such as manufacturing, construction, and electricity, and support the transition into a low-carbon world. Technology if harnessed fully, has the potential to provide breakthrough innovations to mitigate and adapt to climate change. Leveraging these technologies to develop new solutions across industries to address climate change represents a significant opportunity to accelerate sustainable transformation and put the world on the path of low-carbon and climate-resilient development. The decarbonisation potential of these technologies was first examined through desktop research, and then the CGE model was used to quantify the economic value of carbon abatement. Examples of use cases across selected industries include:

The Intelligent Economy could produce **US$4.5 trillion** worth of environmental benefits by 2030

- Manufacturing: Deploying emissions solutions via Industrial Digital Technologies (IDT), which includes IoT, augmented reality, robotics, and additive manufacturing (3D printing), alongside switching to lower carbon fuel sources
- Construction: IoT-enabled building energy management systems, commercial HVAC controls, and smart meters in smart buildings
- Utilities: AI and IoT powered energy management applications that will constantly monitor energy requirements, predict maintenance, predict short- and long-term fluctuations, and increase the efficiency of renewable energy assets
- Transportation: The use of delivery robots, autonomous and electric vehicles, and smart traffic management powered by AI and IoT will help to reduce the quantum of emissions from road transport
- Agriculture: Using AI, 5G+, IoT, robotics, and agritech innovations for farmland optimisation will lead to a reduction in fossil fuel use; precision monitoring of plants and livestock has the potential to increase yield and reduce waste
- Waste and Water: Installing intelligent garbage bins and IoT sensors can help local governments in optimising garbage collection routes, reducing the frequency of waste gathering; AI-driven solutions have the potential to increase the efficiency of waste management, increasing the proportion of waste that is recycled, in turn reducing the global depletion of resources.

In order to meet the goal of limiting the increase in average global temperatures to 1.5 degrees Celsius as set out in the 2016 Paris Agreement, emissions need to be halved by 2030, and in turn reduced to net-zero by 2050.[57] The UNEP

[57] United Nations (2022). "For a livable climate: Net-zero commitments must be backed by credible action". Available at: https://www.un.org/en/climatechange/net-zero-coalition

Emission Gap Report 2021 estimates that total global emissions will need to be reduced by approximately 28 gigatonnes of CO_2 per year by 2030 to meet the 1.5-degree Celsius goal of the Paris Agreement.[58] Based on existing literature, frontier technologies have the potential to reduce global carbon emissions by 11.9 gigatonnes by 2030 – representing over 40% of the required CO2 reduction.

One study suggests that even though the global ICT industry will account for 2% of global carbon emissions in 2030, ICT technologies will help reduce global carbon emissions by over 20% due to its empowerment of other industries.[59] Meanwhile, another study estimates that AI alone has the capability of reducing global carbon emissions by 2.6 to 5.3 gigatonnes.[60] AI has the ability to reduce carbon emissions throughout the entire value chain of a production process and it can do so via three lenses: i) Monitoring Emissions; ii) Predicting Emissions; and iii) Reducing Emissions

AI could support the reduction of global carbon emissions by **2.6 to 5.3** gigatonnes

i. Monitoring Emissions

Companies can use AI to track emissions throughout their production process. They can arrange to collect data from their operations (including business travelling), and from every part of their value chain (including materials and components suppliers, transporters, and downstream users of their products), in order to support AI's predictions of their carbon emissions. AI will also have the capability of generating approximations for missing data in the value chain, whilst estimating at the same time the level of uncertainty in its results. For example, Aeromon is a Finland-based AI startup that utilises mobile and fixed devices to detect, measure, and visualise multiple gases and particulate matter that reveals the true extent of a firm's airborne emissions.[61]

ii. Predicting Emissions

Predictive AI can forecast future emissions across a company's carbon footprint, in relation to current reduction efforts, new carbon reduction methodologies, and future demand. As a result, they can set, adjust, and achieve reduction targets more accurately. For example, NN Investment Partners has developed a model using AI to forecast the carbon emission intensities (specifically, emissions per unit of revenue) of companies. This is particularly useful in the ESG investment realm as investors require up-to-date and real-time information in order to allocate capital appropriately as companies typically only report their emissions once per year.[62]

iii. Reducing Emissions

The ability to reduce emissions comes from a combination of both understanding where a

[58] UNEP (2021). Emission Gap Report 2021. Available at: https://www.unep.org/resources/emissions-gap-report-2021

[59] GeSI (2015). #SMARTer2030. Available at: https://smarter2030.gesi.org/downloads/Full_report.pdf

[60] BCG (2021). "Reduce Carbon and Costs with the Power of AI". Available at: https://www.bcg.com/publications/2021/ai-to-reduce-carbon-emissions

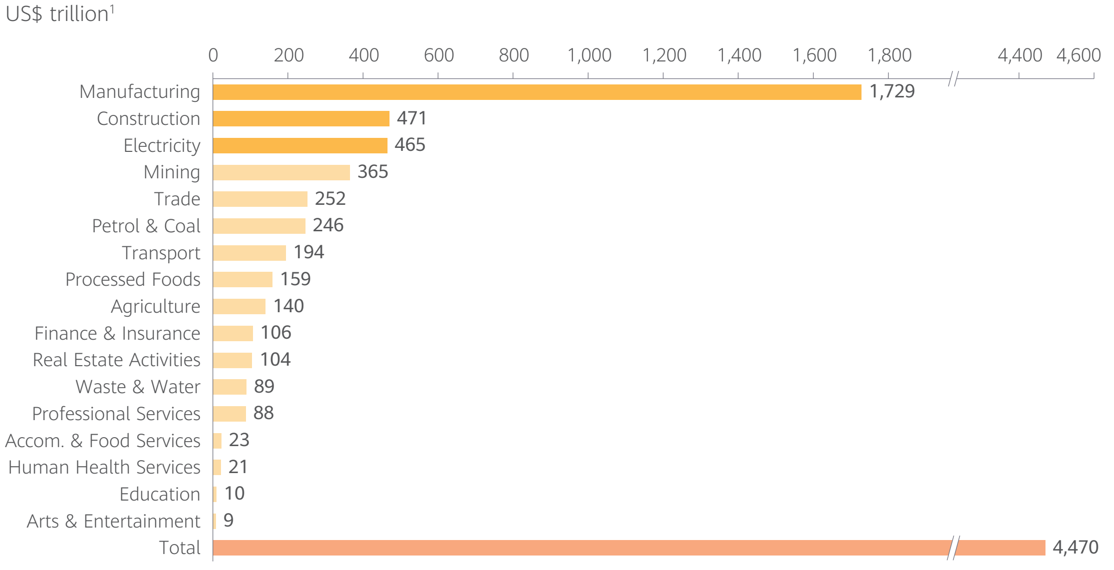
[61] Aeromon (2022). "Aeromon: about". Available at: https://www.aeromon.io/#about

[62] NN Investment Partners (2022). "Carbon emission forecasting: how artificial intelligence can help investors". Available at: https://www.nnip.com/en-INT/professional/insights/articles/carbon-emission-forecasting-how-artificial-intelligence-can-help-investors

firm is emitting the most, and where it is most likely to emit in the future. By providing detailed insight into every aspect of the value chain, prescriptive AI and optimisation can improve efficiency in production, transportation, and elsewhere, thereby reducing carbon emissions and cutting costs. For example, BrainBox AI is a company that specialises in using self-adapting AI that learns precisely how to use less energy and optimise comfort in all zones of a building. This enables transforming heating, ventilation, and air conditioning (HVAC) systems in buildings to consume less energy and reduce their carbon emissions.[63]

The manufacturing, construction, and electricity industries could reap the largest environmental benefits

Assuming an average global carbon price of US$150 (the midpoint of the IMF's forecast for 2030), the 11.9 gigatonnes of carbon abatement represents tax savings of US$1.8 trillion. These carbon tax savings are particularly driven by emission-intensive industries whose tax-burden reduces as emissions fall. In addition, it is assumed that firms could reinvest these savings into other more productive activities that would generate an increase in overall economic output. Together with the carbon tax savings, the CGE model calculates the net economic output to be around US$4.5 trillion (Exhibit 9).



[1] Numbers may not sum due to rounding

Source: Huawei, EY analysis

Exhibit 9: The manufacturing, construction, and electricity industries are likely to gain the most from decarbonisation enabled by the Intelligent Economy

[63] Brainbox AI (2022). "Brainbox AI: about us". Available at: https://brainboxai.com/en/about-us

The results show considerable differences in decarbonisation benefits across industries, with manufacturing, construction, and electricity production standing out as the largest beneficiaries, each being attributed with US$1.7 trillion, US$471 billion, and US$465 billion worth of economic output respectively. Their higher level of benefits can be due to two key factors. First, there is a positive correlation between an industry's carbon-intensity and its potential for decarbonisation. In other words, industries that account for a larger share of global emissions stand to benefit more from the development of more efficient methods of production and a reduction in CO_2 produced. Second, these benefits are likely to be seen more in the industries with a stronger drive towards Industry 4.0. Many companies are recognising the importance of building sustainability into their operations. The move towards intelligent manufacturing can help companies drive towards more energy efficient processes. AI alone can aid in optimising logistics, improving resource allocation, and monitoring value chain emissions.[64]

[64] BCG (2021). "Reduce Carbon and Cost with the Power of AI". Available at: https://www.bcg.com/publications/2021/ai-to-reduce-carbon-emissions

Box 8

Using Blockchain to increase traceability of emissions in supply chains

To support responsible sourcing through more enhanced supply chain transparency, seven leading mining and metals companies have teamed up with the World Economic Forum to form the Mining and Metals Blockchain Initiative in 2019.[1]

The group has since developed a proof of concept for its Carbon Tracing Platform, named the COT, to enhance traceability of emissions from mine to final product. The COT platform is based on the blockchain's distributed ledger technology and is meant to encourage the industry to collectively increase the efficiency and transparency of end-to-end emission reporting to meet increasingly stringent ESG requirements.

Users of these raw materials are also using blockchain technology to improve supply chain traceability. For example, a car manufacturer and a blockchain traceability firm work together to track cobalt usage in the batteries of electric vehicles to ensure that the car manufacturer's supply chain is ethical. It has been reported that around 20% of the mineral originates from artisanal mines in the Democratic Republic of Congo which may have poor and dangerous working conditions.[2]

The oil and gas industry is another industry that has many pilot initiatives to use blockchain to support decarbonisation and the energy transition. For example, Shell plc is exploring various blockchain applications to advance sustainable fuels adoption and to ensure the validity of carbon credit programmes. In 2022, Shell, Accenture, and American Express Global Business Travel jointly launched Avelia, a blockchain powered digital sustainable aviation fuel (SAF) book-and-claim solution for business travel. Avelia uses blockchain technology to ensure secured allocation of SAF's environmental attributes to companies and airlines to reduce their emissions, while ensuring transparency and accountability through the avoidance of double counting.[3]

Sources:

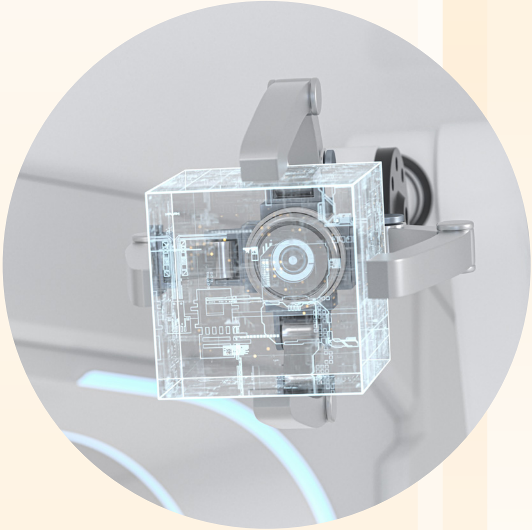
1 World Economic Forum (2020). "How blockchain is helping mining companies reduce carbon emissions". Available at: https://www.weforum.org/impact/the-responsible-sourcing-of-raw-materials/

2 Ledger Insights (2020). "Volvo invests in blockchain startup Circulor for battery supply chain traceability". Available at: https://www.ledgerinsights.com/volvo-invests-in-blockchain-startup-circulor-battery-supply-chain-traceability/

3 Biodiesel magazine (2022). "Shell, Accenture and Amex GBT launch blockchain SAF solution". Available at: https://biodieselmagazine.com/articles/2518190/shell-accenture-and-amex-gbt-launch-blockchain-saf-solution

Chapter 05

Realising the Intelligent Economy



By 2030, the Intelligent Economy could generate an additional US$9.1 trillion of value from augmented productivity, US$5.2 trillion from improved social well-being, and US$4.5 trillion from environmental benefits. However, while these represent a significant prize, steps must be taken to enable countries to enjoy these benefits. A detailed discussion of the requirements to enable the intelligent transition is beyond the scope of this study but this last chapter briefly describes three areas that require close attention.

More investment is required in frontier technologies, particularly to ensure equity of benefits

The Intelligent Economy presents a new source of accelerated growth for global economies following the global slowdown in labour productivity but there is a need for advanced economies to support developing economies in their transition so that the global benefits may be more widespread and equitable. This is because the Intelligent Economy's most advanced solutions are likely to be first adopted by the developed economies as not all countries are equally equipped to capitalise on the potential benefits. The United Nations Conference Trade and Development (UNCTAD) Technology and Innovation Report assesses the progress of 158 countries in using frontier technologies, such as AI and IoT through a "readiness index", and unsurprisingly, the economies most ready are concentrated in Northern America and Europe, while those that are the least ready are in sub-Saharan Africa.[65] Higher levels of investment and transfer of knowledge in frontier technologies to emerging economies is critical to allow them to leapfrog and develop the digital infrastructure needed to participate in the Intelligent Economy. The range of services which people in the developing world may stand to benefit from as

[65] United Nations Conference on Trade and Development (2021). Technology and Innovation Report 2021. https://unctad.org/webflyer/technology-and-innovation-report-2021

a result of the Intelligent Economy span from education to healthcare, and banking to utilities. A cooperative effort for countries to assist each other in the roll out of frontier technologies can help the benefits of the Intelligent Economy become more widespread.

In EY's Reimagining Industry Futures Study 2022, a survey of over 1,000 companies worldwide, 37% of respondents stated that they are concerned that the current use cases of 5G and internet of things (IoT) vendors do not meet their business resilience and continuity needs, with 47% also believing that their sustainability goals are not met by today's use cases.[66] This suggests that more investment in next-generation technologies are needed. Also, the US Competitive Carriers Association (CCA) estimates that it will cost an extra US$36 billion beyond what operators are willing to spend on infrastructure to establish true 5G ubiquity in the US. This indicates that even developed countries run the risk of leaving the rural populations out of participation in the Intelligent Economy (and hence the ability to reap the projected benefits). All of this implies that governments hold an important role in the investment of frontier technologies to ensure that the benefits of the Intelligent Economy are both attained and equitable.

Creating an enabling regulatory environment

Governments have an incentive to drive technological innovation because of the multitude of benefits it can bring to society. One important area to address is the need to create a regulatory environment that enables and incentivises the private sector to accelerate their transition into the Intelligent Economy. More specifically, governments need to ensure that regulations are fair and consistent, accounts for private sector input, and protects the security of society.

First, a fair and consistent regulation of companies will create an environment that promotes competition, leading to a higher chance of companies adopting solutions offered by the Intelligent Economy. They are more likely to be forced to innovate in a competitive market, especially in the face of a quickening changes in consumer demands. A regulatory environment that is inconsistent across companies could hinder progress towards the Intelligent Economy in two ways. If regulation is biased towards inefficient companies, it would force efficient companies who would adopt solutions presented by the Intelligent Economy to lose motivation within the market. On the flipside, regulation biased towards market leaders may create monopolies. Monopolies are generally considered to be bad for consumers and the economy as their market power tends

[66] EY (2022). EY Reimagining Industry Futures Study 2022. https://assets.ey.com/content/dam/ey-sites/ey-com/en_gl/topics/tmt/ey-reimagining-industry-futures-study-2022.pdf

to lure them towards innovation complacency,[67] which could lead to a slowdown in the transition towards the Intelligent Economy. Therefore, by implementing a regulatory environment that is fair to all players, governments could promote a healthy level of competition that drives innovation and assists in realising the value of the Intelligent Economy sooner.

Second, regulation set out by governments should account for the inputs of the private sector. This is because firms, especially the ones in the technology industry, are likely to innovate at a rapid pace over the next few decades. Governments may not always be on top of the latest developments in next-generation technologies, and this could lead to ideological chasms forming. Without working closely and maintaining frequent touch points with the private sector, governments may run the risk of imposing blanket policies that could be impede the transition towards the Intelligent Economy. Therefore, a strong partnership with the private sector when it comes to formulating regulating will allow governments to keep up to date with the latest practices in industries and enact policies that encourage the transition into the Intelligent Economy.

Third, governments should create a regulatory environment that builds public trust in digital adoption. One of ways governments could enhance public trust over technological developments is by having stronger oversight pertaining to cybersecurity. For example, the United Kingdom has set up an entity responsible for defining and driving the cybersecurity agenda of the entire country, the National Cybersecurity Agency. Governments may also consider implementing globally recognised cybersecurity standards, such as the US National Institute of Standards and Technology's Cybersecurity Framework, and developing robust substantive cybersecurity laws, such as those laid out by the Budapest Convention. Steps to ease public fears over privacy and data securities would lead to a higher likelihood of the public supporting firms in their adoption of next-generation technologies and transition towards the Intelligent Economy.

[67] Federal Reserve Bank of Minneapolis (2008). Monopoly and the Incentive to Innovate. Available at: https://www.minneapolisfed.org/research/sr/sr402.pdf

Developing a future-ready workforce to support the Intelligent Economy

The transition into the Intelligent Economy will lead to traditionally laborious and arduous roles becoming increasingly pushed to machines to handle. However, the full benefits of the Intelligent Economy cannot be realised if countries do not have a future-ready workforce that is capable of capitalising on all of the benefits next-generation technologies can provide. Therefore, there is an increasing need for private entities and governmental agencies to develop targeted courses and certifications that are recognised outside the traditional education system to cope with the transition. Focus and support of retraining should also be placed particularly on individuals who have the highest risk of being displaced by frontier technologies. For example, in Singapore, the governmental body, Skillsfuture, not only provides subsidies and credits for individuals to undertake new courses as a part of "lifelong learning", but it also provides a platform for private companies to source for manpower and job seekers to browse the available job postings.[68]

Technology has and always will change the nature in which labour operates in the economy. Subsequently, historical periods with the greatest advancements in technology and innovation coincide with the periods with the greatest economic growth and improvement in standards of living. The advent of the Intelligent Economy presents many exciting opportunities for labour in the upcoming years, and societies will have the challenge of developing a future-ready workforce that is able to to capture the full benefits of the Intelligent Economy and realise its maximum value.

[68] Skillsfuture (2022). About Skillsfuture. Available at: https://www.skillsfuture.gov.sg/AboutSkillsFuture

Appendix

Details of the Computational General Equilibrium (CGE) model

Core CGE Model

Computable general equilibrium (CGE) modelling provides a reliable and respected tool to estimate the net impacts of policy-making and other changes affecting an economy. It is a framework that supports bespoke scenario analysis in a single robust, integrated economic environment, enabling the assessment of the net impact of policies on key macroeconomic indicators such as GDP and employment, and key industrial measures like industry output. CGE modelling is often the preferred framework for gauging the impacts of large, multiyear projects throughout an economy, and is widely recognised by central governments around the world.

The EYGEM itself is a derivative of the Global Trade and Environmental Model (GTEM) initially developed by Australian Bureau of Agriculture and Resource Economics (ABARES) to analyse policy issues with global dimensions. EYGEM has also drawn on the key features of other economic models such as the global economic framework underpinning models such as Global Trade Analysis Project (GTAP), with state and regional modelling frameworks such as Monash-MMRF and TERM. Like all economic models, EYGEM is based on a range of assumptions, parameters and data that constitute an approximation to the working structure of an economy.

By default, the EYGEM model utilises Global Trade Analysis project database (GTAP) database, a primary source of data for global CGE models developed by Purdue University. The GTAP database contains among others, detailed estimates on bilateral trade, transport, energy, emissions, and protection to characterise economic linkages between regions and produce an input-output (I-O) style transaction across industries. Developed for CGE modelling, the database's underlying input-output tables are carefully monitored and made comparable across its variety of data inputs. The current GTAP10 release represents around 141 countries, 65 industries, and 5 labour occupation types. GTAP is the world's leading database for CGE analysis, providing in-depth, updated, and complete data with long-term continuity.

Adjustments and special considerations for this study

The core CGE model has been adjusted to meet the requirements of this study. Specifically, the following changes have been made:

Baseline GDP

The model's baseline GDP numbers were adjusted to reflect the data from the research, which had Oxford Economics estimates and projections for global GDP.

Carbon price

The carbon price in the model was updated to match the carbon price indicated in this study. This ensured that any carbon abatement simulations would be valued in terms of the carbon price identified in the research.

Modelling process

Data collection

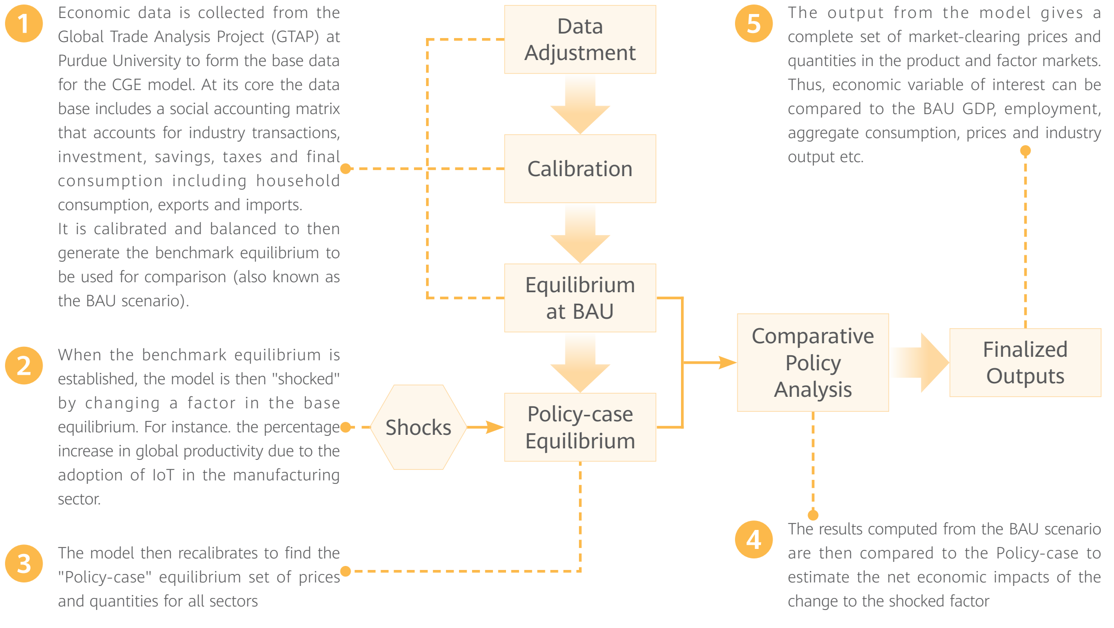
Insights were gathered from desktop research (e.g. literature reviews, internal and external reports), environmental scan and stakeholder consultations.

Assumptions were made based on the inputs gathered to estimate the additional economic outputs from the Intelligent Economy. To generate the forecasts, the CGE model was employed.

CGE modelling and outputs

The following steps were deployed in the CGE model:

Steps in CGE Modeling



The research conducted for this study showed technological implications on global output, productivity, and carbon abatement by industry in dollar terms. The main task was to translate these nominal values to applicable shocks in the CGE model. This involved a few steps:

i. Matching of industries identified in this study to EYGEM industries

The industries identified in this study did not align entirely with the industries used in the CGE model. Some of the industries put matched one-to-one (e.g. Agriculture, Financial Services, Construction) while a few of the industries identified in this study fit into multiple of the CGE industries.

To ensure shocks to these industries were represented accurately, the GVA was aggregated for the CGE industries and their relative industry share was calculated out of the aggregated GVA.

For example, the “Extraction” industry could be matched to Coal, Oil, Gas and Other Mining in the CGE model. Therefore, the GVA of Coal, Oil, Gas and Other Mining were calculated and broken down into their individual share of Extraction GVA. These shares would then be applied to the total Extraction industrial shock, ensuring that each of the sub-industries received a representative amount of the shock.

CGE industry	Industries identified in this study	Share of applicable CGE industry
AG	Agriculture, forestry & fisheries	100%
COL	Extraction	30%
OIL	Extraction	20%
GAS	Extraction	1%
OMN	Extraction	48%
PC	Manufacturing	4%
PFOOD	Manufacturing	10%
MAN	Manufacturing	86%
ELY	Utilities	74%
WTR	Utilities	26%
CNS	Construction	100%
TRD	Retail & wholesale distribution	100%
TRN	Transport & storage services	100%
CMN	Information & communication	100%
OFI	Financial services	100%
OBS	Other Sector (accommodation, professional service, public sector)	100%
HHT	Health care & social work	100%

ii. Nominal to percentage shocks

Running productivity and output shocks in the CGE model, requires a percentage-based input rather than a nominal value input. Therefore, the estimated industry impacts in dollar terms were transformed to growth in percentage equivalents. This involved the following steps:

- Gather the baseline values for industry GVA for 2020-2030 years.
- Add the estimated industry impact to industry GVA in 2020-2030 years.
- Calculate percentage difference in yearly industry GVA growth, generated by technology shocks.
- Use this percentage difference as the industrial shock value.

Industry shocks

The following steps were deployed in the CGE model:

i. Productivity shock

ii. To estimate the impacts of increased industrial productivity, a simulation was run with increases in industry productivity for the world economy. The size of the productivity shocks was estimated using the data points found from research that provided estimates for industry productivity gains in dollar terms.

iii. From the data points found, there were limited literatures that provided strong basis for productivity impacts in the Mining industry. As a conservative estimate, we deduced that the Mining industry would experience 50% of the relative impact to the manufacturing industry.

iv. Output shock

v. For the new market shock, a similar simulation was run. The size of the shock was estimated by increases in quantity of output. Moreover, productivity was endogenised in the model, allowing industrial productivity to react to increases in industry output.

vi. Emissions shock

vii. For the emission shock, a simulation where the level of global emissions was reduced by carbon abatement estimates was ran. The reduction in emissions was valued in terms of the carbon price as identified in Chapter 4

Full data points used as inputs and data sources

This study used a range of data sources to estimate the impact of frontier technologies on the Intelligent Economy. Using the insights gathered, (a) the CGE model then estimated the economic benefits and (b) shed light on the potential societal benefits which frontier technologies might bring (Chapter 4).

Quantification approach for social well-being impacts

The quantification approach for all use cases has been explained in the table below.

Component 1: Increased Time Savings		
Value of time saved from Autonomous Vehicles (AV) adoption – US$128 billion		
Description	Sizing Assumptions	Sources
AVs frees up time for drivers during commute to perform other tasks	• McKinsey estimates that by 2030, 15% of global passenger vehicles sold will be AVs. McKinsey Global Institute also estimates that 2% of the 1.5 billion passenger vehicles globally in 2025 will be AVs. Therefore, based on a historical annual light vehicle production growth rate of 8.5%, we forecast the total number of AVs globally in 2030 to be 53.4 million. • McKinsey also estimates that that an average person spends about 50 minutes a day in travelling time on road. Applying this conservatively to just weekdays, we expect 11.6 billion hours to be saved as a result of AVs in 2030. • Based on ILO's historical global wage rate trends, we forecast a global wage rate of US$11.0 in 2030, giving us the value of US$128 billion in 2030 as a result of time saved from AVs.	McKinsey & Company (2016)[69] McKinsey Global Institute (2015)[70] S&P Global Mobility (2022)[71] McKinsey & Company (2015)[72] International Labour Organization (ILO) Database[73]
Value of time saved from traffic control and maintenance – US$137 billion		
Description	Sizing Assumptions	Sources
IoT and big data analytics optimises traffic operations reduces time spent in traffic congestion	• McKinsey projects that by 2025, there would be 1.5 billion passenger vehicles globally. Based on a historical annual light vehicle production growth rate of 8.5%, we forecast the total number of passenger vehicles globally in 2030 to be 2.2 billion. • A study by Juniper Research suggests that smart traffic management systems have the potential to reduce over 33 hours of time spent in traffic per driver per annum. • Research and Markets estimates that the global market for traffic signals in 2030 will be worth US$240 billion whereas the global market for intelligent traffic systems will be worth US$27.9 billion in 2030. Therefore, we assume that 11.6% of traffic systems in 2030 will be AI-based. • Assuming an average vehicle occupancy of 1.5, we expect 12.5 billion hours to be saved annually as a result of smart traffic management systems. Combining this with our forecast of US$11.0 for the global wage rate in 2030, we receive the value of US$137 billion in total time savings.	McKinsey Global Institute (2015)[74] S&P Global Mobility (2022)[75] Juniper Research (2021)[76] Research and Markets[77] Research and Markets[78] University of Michigan (2021)[79] ILO Database[80]

Value of time saved from autonomous checkouts – US$2.8 billion		
Description	Sizing Assumptions	Sources
Elimination of waiting times through automated checkouts powered by IoT and (e.g., Amazon Go)	• The National Association of Convenience Stores (NACS) estimates a combined average of 63 seconds is spent waiting in checkout and payment lines. • A typical In-Store Autonomous Checkout System (ISACS) handles 140 transactions daily. Extrapolating on data from Statista, we forecast that there could be approximately 286,000 autonomous checkout stores globally by 2030. Thus, a total of 256 million hours can be potentially saved using autonomous checkouts. • Based on ILO's historical global wage rate trends, we forecast a global wage rate of US$11.0 in 2030, giving us the value of US$2.8 billion in 2030 as a result of time saved from autonomous checkouts.	NACS (2018)[81] J. Falcao et al. (2021)[82] Statista[83] ILO Database[84]
Value of time saved from household chore automation – US$815 billion		
Description	Sizing Assumptions	Sources
Household robots performing tasks, freeing up time to perform other tasks	• A study by King's College Professor Mischa Dohler and futurist Dr Ian Pearson predicts that 90% of households tasks like changing bedsheets, dusting, laundry, cleaning dishes and re-stocking of fridge could be performed by household robots in the next two decades. This will free up the equivalent of 33 days' worth of labour hours a year by 2040 (or 792 hours a year). • ABI Research estimates that there will be 79 million households containing robots that are enabled by AI and have voice recognition abilities by 2024. Using a 15.5% household robot market growth rate from Market Research Future as a proxy for the growth rate of households containing robots, we forecast that there will be 187 million households with robots globally in 2030. • Assuming that household robots will be able to free up half of the 792 hours by 2030, and using the global average wage rate of US$11 as the value of time, the total value of time saved is US$815 billion.	Dohler & Pearson (2020)[85] ABI Research (2019)[86] Market Research Future (2021)[87] ILO Database[88]
Value of time saved from more efficient public service delivery – US$442 billion		
Description	Sizing Assumptions	Sources
More efficient government services (e.g., paying of taxes, registering for services etc.) are possible due to AI and machine learning	• Deloitte estimates that Australia is able to save its adult population 8.4 hours per annum of waiting time through the digitisation of public service delivery. We used this piece of data, and combined it with Oxford Insights' Government AI Readiness Index to derive a value for the hours that could be saved for every country included in Oxford Insights' list (160 countries). • By using the World Bank's projections for the adult population in individual countries in 2030, we arrive at an annual global time savings value of 40.2 million hours. • Based on ILO's historical global wage rate trends, we forecast a global wage rate of US$11.0 in 2030, giving us the value of US$442 billion in 2030 as a result of time saved from public service delivery.	Deloitte (2019)[89] Oxford Insights (2021)[90] World Bank (2022)[91] ILO Database[92]

Component 2: Enhanced Health and Safety Benefits		
Value of avoided life loss from AV adoption – US$346 billion		
Description	Sizing Assumptions	Sources
Life loss is avoided through the adoption of AVs	• McKinsey estimates that by 2030, 15% of global passenger vehicles sold will be AVs. McKinsey Global Institute also estimates that 2% of the 1.5 billion passenger vehicles globally in 2025 will be AVs. Therefore, based on a historical annual light vehicle production growth rate of 8.5%, we forecast the total number of AVs globally in 2030 to be 53.4 million. • McKinsey estimates that globally, 95,000 lives could be saved with the deployment of 30 million AVs in 2025. Assuming the same proportion, this implies that potentially 170,000 lives can be saved in 2030 by using AVs. • The US Department of Transportation estimates that value of each statistical life to be around US$11.8 million in 2021. Scaling this figure down by comparing the US' GDP per capita to the rest of the world's, we get an average of US$2.0 million for each statistical life. • Thus, the total value of avoided life loss due to AVs is estimated to be US$346 billion	McKinsey & Company (2016)[93] McKinsey Global Institute (2015)[94] S&P Global Mobility (2022)[95] US Department of Transportation (2021)[96] World Bank Database[97]
Value of homicide reduction from improved police services with AI adoption - US$82 billion		
Description	Sizing Assumptions	Sources
Homicides are prevented, leading to the avoidance in life loss, through the use of AI, IoT and predictive analysis to improve early warning systems	• McKinsey Global Institute estimates that by 2030, the application of AI to improve police services can reduce fatalities by 10%. By combining the declining trend on global homicide rates with the 2030 population projection of the World Bank, we assume that 40,000 of the 400,000 projected homicides in 2030 could be prevented by using AI. • The US Department of Transportation estimates that value of each statistical life to be around US$11.8 million in 2021. Scaling this figure down by comparing the US' GDP per capita to the rest of the world's, we get an average of US$2.0 million for each statistical life. • Thus, the total value of avoided life loss due to AI applications in police services is estimated to be US$82 billion.	McKinsey Global Institute (2018)[98] Our World in Data (2022)[99] World Bank (2022)[100] US Department of Transportation (2021)[101] World Bank Database[102]
Value of a reduction in emergency response time– US$234 billion		
Description	Sizing Assumptions	Sources
Deaths, injuries, and damages reduced through the use of AI to increase emergency response times	• Studies estimate that every minute reduction in response times in the US could generate 8 to 17% decrease in mortality rates in the US. Another paper estimates that every minute reduction in response time in the United States leads to 5.5% decrease in healthcare costs for patients with severe trauma. Another paper estimates that every minute reduction in response times in the US leads to a US$2,700-6,000 reduction in damage costs from fires. Using data from the National Fire Protection Association to get the average damage cost per fire, we assume that every minute reduction in response times will lead to a 28% reduction in damages. • A number of studies show that the mean response times of emergency vehicles varies by location. For example, the NHS in the UK has a target of 7 minutes. In the US, emergency medical service units average 7 minutes from the time of a 911 call to arrive on the scene in urban areas, compared to around 14 minutes in rural settings. Bigdeli's estimates it to be 10.6 for interurban cities in Iran. • McKinsey estimates that by 2030, the application of AI in emergencies surveillance can reduce emergency response times by 20 to 35%. Taking Bigdeli's estimate and the midpoint of 27.5% reduction response times, this implies that AI could lead to a 2.9 minute reduction in response times by 2030.	E. Wilde (2012)[103] RapidSOS (2015)[104] National Fire Protection Association (2022) M. Bigdeli (2010)[105] McKinsey Global Institute (2018)[106] EM-DAT Database (2022)[107]

Description	Sizing Assumptions	Sources
	• Based on historical EM-DAT data, the average number of deaths, injuries and damages per natural disaster could be estimated to be 34, 68 and US$502 million respectively by 2030. Fairtech estimates that there will be 541 disasters around 2030. This implies deaths, injuries, and damages of over 18,000, over 37,000 and US$272 billion respectively in 2030. • Assume 12.5% (midpoint of 8 and 17%), 5.5% and 28% to be reduction in mortality, injury, and damages due to a minute reduction in response rate, AI could reduce the estimated deaths, injury and damages by around 7,000, 6,000 and US$220,000 respectively. • The US Department of Transportation estimates that value of each statistical life to be around US$11.8 million in 2021. The National Safety Council (NSC) estimates that the cost of each injury is around US$44,000. Scaling these figures down by comparing the US' GDP per capita to the rest of the world's, we get a final figure of US$234 billion for the value of death, injuries and damages prevented.	Fair Tech Institute (2022)[108] US Department of Transportation (2021)[109] NSC (2022)[110] World Bank Database[111]
Value of Increasing patient lifespans from the adoption of IoT applications in patient monitoring – US$1,841 billion		
Description	Sizing Assumptions	Sources
Lifespan increased as a result of monitoring apps enabled by IoT technologies	• McKinsey Global Institute estimates that the use of IoT in healthcare could lead to a reduction in disability adjusted life years (DALYs) across 7 chronic diseases, namely, cancer, diabetes, HIV/Aids, sense organ diseases, respiratory diseases, heart diseases, and neurological conditions diseases. These reductions vary across developing and developed countries where IoT adoption differs. For example, for respiratory diseases, the adoption in developing countries could be 5-20% leading to a reduction in DALYs of 10-20%. This is lower than developed countries with an estimated adoption rate of 20-50% and potential for DALYs reduction of 8-13%. • The World Health Organisation (WHO) provided global DALYs for these 7 chronic diseases. Based on WHO's database, the total DALYs for developing and developed countries (one DALY represents the loss of the equivalent of one year of full health) is 127 million years in 2019. Given an annual growth rate of 0.9% in global DALYs, the estimated DALYs for developing and developed countries is around 141 million years in 2030. • Oxford Economics forecasts global GDP per capita to be around US$13,000 in 2030 – applying this to 2030's estimated DALYs results in around US$1.84 trillion of economic value.	McKinsey Global Institute (2015)[112] WHO Database (2022)[113] Oxford Economics[114]
Value of avoided workplace injuries due to AI enabled sensors – US$742 billion		
Description	Sizing Assumptions	Sources
Workplace injuries avoided through the use of AI enabled sensors	• AI enabled sensors can spot unsafe workplace behaviours and send real time alerts to prevent accidents. Studies suggest a reduction in workplace injuries in the range of 52 to 85%. For this study, the low range of 52% is used. • McKinsey estimates a potential AI adoption rate in industries of 50% globally by 2030. • Taking the ILO estimate of non-fatal workplace injuries in 2020 of 340 million as a proxy for 2030 figures, we estimate that AI enabled sensors at workplaces could potentially prevent 97 million workplace injuries in 2030. • The National Safety Council (NSC) estimates that the cost of each injury is around US$44,000. Scaling these figures down by comparing the US' GDP per capita to the rest of the world's, we get a final figure of US$742 billion in avoided workplace accidents in 2030.	McKinsey Global Institute (2018)[115] ILO Database (2022)[116] NSC (2022)[117] World Bank Database[118]

Component 3: Improved social inclusion		
Value of an improvement in credit access for vulnerable populations - US$226 billion		
Description	Sizing Assumptions	Sources
Lenders can widen credit access through predictive patterns identified by AI models	• Using AI and advanced data analytics to analyse unstructured data (e.g., data scrapped from social media) could help in detecting insights for credit ratings compared to traditional sources. For instance, satellite images can be analysed to provide a forecast of past and future incomes of rural farmers, allowing them to gain access to bank loans. • PwC analysis suggests lenders could see up to 15-30% increases in credit approvals with no change in loss rates. • Globally, 1.7 billion people do not have a bank account – conservatively, a 15% increase in credit approvals for this category of potential lender amounts to 255 million new approvals. • Estimates show that the average microloan globally is around US$885. Taking the conservative assumption that these new loans for the unbanked are small in nature, the potential new credit created for the would be around US$226 billion.	PwC (2022)[119] World Bank (2021)[120] Fit Small Business (2021)[121]
Value of rural job creation due to IoT and AI in the agriculture and healthcare industries – US$191 billion		
Description	Sizing Assumptions	Sources
Jobs in rural communities are created due to the applications of various frontier technologies in healthcare and agriculture	• Research shows that IoT and AI could create up to 2.8 million jobs in rural India (across the agriculture and healthcare industries) worth US$8.9 billion by 2030 – each rural job in India is worth around US$3,200. The ratio of global GDP per capita to India's GDP per capita is used to estimate the value of each global rural job. • As the rural population of India is estimated to be around 900 million, the estimated job creation rate due to IoT and AI in rural populations is around 0.32%. This conservative rate is applied to the global rural population of 3.4 billion to arrive at a value of US$191 billion in jobs created for rural communities due to IoT and AI technology.	Broadband India Forum (BIF)[122] World Bank Database[123]

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