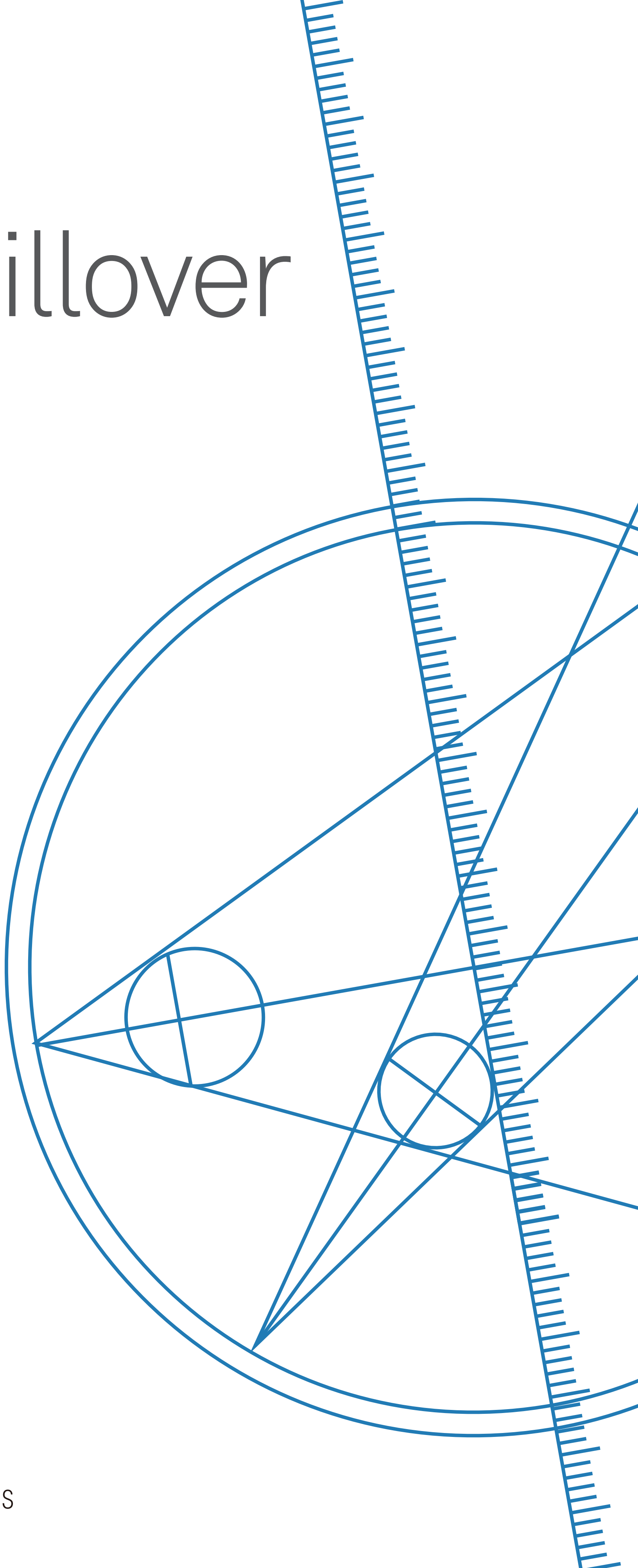
Digital Spillover

Measuring the true impact of the digital economy



HUAWEI | OXFORD ECONOMICS

FOREWORD

+Intelligence: An Engine Driving Industry Digitalization

We are entering an intelligent world where everything is connected. The value of connectivity is being unleashed, and the digital economy is booming.

In 2016, the digital economy worldwide was worth US$11.5 trillion, or 15.5 percent of global GDP. The outstanding performance of the digital economy is mainly attributable to the development of a consumer-driven Internet. By 2025, the industrial Internet is predicted to experience massive growth, with industries across the board seeing high levels of digitalization and intelligence. By then, we expect the digital economy to grow further, to 24.3 percent of global GDP.

How can we take full advantage of the +Intelligence era over the next decade and maximize the impact of digital spillovers on economic growth? This topic should be a focus of every country and every company.

As the digital economy becomes a key driving force behind economic development, a key issue is measuring the output and true impact of the digital economy. To that end, Huawei has partnered with leading global advisory firm Oxford Economics in a research project on the digital economy.

We have conducted in-depth interviews with top think tanks around the world, including digital strategy advisors, digital economy academics, and policymakers from the World Bank, MIT, Stanford University, and Singapore Infocomm Development Authority. By establishing and applying methodologies and research models for quantifying the digital economy, we have identified the positive impact that digital technologies investments have on productivity boost and economic structure optimization, from the perspective of digital spillover. The aim in this is to uncover the underlying patterns of digital transformation and the development of the digital economy.

Our research shows that the long-term return on investment (ROI) for digital technologies is 6.7 times that of non-digital investments, and leveraging intelligent technologies to power traditional industries can maximize digital spillover. Industries and companies are turning digital technologies, including broadband, cloud, big data, artificial intelligence, and Internet of Things (IoT), into key capabilities for digital transformation. The technologies will enhance productivity and spur innovation. As a result, the supply side will be upgraded to better match and further promote ever-increasing consumer demands. Ultimately, +Intelligence will drive and sustain the accelerated growth of the economy as a whole.

We believe that technology will reshape the world and ideas will change how the world is viewed. To address future uncertainties, we look forward to working extensively with global institutions and think tanks in the areas of theory and research. As we do this, we will continue to explore how technology can boost economic development and innovation at both the industry and country levels.

Starting in 2014, Huawei began releasing an annual Global Connectivity Index (GCI) report to assess the development of countries from a technological perspective. This report on the digital economy expands on that work, aiming to verify the value of technologies on a broader economic scale. With this report, we hope to shed light on digitalization for our partners, and help them to update their viewpoints, embrace new trends, and pioneer a new wave of digital transformation.

William Xu

Executive Director of the Board
Chief Strategy Marketing Officer
Huawei Technologies Co., Ltd.

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Rethinking The Digital Economy

The importance of digital technologies to the modern economy is undeniable. All around the world, in every industry and every company, we are digitalizing the things we do. Daily, we make more of our digital assets: developing new applications, new features, new ideas — making us faster, more efficient, more reliable and opening up new spheres of innovation. Adding together this multitude of little digital steps forward, builds to a substantial impact on the economy as a whole.

The digital economy is now firmly established as a core driver of global growth. No longer confined to an elite band of "high-tech" economies, digital investments are being driven across advanced and developing economies, and are delivering returns. Leaders and policy-makers are striving to understand how best to capitalize on the digital opportunity for the benefit of their citizens. They endeavor to convert traditional economic structures and analogue businesses into coherent, dynamic, innovative digital powerhouses that will drive future growth the world over.

Yet despite the increasing importance of the digital economy, we do not have the tools to measure it properly. And until we can measure it, how can we truly understand and plan for it?

The challenge is to figure out what it means to be a digital economy. There are lots of official statistics and established metrics, but none of them truly capture the full impact of digital assets in businesses. National statistics focus on the size of a country's technology manufacturing sector, but this tells us nothing about the digitalization of the rest of the economy. Surveys tell us the degree to which consumers have the latest gadgetry, but this could simply be a thin digital veneer on an otherwise analogue economy.

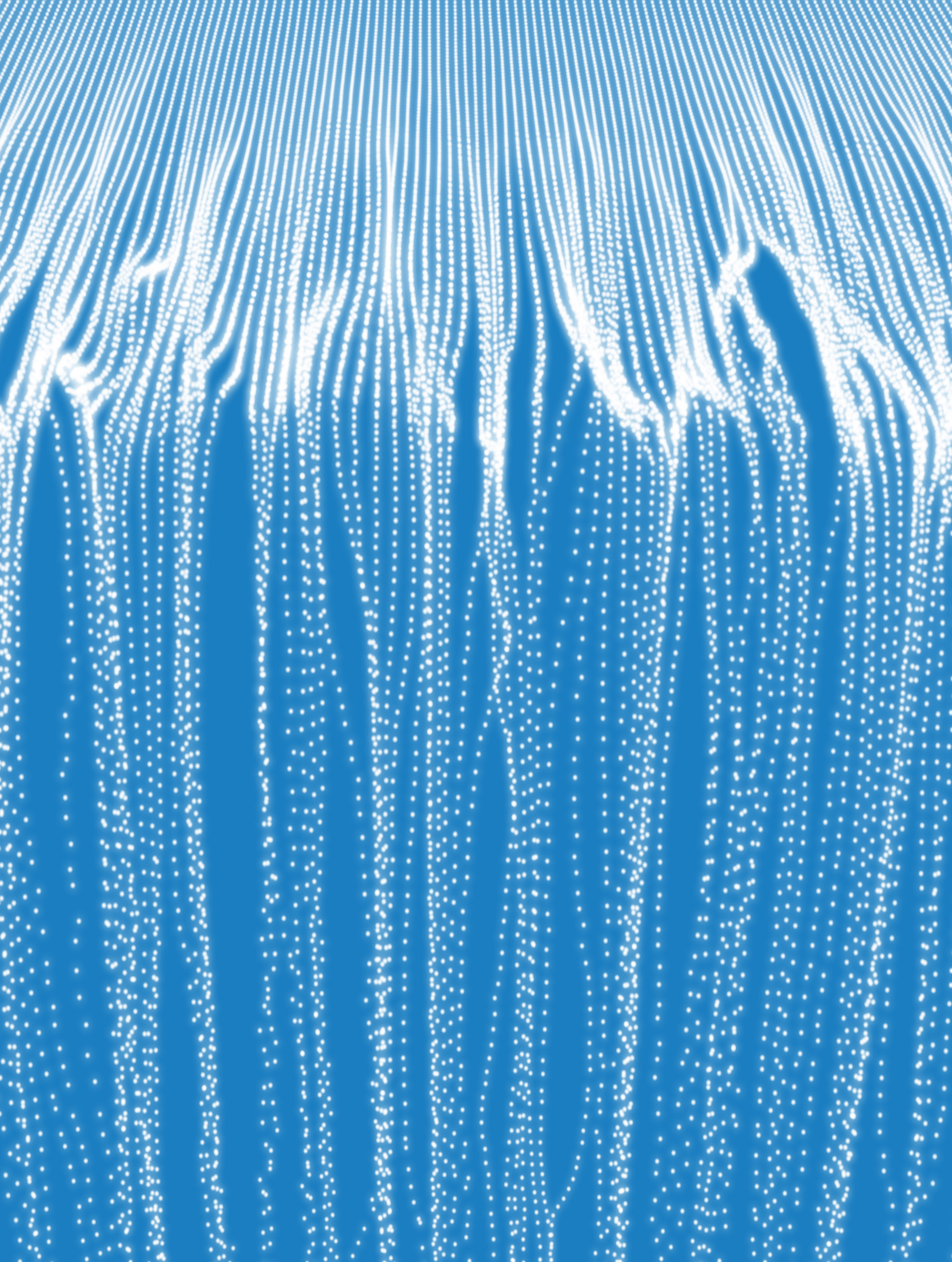
A truly digital economy is one in which industries, from farming to pharmaceuticals, have embedded digital technologies deep in their production processes to boost economic performance. This report rethinks the challenge of measuring this digital economy, going beyond the conventional metrics to capture the ways in which the benefits of digital investments can spill over from one company to the next, multiplying their final impact. In doing so, it reveals that the digital economy is much larger and more widely spread than previously thought and this casts a new light on how to make plans for the future.

This report gives the policymaker a fresh insight into how digital technology really affects economic performance. And in doing so, we start a conversation on the latest technology trends, how they benefit the economy, and what governments can do, in conjunction with other stakeholders, to get the most from the next decade of technological progress.

Adrian Cooper

Adrian Cooper

Chief Executive Officer
Oxford Economics Ltd.



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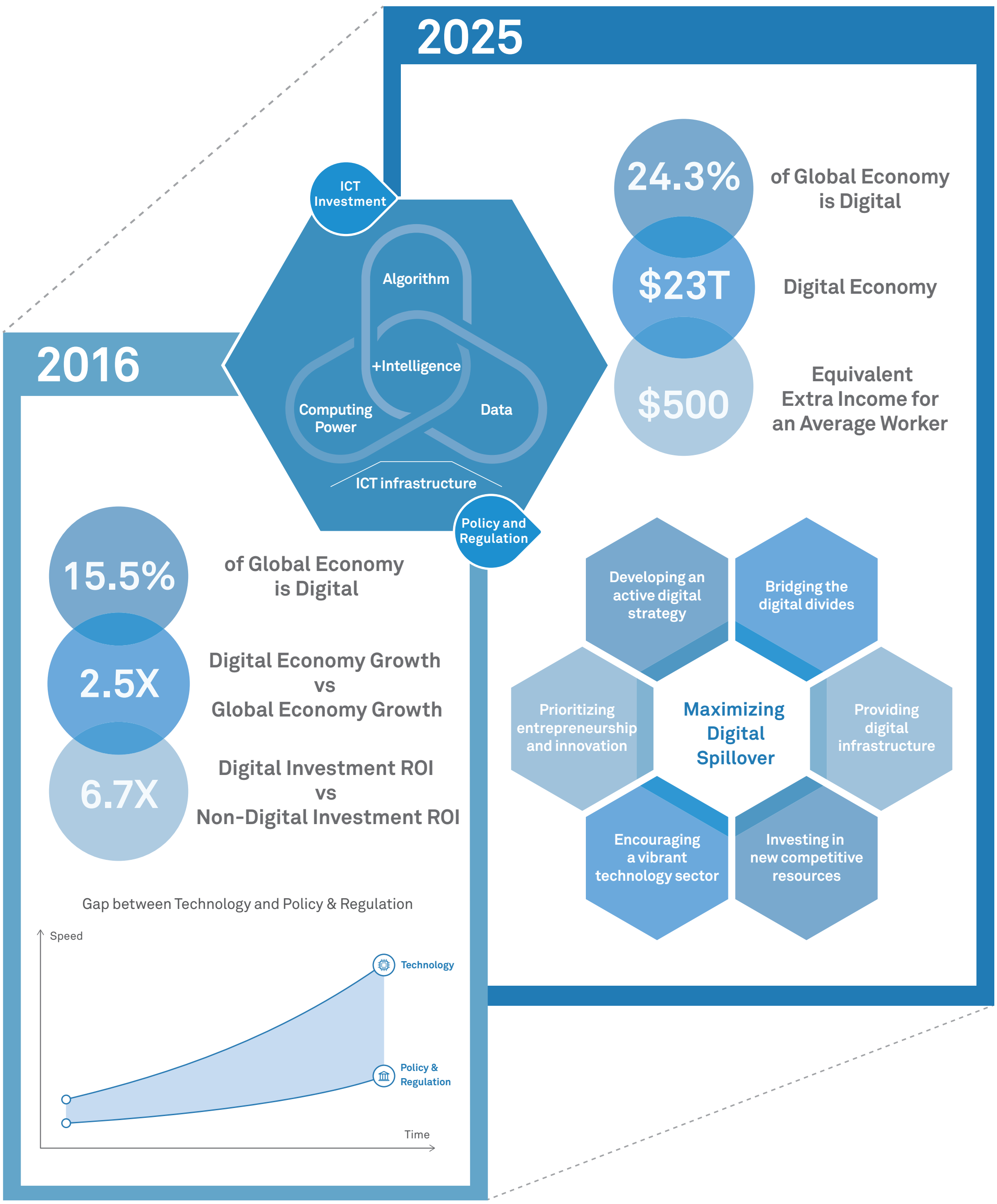
EXECUTIVE SUMMARY

A guide to maximizing the digital spillover



Source: Oxford Economics, Huawei

We are living through an era of spectacular technological change. Digital technologies are becoming faster, more powerful and cheaper, and converging with one another in ever more innovative ways to amplify their potential. Over the last three decades, the virtuous circle of technological breakthroughs has become a central driver of global economic growth and their importance is growing. It has changed the way we work, play, communicate, and think.

The impact of digital technologies is increasingly felt in all parts of the economy. The digitalization of business processes has moved beyond technology manufacturing sectors, where it drove the first wave of digital growth, to encompass a much larger share of economic activity. In fact, recent trends show that the sectors of the economy traditionally considered to be "least digital", such as mining, agriculture, construction and utilities, are amongst the sectors where technology investment is growing fastest. As a result, the nature of the digital economy is changing. We have entered a new era, in which the digital economy encompasses businesses across all sectors of the economy, using digital technologies with ever-more intensity, to profoundly disrupt how value is created.

A truly digital economy is one in which businesses from across the industrial spectrum are investing in digital and making the most productive use of it. The mechanisms by which this is happening are complex and evolving. Over and above the direct productivity boost that companies enjoy from digital technologies, a more profound chain of indirect benefits also takes place, as the impact spills over within a firm, to its competitors, and throughout its supply chain. These "digital spillover" effects materialize through numerous channels, and are integral to understanding the role digital technologies play in the economy.

Our new approach to measuring the impact of digital technologies better captures its true nature, including the scale of digital spillovers. In this report, we decompose existing measurement frameworks and piece them back together in a form more relevant to the new era. We look beyond the sectors producing digital technologies to focus on how those technologies are being used in business, and to measure the direct and indirect value that flows from that use. This is important because it is the use of digital assets that drives productivity gains and economic growth, not just their production. Our analysis suggests that on average over the past three decades, a US $1 investment in digital technologies has led to a US $20 rise in GDP. This return on investment dwarfs the US $3:US $1 return for non-technology investments in the same period. This result shows that for every US $1 investment the average return to GDP is 6.7 times higher for digital investments than for non-digital investments.

The true size of the digital economy is far greater than previously acknowledged. Our new approach to measuring the digital economy, which captures the value of digital spillovers, makes our estimate more than three times larger than traditional measures would suggest. We find that the digital economy is worth US $11.5 trillion globally, equivalent to 15.5 percent of global GDP and that has grown two and a half times faster than global GDP over the past 15 years, almost doubling in size since the year 2000. In that period, China's share of the global total has more than trebled from 4 percent to 13 percent, and India's share has doubled to 2 percent.

Whilst advanced economies are generally much more mature in their digitalization, some developing economies are breaking the mold. Across our 50-country sample, the digital economy constituted 18.4 percent of advanced economy GDP, compared to 10.0 percent of GDP in developing economies. But the leading developing economies, including Malaysia, Chile and China, are matching advanced economies in their accumulation and use of digital assets and demonstrating the contribution digital technologies can make at any stage of development. Even amongst our least digitalized countries, the digital economy accounts for a significant portion of GDP, which is a testament to the pervasiveness of digital technologies in the modern global economy. This is because even in countries with a negligible technology manufacturing sector, businesses are increasingly making use of broadband, benefiting from the cloud and preparing themselves for the adoption of the next wave of technological advancements.

Maximizing the spillover benefits for the digital economy needs buy-in from multiple stakeholders, including governments. The economic potential of digital technologies is enormous, but there are challenges to maximizing their productivity benefits. For policy-makers, the challenge is to enable an environment in which digital businesses can thrive. This means establishing supportive infrastructure and institutions, getting people and businesses online, and incentivizing digital entrepreneurship. It requires governments to work with a wide range of stakeholders; citizens, technology companies, educators, infrastructure providers and businesses.

If governments can rise to this challenge and navigate the path to a highly digital economy, the rewards will be substantial. We estimate that achieving a high-digitalization scenario, where spillovers are maximized, could result in a US $1.7 trillion boost to global GDP in 2025, equivalent by then to putting an extra US $500 per year in the pocket of every person of working-age around the globe. Such a pathway would mean that 24.3 percent of global GDP will come from the digital economy by 2025. Getting there requires rolling out the benefits of digitalization across all sectors of the economy to enable traditional sectors to reap the gains of digital productivity. It also means moving quickly, and investing smartly in digital technologies. The global digital economy is a rapidly changing, competitive arena. As it accelerates, countries and businesses that are left behind will have further and further to catch up.

A NEW ERA FOR THE DIGITAL ECONOMY

Digital technology has transformed the economic landscape. Since IBM announced the world's first random access computer storage system in 1956, the business world has been engaged in the irresistible pursuit of digitalization. Over the course of the last 60 years, Information and Communication Technology (ICT) have evolved from playing a highly specialized and limited role in processing information, to becoming a general-purpose tool that can be applied to almost any activity.

The emergence of the internet in the 1990s catalyzed the production and sharing of data, and transformed the potential of ICT. This has turned digitalization into one of the global economy's primary sources of economic growth. When the mobile internet rose to prominence via the popularization of smartphones, the pace of digital transformation accelerated further as new and innovative business models disrupted the marketplace.

Since 2010 the continual growth of big data together with the increasing availability and capability of computing power has propelled our society towards an "intelligent" digital economy. With the success of AlphaGo in its challenge against human Go masters, Artificial Intelligence (AI) technology has captured the human imagination worldwide. As AI finds its way across all segments of our economy and society it brings forth a more intelligent world that revolutionizes the way we boost efficiency, enables innovation, and improves sustainability. As a result, more countries have begun to weave AI into their national digital strategy.

The influence of digital technologies is not constrained by geography or industry. With every passing year, digital technologies become more widely available and increasingly connected, not to mention smaller, faster and cheaper. As a result, its productivity benefits, which were once heavily concentrated within the technology manufacturing sectors, have begun to spread rapidly through the supply chain and across all sectors of the economy. Compared to previous periods of transformational change, the ground-breaking innovations in digital technologies roll out much more rapidly across the globe. In pre-digital periods, such as the industrial revolution, it took many years and huge sums of capital to transfer an innovative new machine or process from one part of the world to another. But today, many of the most impactful technological innovations are relatively low cost, and ideas can travel round the world with ease. As a result, the production of digital technologies and services is becoming truly globalized, with developing economies accounting for 20 percent of technology manufacturing, globally, and 36 percent of global digital services[1].

If the global economy is to make the most of digital technologies, businesses and governments need to better understand the impact of these technologies on economic performance. We need to better define and measure what the digital economy really is, and how it is evolving. The techniques that are currently used provide a relatively blinkered estimate of the contributions digital technologies are making to economic output. In this report, we set out to do two things. Firstly, we consider how the scope of the digital economy is changing, as we move

[1] Digital services in this report refer to Information, Communication and Technology (ICT) services, and include telecommunications, web-hosting and cloud services.

into a new era of technological progress, and propose a better way of measuring it. Secondly, we highlight how disruptive digital technologies will drive that digital economy forward over the next decade, and the difference this will make to global economic performance.

In chapter two, we highlight the recent acceleration of digital investments driven by the sectors of the economy traditionally considered to be “least digital”, and we detail the forthcoming rise of the +Intelligence era as businesses incorporate cloud, big data, IoT, and AI into their core processes and management systems. In chapter three, we explore the inner workings of the digital economy, including a phenomenon that we describe as “digital spillovers,” and propose a new measurement framework. In chapter four, we set out the four key considerations governments will have to make in their digital strategies for the next decade. In chapter five, we estimate the size of the potential economic rewards on offer and, in chapter six, we summarize our conclusions.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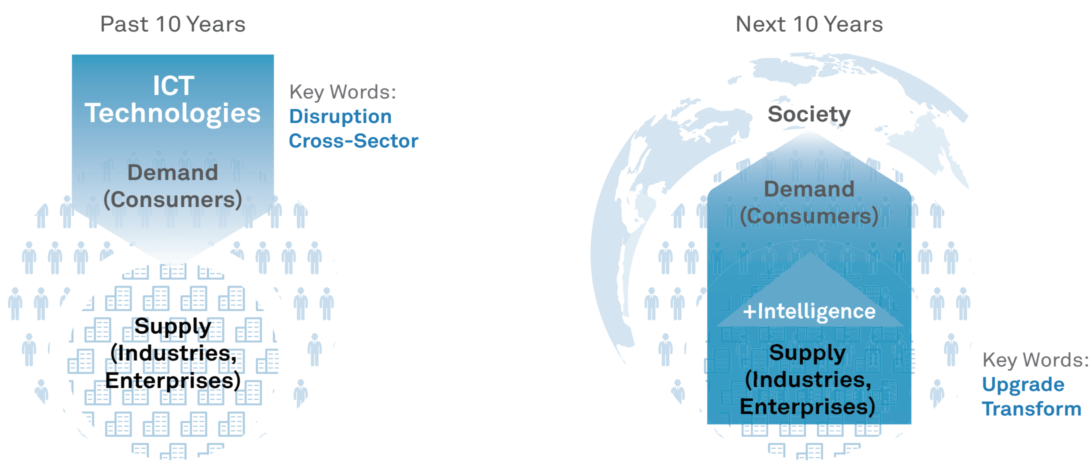
ENTERING THE +INTELLIGENCE ERA

Digital technologies have shaped global economic progress over the past decade, but their impact has only just begun. Over the past 10 years, the Internet (particularly the mobile Internet) has driven a profound digital transformation in consumption behavior and experience. From purchasing channels to payment processes, disruption and cross-industry impact have become the new norm. However we have only witnessed the very beginning of the digitalization process.

+Intelligence will heavily influence the growth of the digital economy over the next 10 years. In the next 10 years, digital transformation will shift its focus to the supply side. To succeed in this transition, industries and companies need to embrace the +Intelligence process: turning digital technologies (such as broadband, cloud, IoT, big data and AI) into key capabilities that would improve the intelligence level in their operation, business and management processes to enhance productivity and enable innovation. As a result the, the supply side will be upgraded to better match and further promote the ever-increasing consumer demands (e.g., cheaper, better, more customized, more readily available). Ultimately, +Intelligence will be the new digitization engine that drives and sustains the accelerated growth of the overall economy in the new era. We consulted eight global experts with experience in a variety of technology areas, to explore the major opportunities driven by digital technologies over the next decade across different countries and sectors of the global economy.

Fig. 1. The new +Intelligence era

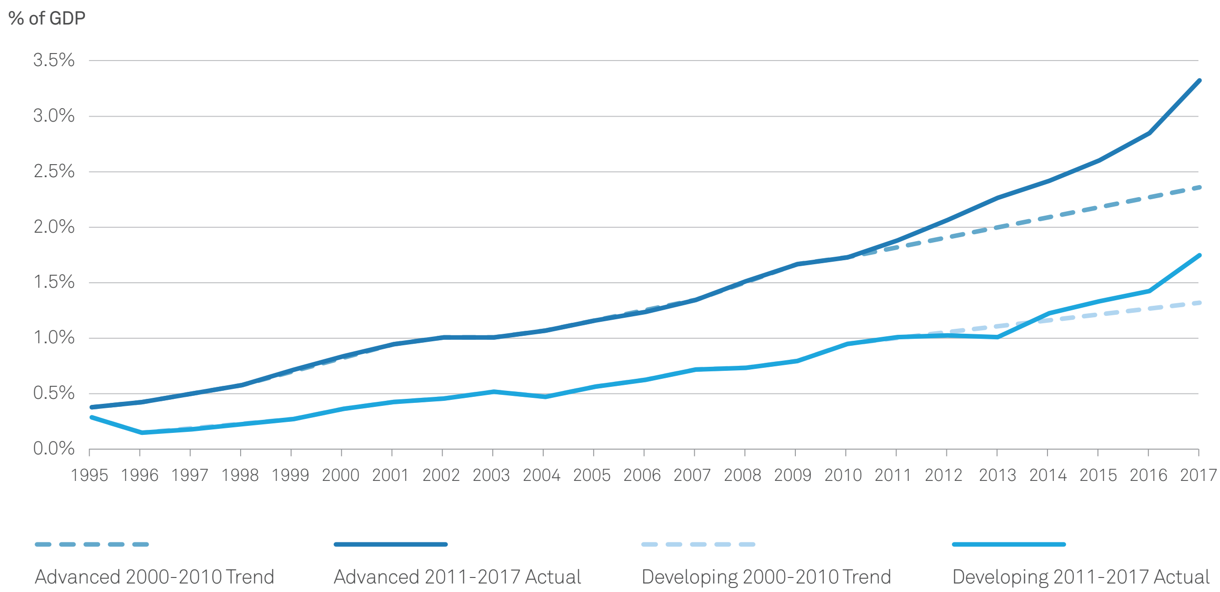


Source: Huawei

AN ACCELERATION IN DIGITAL INVESTMENT[2]

Data shows an upward shift in the rate of digital investment in recent years. The overall rate of investment in digital technologies accelerated around five years ago, inflecting a long-held historical trend. This shift has been apparent in advanced and developing economies alike, suggesting that it transcends national boundaries. The chart in Fig. 2. illustrates this shift by showing the growth in digital investment as a share of GDP, since 2010 (solid line), with what it would have been if the earlier 2000-2010 trend (dotted line) had continued. Even having controlled for cyclical factors, such as the global financial crisis and longer-term drivers of investment such as urbanization, there is an observable uptick in the rate of digitalization since 2010 for both advanced and developing economies.

Fig. 2. The acceleration of digital investment
(Digital investment as a percentage of GDP, actual and trended)



Source: Conference Board, Oxford Economics

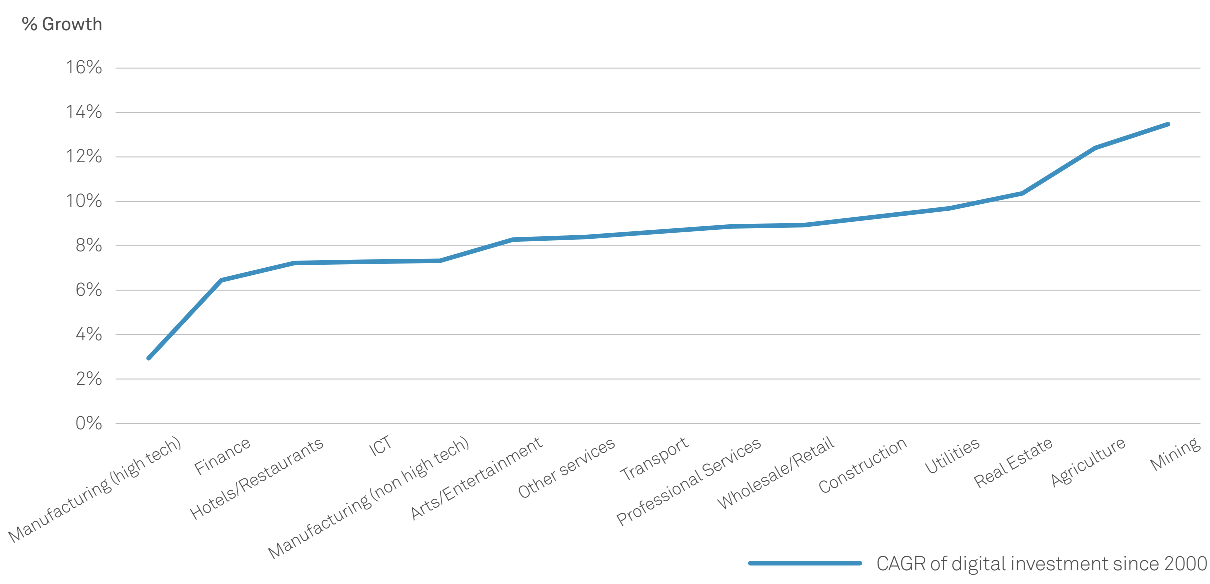
[2] Digital investment refers to Gross Fixed Capital Formation in Information and Communications Technology Assets, including hardware, software and telecommunications equipment.

TRADITIONAL SECTORS BECOMING MORE DATA-DRIVEN

The acceleration of digital investment reflects investment by companies in more traditional sectors. To understand this trend, we split the economy into two groups. The first consists of traditionally data-intensive sectors, such as telecommunications and finance, which tend to trade in information-based services. The second group encompasses all other sectors of the economy. We found that whilst the data-intensive sectors were the earliest and biggest investors in digital technologies in the 1990s and 2000s, in more recent years the latter group has begun to significantly speed up its digital investment behavior. The chart in Fig. 3. shows the compound annual growth rate (CAGR) of digital investment since 2000 across sectors. Whilst digital investments are growing everywhere, it is the non-data-intensive sectors that have been accelerating their investments most rapidly in the last five years, taking advantage of the latest generation of technological breakthroughs. Those sectors that are most aggressively ramping up their digital investments include the mining sector, agriculture, utilities and construction.

What all this reveals is that a new era for the digital economy is underway. The digital services and technology manufacturing sectors are at the digital economy's core, but they are only part of a more complex reshaping of industry value chains and ecosystems that span all sectors of the economy. Falling prices and increasingly innovative applications of digital technologies mean that digitalization is happening on a much broader scale and innovation is coming from many new sources. We are entering the +Intelligence era.

Fig. 3. Growth in digital investment across sectors
(Compound Annual Growth Rate (CAGR) of digital investment since 2000 across sectors).



Source: EU KLEMS, Oxford Economics

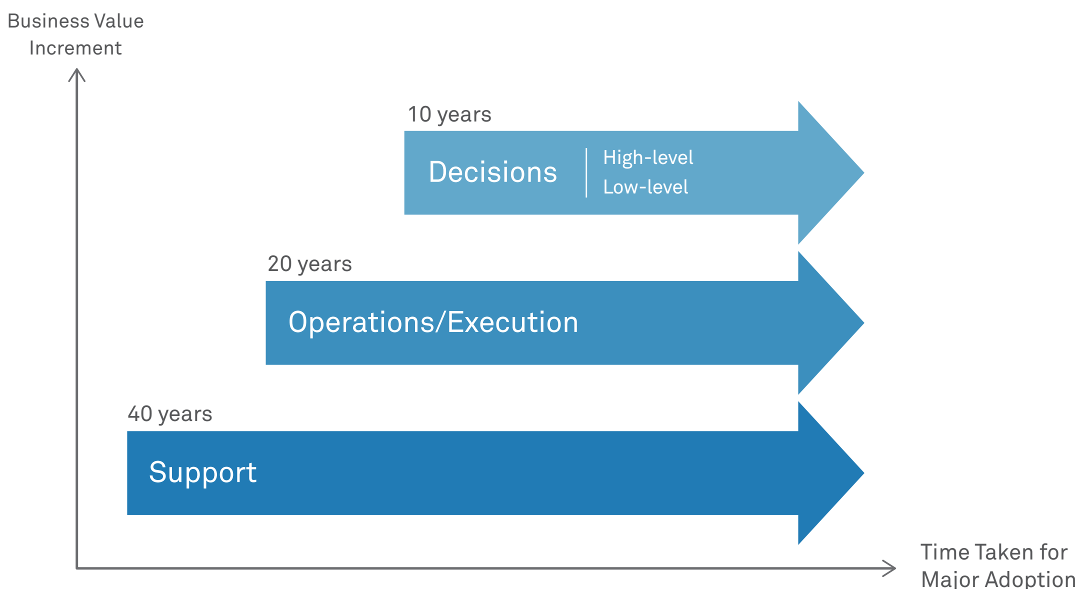
GROWING DIGITAL TECHNOLOGY VALUE

Digital technology is evolving from playing a mere support role in the process system into a strategic role in the decision-making system. This evolution will become a key factor for companies pursuing higher quality and efficiency. We are starting to witness companies moving into the +Intelligence era as they incorporate cloud, big data, the Internet of Things (IoT), and AI into their core processes and management systems. As a result, every aspect of their business is becoming increasingly both digital and intelligent. Companies will be able to achieve the right outcome across all activities from financial judgments to brand strategies by making faster, and more accurate decisions. This new value which digital technology can deliver will materialize over the next 5 to 10 years.

THE RISE OF DISRUPTIVE DIGITAL TECHNOLOGIES

In the +Intelligence era, these disruptive digital technologies will have a broader impact across all industries.

Fig. 4. +Intelligence drives higher digital technology value



Source: Huawei

Reliable high-speed connectivity

Bandwidth-hungry services continue to drive up network speeds as the internet becomes like electricity: essential, ubiquitous and invisible. Broadband technology continues to evolve as more services such as ultra-HD videos, 3D games, virtual reality/augmented reality, video-on-demand, remote-monitoring/traffic surveillance, virtual online assistance, online classroom and other bandwidth-hungry services are introduced.

5G is a major network revolution from its predecessors that will deliver capacity and efficiency not currently possible. It will generate new revenue and instigate new growth through the delivery of ultra-low latency, super-high throughput, and massive connectivity that enable mission critical services. While all industries will benefits from the 5G network, automotive, healthcare and the IoT will experience dramatic transformation through applications such as autonomous driving, real-time health care and cellular-connected drones.

"Broadband is one of the basic foundations of the modern digital economy."

— Wai Leong Lui, Assistant Director, Singapore Infocomm Development Authority

Low cost, high scalability and rapid deployment cloud computing

Low cost, high scalability and rapid deployment of cloud computing has helped unlock innovation. The cloud can dramatically reduce the cost and increase the scalability of computing power so that businesses of all sizes can access whatever they need when they need it, wherever they are. The availability of public, private and hybrid clouds deployment models enables companies to choose the levels of security and management required for their business. The cloud enable them to quickly respond to opportunities and competition through business model transformation, and to adopt a "Fail fast, succeed faster" mentality for rapid innovation.

The cloud means easy access to world-class technology and a reduced carbon footprint for a wider user base. This is a game-changer. Companies can run their business without having to worry about the technical issues, leaving matters to experts providing cloud services. Cloud services also brings down long-standing barriers to entry and enable start-ups and Small and Medium-sized Enterprises (SMEs) to play to their strengths, without being bogged down by administrative costs and processes.

"All of a sudden, the cloud is taking somewhere between US $1,000 and US $100,000 out of the cost of starting a company,"

— Michael Kleeman, Senior Fellow, University of California

Humanized big data analytics

Analytics is becoming increasingly powerful as a tool to drive business decisions. This technology can considerably broaden the appeal of digitalization and incentivize widespread investment in digital assets. Companies need to learn how to collate, analyze and extract maximum value from the vast flows of structure and unstructured data being created into meaningful information to drive better decisions across all scopes from planning better medical treatments to executing better marketing campaigns.

Growing importance of the customer experience: Given the many choices available, customers can easily turn away from brands that do not align with their values and needs, and do not deliver on their customers' experience expectations. Understanding customer behaviors and preferences through analytics does help companies in delivering and enhancing the experience.

"Every corporation will become an information-driven company."

— Timothy Chou, Author and Lecturer in cloud computing, Stanford University

Productive IoT networks

Hundreds of billions of devices connected to IoT will extend the digital economy to every sector of the economy. Real-time data provided by digital twins, which refers to digital replicas of physical assets, processes and systems, can be used to analyze and simulate real world conditions, respond to changes, improve operations and add value. This leads to downtime prevention and better planning. Usage and performance data can also be fed back into the R&D process to improve performance and usability of any product or services across all sectors of the economy.

Open source is driving IoT Platform interoperability. We are currently experiencing an explosion in IoT deployments around the world, from smart cities to smart homes. To create a true IoT ecosystem, where systems of systems interact and generate value from diverse streams of data, interoperability is essential. Open source approach helps to create this interoperability connection in the IoT ecosystem.

"You need to make use of data in ways you didn't expect, to find opportunities for integration and interoperability which you had no idea were available before."

— Richard Mark Soley , Chairman/CEO of the Object Management Group and Executive Director of the OMG's Industrial Internet Consortium

Get ready for AI

AI enables people to leverage tools and data with minimal technical expertise. This will help accelerate knowledge dissemination and reduce information asymmetry. For instance, voice-controlled smart speakers that are being put to work as digital voice assistants. One can order a cab through voice commands without having to navigate cab hailing application. This is made possible through natural language processing technology analysing dialects, casual speech and natural speech patterns. In future with machine learning, these digital voice assistants will be able to take it on themselves to pre-empt their users' needs.

The increased capabilities of intelligent robots and advanced manufacturing methods will redefine the nature of jobs, and rearrange the location of factories. Companies will introduce new business models, moving from shipping products to selling ongoing services based on outcomes, for example crop yields, energy savings or flying hours. In the long term, AI promises to boost productivity across every sector, as more activities are released from the constraints of human limitations and machines continuously seek optimization.

"We're going beyond analysis of existing datasets to creating new datasets, linking them up and modelling. And we're now in the early stages of machine learning."

— Jim Cortada, Senior Research Fellow at the University of Minnesota

"We are in the in the early stages of understanding how to best leverage data science and data driven artificial intelligence; it's all very, very exciting."

— Irving Wladawsky Berger visiting lecturer at MIT's Sloan School of Management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A NEW APPROACH TO THE DIGITAL ECONOMY

The impact of digital technologies can be felt in all parts of the economy. There was a time when the growth of an economy's technology manufacturing sector was a suitable barometer for the digital economy's health. In the new era of technological progress, it can no longer be defined through such a narrow lens. The impact of digital technologies now cuts across industrial structures and national borders to boost the performance of an increasingly diverse, global network of connected businesses. In today's digital economy, businesses can have access to technological know-how, uninterrupted digital services, and a data-driven understanding of the world around them through professional offerings available in any corner of the world.

In this light, how we measure the digital economy needs a profound rethink. The digital economy has changed, but thus far, the way we measure it has not. We worked with world leading economic analysts at Oxford Economics to propose a new approach to quantifying its impact.

WHAT DOES IT MEAN TO BE A "DIGITAL ECONOMY" TODAY?

In order to measure the digital economy correctly, we must be clear about what it means to be digital. Certainly, the size and growth of an economy's technology manufacturing sectors (i.e. high-tech manufacturing and ICT services) are important indicators. But as we embark on the next era of technological progress, we need to consider a wider scope. It is the extent to which economies are drawing on digital technologies across a broader spectrum, to enhance productivity and improve their growth potential, which determines how digital they really are.

A measure of the digital economy should reflect the economic returns being made to digital investments. This includes the value flowing directly from the use of technology in business, such as the productivity gains of investing in a new robotic arm on the production line. But the full economic returns to technology are greater than that. Digital investments also lead to knock-on effects throughout the economy, which amplify their final impact. These "digital spillover" effects are central to understanding the true economic impact of technology, and must be included in any meaningful assessment of the size of the digital economy.

6.7x

Digital investment ROI
vs
Non-digital investment ROI

WHAT IS THE "DIGITAL SPILLOVER"?

The digital spillover happens when technology accelerates knowledge transfer, business innovation, and performance improvement within a company, across supply chains and amongst industries, to achieve a sustainable development economic impact. The digital spillover is crucial to the growth of the digital economy. In partnership with Oxford Economics, we modelled the impact that technology investments have had on GDP, across a sample of around 100 countries over three decades. We found that their full impact on the economy was much greater than what might be inferred from the direct gains flowing to the investor. This extra impact is driven by the digital spillover, and it makes a considerable difference. Our analysis shows that every US $1 invested in digital technologies over the past three decades has added US $20 to GDP, on average. This is an enormous return compared to non-digital investments, which delivered an average return of around US $3 to US $1 invested.[3] This result shows that for every US $1 investment the average return to GDP is 6.7 times higher for digital investments than for non-digital investments.

The indirect impact of digital investments can often outweigh the direct returns to the investor. Every investment businesses make in digital assets — such as upgrading their computer hardware, building new software solutions, strengthening their network infrastructure — is designed to boost productivity. But zooming out from these case-by-case investment decisions, the true economic impact of digitalization is much broader, more complex and far-reaching than this. Over and above the private gains to the investor, a more profound chain of indirect benefits also rolls out when businesses invest in digital technologies. There are three key channels through which it can materialize, namely internal, horizontal and vertical channels.

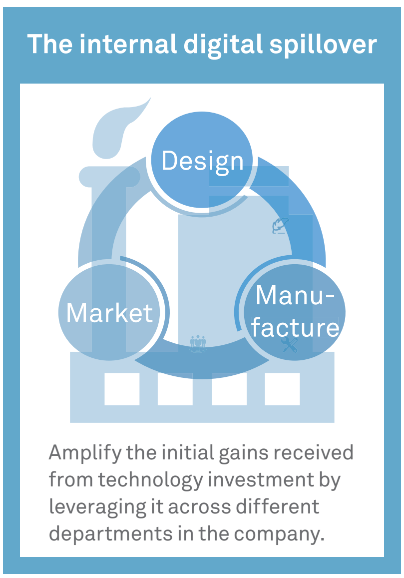
Internal channels: Learning by doing within departments

The internal channel describes how companies can often significantly amplify the initial gains they receive from their technology investment, as they learn more about how to leverage it. For example, the global logistics firm, UPS, invested in Global Positioning System (GPS) tracking and digital maps for all of its delivery vehicles to improve the tracking and efficiency of their deliveries. This initial outlay delivered considerable improvements to the reliability and speed of UPS deliveries, successfully lowering unit costs. But over time, the company discovered new ways to leverage those on-board technologies and the data being produced by deliveries in new, impactful ways. In one example, UPS reconfigured its vehicle routing algorithms to "stop turning left" (in countries with right

[3] This result is derived from regression analysis and represents an average return to ICT investment across multiple countries, over time, not a marginal rate of return.

hand traffic), which had been identified via analytics as a move that raised the chances of an accident and involved longer periods in standing traffic. This innovation led to a 10-million-gallon reduction in fuel consumption, 20,000 tons fewer carbon dioxide emissions and 350,000 more deliveries being made, per year. These gains could not have been possible without the initial investment in on-board computers and GPS technology that the company made, but the full effect of early investments took years to come to fruition.

Fig. 5. The internal digital spillover

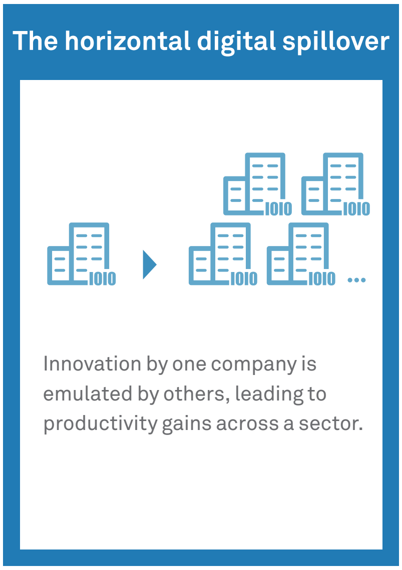


Digital technologies are speeding up our ability to leverage our own knowledge and experience. Advances in AI, analytics and the IoT will speed up our abilities to make sense of the impact new technologies are having. Many companies, especially those with offices scattered around the world, use internal collaborative platform tool to encourage employees to share new ideas that can help to improve business.

Horizontal channels: Competition effects within the sector

The horizontal channel describes the process by which an innovation by one company is emulated by others, leading to productivity gains across a wider sector. This is the hallmark of a competitive market and you can see examples everywhere you look. The first real estate agents that digitized their property listings, dramatically cutting the cost and time of getting their properties to market, led the way for the whole sector to shift its marketing activities online. Similarly, the earliest investors in precision agriculture, which developed satellites, software and pattern recognition technologies to gain valuable improvements in their crop yields, established techniques that were quickly emulated by farmers and producers around the world. Likewise, the banks and fintech start-ups investing heavily in blockchain and instant payment mechanisms today, are devising solutions that will be eventually replicated throughout the financial service sector. Horizontal spillovers depend on information held by one company transferring across to others. This can come from the movement of staff, the publication and sharing of knowledge, or simply by replication.

Fig. 6. The horizontal digital spillover

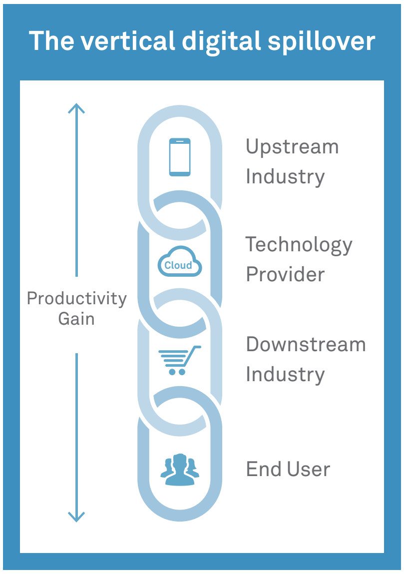


The horizontal spillover is traditionally best understood as a within-sector phenomenon, but digital technologies extends its scope. The ubiquity of networked computers means that companies across all sectors are increasingly technology-dependent and data-intensive. Information about a technological innovation by one company, in one sector, can be quite valuable across a whole host of sectors, where its success might be emulated. Furthermore, the low cost of information transfer that has been established by global internet coverage and cloud technologies means that information about new innovations can just as quickly spread from Berlin, to Bangalore or Boston. The implications of any given technology innovation are now rapidly global.

Vertical channels: Supply chain effects across various sectors

The vertical channel describes the process by which the productivity gains achieved in the delivery of digital goods and services are passed down the supply chain from primary producers to end users. For example, when Amazon Web Services (AWS) constructed its first Australian data center in 2012 and started offering cloud computing services to the Australian market, it helped companies to bring down their technology investment costs. With every new investment that AWS and other cloud providers made to improve their data center engineering for example, the reduction in cost per unit was similarly passed through the supply chain, to the benefit of many sectors of the economy. The benefits generated by the cloud services spillover effects result not just from lower costs but also from access to a wider, more up-to-date, set of technologies; flexibility in consuming these technologies; and ability to use these technologies in any connected part of the world. Australian companies were able to improve their time-to-market delivery thanks to the cloud, sending productivity gains rippling down the supply chain.

Fig. 7. The vertical digital spillover



Vertical spillovers can occur in any supply chain, but the effect is particularly powerful with digital innovations. This is because a) digital technologies are now so broadly embedded in a wide range of sectors and business activities, and b) improvements have the potential (via systems upgrades, or infrastructure improvements) to roll out extremely quickly across a large network of users. In this new era, the source of technological innovations is widening and growing more complex, and the benefits can spillover to other companies, up and down the supply chain. E-commerce platform is an example of a digital investment in the middle of a supply chain which provided vendors and customers with more efficient channels to connect, instigated producers upstream to digitalize their business models as well catalyzing a digital transformation of logistics and transportation networks downstream. Many technology-related innovations are now taking place outside the technology sectors, in financial services, health and manufacturing for example, meaning the number of channels for these supply-chain effects is multiplying.

A BETTER WAY TO MEASURE THE DIGITAL ECONOMY

We propose a new approach to measuring the digital economy that captures the true contribution of digital technologies, including their spillover effects. We use existing official data sources which covers a large number of countries. We make a number of innovations to adapt and augment these metrics in order to ensure they are relevant for the new era of technological progress. These innovations are detailed in Box 1.

Our approach offers a unique perspective on the rate of digitalization taking place. It reveals just how important the indirect spillover effects that flow from the use of digital technologies have become. In fact, our analysis suggests the spillover effects outweigh the direct effects that firms gain from digital technologies by almost three to one.

HOW DO WE MEASURE THE DIGITAL ECONOMY?

BOX 1. HOW DO WE MEASURE THE DIGITAL ECONOMY?

Working with Oxford Economics, we propose three innovations to the way the official statistics on the digital economy are traditionally used. For a more detailed explanation, please refer to Annex 2.

Innovation 1: We measure the value flowing from accumulated digital assets.

Our approach estimates the value generated by businesses each year from their stock of digital assets, rather than the amount of money they spend on it. Digital assets refer to hardware, software and telecommunications equipment and the value estimates are drawn from the Conference Board's Total Economy Database™, with adjustments to capture the differences in the marginal cost of capital investment across countries and quality improvements over time.

Innovation 2: We expand the definition of digital assets beyond traditional national accounting definitions of "ICT capital stock".

Firstly, we reclassify certain digital expenditures which are not considered investments in pure accountancy terms. GDP estimation is a highly complex and rigorous accounting process, based on rules established over many decades. As part of that process, national accountants gather data from companies on their spending behavior, to distinguish between different types of expenditure on digital technologies. Some of it will be labelled as capital expenditure, which we regard as investment if it is a significant purchase that will last beyond the term of the financial year. Some of it will be labelled as current expenditure and recorded as intermediate inputs to production, which relates to items that are used up in the production process.

Our analysis of current expenditure on digital technologies revealed two types of purchases: i) digital component parts that are implanted into the production of something else, and ii) digital goods that contribute to the production process in the same way as digital assets, but are registered as current expenditure because they are short-lived (i.e. they expire or depreciate within the year), small-scale or purchased as part of an upgrade to an existing piece of capital stock. The second type of expenditure shares the same characteristics as digital assets in terms of its contribution to the digitalization of the production process, and we therefore include it in our definition of digital assets. An example of this type of digital good might be buying new software or an IT network infrastructure upgrade.

Secondly, in the context of the digital services sector (i.e. telecommunications, cloud services, web-hosting), we extend the definition of digital assets to capture all forms of capital asset in that sector. By the nature of the services this sector provides, all capital assets are used in the production of digital services. In this sector, we also include the net imports of services from digital assets held abroad. This means that if an economy is characterized by a highly advanced cloud services market, but relies on overseas data centers, the use of those cloud services will still be captured in our measure of the digital economy. This is more reflective of the modern realities of the global digital economy.

Innovation 3: We include the indirect spillover effects from digital assets.

Our analysis has shown that digital assets stimulate spillover effects across the entire economy. We estimate this effect by contrasting our estimate of the total returns to digital investment, which we derive using econometric analysis, with an estimate of the private returns to the stock of digital assets that companies receive, which is derived from growth accounting data. For more detail on our approach, please refer to Annex 1.

HOW LARGE IS THE DIGITAL ECONOMY?

US $11.5 tn

2016 global digital economy

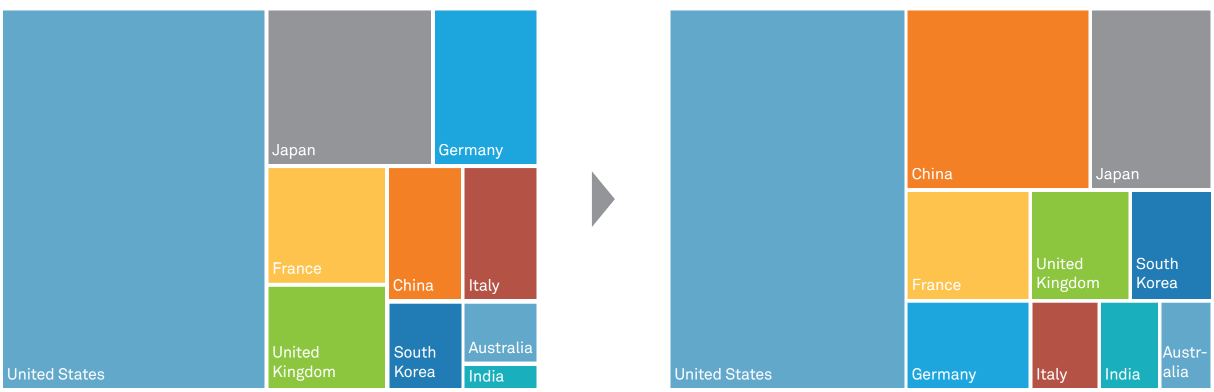
Using our new measure, this equates to 15.5 percent of global GDP

Our innovative approach to measuring the digital economy offers a whole new perspective on its size and evolution. Existing assessments of the global digital economy tend to be dominated by the world's major high-technology producers. Our approach is more revealing of the much broader impact digital investments are having.

We conclude that the digital economy is much larger than traditional metrics would suggest and is more evenly spread across countries and sectors of the economy.

We estimate the global digital economy to be worth over US $11.5 trillion dollars. This is equivalent to more than 15.5 percent of global GDP in 2016. The lion's share of that value is produced in the world's largest economies, with 35 percent in the United States, 13 percent in China, 8 percent in Japan and around 25 percent collectively in the European Economic Area [4]. But the global digital economy is growing rapidly and constantly evolving. It has grown 2.5 times faster than global GDP over the past 15 years, almost doubling in size since the year 2000. In that period, China's share of the global total has more than trebled from 4 percent to 13 percent, and India's share has doubled to 2 percent (see Fig. 8 for details).

Fig. 8. Share of the global digital economy by country, 2000 to 2016

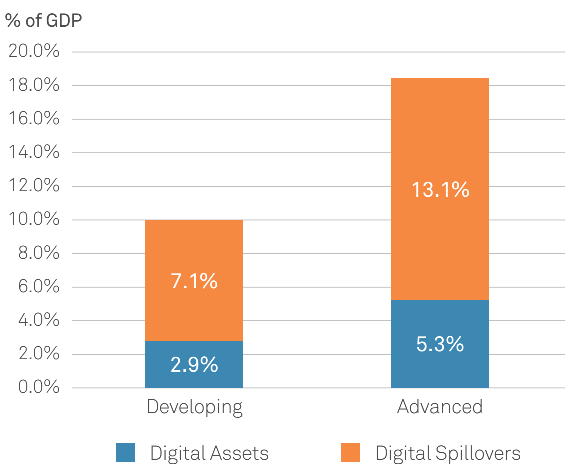


Source: Oxford Economics, Conference Board, Huawei

[4] EAA = 28 European Union (EU) member states + 3 of the four member states of the European Free Trade Association (EFTA), namely Iceland, Liechtenstein and Norway.

Beyond the world's largest economies, the growth of the digital economy has been a truly global phenomenon. In Fig. 9. we set out the results of our country-level analysis, which reveals the differences in the digital economy between advanced and developing economy groupings. The digital economy constitutes the value flowing directly from "Digital assets" and indirectly from "Digital spillovers". Our assessment of the value flowing from digital assets is based on official data, as explained in Box 1 (for further detail, please refer to Annex 2). We estimate the size of the digital spillover using econometric analysis, based on a historical panel dataset, detailing investment trends and economic performance in over 100 economies.

Fig. 9. Size of the digital economy in advanced and developing economies
Percentage of aggregated GDP, 2016 [5]



Source: Oxford Economics, Huawei

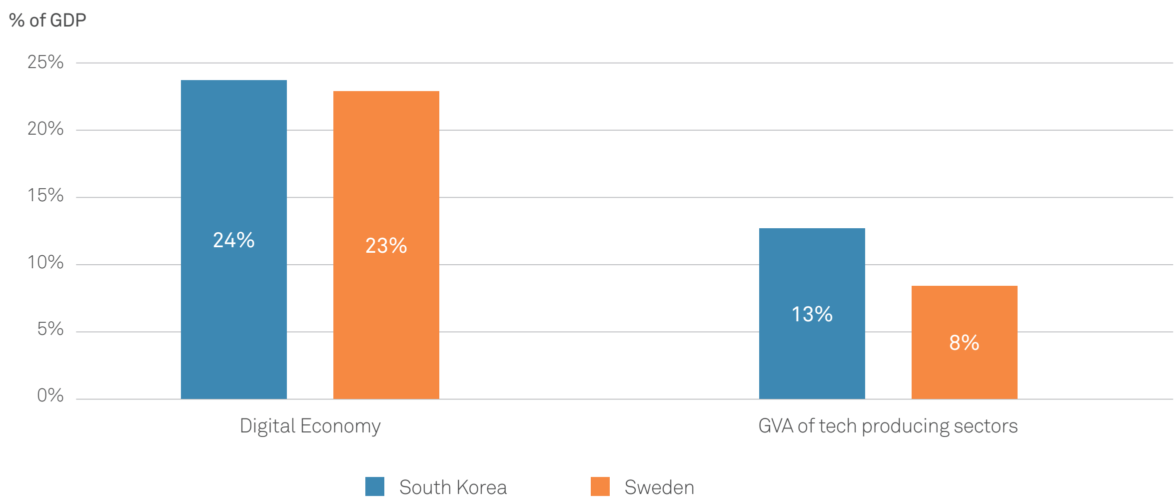
The results reveal the digital economy to be much more mature in advanced economies than in developing economies. Across our 50-country sample, the digital economy constituted 18.4 percent of advanced economy GDP, compared to 10.0 percent of GDP in developing economies. This gap reflects the progress that has been made in advanced economies in the accumulation of digital assets, the embrace of digital services such as web hosting, broadband and the cloud, and the capabilities companies from across the economy have developed to make use of digital technology.

The level of digitalization taking place in some developing economies is rivalling that of advanced economies. The digital economy ranges in size from 10% to 35% of GDP in advanced economies and 2% to 19% of GDP in developing economies. Malaysia, Chile and China lead the way in our developing economy grouping, matching advanced economies in their use of digital assets and demonstrating the contribution digital technologies can make at any stage of development. It is a testament to the pervasiveness of digital technologies in the modern economy that even amongst our least digitalized countries, the digital economy accounts for a significant portion of GDP. This is because even with a small technology manufacturing sector, businesses are increasingly making use of broadband, benefiting from the cloud and preparing themselves for the adoption of the next wave of technological advancements.

[5] Countries categorized in line with Huawei Global Connectivity Index groupings. Developing economies also include emerging economies, as defined by the International Monetary Fund.

This new perspective enables policy-makers to expand their scope in supporting the digital economy. The chart in Fig. 10 shows how our estimate of the digital economy compares with traditional metrics. Our approach suggests the digital economies of Sweden and South Korea are a similar size, at around 23 percent of GDP. This is because the two economies gain a similar amount of value from their digital assets and digital services, and have accumulated sizeable knowledge and experience in digitalization to achieve substantial spillovers. Yet, if we compare the Gross Value Added (GVA) of the technology sectors in these two economies, Sweden's size pales in comparison to South Korea's. Our broader approach to measuring the value added by digital technologies, rather than the size of the technology manufacturing sector alone, can offer more useful signals to policy-makers as to where the gains from digital technologies are really being felt.

Fig. 10. Digital economy estimates for Sweden and South Korea
New approach to measurement, versus traditional, GVA approach.



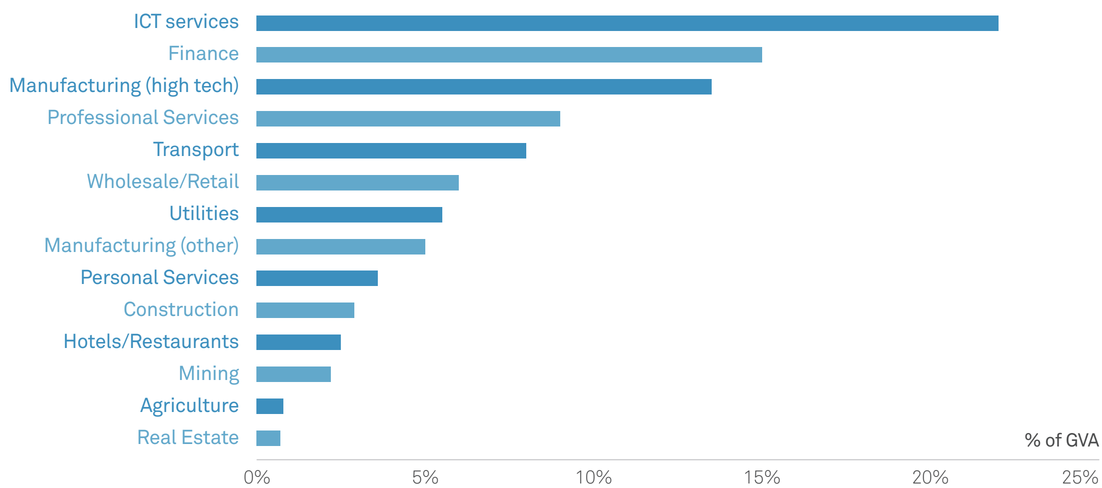
Source: Oxford Economics, Huawei

THE FUTURE OF DIGITAL SPILLOVERS

In the next decade, disruptive technologies will dictate the rate at which countries grow their digital economies further. These disruptive technologies will facilitate a broader application of data-intensive solutions across sectors, as well as multiplying and amplifying the channels through which the digital spillover effect can operate. The route to a larger, more productive digital economy in the future, is via smart investments in these digital assets across all sectors of the economy.

Companies outside the technology manufacturing sectors have already been laying the foundations for a more productive, digital future, but some are lagging behind. We analyzed the sector-dynamics of the digital economy to explore their differing levels of maturity in embracing digital technologies. We used data from 10 European economies, sourced from the EU KLEMS database and replicated the national level methodology described above, as far as possible.[6] The estimates in Fig. 11. exclude the digital spillover because this is a phenomenon that occurs across sectors, up and down the supply chain, and is therefore not meaningful when broken down by each sector. Nevertheless, our estimate of the value flowing from the underlying digital assets reveals the relative size of the digital economy across sectors.

Fig. 11. Value flowing from digital assets across sectors in 2016
(Based on a sample of 10 European economies)



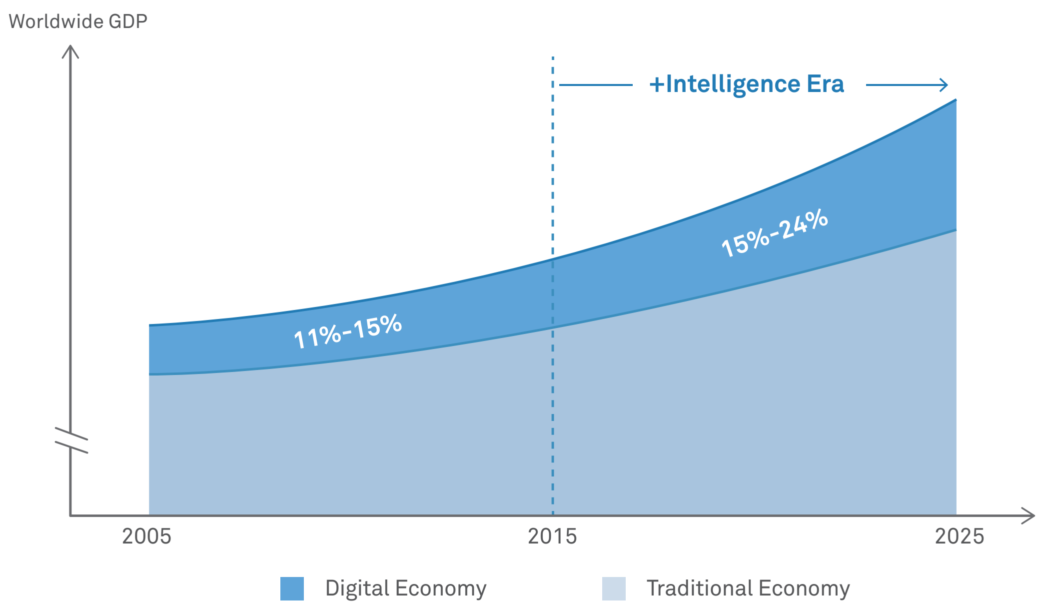
Source: EU KLEMS, Oxford Economics

[6] EU KLEMS is a research project initiated by the European Commission and carried on by the Conference Board, which aims to create a database for research into the drivers of economic growth.

The ICT services, finance and technology manufacturing sectors have led the way so far. With digital assets contributing 21.5 percent, 15 percent and 13.5 percent respectively to sector GVA, these data-intensive sectors are at the frontier of the digital revolution. However, even the more traditionally non-data-intensive sectors have amassed large stocks of digital assets that are already delivering value. In transport, wholesale/retail, utilities, and manufacturing (non-high-technology) for example, digital assets are contributing more than five percent of sector GVA.

Over the next 10 years, digital technologies will improve and find new uses across the economy. Already, in healthcare, AI and big data analytics are being applied to diagnosis, and ever-growing databases of digital health records are being leveraged for analytical insights. In construction, smart, adaptable and sustainable buildings are changing what is possible in terms of building management, and creating new opportunities for the use of office space. In mining, automated equipment is multiplying potential yields. These breakthroughs will grow the digital asset base across sectors in the coming years and amplify the spillovers that flow from it. While in the past 10 years, the digital economy has grown from around an 11 percent to 15 percent of global GDP. We expect it to grow further to 24.3 percent of global GDP by 2025, as the +Intelligence era plays out.

Fig. 12. Projected growth in global digital economy



Source: Oxford Economics, Huawei

[5] Countries categorized in line with Huawei Global Connectivity Index groupings. Developing economies also include emerging economies, as defined by the International Monetary Fund.

MAXIMIZING THE DIGITAL SPILLOVER

Governments will need a strong digital strategy to overcome adoption challenges and make the most of technological progress in the next decade. Private businesses will play a major role in delivering innovations using digital technologies. But governments need to create an environment in which these businesses can flourish. They will have to work with a wide range of stakeholders, including citizens, technology companies, educators, infrastructure providers and businesses, to enable digital spillovers to operate as effectively as possible.

> "Governments need a whole of government approach to ICT."
>
> — Randeep Sudan, Advisor on Digital Strategy, World Bank

There is no generic strategy template for governments to adopt in their pursuit of the digital economy. The message from the experts, however, is that in this new digital era, a more holistic, and proactive approach is needed to achieve the economic potential of digital technologies. That means a strategy that is cognizant of the potential benefits of technology across all spheres of economic activity, and the obstacles that stand it its way.

Fig. 13. Six key priorities for government, to develop the digital economy

DEVELOPING AN ACTIVE DIGITAL STRATEGY

For all countries, the optimal digital strategy will be tailor-made to their own strengths and constraints. This reinforces the need for a more accurate measure of the true value of the digital economy. The leading digital economies will seek to maintain their position by building on their large digital asset base with the most cutting-edge technologies, and expand their highly skilled workforce to best leverage it. Many developing countries will seek to expand their digital asset base more widely, getting more consumers and businesses online and increasing their participation in the digital economy.

Governments must combine strategic oversight with direct intervention. Direct actions include regulating against market failures, investing in infrastructure and incentivizing private sector activity. Government also plays an important role in setting the regulatory framework for the digital economy, establishing a competitive playing field and establishing rules for the use of data. Many issues transcend national boundaries, particularly in regulatory terms, so international co-operation will be paramount. Governments need to work together to reduce the barriers to international data flows and digital trade (e.g. regulation on data sovereignty) and co-operation will be an important weapon in combatting international cyber threats. Poor policy decisions, for example those that stifle innovation, the free flow of information and digital trade, or that allow dominant suppliers to undermine consumer trust, could hold countries back, at any stage of technology maturity.

BRIDGING THE DIGITAL DIVIDES

If the gains of digitalization are only felt by few, this will undercut the incentives for further investment and dampen the potential of digital spillovers. Increasing participation in the digital economy will broaden the potential network of consumers and entrepreneurs, and also incentivize digital technology providers to continue innovating. Initiatives to boost the competitiveness of major cities, or technology hubs, will have to be balanced with the imperative to spread the opportunities from technology equitably across the country. The former will boost the productivity of the technology intensive sectors in the short term, but a larger market nationwide will benefit long term growth by boosting demand economies of scale for digital technology providers.

In advanced economies, governments will focus on delivering high-speed connectivity, skills and awareness. Whilst internet coverage is already close to complete, the quality of internet connections, the ability of individuals and businesses to make use of it, and their willingness to engage, still differ starkly across different sections of society and geography. Broad and equitable engagement in the digital economy are just as important as achieving full internet coverage.

In developing economies, the challenge of providing universal access to the internet is still paramount and innovative approaches may be required. Despite many cases of excellent internet access in high-tech urban centers, where smartphone owning consumers and globally competitive businesses drive demand, many developing economies face huge costs to roll out the infrastructure more broadly. In many, there is an added challenge of servicing a population that may not yet be able or willing to pay for commercial digital services anyway. India's national digital ID scheme, Aadhaar, is an example of a government scheme that has successfully stimulated widespread engagement in the digital economy. By creating a unique, digital ID for Indian citizens, now covering 94 percent of the population, over one billion people, Aadhaar has enabled citizens to access welfare payments digitally, thus engaging in the digital economy. The scheme has had the knock-on effect of stimulating digital transactions and savings schemes more widely, with positive economic benefits.

"For some developing countries, providing ubiquitous high-speed internet is not going to materialize in one or two years, it's going to take 10 years."

— Raul Katz Director, Business Strategy Research at Columbia Institute for Tele-Information

PROVIDING DIGITAL INFRASTRUCTURE

The transformative potential of digital technologies relies on having the necessary hard and soft infrastructure in place. Higher investment in hard infrastructure, like high quality telecommunications networks and supporting utilities, transport and cities infrastructure will incentivize a broader uptake of digital assets. It is also important for the feasibility and adoptability of technology investments that power supplies and heat generation implications can be balanced. Better hard infrastructure will facilitate digital spillovers by reducing the costs of connectivity in the supply chain and increasing the potential of networking effects. Highly data-intensive new technologies like blockchain and AI cannot succeed without powerful data centers as well as uninterrupted broadband and energy services.

"The cities, countries and even continents that build the best and most open data infrastructure will have an enormous advantage in the 21st century economy."

— UK's Open Data Institute

Soft infrastructure, like skills, data availability and a supportive business environment are equally important to the productivity gains that digital investment can bring. Governments need to target skills provision simultaneously at the minority, who are pursuing highly technical jobs, and the majority, who will increasingly need more digital proficiency to engage in the wider economy. The latter requires life-long learning initiatives to enable workers – especially those in non-technical jobs, to enhance and adapt their digital skills over time. The rise of global digital educational services, in particular from remote education (for example, Massive Open Online Courses) initiatives, mean the opportunities will be broadly spread.

Data infrastructure, including the institutions and governance procedures that help to create and share open trusted data, is another catalyst for innovation. Governments can play an active role in providing reliable data sources in convenient formats that are free to share. Examples include state-produced but publicly available weather, traffic and mapping data.

INVESTING IN NEW COMPETITIVE RESOURCES

Leveraging computing power, algorithms and data as the new competitive resources will be key to securing a leading position in the +Intelligence era. With the convergence of IoT, big data and AI, government needs to be prepared for new markets and new jobs. Knowing that high computing power, sophisticated algorithm and massive data availability play vital roles in shaping the market development and adoption, governments should take into account these resources planning their policy frameworks in order to realize the full potential of this revolution. Governments will be able to understand these technologies and their implications through greater usage. Their trials and experiments will give better understanding on matters such as algorithm bias, ethics, and data privacy that have possible impacts on human rights.

Governments will also need to create the regulatory framework to provide security, trust and confidence in data that will incentivize investment. Doing so requires an intricate balancing act but successful regulations will be those that help to protect the rights of consumers and businesses in sharing sensitive data, whilst at the same time reducing unnecessary barriers to the free movement of data. Approaches vary considerably across different countries and regions, with the US and China generally implementing fewer restrictions on data sharing compared with the EU. Governments will have to be agile and responsive to the evidence regarding which approach works best in their context.

ENCOURAGING A VIBRANT TECHNOLOGY SECTOR

The digital economy will be driven by the use of digital technologies across sectors, but the technology sector will still play a crucial role in spurring innovation. Many of the most important technology developments of the next decade are in the hands of the world's largest technology companies, whose headquarters are concentrated in only a few countries. But the innovations emerging from this sector will flow quickly across the global marketplace. Local digital services providers, such as software developers and technicians, will also be a key source of digital investment and innovation, which will stimulate productivity gains more widely across the economy.

Collaboration and openness are the key to innovation and governments need to create the spaces for it to happen. Technology hubs tend to emerge in places that technology-talented people choose to work in, usually in major cities for example San Francisco, New York, London, Paris, Berlin, Beijing and Singapore. But with the right incentives, hubs can be nurtured in less obvious destinations. For example, in the UK, one of the most impressive sources of growth in digital jobs is in the Redruth and Truro cluster in Cornwall, which is one of the most remote and economically deprived regions of the country, but with excellent surfing facilities and a quality of life to attract software developers. Governments should focus their efforts on providing the infrastructure and incentives for technology companies to thrive and avoid policies that actively discourage companies to locate in a given destination, for example, strict controls over immigration, which affects the recruitment of skilled staff.

PRIORITIZING ENTREPRENEURSHIP AND INNOVATION

Whilst invention will be driven by the technology sector, the way it impacts the wider economy will depend on innovative application of technology more broadly. SMEs are central to the development of the digital economy. As start-ups, they can be valuable disruptors, injecting competition and new ideas across sectors. As they scale up, they become valuable investors in digital assets, employers and service providers to larger companies, contributing to dynamic industry ecosystems. Cloud technologies provide a huge opportunity for start-ups and SMEs across all countries, to join and compete in the digital economy.

Success in the digital economy depends on the government's ability to nurture a better business environment more broadly. This means one that incentivizes entrepreneurship and rewards innovation. Governments can do this by providing information and guidance as to the opportunities in the digital economy and the challenges they will face in the early stages of growth. Regulatory policy can help create a healthy competitive market-place by tackling the barriers faced by small and growing companies (e.g. over burdensome regulation, planning and employment restrictions). And governments can encourage innovation through more targeted initiatives, such as:

- **Funding and grants:** providing awards for particular projects or to fund specific investments aimed at high priority sectors.
- **Competitions:** organizing competitions in core areas, with a prize offered to the winning concept, perhaps with additional business support (e.g. a partnership with an established company to help take the innovation to market).
- **Tax incentives:** providing tax relief on research and development expenditure or other tax incentives (e.g. relief on payroll or corporation taxes for start-up and early stage companies).

If governments can meet these challenges and achieve a successful policy mix, the rewards will be substantial. A more digitalized economy will deliver faster growth and higher levels of prosperity. In the following chapter, we model the potential impact of high and low digitalization scenarios to estimate the size of this impact.

Figure 4: Specific trade concerns raised in the TBT Committee
New concerns
Previous concerns
1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008
Figure 2: SPS trade concerns by subject, 1995 to end 2010

REAPING THE REWARDS

Over the next decade, we will see a dramatic shift in the global economy's relationship with digital technologies. Innovators will leverage digital technologies to disrupt and transform business processes across sectors and national borders. To make the most of this, governments will need to work hard within their own constraints to create an environment where private companies can invest, and where the spillover effects from the investments being made can be maximized. If they do this, the rewards will be considerable.

In the right conditions, the digital economy will flourish. We are likely to see digital spillovers finding new channels to spread the productivity impacts of technology around the economy, delivering a major boost to GDP growth. In this chapter, we seek to understand the scale of the impact that digital technologies might have over the coming decade. We modelled four potential future pathways, to explore the implications of different digitalization scenarios.

FOUR SCENARIOS FOR A DIGITAL FUTURE

Our future scenarios illuminate the potential pathways the digital economy might take. We started by analyzing historical data to understand the returns countries have achieved from their technology investments in the past. Using an econometric model, we established the statistical relationship between economic growth and investment in digital assets. We used historical data and forecasts from the Oxford Economics macroeconomic model, in combination with our modelling results to produce a baseline projection to 2025, for 50 countries. This baseline is already bullish, predicated on an assumption that digital investments continue to grow at the same rate as in the last five years. This implies a growth rate of more than eight percent per year for global digital investments as a whole.

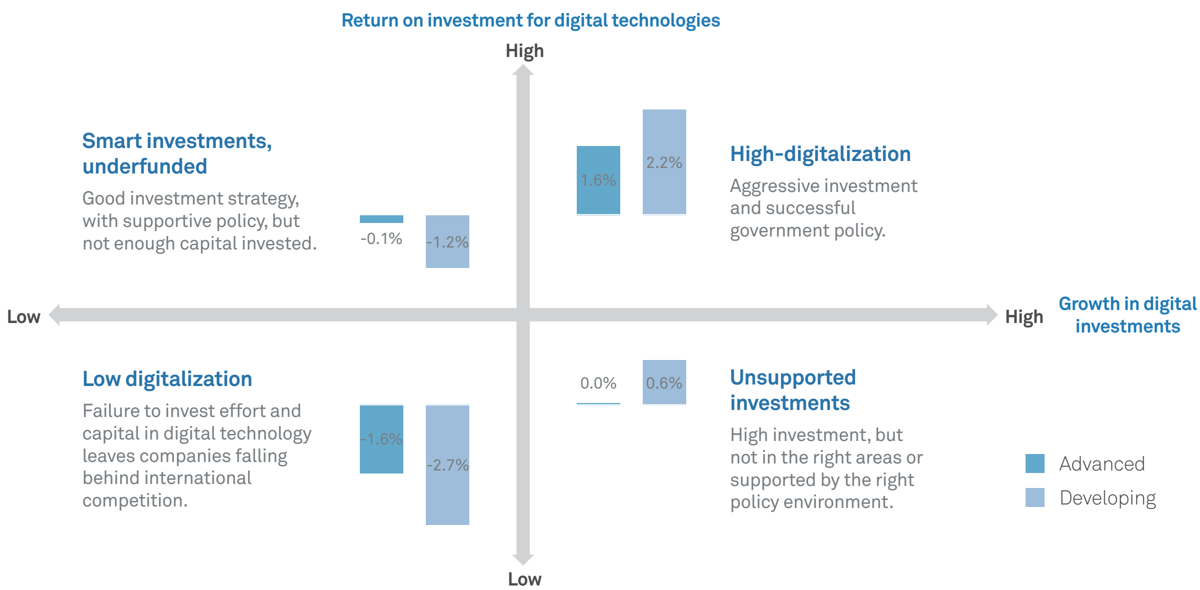
Our scenarios are defined by two important variables, as shown in Fig. 14., which dictate the rate of digitalization that takes place across countries. Adjustments to these two variables are what varied the scenario results from the baseline.

- **The rate of investment in digital assets.** Globally, investment in digital assets has been growing steadily for decades but accelerated significantly in the past five years. In our high-digitalization scenario, we assume that this growth rate accelerates by the same amount in the next 10 years as it did in the past five. In the low-digitalization scenario, we assume that the rate of investment falls back to pre-2011 levels.

- **The return on investment (ROI) for digital technologies.** Our baseline projection assumes the average return on investment to digital investments remains the same as it has been historically, as estimated by our econometric model. In the high-digitalization scenario, we assume that due to a smart digital strategy and success in overcoming the obstacles to technology adoption, the return on investment from digital investment increases. For a low-digitalization scenario, we assume that it decreases. We based these assumptions on a statistically plausible upper and lower bound, based on the results of the econometric analysis.

For more details on our scenario assumptions and methodology, please refer to annex 3.

Fig. 14. Four scenarios for a digital future



Source: Oxford Economics, Huawei

THE REWARDS OF A HIGH-DIGITALIZATION SCENARIO

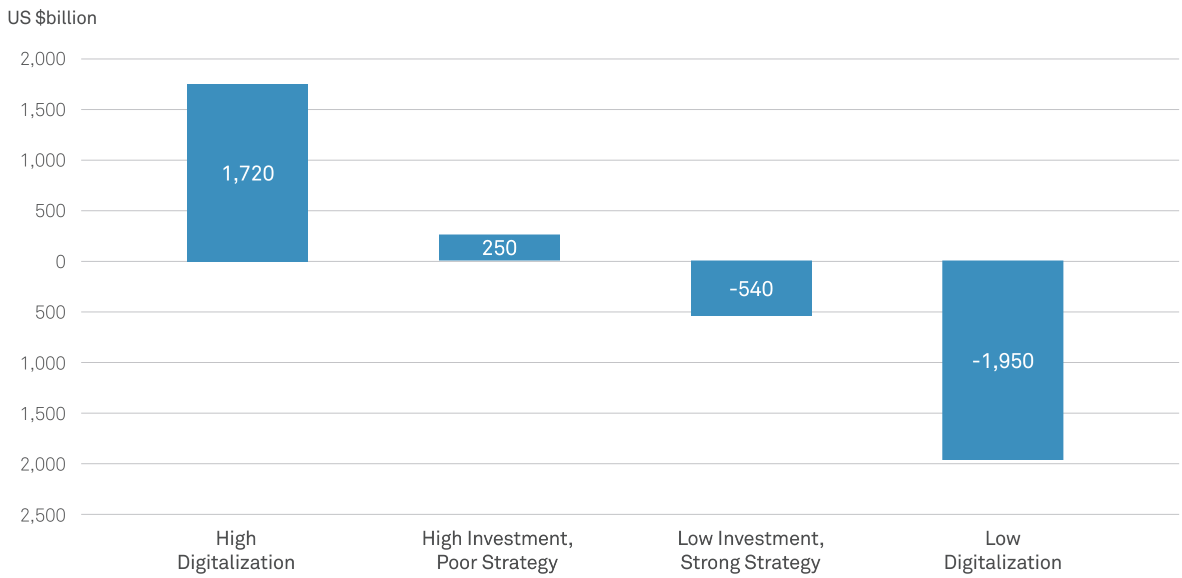
In our high-digitalization scenario, we estimate that the right policies and investments could deliver a US $1.7 trillion boost to the size of global GDP in 2025[7]. This scenario, which entails continued acceleration in the rate of digital investments and a successful strategy to maximize the synergies between new technologies, implies global GDP will be 1.9 percent larger than it otherwise would have been in the baseline scenario. A US $1.7 billion boost to global GDP (Fig. 15) is the equivalent of putting an extra US $500 per year in the pockets of every working-age member of the global population.

US $1.7 tn

Boost to 2025 global GDP

Equivalent to putting an extra US $500 in the pocket of every person of working-age person around the world

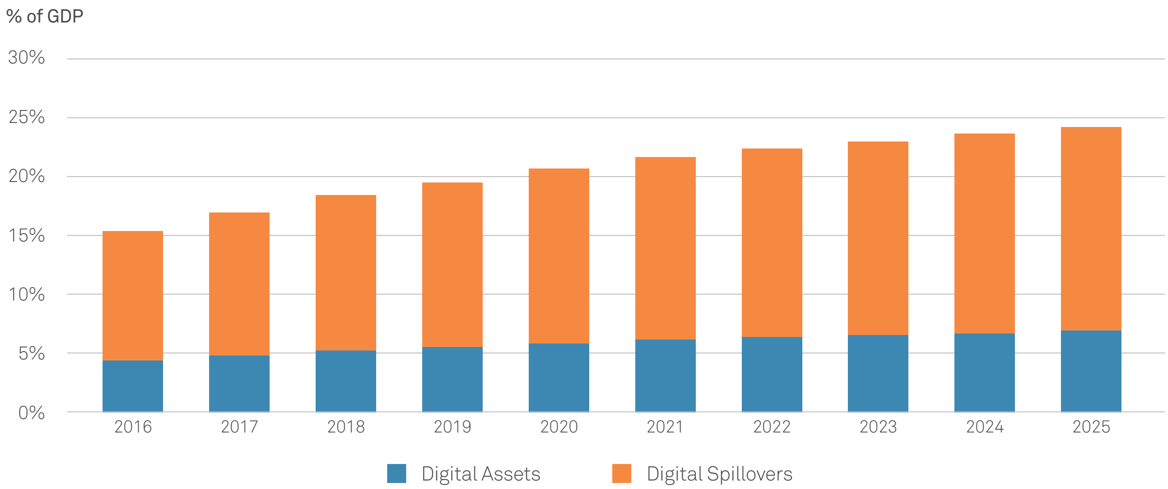
Fig. 15. High to low digitalization scenarios for the global economy (Difference to baseline global GDP in 2025, US $billion)



Note: Baseline - Global GDP CAGR over the period is 2.7% per year
Source: Oxford Economics, Huawei

[7] Estimate reflects an increase in the 2025 value of global GDP, and is over and above baseline projections.

Fig. 16. Trajectory of global digital economy, under high digitization scenario
(Projected growth in digital economy as percentage of global GDP)



Source: Oxford Economics, Huawei

Under the high-digitalization scenario, the global digital economy could grow to account for 24.3 percent of global GDP by 2025. This scenario assumes all 50 economies in our study can maintain an aggressive pace of digital investment and work together to deliver a strong digital strategy, including a supportive infrastructure, a thriving entrepreneurial class and a vibrant technology sector (Fig. 16).

24.3 percent

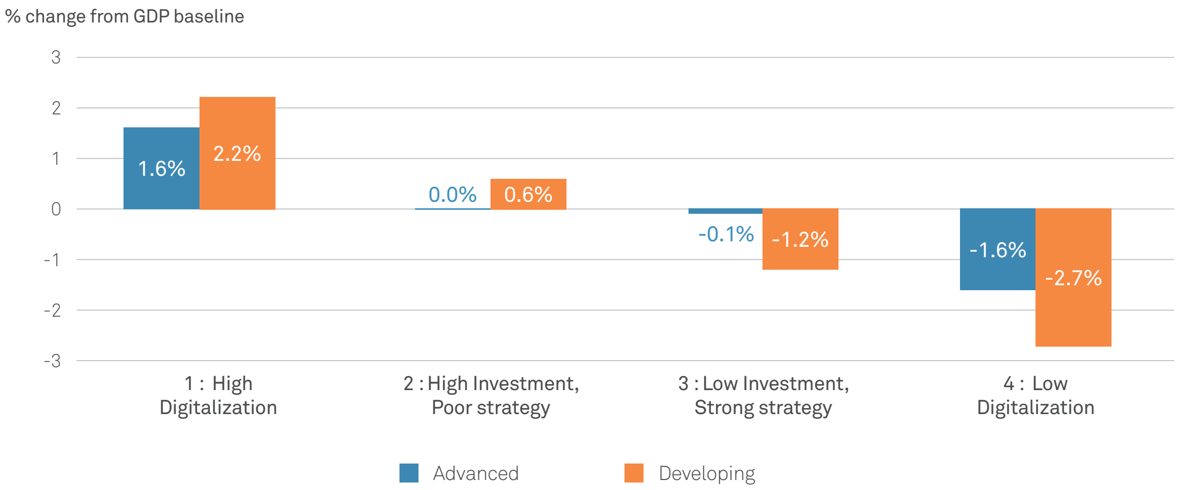
Digital economy share of global GDP in 2025

Under our high-digitalization scenario

This equates to US $23 tn global digital economy in 2025

The gains of digitalization will be widespread across the global economy. We project that most economies will see their GDP rise by one percent to three percent by 2025, under the high-digitalization scenario. The rewards for getting it right are relatively higher for developing economies than advanced economies, but the risks of getting it wrong are greater too. Developing economies could see a 2.2 percent boost to 2025 GDP in the high-digitalization scenario, relative to the baseline, compared with a 2.7 percent reduction in GDP in the low digitalization scenario. For advanced economies, we project a 1.6 percent increase in 2025 GDP in the high-digitalization scenario, compared to a 1.6 percent reduction under the low digitalization scenario (Fig. 17).

Fig. 17. High to low digitalization scenarios for advanced and developing economies
(Difference to baseline GDP in 2025, percent of GDP)

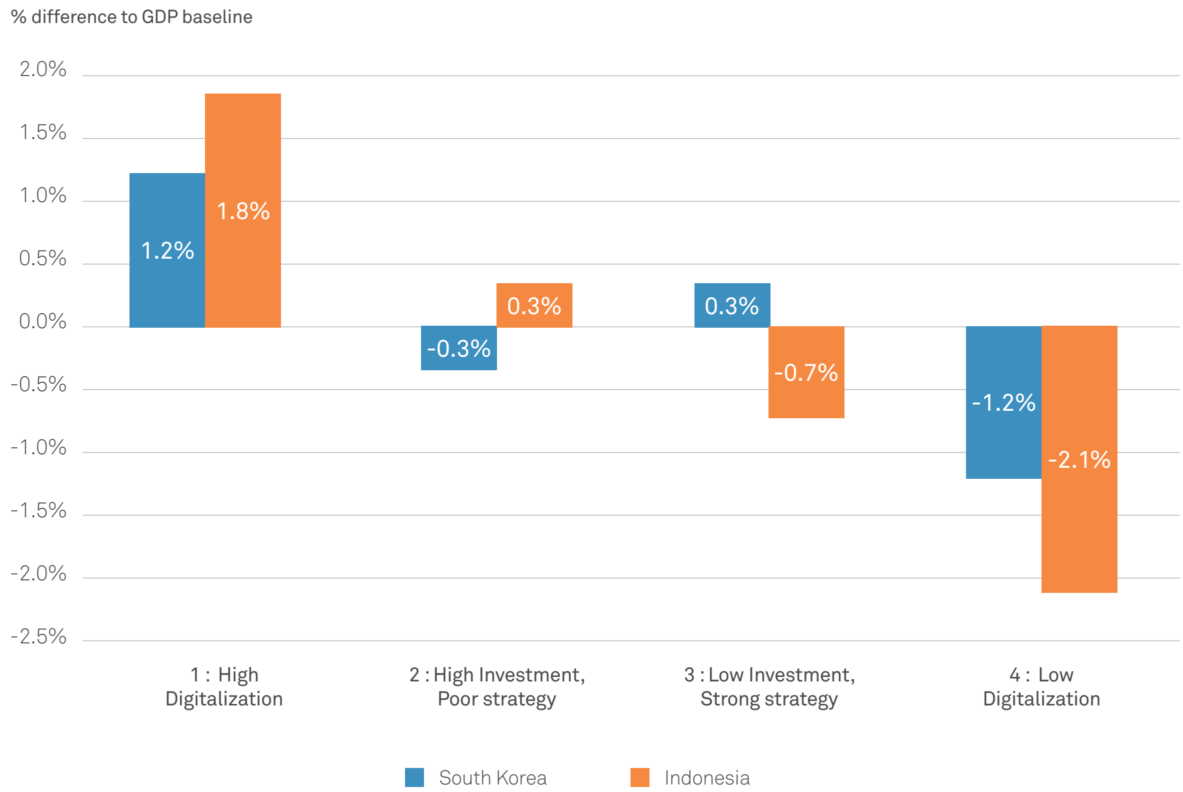


Note: Baseline - Global CAGR over the period is 1.6% per year in advanced economies and 4.5% in developing economies.

Source: Oxford Economics, Huawei

A closer look at the country-level scenarios reveals the divergent conclusions for different economies in our study. Indonesia stands to gain a lot from high levels of investment and a smart digital strategy over the next decade, with our high-digitalization scenario suggesting a 1.8 percent uplift to 2025 GDP. If the high-digitalization scenario cannot be fulfilled, the country would attain a larger boost from "Scenario 2: High investment, Poor strategy", than "Scenario 3: Low investment, Strong strategy". The outcome is similar for many less mature digital economies, indicating that there is still a lot to be gained from deepening the digital asset base over the next 10 years. In contrast, South Korea, which is a more mature digital economy, stands to gain more from Scenario 3, than Scenario 2. This suggests the marginal gains of adding more digital assets to the South Korean economy are outweighed by the gains from smarter use of the assets it already has (Fig. 18).

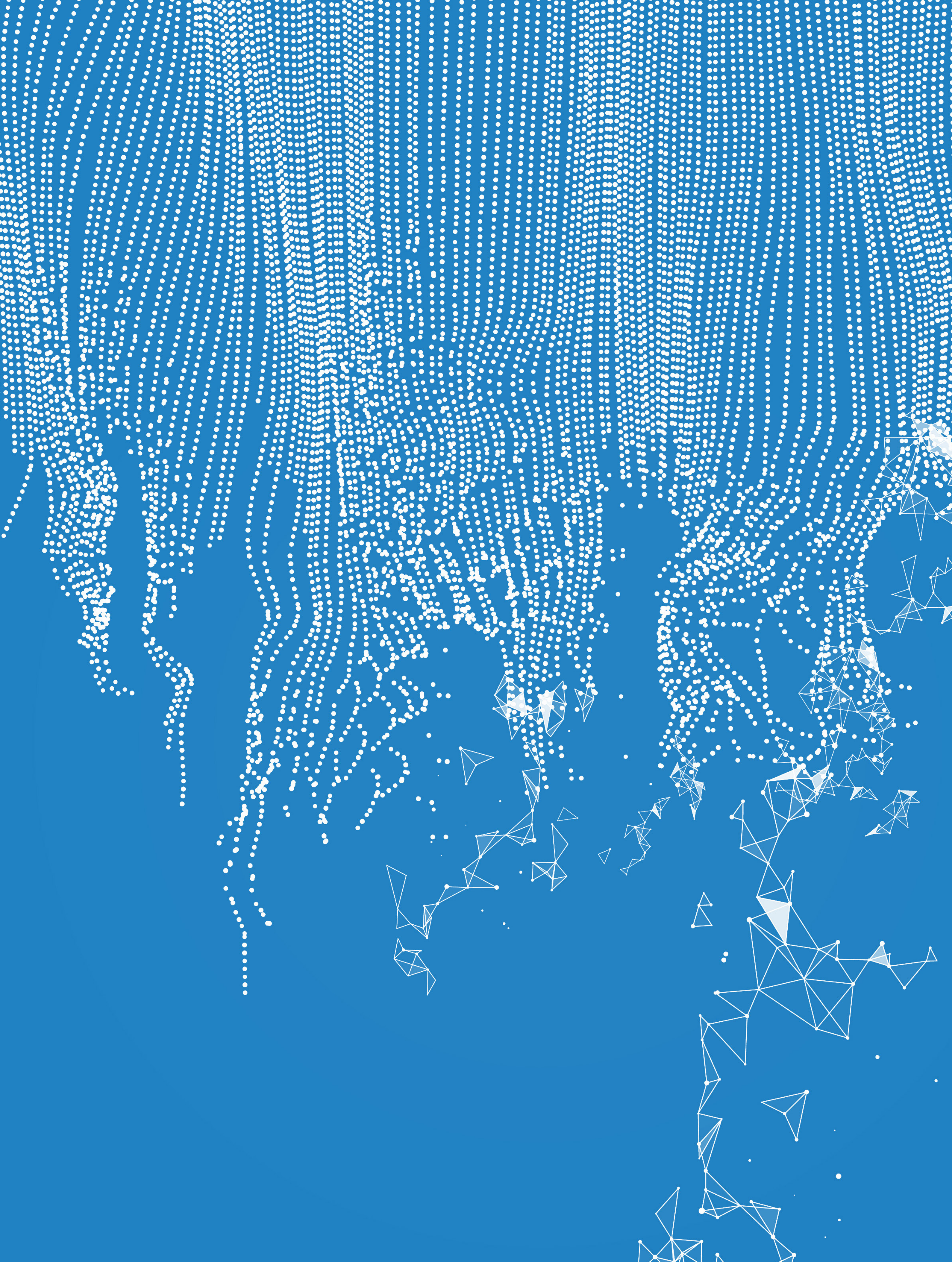
Fig. 18. High to low digitalization scenarios for South Korea and Indonesia



Note: Baseline - GDP CAGR over the period is 2.5% per year in South Korea and 5.2% in Indonesia

Source: Oxford Economics, Huawei

Our scenario analysis underlines the importance of countries pursuing a tailor-made digital strategy. Placing an economy on the high-digitalization pathway is not straightforward. But policy-makers can endeavor to create an environment that incentivizes investment in digital technology solutions, creates the space for companies to innovate and thrive, and opens the doors to the digital economy to as wide a pool of individuals and companies as possible, to try make it happen. Each government will have to assess and understand the rewards to digitalization in its own local context. How mature is the digital asset base? What constraints stand in the way of adoption? Which technology applications are the economy best placed to exploit? If they succeed, the economic rewards will be substantial.



CONCLUSION

Our analysis suggests that the rewards from faster digitalization over the next decade will be large and wide reaching. In our high-digitalization scenario, we estimate that US $1.7 trillion could be added to global GDP by 2025 if governments can create the right conditions for businesses to make the most of technological progress. But if governments are to capitalize on the potential of digital technologies, they need to understand the nature of the digital economy and its evolution.

In the future, the digital economy will reach across traditional industrial boundaries and transcend national borders. Our research has made it clear that the methods used today are not capable of capturing this dynamic. We propose a new approach to measuring the digital economy that abstracts away from the producers of technology and places those who are using digital assets at its center. Understanding the impact of digital means understanding not only the private returns to those investing in digital assets, but the spillover benefits that accrue further down the line from that investment, to the firm itself, its competitors, and others in the supply chain.

Measuring the digital economy this way reveals a startling difference from traditional measures. The digital economy is much larger than previously understood, worth US $11.5 trillion worldwide. The global leaders in the digital economy today are those that have invested heavily and wisely in digital assets, embraced digital services and are thus reaping the rewards of the digital spillover effect. But the future of the global digital economy is all to play for. In the next decade, countries will need to understand the potential of new digital technologies to capitalize on them. It will be the countries that are best able to overcome the obstacles to technology adoption, to create an environment that incentivizes investment and to welcome participation and innovation, which will lead the way in the global digital economy.

ANNEX

ANNEX 1: MODELLING THE SIZE OF THE DIGITAL SPILLOVER

A central part of our approach to measuring the digital economy is to recognize the indirect "spillover" impacts digital technologies have on the economy, over and above the benefits businesses derive directly from using them. We hypothesize that the productivity gains from investment in new technologies flow vertically down the supply chain, horizontally across the sector and internally within the firm itself, such that the overall impact of a technology investment is much bigger than the initial returns felt by the firm making the investment.

But how big is the digital spillover? One reason it is not widely reported in other studies is that it is a rather intangible concept. In this study, we estimated the size of the digital spillover by analyzing the difference between the private returns to technology investment and the overall returns. That means adding up the private returns felt by all companies investing in technology assets, and comparing it with their impact at the overall economy level. Any gains felt at the economy level that are not experienced directly by firms from their investment, must be explained by these knock-on, spillover effects.

Estimating the private returns to technology investments

We use new data from a November 2016 data release by the Conference Board – Total Economy Database (TED), which provides a detailed breakdown of the various components of GDP growth, including the accumulation of technology assets. This latest release is innovative in that it takes into account in its calculation of the contribution of technology assets, for the first time, recent developments such as the productivity improvements in cloud computing.

Using techniques in the growth accounting literature, we derive from TED data our estimates of the income generated by technology assets (in the same way salaries are the income generated by labor) for multiple countries. We produce what one might consider a "naïve" estimate of the returns to technology assets, because they do not account for the spillover effect. These results suggest the average returns to technology assets for the 50 countries in our sample are around 2.7 percent of GDP.

Estimating the overall returns to technology investment

The growth accounting approach must make certain assumptions about the economy to arrive at its estimate of technology's income share. An important one is that of perfect competition. The measurable income being made by different inputs to production (i.e. labor and different types of capital) must represent the value of the contribution they make to the economy. But these do not necessarily represent the true contribution those inputs make.

To capture the fuller contribution of technology investment, we leverage the TED data in an econometric modelling framework. Our model is able to derive the overall contribution of technology assets to GDP, no matter who gets paid for that contribution. This extra income generated, over and above the private returns of TED, represents the digital spillover.

Our core model is based on a seminal paper by Mankiw, Romer and Weil (1992[8]) . We refine their original model to bring it up to date, by a) incorporating technology investments, and b) allowing for knowledge diffusion, whereby we allow for a lag between investing in new digital technologies and realizing their full benefits. Our core model, in equation form, is as follows, where Y is national output (GDP), L is workforce, I^N and I^D are investment in non-digital and digital technologies, n is the growth in the workforce, A is initial level of technological efficiency, and e is the model's residual. Within the curved brackets, 0 and t indicate the start and end of each period. Investment is measured as the average investment over each five-year period. Variables are expressed in logarithm, denoted ln.

$$ln\left[\frac{Y(t)}{L(t)}\right] - ln\left[\frac{Y(0)}{L(0)}\right] = (1-e^{-\lambda t})\frac{\alpha}{1-\alpha-\beta}ln\left(\frac{I^D(t)}{Y(t)}\right) + (1-e^{-\lambda t})\frac{\beta}{1-\alpha-\beta}ln\left(\frac{I^N(t)}{Y(t)}\right) - (1-e^{-\lambda t})lnA(0) - (1-e^{-\lambda t})\frac{\alpha+\beta}{1-\alpha-\beta}ln(n) + e(t)$$

Our model is dynamic (the λ) and our data set is a panel, including more than 100 countries, over 25 years (expressed as five, five-year periods). It explains the change in labor productivity (left-hand-side of the equation) in terms of investment rates (relative to GDP) in digital and non-digital technologies, growth in the workforce and the initial level of technological efficiency. Also, shown on the right-hand-side of the equation are expressions involving two important parameters, α and β. These are the marginal products of capital, for digital and non-digital capital, respectively, and are what we use to estimate the returns to technology investment. The term $1 - e^{-\lambda t}$, which measures the rate of knowledge diffusion, allows us to measure the full benefits of investments, even when these take time to be fully realized. We also apply the Arellano-Bond estimator to bring the original model in line with more recent developments in the field. The marginal product of digital technology investments, α, is the key parameter. We find this to equal 0.009, which implies that a one percentage point increase in the digital investment-to-GDP ratio is predicted to increase labor productivity by 0.9 percentage points, on average. This is full, long-term investment benefit, with statistical tests indicating that it is precisely estimated.

The results imply that ICT capital's overall contribution is worth 9 percent of GDP, over time, on average across our sample of economies. This is 3.5 times greater than the observable private returns to ICT capital investment, and this is our estimate of the size of the digital spillover.

Calculating the relative rates of return from technology and other investments

To estimate the economic return on investment of ICT investment, we adjust the marginal product outputs from our model by the ratio of the digital capital stock over GDP (the capital-to-output ratio). Given that our model estimates the marginal product from our panel dataset, the appropriate capital-to-output ratio should also be a similar panel average that reflects the countries and timeframe of our analysis. We find that digital technology investment returns on average US $20 to every US $1 of investment over the period. This compares with a US $3 return to every US $1 of non-technology capital investment.

[8] 'A Contribution to the Empirics of Economic Growth', by Gregory Mankiw, David Romer, David Weil, The Quarterly Journal of Economics, May1992, pages 407-437.

ANNEX 2: DEFINING AND MEASURING THE NEW DIGITAL ECONOMY

Innovation 1: Estimating the value flowing from technology

Our approach to measuring the digital economy is to focus on the value being produced by digital assets, rather than the money being spent on them. Our core data source is the Conference Board's Total Economy Database (TED), which provides data on the growth in the services flowing from ICT capital stock and the contribution of ICT capital stock to GDP growth. From this, we derive the value of services flowing from ICT capital as a share of GDP, which is our measure of the overall returns to this subset of what we later define (Innovation 2) as "digital assets". We estimate the value of services flowing from ICT capital stock by manipulating the following formula, which is implied by the TED dataset:

$$S(t)_{KICT} = \frac{\Delta S_{KICT}{}^{t,t-1}}{\Delta GDP_{ICT}}$$

Where $\Delta S_{KICT}{}^{t,t-1}$ is the growth in services from ICT capital between year t-1 and year t, and ΔGDP_{ICT} is the contribution of ICT capital to GDP growth. Both these variables can be derived from TED data. We then estimate $S(t)_{KICT}$, which is the services flowing from ICT capital in year t.

Innovation 2: Extending the traditional measure of digital assets

The unit of measurement for technology investment in TED is the stock of ICT capital, this includes hardware, software and telecommunications equipment. For the purposes of our report, we redefine the concept as digital assets, which is based on ICT capital stock but with a number of adjustments.

Intermediate consumption of digital assets:

The first adjustment is to incorporate some digital goods and services expenditure that we regard as being missed by national accountants in their estimate of the ICT capital stock. In the national accounts, data are collected on different types of capital investment via business survey. Technology expenses are categorized as either capital investment or current spending. That which is labelled capital investment goes into the national accounts as gross fixed capital formation and current spending as intermediate consumption. Analyzing detailed US Input-Output (I-O) tables, we identify a subset of intermediate consumption on technology goods and services that we deem to contribute to the production process in the same way as capital goods and services. Specifically, we identify digital technologies that are not used up in the production process like other intermediate inputs (e.g. raw materials) or simply implanted into the production of other goods (e.g. a light that fixes on top of a device), but are counted as intermediate consumption simply because they have a life-span of less than a year or are considered to be an upgrade to another piece of capital equipment. Under our definition of digital assets, we identify the share of intermediate technology inputs that we think qualifies for this description and include it in our measure of the total stock of digital assets.

To determine the share of intermediate technology inputs, we draw on highly detailed US I-O tables from the Bureau of Economic Analysis. We split the various categories of technology inputs as follows:

Products	Labelled as digital assets? (Y/N)
Electronic computer manufacturing	Y
Computer storage device manufacturing	Y
Computer terminals and other computer peripheral equipment manufacturing	Y
Telephone apparatus manufacturing	Y
Broadcast and wireless communications equipment	Y
Other communications equipment manufacturing	N
Audio and video equipment manufacturing	N
Other electronic component manufacturing	N
Semiconductor and related device manufacturing	N
Printed circuit assembly (electronic assembly) manufacturing	N
Electromedical and electrotherapeutic apparatus manufacturing	N
Search, detection, and navigation instruments manufacturing	N
Automatic environmental control manufacturing	N
Industrial process variable instruments manufacturing	N
Totalizing fluid meter and counting device manufacturing	N
Electricity and signal testing instruments manufacturing	N
Analytical laboratory instrument manufacturing	N
Irradiation apparatus manufacturing	N
Watch, clock, and other measuring and controlling device manufacturing	N
Manufacturing and reproducing magnetic and optical media	N

Using the weighted share established in the US I-O table, we calculate the sector-specific share of total intermediate technology inputs that we wish to reclassify as digital assets. We then apply these ratios to our international sample, via country specific data on intermediate consumption from the World Input Output Database and the OECD Input Output tables.

Digital services:

Our analysis of digital services is focused on a specific subset of the ICT services sector, as traditionally specified in national accounts. Based on the ISIC Rev 4 classification of sectors, we focused on sectors 61: Telecommunications services, and 63: Information services (relating to data processing and web hosting). To remain internally consistent with our wider methodology, we exclude sector 62: Computer programming and consultancy from the group. That is because sectors 61 and 63 primarily describe data services, delivered by capital assets, whereas sector 62 primarily describes labor-based services. Our definition is focused on the value added by technology only.

We reclassify all capital assets in the digital services sector as "digital assets" as they are all used in the production of digital services. To avoid double counting, we strip the digital services sector's share of the services flowing from ICT capital stock, as defined in Innovation 1. We then estimate the services flowing from all capital stock in this sector using data from EU KLEMS[9] on the capital share of GVA. Due to a lack of data over a wider geographical area, we assume the European sample in EU KLEMS to be representative of the wider country sample and apply the capital ratio to the GVA of the digital services sector of all countries. This serves as a proxy for the services flowing from the capital stock in this sector.
Further adjustments are made to account for the trade in digital services. We want to acknowledge where the services flowing from digital assets are consumed, rather than where the service providers are based. Therefore, we exclude exported digital services (from domestically held digital assets) and include imported digital services (from digital assets held overseas). The World Input Output Database (WIOD) is used to calculate an average share of output from the digital service sector that is exported. Values of imported digital services are available for each country from either the WIOD or OECD.

Our estimate of the services flowing from digital assets is the sum of these various components. We make one further adjustment, a method established by Caselli and Feyrer (2007)[10] which provides a closer representation of the marginal product of technology assets than is supplied by income share estimates. Caselli and Feyrer's work found that the income generated by technology assets, as a share of GDP, is often a misrepresentation of the actual value generated by those assets in the economy, and that is driven by differences in the relative cost of capital investment between countries. We leverage the cost of capital ratios proposed by Caselli and Feyrer, in combination with capital price data from the Oxford Economics databank and the US Bureau of Economic Analysis to adjust our estimates of the returns to technology assets felt by economies.

Innovation 3: Including the digital spillovers

Our approach to estimating the size of the digital spillover is set out in Annex 1. We apply this to our estimate of the size of the digital economy by multiplying our estimate of the size of the digital assets by the spillover factor of 3.5, to account for the large digital spillover implied by our econometric analysis.

[9] EU KLEMS is a research project initiated by the European Commission and carried on by the Conference Board, which aims to create a database for research into the drivers of economic growth.

[10] Caselli, Francesco, and James Feyrer. "The Marginal Product of Capital." The Quarterly Journal of Economics (2005): n. pag. Web.

ANNEX 3: MODELLING DIGITALIZATION SCENARIOS

Modelling the GDP impact scenarios

In chapter five, we describe four potential future scenarios relating to different degrees of digitalization that could occur between now and 2025. We characterize the four digital scenarios by varying two factors, the return on investment to digital technologies and the growth in digital investment.

Varying the return on investment to digital technologies

This assumption relates to how effective governments and businesses will be in establishing the right conditions for digital spillovers to grow. It relates to α (the marginal product of digital capital) in our econometric modelling framework (See Annex 1). In the baseline, α is held constant in line with the historical result.

Our assumptions for the high and low digitalization scenarios are based on our econometric modelling outputs. The coefficient, α, represents the mean value on a normal distribution. In our high scenario, we assume that the coefficient on the digital investment-to-GDP ratio is such that it yields a probability of 2.5 percent for a 'cumulative from mean' table. Using this as the upper and lower bound leaves us with a 0.84 percent increase in α in our high scenario and a 0.84 percent decrease in α in our low scenario (because the normal distribution is symmetrical). Given the lack of evidence about the change in spillovers across countries and over time, we use this as a reasonable benchmark for the potential change we could see in the digital spillover over such a time period.

Varying the growth in digital investment

This assumption relates to how aggressive businesses will be in investing in digital in the future. The baseline 10-year forecast assumes that the digital investment-to-GDP ratio for every country continues on its trend since 2011. The global rate of digital investment accelerated sharply in 2010, as explained in Chapter two, so this is a relatively bullish assumption.

Our assumptions for the high and low digitalization scenario are based on historical investment trajectories. For the high scenario, we assume the acceleration in the rate of growth in digital investment to GDP, globally, between the period 2006 to 2010 and 2011 to 2016, is repeated in the future. That means digital investments accelerate by just as much between 2017 and 2022 (and in the three years hence) as they did between 2011 and 2016. For the low digitalization scenario, we assume the rate of growth in digital investments falls back to the trajectory of the slower period, 2006 to 2010.

The four scenarios result as follows:

The high-digitalization scenario is represented by an increase in the 2025 baseline digital investment-to-GDP ratio by 0.42 percentage points and an increase in α by 0.84 percent. This represents an aggressive investment strategy and the optimal policy mix.

The high investment, poor strategy scenario is represented by an increase in the 2025 baseline digital investment-to-GDP ratio by 0.42 percentage points and decrease in α by 0.84 percent. This represents high spending, but not in the right areas, or supported by the right policy environment.

The low investment, strong strategy scenario is represented by a decrease 2025 baseline digital investment-to-GDP ratio by 0.30 percentage points and an increase in α by 0.84 percent. This represents good digital strategy, with supportive policy, but not reaping full benefits.

The low digitalization scenario is represented by a decrease in 2025 baseline digital investment-to-GDP ratio by 0.30 percentage points and a decrease in α by 0.84 percent. This represents a failure to invest effort and capital in digital technologies leaving companies falling behind international competition.

Estimating the GDP impact in 2025

To generate our forecasts under each scenario we use the same theoretical 'sources of growth' framework that we employed in the econometric modelling. We recast the theoretical model as follows:

$$Y(t) = K(t)_{ICT}{}^{\propto} K(t)_{N-ICT}{}^{\beta} L(t)^{\gamma} A(0)(1+g)^{t}$$

In addition to the variables described in Annex 1, K_{ICT} is the digital capital stock (meaning the ICT capital stock for the purpose of modelling), $K_{(N\text{-}ICT)}$ is the non-digital capital stock (meaning stock of all other capital assets apart from ICT capital) and g is the rate of technological progress.

Our results are driven by two principle channels of impact. Firstly, changing α has a direct impact on GDP by raising the productivity of digital technologies. Secondly, the rate of digital investment impacts GDP indirectly through changing the size of the digital capital stock. An important consequence of this is that even if one moved from a low to high investment scenario today, the full benefits would not be felt until the capital stock had fully adjusted to its new long-run higher level. As such there is a delay between investing and reaping