INFOCOMM MEDIA DEVELOPMENT AUTHORITY

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SINGAPORE DIGITAL ECONOMY REPORT 2023

Jointly by: Infocomm Media Development Authority &
Lee Kuan Yew School of Public Policy, National University of Singapore

CONTENT

Objective

The inaugural Singapore Digital Economy (SGDE) report is published by the Infocomm Media Development Authority (IMDA) and Lee Kuan Yew School of Public Policy, National University of Singapore (LKYSPP)[1,2]. It provides a holistic analysis of the landscape and performance of Singapore's digital economy.

Executive Summary

There is a lack of consensus internationally on how to define and measure the digital economy. Various countries, organisations, and academics have used different definitions of digital economy, with different assumptions and methodologies. Therefore, estimates on the size of digital economy are not easily comparable across jurisdictions. Caution needs to be exercised with international comparison of estimates of the digital economy. Instead, **our main purpose in estimating the size of the digital economy in Singapore is to get a sense of its economic contribution and pace of change.**

We have defined Singapore's digital economy as comprising both the value-added (VA) of the Information & Communications (I&C) sector and the VA from digitalisation in the rest of the economy. The size of SGDE with Singapore's digital economy is about 17.3% of Singapore's gross domestic product (GDP) in 2022, up from 13% of GDP in 2017. Overall, SGDE with Singapore's digital economy grew at a compound annual growth rate (CAGR) of about 12.9% p.a. since 2017, outpacing the overall economy.

The I&C sector supplies core digital services and is a key driver of digitalisation. It was the fastest growing sector from 2017 to 2022, backed by the strong growth of sub-sectors such as Games, Online Services, and E-commerce. Digitalisation in all other non-I&C sectors has also contributed substantially to Singapore's digital economy, registering rapid growth over the same period.

The expansion of the digital economy has come on the back of increasing adoption of digital technologies by enterprises, which in turn contributed to the robust growth of tech manpower. The number of tech professionals[3] has increased from around 155,500 in 2017 to 201,100 in 2022, driven by demand across all the sectors. The share of tech professionals out of total employment reached 5.2% in 2022, up from 4.2% in 2017.

The demand for tech professionals over the past few years has benefited local workers[4], with the latter accounting for more than 70% of overall tech jobs and enjoying good wages. Despite the tech layoffs in 2022/2023 which affected Singapore as well as other tech hubs globally, tech professionals will likely remain in demand as the economy digitalises.

Overall, Singapore's digital economy has been growing strongly and its longer-term outlook remains positive. The Singapore government continues to be committed to growing a competitive digital economy and fostering a technology-skilled workforce.

[1] *We acknowledge the contributions by Dr Vu Minh Khuong, Associate Professor at the Lee Kuan Yew School of Public Policy, National University of Singapore.*

[2] *With inputs and data support from Ministry of Trade and Industry (MTI), Ministry of Communications and Information (MCI), Ministry of Manpower (MOM), Department of Statistics (DOS), Economic Development Board (EDB), and Building and Construction Authority (BCA).*

[3] *Tech professionals refer to those engaged primarily in infocomm and digital technology-related work either in an IT, online, software or telecommunication equipment and/or services provider, or user organisation (such as in a bank). The scope of work may include the development, distribution, implementation, support, operation, sales or marketing of telecommunication, computer hardware/software, IT services or multimedia contents.*

[4] *Local workers refer to Singapore Citizens and Permanent Residents.*

Introduction

This is an inaugural report that seeks to define and measure the size of Singapore's digital economy, published by the Infocomm Media Development Authority (IMDA) and Lee Kuan Yew School of Public Policy, National University of Singapore (LKYSPP). The report seeks to assess the performance of Singapore's digital economy.

There is a lack of consensus internationally on how to define and measure the digital economy. Various countries, organisations, and academics have adopted different definitions of the digital economy, using different assumptions and methodologies to measure its size. Therefore, estimates on the size of the digital economy are not easily comparable across jurisdictions as well as across studies.

This report presents our approach of defining and measuring our digital economy, which we can subsequently use to monitor its contribution to the Singapore economy over time.

Definition & Methodology

There is no internationally agreed standard on what constitutes the digital economy.

Some countries and international organisations attempted to define and measure the digital economy by estimating the size of "digital sectors" that contribute directly to or enable the digital economy. Some other studies also considered the economic values from the broader economy due to digitalisation or economic spillovers from digital sectors[5].

Considering the various studies internationally, for the purpose of this report, we have defined Singapore's digital economy as comprising two components:

a) Value-added (VA) of the Information & Communications (I&C) sector;

b) VA generated from digitalisation in the rest of the economy (i.e. excluding I&C sector).

I&C sector

The I&C sector is a key driver of digitalisation, supplying digital services such as telecommunication, computer programming & IT consultancy, cloud computing, software developments, as well as production and distribution of content and media. The I&C sector is commonly used by national statistical offices (NSOs) for gross domestic product (GDP) sectoral classification purposes, including in Singapore.

In the Singapore Standard Industrial Classification (SSIC) system, the I&C sector corresponds to SSIC (2020) codes 58-63. By the business activities and services provided, the I&C sector could be further segmented into a few sub-sectors, namely Software, IT services, Hosting services, Online services, IT consultancy, E-commerce, Telco services, Games, Publishing, Broadcasting, Film & video, and Music.

[5] *A detailed review of the literature on digital economy measurement is documented in Annex A.*

Digitalisation in the rest of the economy

For this component of Singapore's digital economy, we define it as the value generated from investments and spendings in digital capital across all sectors outside of the I&C sector. Firms invest in digital technologies to better reach customers, optimise business processes as well as for product and service innovation, which may in turn lead to better economic outcomes. Hence, part of their VA can be attributable to such digital investment. We estimate such VA based on the returns from digital capital investment and spending by different sectors using growth accounting techniques[6].

Longer term efforts to define the digital economy

The Organisation for Economic Cooperation and Development (OECD) has been active in efforts to develop frameworks to define and measure the digital economy. In particular, the OECD has suggested developing Digital Economy Satellite Accounts (DESA), which relies on the compilation of digital supply-use tables (SUTs) to measure the different aspects of a digital economy including key indicators such as the output and VA of Digital Industries, in an internationally consistent and comparable manner[7].

The scope of the Digital Industries under DESA is broader than the I&C sector. For instance, one component of the Digital Industries is the group of industries that produces and distributes ICT goods (i.e. ICT goods-related industries[8]), which facilitate the functioning of information processing and communication by electronic means, including transmission and display. The I&C sector and ICT goods-related industries collectively is similar to the definition of "digitally enabling industries" – a sub-industry within Digital Industries[9].

The DESA Digital Industries also intend to capture the values arising from the use of digital technologies in the broader economy. For instance, one sub-industry within Digital Industries is "firms dependent on intermediary platforms". The scope of this sub-industry includes firms that transact significantly with consumers via a third-party digital platform. Such firms may extend across sectors like wholesale and retail trade, transportation, healthcare etc..

Some countries such as Canada and the United States, have released specific digital economy-related statistics with varying degrees of comprehensiveness. In Singapore, the Department of Statistics (DOS) is exploring the DESA framework to develop digital economy-related statistics for better monitoring and sizing of Singapore's digital economy. When completed, the DESA could be used to size the digital economy in Singapore.

[6] *The growth accounting technique is used to estimate the portion of the VA in other sectors (finance & insurance, wholesale trade, manufacturing, etc.) of the economy that is contributed by digital capital. For the detailed methodology and data sources to calculate the VA from digitalisation, see Annex B.*

[7] *While the OECD has recommended compiling the digital SUTs, it also acknowledges the challenges faced such as availability of data and has thus proposed developing a set of high priority indicators (HPIs) as immediate priorities in populating the digital SUTs. The HPIs include i) Output, Gross Value Added (GVA) and its components, of digital industries; ii) Intermediate consumption of digital products; and iii) Expenditures split by nature of transactions.*

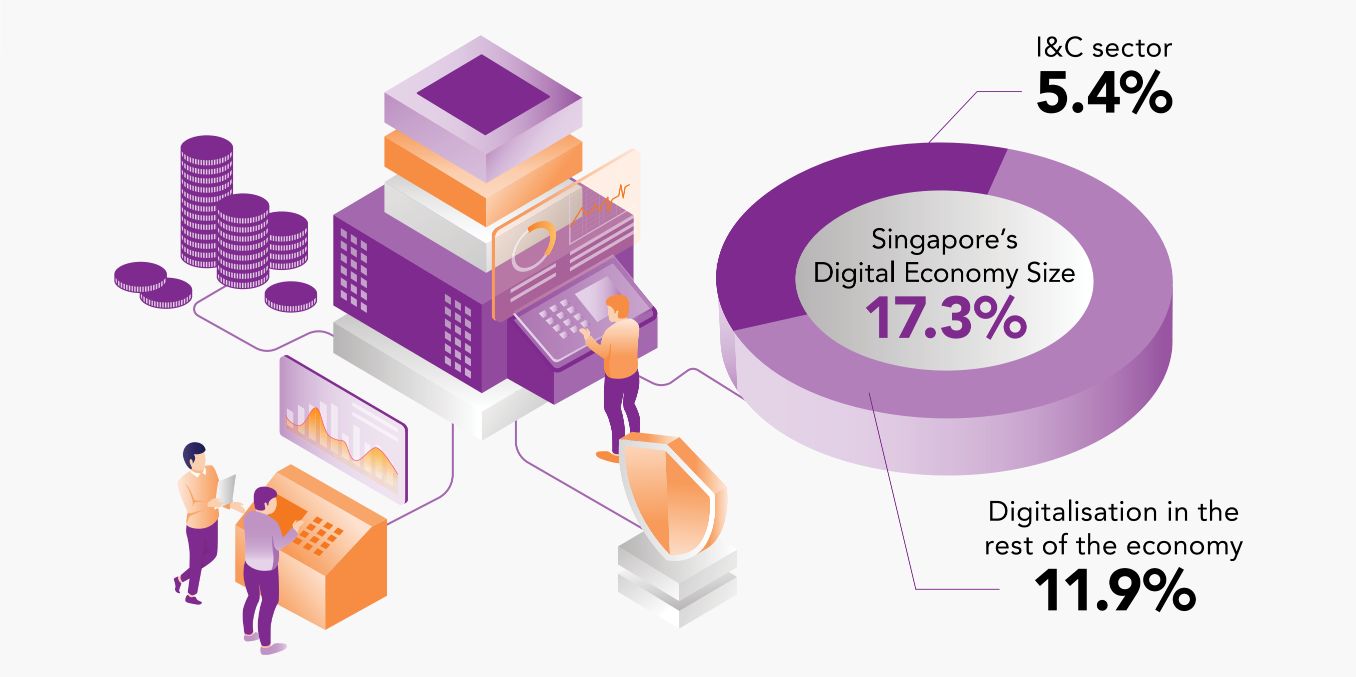
[8] *According to OECD's definition, the ICT goods-related industries include the manufacture of ICT hardware, the wholesale trade of ICT hardware and software, and the repair of computers and communications equipment.*

[9] *The Digital Industries consist of seven sub-industries namely (i) digitally enabling industries, (ii) digital intermediary platforms charging a fee, (iii) data and advertising driven digital platforms, (iv) firms dependent on intermediary platforms, (v) e-tailers, (vi) digital only firms providing financial and insurance services, and (vii) other producers only operating digitally.*

Overview of Singapore's Digital Economy

Based on the definition set out in the Definition & Methodology section, the overall nominal VA of the digital economy in Singapore amounted to S$106 billion in 2022, equivalent to 17.3% of Singapore's nominal GDP, up from 13% of GDP in 2017. It has grown at a compound annual growth rate (CAGR) of about 12.9% p.a. since 2017. The I&C sector accounted for around one third of Singapore's digital economy, with the remaining two thirds attributable to the VA from digitalisation in the rest of the economy. Please see Infographic 1 for details.

Infographic 1: Composition of Singapore's digital economy size (% of GDP), 2022



If we take into account the ICT goods-related industries, the contribution of this cluster alone is substantial. In 2022, the VA from this cluster contributed to 16.4% of Singapore's GDP, with a CAGR of 14.4% p.a. since 2017[10], reflecting Singapore's position as a global electronics manufacturing hub[11].

Using our definition and methodology, we attempted to estimate the DE sizes for a few open economies[12]. Based on the latest available and comparable data, we estimate that in 2020, the digital economies of Estonia, Sweden and United Kingdom accounted for 16.6%, 15% and 16.1% of their respective GDP, whereas the Singapore digital economy was 16.7% of GDP in 2020. In gist, Singapore's DE compared favourably with these advanced economies [Table 1].

Table 1: Estimated DE size for selected countries, 2020

Overall DE size (2020)	Singapore	Estonia	Sweden	United Kingdom
% of GDP	16.7%	16.6%	15%	16.1%

Source: Authors' calculation based on data from EU KLEMS & INTANProd database and EUROSTAT European System of Accounts (ESA) supply and use tables database

The subsequent sections will examine the various aspects of Singapore's digital economy in greater details.

[10] *Source: DOS, authors' calculation.*

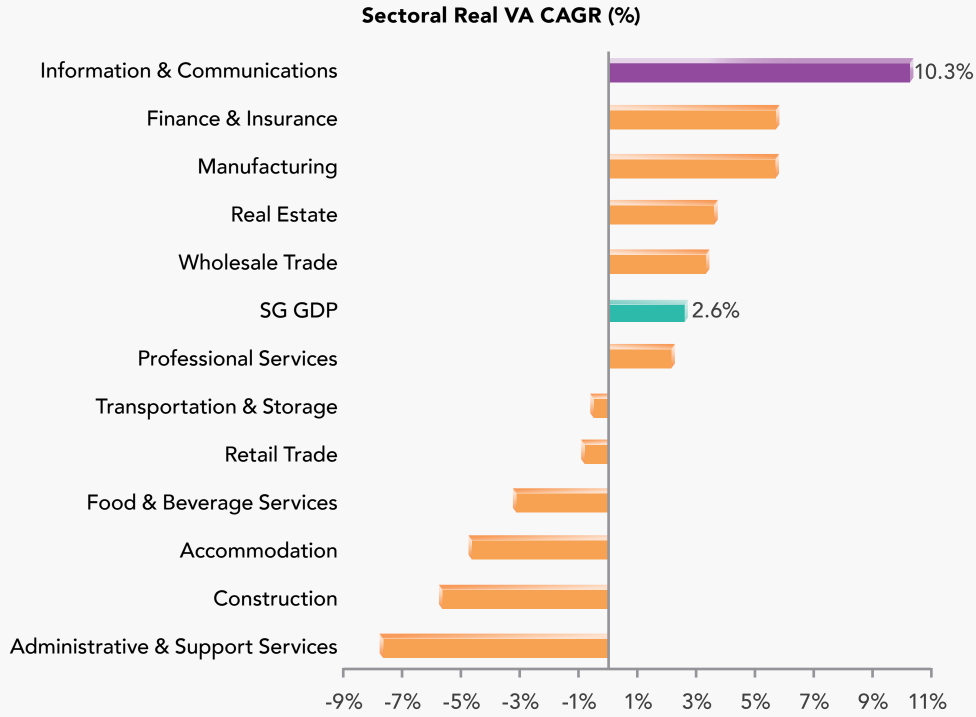
[11] *The strong performance of these industries coincided with the global surge in demand for semiconductor chips over the past two years.*

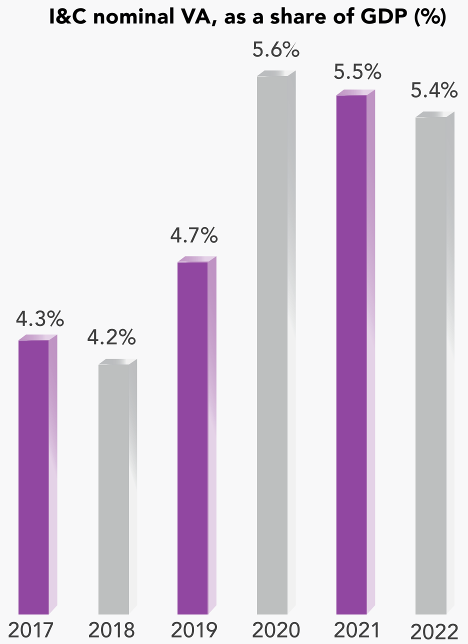
[12] *Methodologies to quantify the digital economy vary across studies, and thus caution needs to be exercised when comparing estimates of DE sizes across economies. Jurisdictions that have reported their digital economy sizes include: Canada's 5.9% (2020), United States' 10.3% (2021), and United Kingdom's 5.0% (narrow definition of DE) and 20.7% (wider definition) in 2020. Annex A provides detailed discussions on the methodologies in various studies and reports.*

Information & Communications Sector

The I&C sector is one of the key growth engines of the Singapore economy. Driven by healthy demand for digitalisation by enterprises, the I&C sector was the fastest growing sector, with a real VA CAGR of 10.3% p.a. over the 2017 to 2022 period as compared to the real GDP CAGR of 2.6% p.a. over the same period [Figure 1]. In 2022, the I&C sector accounted for 5.4% of overall GDP, increasing from the 4.3% recorded in 2017.

Figure 1: I&C sector value-added, CAGR growth, and share of overall economy, 2017-2022

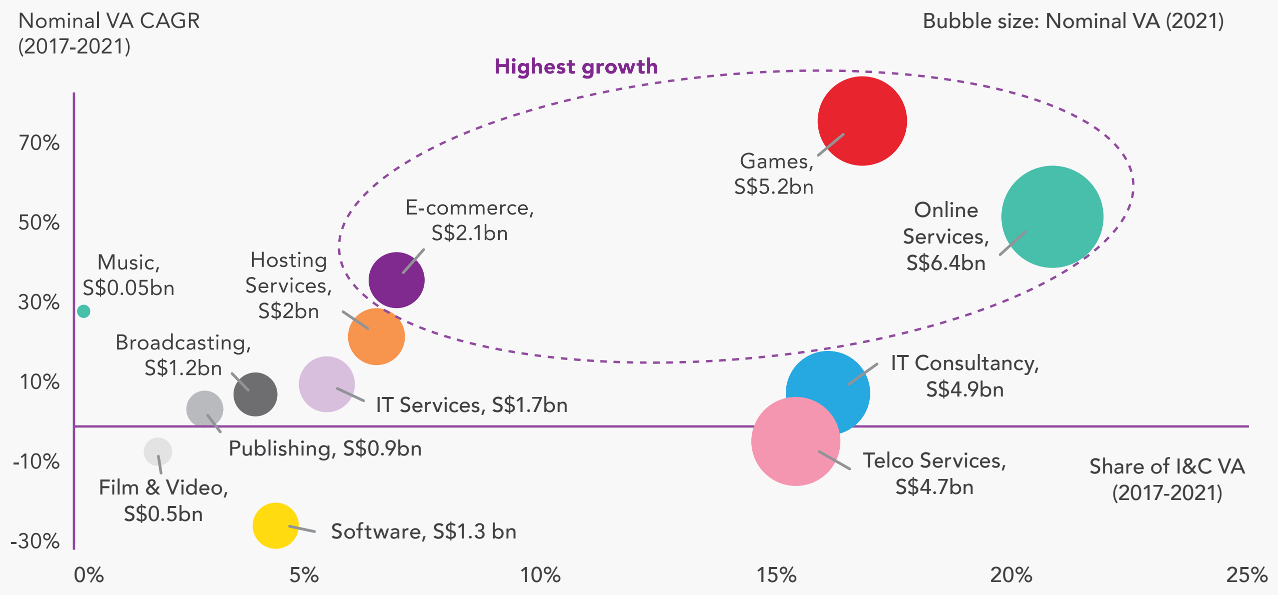




Source: DOS

Within the I&C sector, the key sub-sectors driving growth were Games, Online Services, and E-commerce [Figure 2]. Such sub-sectors saw double-digit growth of up to 70% p.a. CAGR, driven by the accelerated digitalisation and new technology trends such as the shift to clouds, especially during the COVID-19 pandemic.

Figure 2: I&C sub-sector share of VA and VA CAGR, 2017-2021

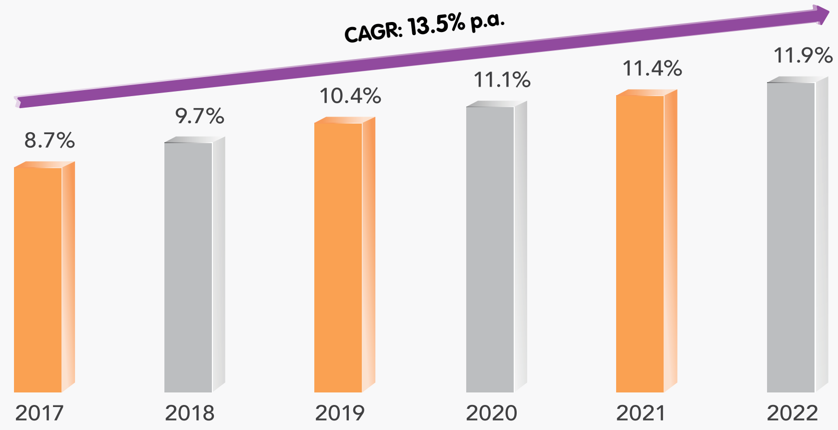


Source: DOS

Digitalisation in the Rest of the Economy

The VA from digitalisation in the rest of the economy has also demonstrated robust growth, increasing from S$38.6 billion in 2017 to S$72.8 billion in 2022, equivalent to a CAGR of 13.5% p.a.. This was faster than the growth of the overall economy. As a result, the VA from digitalisation as a share of GDP rose steadily from 8.7% in 2017 to 11.9% in 2022 [Figure 3].

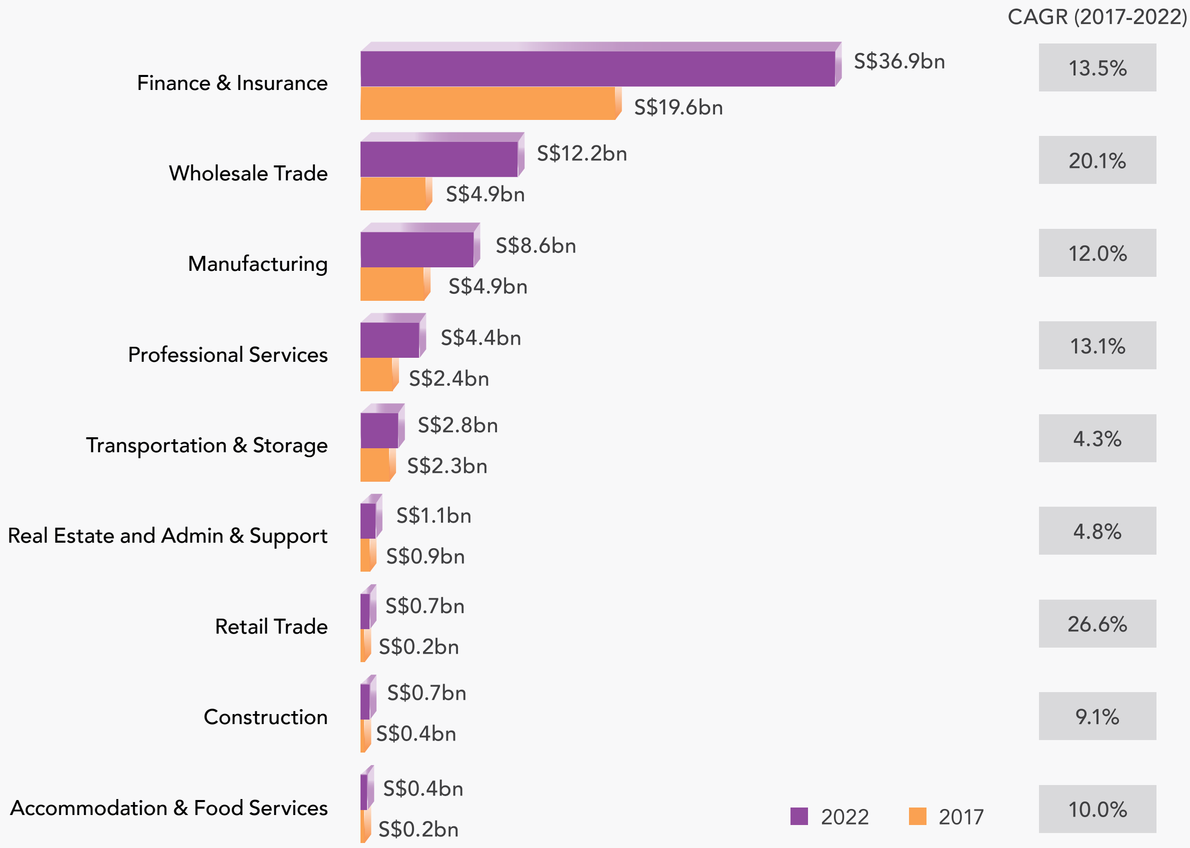
Figure 3: VA from digitalisation in the rest of the economy (% of GDP), 2017-2022



Source: Authors' calculation

We further analysed the breakdown of the VA from digitalisation for key sectors of the economy, excluding I&C sector [Figure 4]. The bulk of this VA was contributed by the Finance & Insurance, Wholesale Trade, and Manufacturing sectors.

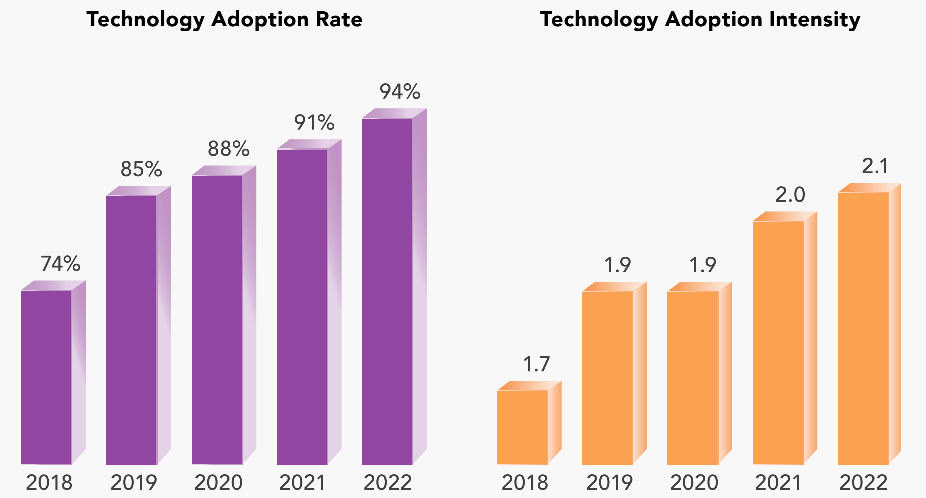
Figure 4: VA from digitalisation for key sectors (S$ bn), 2017-2022



Source: Authors' calculation

The growth of the VA from digitalisation in the rest of the economy has come on the back of more firms using digital technologies more intensively [Figure 5]. According to IMDA's Annual Survey of Infocomm Usage by Enterprises, the technology adoption rate (percentage of firms adopting at least one digital technology[13]) grew from 74% in 2018 to 94% in 2022. The technology adoption intensity (average number of digital technologies adopted per firm[14]) also increased from 1.7 to 2.1 over the same period.

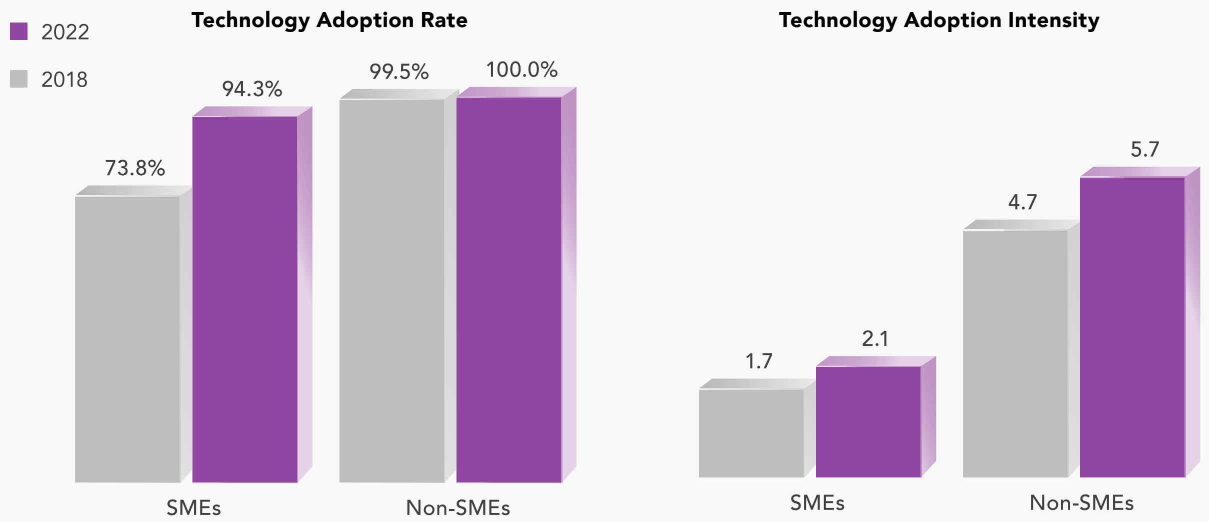
Figure 5: Overall technology adoption rate and adoption intensity, 2018-2022



Source: IMDA

Digitalisation among both Small and Medium Enterprises (SMEs) and non-Small and Medium Enterprises (non-SMEs) has improved over time, especially for SMEs, whose technology adoption rate increased from 73.8% in 2018 to 94.3% in 2022. However, there is a significant gap between SMEs and the larger firms (non-SMEs). For instance, the technology adoption intensity of SMEs improved to 2.1 in 2022, but this is considerably lower than the 5.7 for their larger counterparts [Figure 6].

Figure 6: Technology adoption rate and intensity by SMEs and non-SMEs, 2018-2022



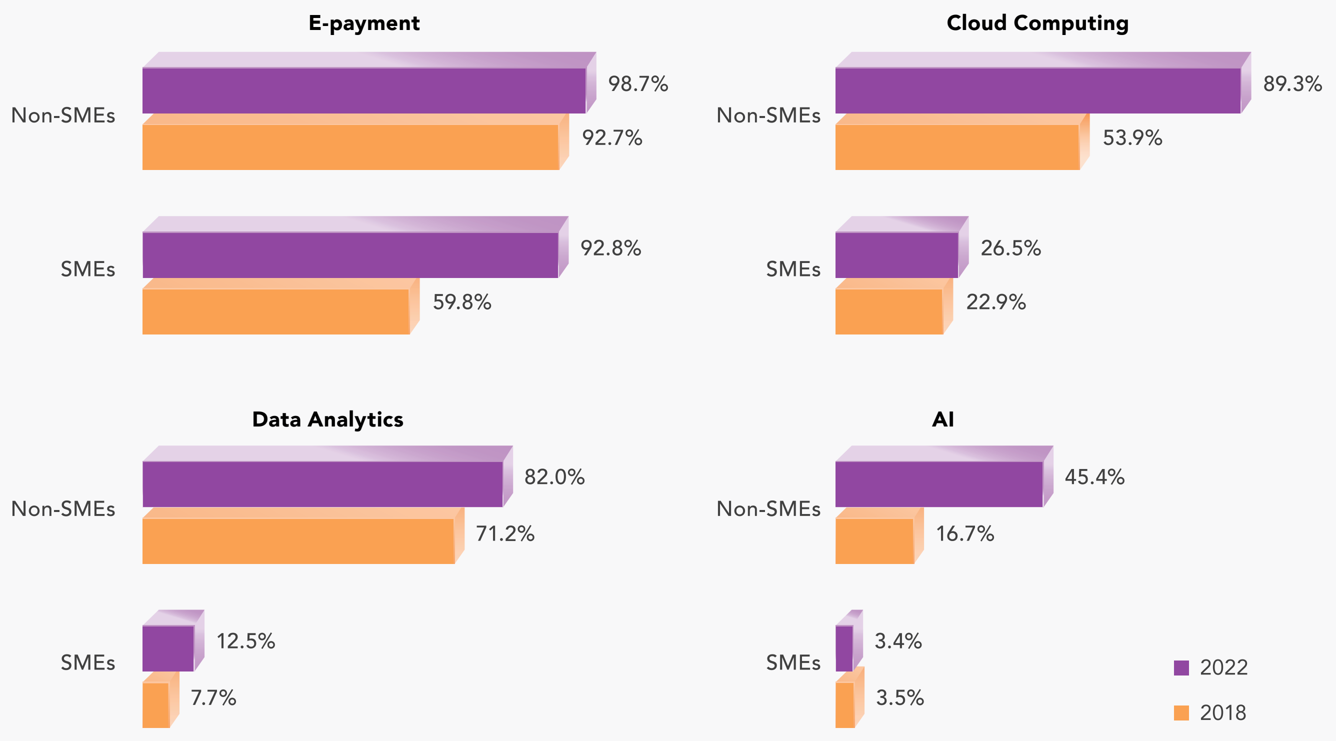
Source: IMDA

[13] *Percentage of firms that adopted at least one digital technology from nine categories of digital technologies, namely Cybersecurity, Cloud, E-payment, E-commerce, Data Analytics, AI, Internet of Things (IoT), Blockchain, and Immersive Media. Data collection for Blockchain and Immersive Media only commenced in 2018 as they are relatively new technologies.*

[14] *Average number of digital technologies adopted per firm out of the nine technology categories listed above.*

Notably, there are differences in the rate of adoption of different digital technologies between SMEs and non-SMEs [Figure 7]. In general, non-SMEs registered higher levels of adoption over time across a range of technologies including Cloud Computing, Data Analytics, Artificial Intelligence (AI), etc.. On the other hand, progress among SMEs was relatively mixed. For instance, while SMEs have made substantial improvement in taking up E-payment, its level of adoption across other digital technologies like Data Analytics and AI remains comparatively lower.

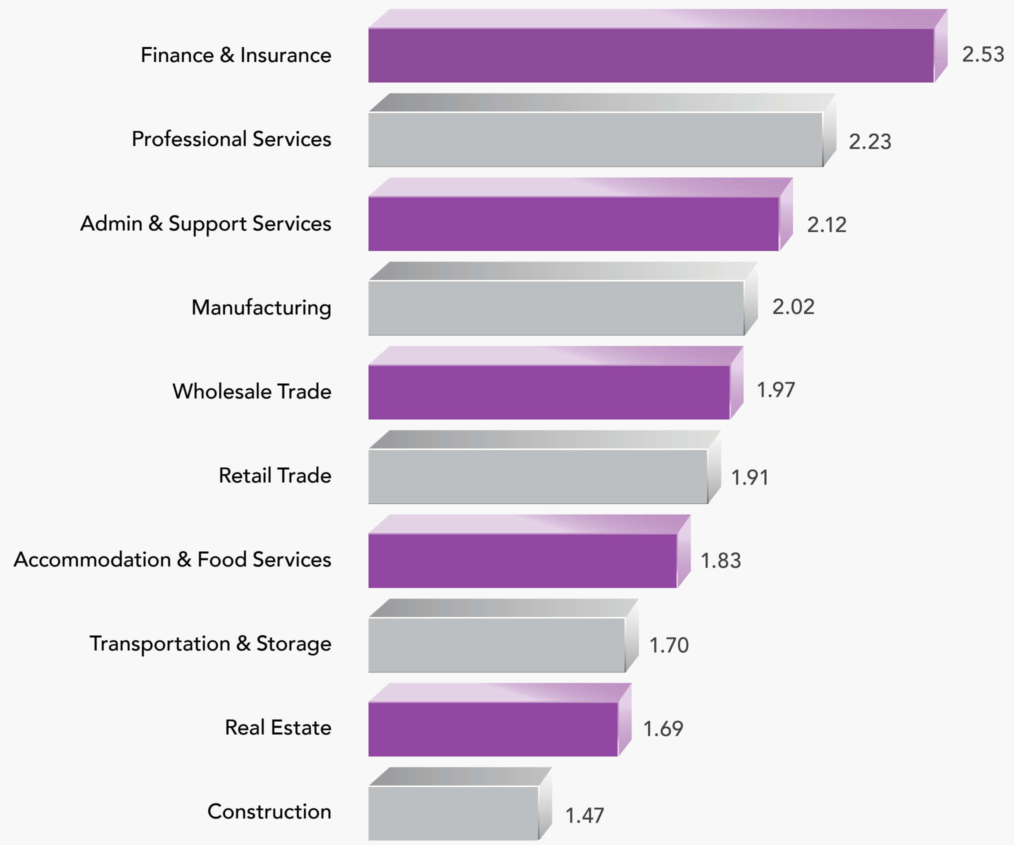
Figure 7: Adoption rates of selected technologies by SMEs and non-SMEs, 2018-2022



Source: IMDA

There is also significant variation in the adoption of digital technologies across sectors [Figure 8]. Sectors like Finance & Insurance and Professional Services have adopted relatively more types of digital technologies on average, as compared to sectors like Construction, Real Estate, and Transportation & Storage.

Figure 8: Average technology adoption intensity for key sectors, 2020-2022



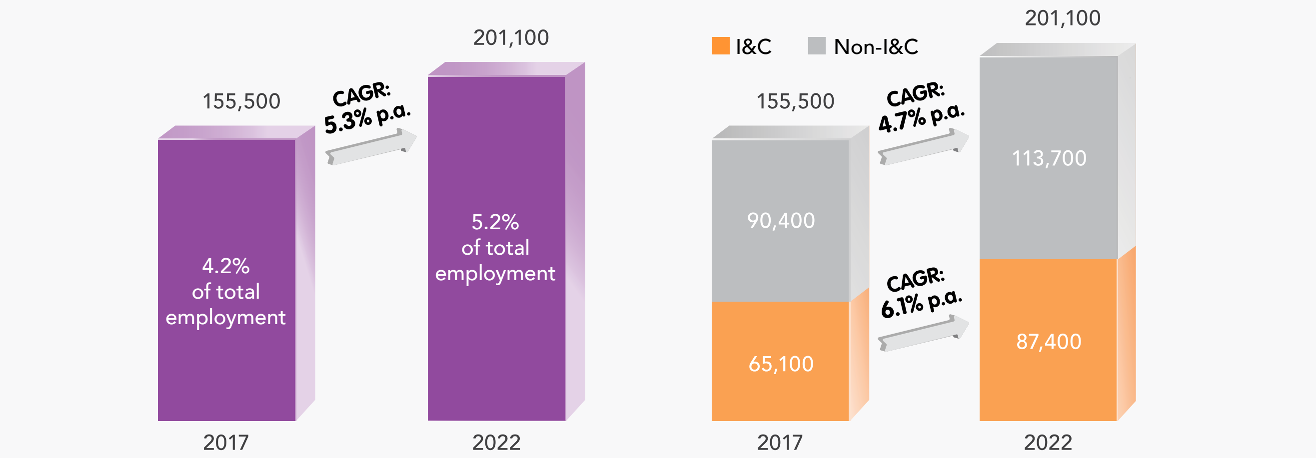
Source: IMDA

Manpower Associated With the Digital Economy

Manpower in infocomm and digital technology-related roles is essential for sustaining the growth of the digital economy. With continued digitalisation, tech professionals will continue to be in demand across the economy.

According to the IMDA Annual Survey on Infocomm Media Manpower, the number of tech jobs has grown at a CAGR of 5.3% p.a., from around 155,500 in 2017 to around 201,100 in 2022 [Figure 9]. Hence, their share of total employment[15] reached 5.2% in 2022, up from 4.2% in 2017. The growth of tech professionals was driven by demand from both the I&C sector and non-I&C sectors, with the latter accounting for around 57% of the total number of tech jobs in 2022.

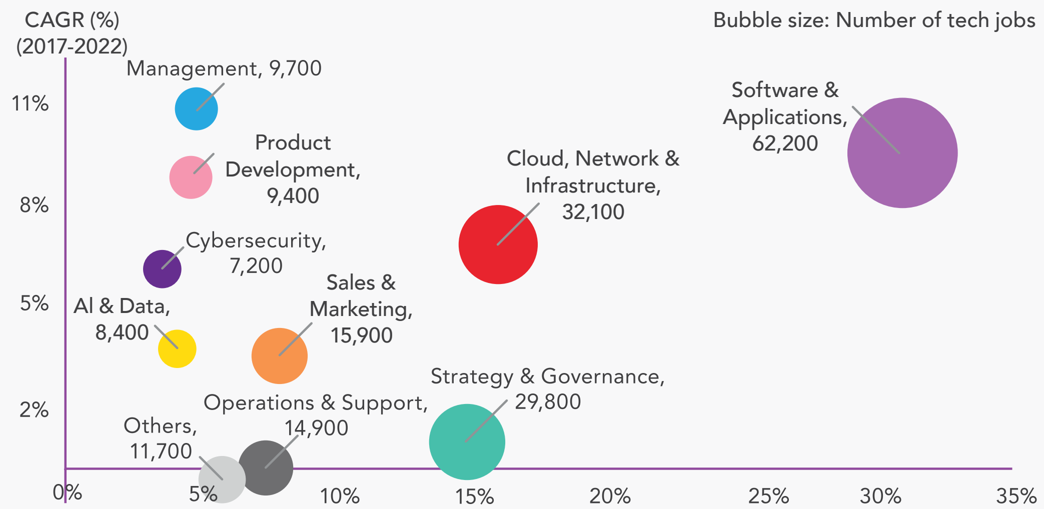
Figure 9: Number of tech jobs, 2017-2022



Source: IMDA

In terms of tech manpower profile, job roles related to Software & Applications account for the bulk of tech jobs with significant growth [Figure 10]. Likewise, there has been healthy growth in the number of job roles related to Cloud, Network & Infrastructure, Management, as well as Product Development[16].

Figure 10: Tech manpower profile and growth rates, 2017-2022



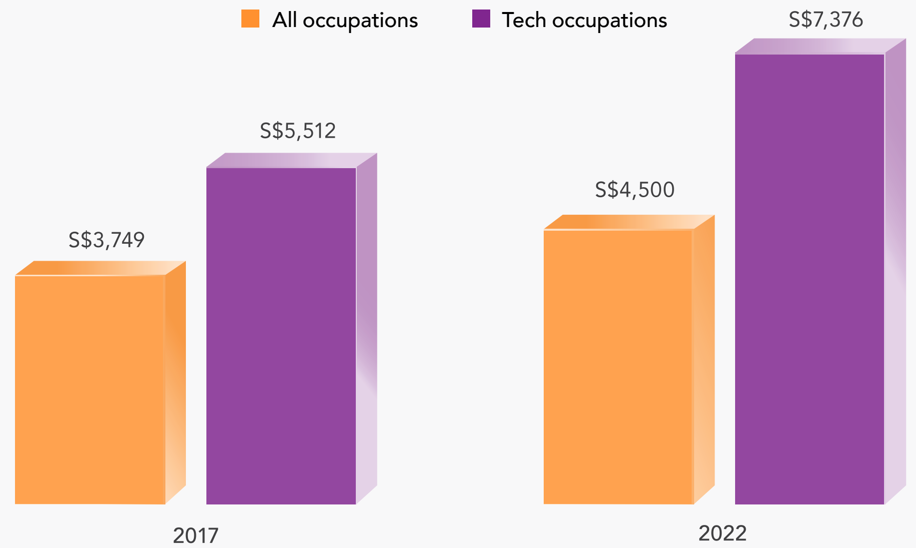
Source: IMDA

[15] *Total employment is based on administrative records and the Labour Force Survey, MOM.*

[16] *Software & Applications covers job roles such as software engineer, developer engineer, etc.; Management comprises job roles as such chief information officer, chief technology officer, chief data officer, etc.; Product Development job roles consist of product manager, quality assurance engineer, etc.; Cloud, Network and Infrastructure job roles include infrastructure engineer/architect, network, automation & orchestration engineer, etc.; Cybersecurity job roles include cyber risk analyst, security engineer, etc.; AI & Data job roles include data/AI scientist, AI/Machine Learning engineer, etc.; Sales and Marketing job roles include roles such as ICT channel sales manager, ICT sales account manager etc.; Strategy and Governance job roles include business analyst, project manager, etc.; Operation and Support job roles include database support engineers, etc..*

The demand for tech manpower has benefited local workers [Figure 11], with locals accounting for more than 70% of tech jobs in Singapore. These jobs command a good wage, significantly higher than the overall residents' median wages. The median wages of local tech professionals have also enjoyed steady growth over the years.

Figure 11: Resident median monthly wage by all occupations and tech occupations[17] (S$), 2017-2022



Source: MOM

[17] *Data for "All Occupations" pertains to median gross monthly income from work (excluding employer CPF) of full-time employed residents from Comprehensive Labour Force Survey, MOM. Data for "Tech Occupations" pertains to median gross monthly wages (excluding employer CPF & bonus) of full-time resident employees from Occupational Wage Survey, MOM. Data for 2022 were based on Singapore Standard Occupational Classification (SSOC) 2020 and data for 2017 were based on SSOC 2015.*

Conclusion

We start from a position of strength. Our digital economy contributes a sizable 17.3% of Singapore's GDP and is growing robustly. The rise in digitalisation across the economy has also contributed to healthy demand for our tech manpower, which in turn has benefited local workers, across all sectors. Despite the recent tech sector lay-offs, the demand for tech jobs is likely to remain resilient, as the digitalisation of the economy deepens.

The tech space is a fast-moving one. There are many competitors to Singapore's status as a technology hub. IMDA will double our efforts and work with the industry, the labour movement, academia, and research institutions to raise our game. We are putting in place enablers at the national, sectoral, and firm levels, such as InvoiceNow, Industry Digital Plans, and SMEs Go Digital program respectively. We will continue to support enterprises in digital transformation and empower Singaporeans with the skills needed to seize opportunities in the digital domain. Together, our efforts will help build a stronger digital future for Singapore and Singaporeans.

Annex A:
Review of Literature on the Measurement of the Digital Economy

A1. In this section, we will review the various works on digital economy measurement by different countries and international organisations.

A2. There is no consensus or globally agreed method on how to practically measure the digital economy. Over the years, there have been several studies that attempted to measure the size of the digital economy. Notably, these studies have varied interpretations of what components of the economy could be defined as "digital", which aspects of the digital economy could be delineated and measured, as well as what methodologies could be used to measure the size of the digital economy.

A3. Due to the definitional and methodological differences, the scopes of digital economy measurements also vary across studies. Thus, estimates of the digital economy sizes are not easily comparable across jurisdictions as well as studies. Caution must be exercised with international comparison. Instead, our main purpose in estimating the size of our digital economy in Singapore is to monitor its direction and pace of change.

A4. The following paragraphs summarise some studies that proposed to define and measure the size of the digital economy.

A5. To advance efforts to measure the digital economy in an internationally consistent manner, OECD has proposed a framework to develop digital supply-use tables (SUTs) which is core to the compilation of the Digital Economy Satellite Accounts (DESA)[18]. One of the key components of the DESA is the identification and the definition of Digital Industries. The scope of the Digital Industries is broad, encompassing the ICT sector as a key driver/enabler of digital transformation and other digital industries that use digital technologies significantly as part of their business models (e.g. digital only firms providing financial and insurance services, e-tailers).

A6. Some NSOs and organisations have started publishing experimental sets of digital SUTs and using them to provide estimates of their respective countries' Digital Industries to represent the digital economy:

a. The United States Bureau of Economic Analysis (BEA) published annual reports on the US Digital Economy. In its latest report[19], it is estimated that the digital economy accounted for 10.3% of United States' GDP in 2021.

b. Applying the DESA framework, Statistics Canada published digital SUTs at aggregate level[20] with estimates of Canada's digital economy to be 5.9% of GDP in 2020.

c. The Office for National Statistics of United Kingdom (ONS) utilised similar digital SUTs framework and developed the definition of digital products and "digitally affected" non-digital products. Based on the ONS's estimates[21], a "narrow" digital economy size covering digital products was reported to be 5.0% of UK's GDP in 2020, while a "broad" digital economy size based on both digital products and a broad definition of "digitally affected" non-digital products, was reported to be 20.7% of UK economy.

[18] *Internationally, work on the DESA is still on-going to discuss matters pertaining to the conceptual (ensuring consistent definition of concepts) and practical (ensuring availability of relevant data) aspects of developing the digital SUTs.*

[19] *"New and Revised Statistics of the U.S. Digital Economy, 2005–2021", Bureau of Economic Analysis, U.S. Department of Commerce, November 2022.*

[20] *"Digital supply and use tables, 2017 to 2020", Statistics Canada, July 2023.*

[21] *"UK Digital Economy Research: 2020", the Office for National Statistics, May 2023.*

d. The International Monetary Fund (IMF) also released experimental digital economy measurements[22] using a simplified SUTs approach to derive the VA of digital industries for a select group of countries. The size of the VA of digital industries for countries such as Australia, Colombia, and the United States were approximately 5.8%, 4.7%, and 9.9% of each country's GDP in 2019 respectively.

A7. In contrast, there are significantly fewer studies that attempted to estimate the economic value arising from the digitalisation across the rest of the economy.

A8. One such example is the Oxford Economics and Huawei's (2017) report[23]. This report did not attempt to define digital industries. Instead, the authors used a growth accounting approach to estimate the returns to digital assets across all sectors of the economy, and further estimated an average spillover impact of such accumulated digital assets over a longer time horizon using econometrics modelling. They concluded that the digital economy accounted for 15.5% of global GDP in 2016. The Oxford Economics and Huawei's approach borrows from the extensive literature using growth accounting methodology to estimate the contributions of ICT capital. For example, Jorgensen's (2001) work "Information Technology and the U.S. Economy" was among the key works on the role of IT investment as a source of the economic growth. Vu (2013)[24] similarly applied the same approach to Singapore and examined the contributions of ICT investment to Singapore's GDP growth during 1990-2008. Our methodology for estimating the VA from digitalisation aligns with these growth accounting works.

A9. A study by Asian Development Bank[25] (ADB) on the measurement of the digital economy in 2021 attempted to measure the size of the digital economy by using the input-output framework to estimate the GDP attributable to digital economy, which comprises (i) the VA of "the core of the digital economy" or "digital industries", and (ii) the VA from other "non-digital industries" arising from their supply of inputs to the core. The former is similar in approach to studies described in paragraph A6. The latter is conceptually not the same as the VA from digitalisation used in this report and in paragraph A8. Instead, it reflects the portion of the non-digital industries' VA that enables production in the digital industries.

A10. Based on their approach, ADB reported the digital economy size for selected countries such as Denmark (4.9% in 2016), Japan (5.9% in 2015), Korea (5.1% in 2018), Singapore (6.8% in 2016), and US (9.2% in 2019), to name a few.

A11. In conclusion, a variety of proposed definitions and measurement methods related to the digital economy exist. **There is no globally agreed standard for defining and measuring the size of digital economy. Different organisations and economies have used different definitions, assumptions, and methodologies.**

A12. Therefore, estimates on the size of the digital economy are not easily comparable across jurisdictions. Caution has to be exercised when comparing different estimates of the size of the digital economy.

A13. Instead, our main purpose in estimating the size of Singapore's digital economy is to monitor its direction and pace of change over time.

[22] *"Experimental Indicators of Digital Industries in Select Countries", International Monetary Fund Working Papers, WP/22/197, September 2022.*

[23] *"Digital Spillover: Measuring the True Impact of the Digital Economy", Huawei and Oxford Economic, 2017.*

[24] *"Information and Communication Technology (ICT) and Singapore's economic growth", Vu, Information Economics and Policy, 2013(25) 284-300.*

[25] *"Capturing the Digital Economy: A Proposed Measurement Framework and its Applications", Asian Development Bank, August 2021.*

Annex B:

Methodology for Estimating the VA From Digitalisation in the Rest of the Economy

B1. In the economics literature, growth accounting is established as a well-tested approach to quantify the contributions of different input factors to output and productivity growth. The strength and intuitive appeal of this methodology lies in determining the sources of output and productivity growth based on a well-designed and consistent economic framework.

B2. Our method of measuring the VA from digitalisation is built on this approach, with innovations in identifying and accounting for the digital spendings as intermediate inputs, and hence estimating the comprehensive contributions of digital capital and spendings in gross value-added across the non-digital sectors of the economy.

B3. Following Jorgenson (2001) and Cardona et al. (2013), we started from a Cobb-Douglas production function, which postulates the relationship between output and input factors:

$$Y = AK^{\alpha}L^{\beta},$$

where K is capital inputs, L is labour inputs and A refers to total factor productivity. Applying a set of the neoclassical assumptions of competitive markets and constant returns to scale, together with the decomposition of digital versus non-digital capital, the above equation could be transformed into:

$$\Delta lnY = \ v_{Knd}\Delta lnK_{nd} + v_{Kd}\Delta lnK_{d} + v_{L}\Delta lnL + \Delta lnA,$$

where v refers to the average share in the total factor income of the subscripted inputs. Essentially, this equation decomposes output growth into contributions of capital inputs (including both digital capital and non-digital capital) and labour inputs as well as the total factor productivity. The assumption of constant returns to scale of the aggregate input function implies that:

$$v_K = \ v_{Knd} + v_{Kd} = 1 - v_L,$$

where v_{Kd} is the income share of digital capital in total output, which is central in our estimation. Following Vu (2013), we could obtain the income share of capital inputs v_K (including digital and non-digital capital) based on the relative size of gross operating surplus, compensation of employees and GDP. The remaining task is to estimate v_{Kd}.

B4. In order to differentiate the contribution of digital versus non-digital capital, the key is to identify a measurable category of digital capital, out of the traditional capital inputs. Based on the prevailing growth accounting exercises in Singapore context, we defined a total of 6 capital categories and grouped them into non-digital and digital capital, detailed in the table below.

Item	Capital Category	Abbreviation	Group
[i]	Land, Building and Structure	Buildings	Non-digital Capital
[ii]	Transport Equipment	Transport	
[iii]	Non-computer Machinery & Equipment	Machinery	
[iv]	Research & Development	R&D	
[v]	Computer, Peripheral & Telecommunication Equipment	Hardware	Digital Capital
[vi]	Computer Software	Software	

B5. To account for the intermediate consumption of digital goods and services, which we deem to contribute to the production process the same way as the digital capital but was excluded from the national accounting capital stock series, we identified the share of relevant intermediate inputs, such as software programming and IT services, and added them into the Software capital category.

B6. Hence, by the above definition, using data sources provided by Singapore Department of Statistics (DOS), Singapore Economic Development Board (EDB), and the Building and Construction Authority (BCA), we could construct the annual real capital stock series by digital and non-digital categories, as well as by industries. Applying the standard growth accounting techniques and a set of assumptions on real interest rates[26], depreciation rates[27] etc., it then led us to the estimation of income share for digital capital out of GDP. This allows us to estimate the portion of the VA in other sectors (e.g. finance & insurance, wholesale trade, manufacturing etc.) of the economy that is contributed by digital capital, i.e. VA from the digitalisation in the rest of the economy (after removing the overlaps with the I&C sector).

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[26] Following the literature, we used real interest rates, representing "exogenous rate of return", in our estimation. There are discussions in the choice of rates for real interest rates, with the theoretical ground that it should be a uniform rate across years and across different types of capital categories. In Singapore context, we adopted an average of deflated prime lending rates to proxy the real interest rates for our study period.

[27] Depreciation rates for each capital category were derived by assuming a linear depreciation and an average service life. The average service lives assumptions are aligned with the prevailing practice of DOS in compiling capital stock series, as well as with reference to US BEA, and that of the Eurostat and OECD's recommendations (Joint Eurostat OECD Task Force on Land and Other Non-Financial Assets, 2020).

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