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Taxonomy Guide: Infrastructure in the Digital Economy

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The Trade Competitiveness Briefing Paper series provides evaluative and strategic research on new and emerging trade issues of relevance to the Commonwealth member countries. The series focuses on the practicalities of addressing these new issues as well as long existing (but still very current) policy challenges in a time-bound, targeted and effective manner; taking into account both opportunities and challenges that emerge due to changes in global trade landscape. The views expressed here are those of the author(s) and do not necessarily represent those of the Commonwealth Secretariat.

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1. Introduction

Technological innovation has become a key driver of economic development. Technological progress results in countries' ability to produce beyond their typical production possibilities, while also altering how they consume.[4] Over recent decades, however, the expansion of technology and innovation has evolved with new and more efficient ways of delivering goods and services. For example, new technology such as nanotechnology, artificial intelligence (AI) and photonics[5] are upgrading old technologies, contributing to the expansion of new trade in the service sector. The COVID-19 pandemic has also added to the acceleration of deeper digitalisation among countries and across industries and businesses.[6]

The impact of this trend has resulted in both global demand- and supply-side shocks disrupting global value chains. Despite the push towards the digital economy and changes in export and import patterns, with more digital demand for online goods and services, the total welfare gains differ significantly across countries.[7] Countries and industries that had a sound digital infrastructure in place have been able to benefit more via the first mover advantage[8] and by having a competitive edge relative to countries that do not have a sound digital infrastructure in place. For example, for every minute of the first three months of 2021, the combined profits of Apple, Google's owner (Alphabet), Amazon, Facebook and Microsoft before tax totalled US$88 billion, amounting to more than US$1 billion in profits for every working day.[9] Looking beyond financial inequality and even though there have been global gains from deeper digitalisation, the digital divide remains significant across countries.[10]

The World Intellectual Property Organization's (WIPO) 2021 *Global Innovation Index* report[11] demonstrates the difference in the level of innovation across countries. Developed economies such as Sweden, Switzerland, the United States and the United Kingdom rank among the top-ten economies globally. On the contrary, but perhaps unsurprisingly, developing and least developed countries rank in the middle or lower tiers.[12] Refining our analytical lens to focus solely on Commonwealth nations, The Commonwealth Secretariat's 2021 *Assessment of Digital Infrastructure Divide* report[13] also highlights differences in the level of digital infrastructure development across countries and regions of the Commonwealth concerning access, quality, affordability and soft infrastructure skills. These results have been further reinforced by the Secretariat's paper on the post-COVID-19 Economic Response Survey (Commonwealth Secretariat, 2020)[14], which underscores the importance of the digital economy, with improvements in digital infrastructure being a key pillar of development. In 2019, members of the Physical Connectivity Cluster of the Commonwealth Connectivity Agenda also developed the 'Agreed Principles of Sustainable Investment in Digital Infrastructure',[15] which further emphasised the need for development of the infrastructure pillar of the digital economy to close the digital divide. All of these developments within Commonwealth nations also reflect much wider multistakeholder work being done at the local, regional and international levels to address the digital divide, from community networks[16] and non-governmental organisations like the World Wide Web Foundation's Alliance for Affordable Internet (A4AI)[17] and its work on meaningful connectivity,[18] to intergovernmental organisations like the World Bank,[19] governments such as the European Union[20] and the Internet Governance Forum (IGF).[21]

Despite all the work being done to bridge the digital divide, significant policy gaps and regulatory challenges arise from the lack of a holistic approach to the myriad elements that constitute the digital economy beyond mere access to the internet. Look no further than the complexity of the technology underpinning the digital economy and the multiple fields of work it spans, from information technology (IT) and finance to consumer goods and logistics. Any assessment of the digital economy entails different disciplines, ranging from trade, economics, computer science and data engineering, which merit the creation of synergies and interrelationships to better understand the entire ecosystem. This, in turn, creates a divide and barriers to concepts and understanding that would enable policy-makers to make better policy decisions. Such challenges arise due to the multidimensional and cross-cutting nature of the digital economy, comprising digital infrastructure, regulations, the business interface including micro-, small- and medium-sized enterprises (MSMEs), sectoral issues, macro and microeconomics, and much more. Yet, we lack a common language to describe or understand the digital aspect of its digital economy's various interconnected components. Many of the descriptions used today oversimplify or misrepresent the complex nature of the entire ecosystem – from infrastructure and data to hardware and software, to business models and products.

Furthermore, in numerous international fora, be it the World Trade Organization (WTO), the United Nations, or regional organisations, debates are increasingly more common regarding privacy, data ownership and sovereignty. Those debates, however, often overlook that data is not generated by accident, nor is it monetised by machines. Rather, it is simply the means by which software applications via application programming interfaces (APIs) communicate with each other and store inputs and outputs. All these inputs, the machines, and the software that processes our inputs into outputs, are people-made and generate tangible value for offline companies and institutions.

It is for these reasons that we need a taxonomy to better define and inform these terminologies for policy-makers, regulators, researchers, economists, infrastructure providers, IT operators and other interested stakeholder groups to make sound and practical policy decisions. In other words, this taxonomy guide will help ensure the real benefits of digitalisation by closing these knowledge gaps.

2. The current state of the digital economy

This section reflects on some of the existing literature relating to digital infrastructure and supporting policies to help illustrate the current state of the digital economy. Regarding the developmental implications of digital infrastructure, the UN Conference on Trade and Development (UNCTAD) 2021 *State of the Digital Economy Report* assesses the development implication of cross-border data flows.[22] It specifically states that the international debate on how to regulate cross-border data flows is at an impasse, and positions tend to be polarised. Therefore, given that digital infrastructure technologies are evolving rapidly using technologies such as big data analytics, AI, blockchains, the internet of things (IoT), cloud computing and other internet-based services, the importance of understanding the digital infrastructure ecosystem is paramount.

Further research has identified that digital infrastructure is beyond the first mile of broadband technology. Digital infrastructure in the recent digital economy is fuelled by a range of technological ecosystems, which include IoT sensors, data centres, edge computing, and applications for smart cities, transportation, telemedicine and agriculture for effective and productive development. Digital infrastructure is therefore the technology ecosystem that serves as a gateway to the digital economy.

As a result, many countries have published or are in the process of developing strategies for the digital economy. Despite digital infrastructure being integral to the development of digital industries and requiring a certain degree of investment, however, many digital development strategies have only focused investment at a broader level, taking a more generalist approach. Statistics demonstrate that less than 25 per cent of current digital development strategies detail investment requirements for infrastructure, while less than 5 per cent relate to infrastructure for digital industries.[23]

Nonetheless, the latest trend is that businesses in all economic sectors are moving activities online and aiming to build digital relationships with customers – a trend that the COVID-19 pandemic has further accelerated.[24] As a consequence, the demand for products, ranging from software and cloud infrastructure to chips and cybersecurity applications, is increasing as well.

The investor focus has also changed in relation to digital infrastructure investments. Alongside traditional sector investments, there are digital infrastructure additions in the basket of infrastructure assets. The trend has been increasing, with internet content being delivered to and from mobile-enabled devices for just over half (51.5%) of all global website traffic.[25] This underscores the magnitude of digitisation and indicates the rise in demand for digital infrastructure. According to both UNCTAD[26] and the Organisation for Economic Co-operation and Development (OECD),[27] the COVID-19 pandemic has also become a primary catalyst behind the transition from physical shopping to e-commerce, accelerating it by an estimated five years (at least in the United States) according to research from IBM's US Retail Index.[28]

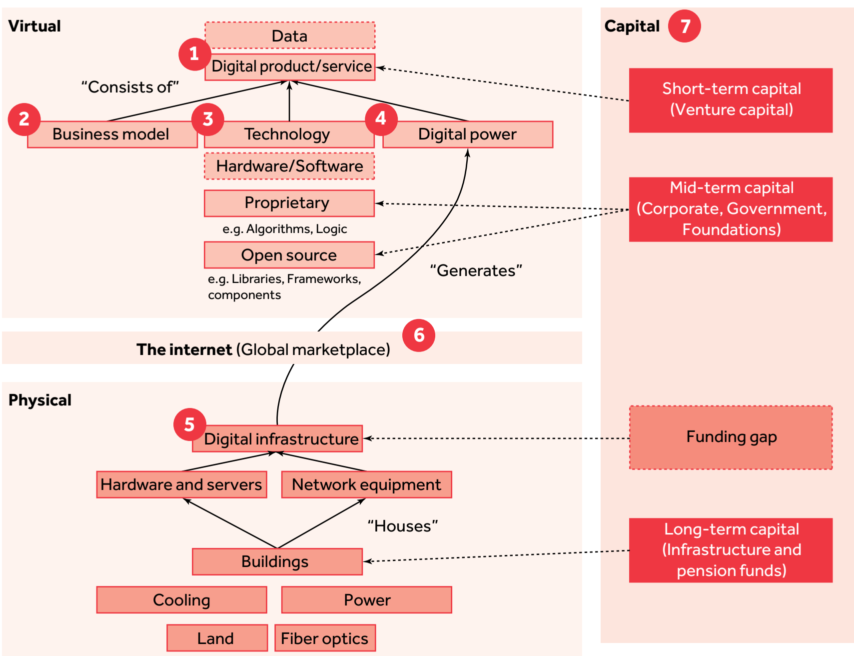
This is therefore indicative of the rate at which digital infrastructure needs to evolve and ultimately develop both hard and soft infrastructure.[29] Coupled with changes to corporations' technology status,[30] there will be a significant need for scalable and secure data storage and processing capacity with the shift from storing data on-premise to outsourcing to cloud providers. According to research from the Synergy Research, in 2020, spending on cloud infrastructure and services for the first time surpassed spending on data centres and IT hardware.[31] The COVID-19 pandemic has further expanded the need for digital infrastructure development. As such, it is no longer a peripheral subsector of infrastructure investment, but is now considered as a specialist class of assets.[32]

In addition, as new technologies emerge, there will be increased demand for infrastructure. Along with this, there will be the need to balance between transparency and efficiency, transitioning to sustainable infrastructure and business models, as well as investing in climate-resilient assets. Thus, financing digital infrastructure investments in every industry will require innovative and viable planning, financing, delivery mechanisms and infrastructure maintenance. It will require a substantial shift in policy, with new financing solutions, inclusive, systems-based approaches, and sustainability at its core.

In sum, it is imperative that policy-makers understand the basic key concepts of digital infrastructure, in order to better develop practical, cross-sectoral and holistic digital strategies.

3. Understanding key concepts in the digital infrastructure ecosystem

Figure 1. An overview of the overall digital ecosystem



Source: Illustration of Physical and Digital Infrastructure Ecosystem, based on authors' own depiction.

3.1 Defining a digital product or service

A digital product or service is what a company or a consumer might buy. As it is always either made of software or a combination of software and hardware, it also deals with data, which represents its inputs (by the users) that it transforms into outputs. The quality of a digital product is often measured by how well it carries out this conversion of inputs to outputs, how those outputs are visualised, how easy it is to input something, how fast it does the conversion, and with what rate of error.

Take the example of a word processor. It is high quality if:

- it recognises your typing inputs in real time, e.g., letters appear instantaneously (speed);
- it does not crash and lose your work/typed inputs (rate of error);
- it offers the ability to visualise your inputs differently or manipulate your inputs in a useful way, such as inserting the current date (visualisation); and
- it does not require you to learn a new keyboard layout or special input mechanism to use it (ease of use).

Fundamentally, and this is important, all digital products deal with data, generating new outputs from inputs given by the users. These inputs are given voluntarily. What is involuntary, and well-described in the 2019 tome *Surveillance Capitalism* by Shoshana Zuboff is when the machine observes the behaviour of the user and stores this behavioural data without consent – as this data was not an actual input to the machine. Think of the machine observing how fast you type, how many spelling errors you make, how much you type per day. Building such an observing function is, again, people-made, and it may serve as the input for another digital product (e.g., to sell advertising based on people's behaviour).

3.2 The underlying business model of a digital product or service

Now, digital products are delivered to customers in various ways. The business models behind these products have evolved significantly from the original idea of selling licenses for software products that are delivered on compact disks.

Here are a few business models that one is likely to come across in the new digital economy:

- **Software-as-a-service (SaaS):** This refers to renting access to software on a month-to-month or annual basis. It also reflects the evolution of the license model, which replaced the older model of buying a license for software and renewing it or upgrading to a new version. The software comes with its infrastructure built-in, which is what is often referred to as 'the cloud'. The SaaS model has meanwhile been adopted across other industries (think of car-sharing models, which is essentially a 'car-as-a-service' business).
- **Advertising:** The biggest internet-based businesses are advertising driven, such as Google and Facebook. They allow you to use their services for free, such as search, maps, social networking, etc., but in return, the user is allowing themselves to be observed, effectively 'watched' so these firms can 'mine' their behaviour patterns. This then enables the business to model on them, to allow advertisers to bid and influence the future behaviour of users.
- **Freemium**: This is a hybrid of advertising-based models and SaaS. Usually, a free version of the product exists, which is financed by advertising. It has a limited set of features. To unlock more features or the whole product, one must pay a monthly subscription fee, essentially using the product as a service (the user's access stops when the user does not pay the monthly fee, therefore the user does not own the product).
- **Subscriptions**: This is a very popular model for content-related services, such as the well-known examples of Netflix and Spotify. The user never becomes the owner of the content, meaning that when the subscription is cancelled, the content is not accessible anymore. One could compare this with the leasing versus financing of a car. Subscriptions are mostly a business-to-customer proposition; however, there are dedicated content subscriptions that target businesses as well (for example, Statista provides statistical data to businesses as a subscription[33]).

These business models can and have been impacted by regulation, especially around data privacy. These regulations, GDPR (General Data Protection Regulation) as an example, have led to changes in the practices related to these business models, with the highest impact on advertising (Urban et al. 2019). Further, by regulating what data can be gathered and clarifying ownership for data generated by individuals, machines or collectively as a business or community, there is further potential for governments to shape the economics of digital business models.

3.3 Digital technology enables digital products and services

So far, we have covered the business of digital products, with the product, its qualities, and the model of how it generates value. Now, despite common perception, most digital products are not technological innovations. Think of Delivery Hero, Zillow, Netflix or Zalando – none of them invented their own technology (although granted they made significant improvements to existing technology to support the scale they needed to operate at). But these businesses **assembled** digital technology – software components, libraries, etc. – and combined them with a new **business model,** offering them through a new digital channel, **the internet**, to customers around the world.

It is safe to say that most digital businesses are not built on the foundation of a technical invention, but rather get their uniqueness from a specific assembly of branding, marketing, business model, existing software frameworks and components such as network effects.

These elements come in two fundamental components: as licensable proprietary software or as open source, mostly free components with a community-driven maintenance strategy. It is safe to say that most digital products today only exist because the fundamental software components, the technical innovation, is available as open-source technology. This has spurred innovation and made many new business models financially and technically viable.

There remains a market for proprietary software as well, especially in large-scale enterprise, energy or defence applications; however, commercial open source has been found to have a higher impact on social welfare and value for the customers (Xing 2014).

3.4 Digital power is the fuel of digital technology

Digital technology does not run without infrastructure, however, and the internet is a communications network rather than an infrastructure that can process and store information. For this, we need servers – computers sitting in large buildings with reliable electricity that is connected to the internet. The main input for this infrastructure is electrons (i.e., electrical power).

To put it simply, electrons are used to power data centres, which are running servers; these in turn are converting the electrons into digital power, a new commodity resource consisting of computation and storage capacity, which is consumed by software when it is processing or handling data.

The concept of 'digital power' is new and builds on the fact that Moore's law has ended and therefore computing equipment slowly turning into commodities (Theis and Wong 2017). Moore's law is a term used to refer to the observation made by Gordon Moore in 1965 that the number of transistors in a dense integrated circuit (IC) doubles about every two years. This hasn't held true any more for the recent advancements in silicon chip design. Therefore we see IT equipment, especially servers, to become more of the similar as the computing chips are less of a differentiator.

However, there is another advancement in software and IT infrastructure itself which is further facilitating the commoditization of IT equipment, the paradigm of 'cloud computing'. This paradigm has led to cloud infrastructure, the abstraction of computing and storage resources into pure, infinite commodities ('digital resource primitives') that can be consumed by software.

To illustrate the concept of digital power and the important difference the concept of data which is often referred to as the 'fuel' or the 'new oil' (Charles 2013) of digital era, let's look at an example from a traditional industry: steel.

The principles are similar. Fundamentally, one takes iron ore, throws it into a furnace, and melts it into an iron bar. The furnace is run on fuel – mostly coal, and perhaps soon, hydrogen.[34] Then layer upon layer of processing is added, from rolling it into steel, blending and cutting it, to eventually making a product out of it such as a stainless-steel pot.

Now, consider the digital economy and its similarities. One takes raw data, say the input of a user, and software 'melts' it into something potentially more valuable than before. In other words, the data is converted into a form where more value is added to reach the end product. In this process, the equivalent of fuel is digital power, which, in turn, is produced by servers – just as how coal is produced by mines. Digital power is ultimately what is needed for the software to run. Even your laptop or iPad is a digital power generator, running the applications and software you want, turning your inputs (data) into something more valuable (e.g., a digital drawing). Many different layers of software (like the value creation of the steel industry) improve, manipulate, process, visualise or do things with your inputs (the iron ore) until it eventually becomes a full digital product (for example, turning your hand-movements with an Apple Pencil on an iPad screen into a digital illustration).

So, the fuel of the digital economy is not data. The fuel of the digital economy is digital power. The same is true with coal for steel or electrical power for bauxite (aluminium production) – coal and electricity are merely the catalysts that transform iron and aluminium, respectively, into something more useful. As explained above, however, business models dependent on behavioural data to process or store this data do exist; the same digital power is needed to fuel the software that delivers search engine predictions and YouTube advertising. The raw data on its own is not useful; it is more like raw iron ore, which has to be refined by fire to convert into a usable product.

Thus, the question is: what is digital power? Digital power, the fuel of the digital economy, is produced by the digital infrastructure that we are going to explore next.

3.5 Digital infrastructure produces digital power

Electrical power is made in power plants. It is fuelled by gas, coal, oil, the sun, wind, water, geothermal heat or by splitting atoms. Electricity is then transported by power grids to customers. Digital power is generated in data centres and server rooms, where servers are fuelled by electrical power. The resulting digital power is made available via network infrastructure, either private or public, so that data can be transported and processed by software that utilises digital power as its fuel.

Large generators of digital power are often referred to as 'hyperscale facilities'; they are comparable to large power plants, like nuclear reactors, outside urban areas. The largest markets for procuring digital power are now cloud providers (i.e., big technology companies such as Microsoft, Amazon, Oracle and Google). However, there are many providers of digital power, providing the commodity with various degrees of service (i.e., managed services – digital power with support and services ensuring its availability) or 'bare metal' (meaning raw digital power, with limited support and management of only the network infrastructure). Program logic – software – is then what consumes digital power in the process of processing and converting data into something more valuable and potentially more useful.

3.6 The internet and networks are the transport highways for data

Networks – be they public, such as what we refer to as 'the internet', or private, such as the internal networks of large corporations – are the transport lanes for data (e.g., user inputs) to arrive at remote facilities where digital power is available to process those inputs. Think of it as the large ships or trucks that transport iron ore to the furnace; however, in the case of digital networks, this takes place at the speed of light.

Mostly these networks are used to exchange data between users, companies or software/machines with each other. They are also used to expand the capabilities of your local small-scale digital power generator (e.g., your iPad or Android phone) with a larger digital power generator, such as the data centre of a cloud provider, where more complex operations on your inputs are possible.

3.7 Capital financing is focused on digital products as services as well low-level infrastructure

Venture capital and start-up financing has grown significantly over the past decade.[35] This is a high-risk and fast-paced financing environment, exploiting a largely unregulated, global marketplace through the internet, as well as building on top of license-free open-source technologies. Funding for digital products and services appears to be available in abundance, with great emphasis put on growing start-ups set by many Western governments, such as those of the European Union[36] or the United States.[37]

At the same time, infrastructure funds and other long-term investors are pouring into data centre facilities and buildings in order to capture the growth of the digital economy on the infrastructure side. The thesis is simple: as more data is stored and processed while at the same time creating more and more digital products and services, somewhere the data storage and processing capacity needs to be housed; therefore, data centre buildings and facilities represent a logical investment opportunity.

The development of another building block – open-source technologies – is financed through non-profit foundations, set up by corporations, late-stage start-up companies, as well as big technology companies, such as Google, Red Hat, Microsoft and others. Examples include the Eclipse Foundation, Linux Foundation and the more recent Cloud Native Foundation.

With data centre buildings, technology development and start-ups having access to financing, this leaves us with an important gap: the IT server hardware itself. Not the laptops, but the massive number of IT servers required to produce the digital power that all digital companies – both start-ups and large enterprises – require to provide digital products and services. For a large enterprise, such investments into capital goods are part of the traditional business cycle. However, for new market entrants, as well as small and medium-sized enterprises (SMEs), it is not feasible to invest large amounts of capital upfront into server hardware, without having respective customer contracts or potential revenues already secured.

Furthermore, neither venture capitalists, infrastructure funds, banks or other common financiers will invest capital into IT servers; after all, they depreciate in value quickly (for example, over three years in Germany[38]) and have no residual value from an accounting perspective. Even though research has shown that servers actually have a much longer lifetime than assumed in financial accounting, and that there is a residual value, they remain assets that most investors prefer not to invest in.

This is a gap that was recognised early on by cloud providers, such as Amazon AWS. With an abundance of cash from its existing business, it could finance large investments into IT server hardware, which the company had to do anyhow as part of its core business. It could also then provide the digital power resources generated by those servers to customers 'as a service', absorbing the risk of the servers being idle and unused.

This allocation of capital by the large cloud providers turned out to be a very smart investment of their available cash: Amazon AWS last reported an operating margin of 30.3 per cent,[39] which implies an outsized return on capital employed – especially for a de facto infrastructure asset.

This financing gap remains unaddressed and is part of the reason why small and medium-scale cloud providers, as well as regional IT service providers, are struggling to compete with the cloud operations of large digital product and service companies. They simply cannot afford the upfront investment in IT server hardware necessary to compete.

4. Big Tech: vertical integration of products, services, digital infrastructure and networks

When we refer to 'Big Tech', it is referencing a group of large-scale technology companies. We are not talking about SAP (a digital product for enterprise) or Wikipedia (a digital product for consumers), we are talking about the few companies that have accomplished a certain level of vertical integration and global dominance.

The most integrated example of all is Google (Alphabet), closely followed by Microsoft, as its vertical integration is by design. Apple provides a great example for vertical integration across hardware and software. Amazon and Facebook are further examples of companies that are working to become more integrated. In the case of Amazon, its focus is still on logistics, whereas Facebook is integrating to maximise reach, time spent on the platform and engagement.

Let's examine Google's approach to vertical integration:

- **Digital products**: Google produces a vast portfolio of digital products, such as Maps, Workplace, Search, Mail, Cloud, etc.
- **Business models**: Across its portfolio of digital products, Google utilises the full breadth of available business models – from advertising (e.g., Google AdSense) and subscription based (e.g., YouTube Music), to software-as-a-service (for Google Workplace), freemium (Google Photos and Google Drive for storage), and consumption based (Google Cloud).

  Technology: Google is considered a technology company because unlike many start-ups, it does invent and create its own technological innovations and it is founded based on a proprietary technical device: the PageRank algorithm (named after one of its founders). Many other inventions have followed, such as its own database and Big Table, while Google employs some of the most gifted researchers, scientists and inventors in the world.
- With its acquisitions of Motorola and Fitbit, Google is also venturing into the hardware space. Yet, more importantly, it is well-known that Google is designing its own servers (the digital power generators), as well its own chips Tensor processing units (TPUs), to improve the performance of its data processing operations.

Many of these inventions have been released as open-source technologies, free from patents (e.g., TensorFlow, Kubernetes and many others). However, Google's key technologies, such as the PageRank algorithm or its database system, remain closely guarded secrets.

- **Digital power**: As is well known, Google is constructing its own digital power generation facilities, hyperscale facilities, designed and owned by Google itself.
- **Digital infrastructure**: Aside from building and owning its digital power generation facilities (data centres) and designing (but not manufacturing) its own digital power generation machines (servers and chips), Google also owns a significant proportion of intercontinental fibre-optic cables (undersea cables). These interconnect its vast global portfolio of digital power generation facilities with each other, as well as provide its own internal, private network (it is own 'Google-net') to move data across the globe for processing or combining.

This infrastructure is likely going to further expand. In the United States, for instance, Google also directly offers fibre-optic connectivity to private households and businesses. It is also experimenting with its own mobile network, which would further expand its integration, getting closer to the user input and therefore being able to provide a faster, less error-prone experience (similar to the logic behind Apple's integrated – and guarded – hardware and software ecosystem). Owning these networks is significant, as it also allows for the generation of more behavioural/observational data, which can then be used to fuel some of Google's advertising-based business models.

5. Digital infrastructure and the digital economy

Together, this exemplifies the digital economy: digital products that generate value for users from their input data, using digital technologies and digital power to transform these inputs to improved outputs.

From an economic perspective, one could argue that most software is an economic service, as it can only transform inputs into something else. On the other side, content, such as digital music, is an economic good that is provided with a new business model through a digital product.

With these insights, policy-makers in the digital economy should adopt a multidimensional view and understanding of these taxonomy and technical issues, which are key to solving/enacting some of the biggest policy issues without hampering innovations.

As mentioned previously, and using the example of Google, the concept of vertical integration from traditional economics remains in the digital economy; however, the transposition of it into the digital economy differs. The insights from this paper aim to better enable policy-makers and researchers that may be new to digital economics to understand key concepts and better develop multidimensional and holistic policies.

6. Conclusion

This technical taxonomy guide on digital infrastructure and the digital economy provides technical insights for policy-makers in the digital economy to adopt a multidimensional view and understanding of these technical issues, which are key to solving/enacting some of the biggest policy issues without hampering innovation. Digital infrastructure is the digital power that fuels the entire digital ecosystem. Digital products, business models and entire networks depend on digital infrastructure.

As mentioned previously and using the example of Google, the concept of vertical integration from traditional economics remains in the digital economy; however, the transposition of it into the digital economy differs.

Various international fora are having fragmented discussions on aspects of the digital economy, without having a holistic understanding of the technical aspects of the digital infrastructure ecosystem. The taxonomy aims to provide insights and close the digital knowledge gap, so enabling better policy decisions and complementing existing literature by encouraging policy-makers to understand the concepts in a more multidimensional and holistic way. This information will also be useful for Commonwealth member countries and interested stakeholders in the ongoing joint statement initiative negotiations on electronic commerce (World Trade Organization, 2019) Lastly, this taxonomy guide will be used in further discussions concerning the digital infrastructure prioritisation framework for Commonwealth countries.[40]

Notes

1 Sustainable Digital Infrastructure Alliance (SDIA). Email: max.schulze@sdialliance.org
2 Adviser, Infrastructure Policy, Commonwealth Secretariat. Email: r.kumar@commonwealth.int
3 SDIA. Email: michael.oghia@sdialliance.org
4 https://en.wikipedia.org/wiki/Solow%E2%80%93Swan_model
5 www.technologyhq.org/technology-changing-manufacturing-process/#:~:text=Automated%20systems%20and%20complex%20machinery,the%20low%20cost%20of%20manufacturing
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11 www.wipo.int/global_innovation_index/en/2021/index.html
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17 https://a4ai.org/leaving-no-learner-behind-closing-the-digital-divide-in-africa-is-more-important-than-ever/
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19 www.worldbank.org/en/publication/wdr2016
20 www.researchgate.net/publication/348365501_Digital_Divide_in_the_European_Union
21 www.intgovforum.org/en/content/policy-options-for-connecting-and-enabling-the-next-billions
22 https://unctad.org/page/digital-economy-report-2021
23 https://worldinvestmentreport.unctad.org/world-investment-report-2017/chapter-4-investment-and-the-digital-economy/
24 www.ncbi.nlm.nih.gov/pmc/articles/PMC8437806/
25 www.macquarie.com/au/en/perspectives/digital-infrastructure-an-essential-backbone.html
26 https://unctad.org/system/files/official-document/dtlstictinf2020d2_en.pdf
27 www.oecd.org/coronavirus/policy-responses/e-commerce-in-the-time-of-covid-19-3a2b78e8/
28 https://techcrunch.com/2020/08/24/covid-19-pandemic-accelerated-shift-to-e-commerce-by-5-years-new-report-says/
29 'Hard infrastructure' refers to the physical components of the infrastructure, such as data centres, network cables, etc., while 'soft infrastructure' refers to the training, media literacy and capacity building necessary to utilise digital infrastructure, including skills such as programming, application development, etc.
30 www.macquarie.com/au/en/perspectives/digital-infrastructure-an-essential-backbone.html
31 www.srgresearch.com/articles/2020-the-year-that-cloud-service-revenues-finally-dwarfed-enterprise-spending-on-data-centers
32 www.macquarie.com/au/en/perspectives/digital-infrastructure-an-essential-backbone.html
33 Statista Corporate Subscription page, available at: https://www.statista.com/accounts/ca
34 Note, however, that hydrogen has many obstacles to overcome before becoming viable.
35 https://pitchbook.com/news/articles/2021-us-vc-fundraising-exits-deal-flow-charts
36 https://digital-strategy.ec.europa.eu/en/policies/startup-europe
37 https://obamawhitehouse.archives.gov/startup-america-fact-sheet
38 https://assets.ey.com/content/dam/ey-sites/ey-com/en_gl/topics/tax/guides/worldwide-capital-and-fixed-assets-guide-2016.pdf (p 43)
39 www.cnbc.com/2021/10/28/aws-earnings-q3-2021.html#:~:text=The%20AWS%20operating%20margin%2C%20at,28.3%25%20in%20the%20second%20quarter
40 https://thecommonwealth.org/sites/default/files/inline/D16991_TRD_Connectivity_Action_Plan_All.pdf

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