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REPORT FOR GOOGLE

ECONOMIC IMPACT OF GOOGLE'S APAC NETWORK INFRASTRUCTURE - 2022 UPDATE

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Contents

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Abbreviations used

The following acronyms and abbreviations are used in this report.

Term	Meaning
APAC	Asia–Pacific
ASEAN	Association of South-East Asian Nations
CAGR	Compound annual growth rate
CASP	Content, application and service providers
EB	Exabytes
eDSL	e-Domestic Shipping Licence
GDP	Gross domestic product
GGC	Google Global Cache
GSMA	Global System for Mobile Communications
GVA	Gross Value Added
ICPC	International Cable Protection Committee
ICT	Information and Communications Technology
IMF	International Monetary Fund
IP	Internet Protocol
ISP	Internet service provider
IXP	Internet exchange point
MNO	Mobile network operator
OSNR	Optical signal-to-noise-ratio
PoP	Point of presence
RFS	Ready for service
SADEA	Singapore–Australia Digital Economy Agreement
SDM	Space division multiplexing
UKSDEA	UK–Singapore Digital Economy Agreement

1 Executive summary

This report is an update of the *Economic impact of Google's APAC network infrastructure* report, released in 2020. The original report described how network infrastructure is the critical link between content and services in content, application and service provider (CASP) data centres, and customers and end users on internet service provider (ISP) networks. The original report and this updated version examine how Google's investments in network infrastructure have made, and continue to create, a positive impact on the connectivity ecosystem across Asia–Pacific (APAC). The favourable effects of such investment include higher bandwidth, lower latency and lower IP transit prices and bring about increases in the number of internet users and internet usage. These, in turn, create remarkable economic impact, not only directly in the telecoms sector but also flowing over into other sectors of the economy.

Network infrastructure investments made by Google in APAC have continued since the publication of our previous report, supporting accelerated growth in internet usage, driven by the Covid-19 pandemic. As of September 2022, Google is an investor in six submarine cable systems in APAC that are ready for service and has made announcements in six more. Points of presence have now been deployed in 15 cities across nine economies and Google Global Cache nodes across 322 cities in APAC.

The econometric models we updated for this report estimate that these network infrastructure investments by Google led to 1.3 million additional jobs as of 2021 and USD 640 billion in aggregate GDP for the region (real 2020 USD) from 2010 to 2021. Continued network investments from Google are expected to support 3.5 million additional jobs by 2026 and drive additional economic benefits of approximately USD627 billion in GDP (real 2020 USD) over the next five years (2022–2026).

Google's further investments in submarine capacity in APAC not only benefit Google, they also benefit the connectivity ecosystem across APAC economies they land in. Submarine cables are also vital infrastructure supporting digitalisation of enterprises and contributing to more sustainable outcomes for enterprises, governments and consumers.

As digital economies continue to grow, regions have introduced digital transformation agendas and begun to expand trade agreements to include digital trade – some of these digital trade agreements include submarine cables as a key module. Further consideration of conducive regulatory and investment policies, supported by transparent and thoughtful laws, could attract further investment in new network infrastructure. Key positive developments we have observed in APAC from the publication of the original report to the present day include the following:

- Singapore signed digital economy agreements with Australia in August 2020 and the UK in December 2021. These agreements include regulatory guidelines for submarine cables, which comprise improved terms relating to submarine cable installation, maintenance, licensing, permitting, charting and protection.

- In December 2021, the Philippines lifted foreign ownership restrictions on selected public services, which will promote foreign investment in telecoms infrastructure.

Tailored regulation can enable protection of submarine cables and support quick and effective repairs on submarine cables during disruptions. Australia's leading submarine cable regulation was evidenced by the repair of the Australia Singapore Cable (ASC) in August 2021 in a record time of 13 days – a process which on average takes months.

There remain regulatory barriers that persist across some APAC markets which may impede or deter further network investments, however the region on the whole has strengthened its regulation to be more conducive to the deployment, management and licensing of network infrastructure.

Google's network infrastructure investments include

Investments in submarine cables

Unity
2010
CABLE LANDING POINTS
Japan, USA

Indigo
2019
CABLE LANDING POINTS
Singapore, Australia, Indonesia

MIST
2022
CABLE LANDING POINTS
Singapore, Malaysia, Myanmar, Thailand, India

IAX
2023
CABLE LANDING POINTS
Singapore, Malaysia, Thailand, India

SJC
2013
CABLE LANDING POINTS
Singapore, Hong Kong, Japan, China, the Philippines, Brunei, Thailand

PLCN
2020
CABLE LANDING POINTS
Taiwan, USA, the Philippines

Topaz
2022
CABLE LANDING POINTS
Japan, Canada

Apricot
2024
CABLE LANDING POINTS
Singapore, Japan, Indonesia, the Philippines, Taiwan, Guam

FASTER
2016
CABLE LANDING POINTS
Japan, Taiwan, USA

JGA-S
2020
CABLE LANDING POINTS
Australia, Guam

Echo
2023
CABLE LANDING POINTS
Singapore, Indonesia, USA, Guam

Raman
2024
CABLE LANDING POINTS
Jordan, Saudi Arabia, Dijibouti, Oman and India

300+ cities with GGC nodes

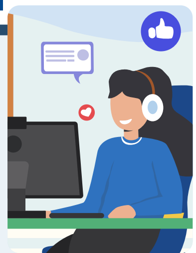
70+ peering locations in 15 cities

Benefits to digital connectivity

SUPPORT USE-CASES FOR POST-PANDEMIC DIGITAL TRANSFORMATION:

- Cloud services
- e-Commerce
- Video-conferencing

2026 FORECAST



15-36% USAGE OF INTERNET ENABLED

16-37% REDUCTION IN END-USER LATENCY

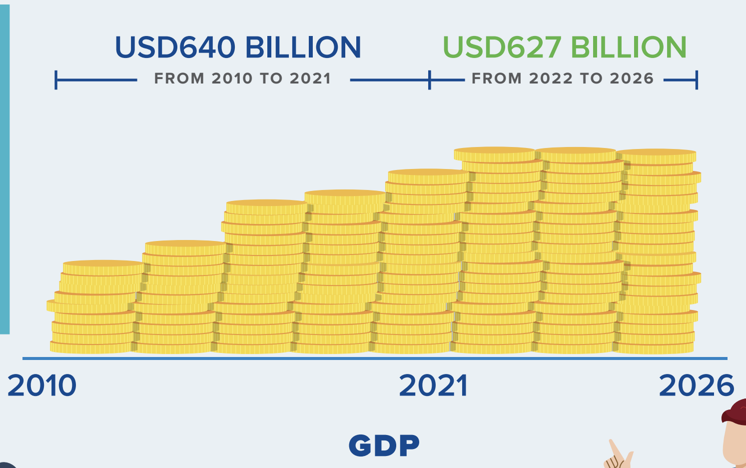
4-37% REDUCTION IN IP TRANSIT PRICES

6-38% INCREASE IN INTERNET BANDWIDTH

Economic impact

Forecast to support up to
3.5 million additional jobs
in 2026

Supported up to
1.3 million additional jobs
in 2021



Regulatory and investment regime

Need to enable ease of :

Deployment and landing of submarine cables

Protection and maintenance of submarine cables

Best-practices from Singapore, Japan and Australia provide considerations for other APAC economies to follow:

Noticeable recent developments in APAC

Singapore Digital Economy Agreements

New digital trade agreements include submarine cables as a key module which highlights the infrastructure as integral components of digital connectivity that play an important role in digital trade

Australia Singapore Cable fast repairs

Conducive regulatory regime enabled repair of the ASC cable within 13 days - a process that normally takes months

The Philippines foreign equity limit

40% foreign ownership restrictions on all utilities, including telecoms infrastructure, was removed

2 Introduction

This 2022 update builds on a previous report, *Economic impact of Google's APAC network infrastructure*, published in 2020.[1] Since then, Google has announced future investments in six submarine cable systems in Asia–Pacific (APAC) and continued deployment of points of presence (PoPs) and Google Global Cache (GGC) nodes across APAC cities.

Since the publication of the original report, the APAC region has also seen huge accelerations in internet data usage, driven largely by the prolonged Covid-19 pandemic. This has necessitated a rapid digitalisation effort across economies, with continued adoption of online services seen across the whole population.[2] Digital merchants, food-delivery companies, video-subscription services, e-commerce, and many other internet-based enterprises are booming due to this digitalisation trend. Google's investments in network infrastructure have been critical in supporting the growing consumption of these internet services.

Besides providing an estimate of the economic impact of these new Google investments in APAC,[3] this report also examines nine APAC economies in more detail. In addition to the seven economies covered in the original report (Australia, Singapore, Japan, Taiwan, Indonesia, the Philippines, South Korea), this updated report also includes Malaysia and Thailand – two countries that are developing their digital economies and would benefit from additional investments in network infrastructure.

The remainder of this document is laid out as follows:

- Section 3 describes the continued and additional investments into network infrastructure across APAC by Google
- Section 4 assesses the economic impact of Google's network investments, including announced submarine cable deployments over the next five years, covering analysis on GDP impact and enabled job creation
- Section 5 discusses environmental impacts and sustainability outcomes from the deployment of submarine cables
- Section 6 explains how regulatory and investment policies could evolve to support network infrastructure investments and further enable APAC economies to reap the benefits of future investments.

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1 Analysys Mason – Economic impact of Google's APAC network infrastructure, see: www.analysysmason.com/consulting-redirect/reports/impact-of-google-network-apac-2020/

2 e-Conomy SEA 2021 report – Google, see: economysea.withgoogle.com

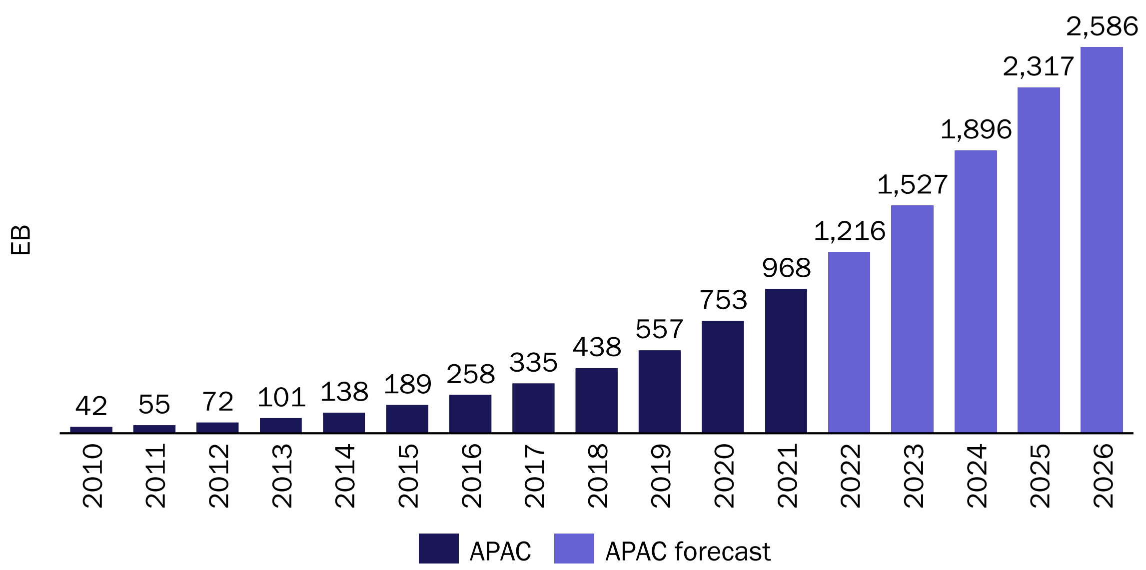
3 For the avoidance of doubt, the economic impact assessment numbers exclude impact on India as the panel data used to develop the econometric equations provided under Annex A excludes India

The report includes an annex that details the methodologies employed in assessing the economic impacts of Google's network infrastructure investments.

3 Network infrastructure investments made in APAC by Google continue, supporting accelerated growth in internet usage driven by the Covid-19 pandemic

As the Covid-19 pandemic enters its third year of impact, the world's internet usage has continued to accelerate. This trend has promoted the adoption of new online services and increased the necessity of being connected. In South-East Asia alone, 80 million new internet users have come online since the beginning of the pandemic, and digital services across e-commerce, food delivery, ride-hailing, and video and music streaming have seen significant increases in uptake in APAC, with strong growth set to persist in 2022.[4] Many businesses have transitioned to digital platforms and experienced benefits, such as increased opportunities to sell to a larger online customer base, and sustained revenue through the pandemic where various degrees of restrictions on physical movements of people were implemented. Consequently, internet traffic in APAC has experienced unprecedented growth as consumers become video-focused and businesses become internet-based.[5] We expect internet traffic in APAC to grow from 968EB in 2021 to 2586EB in 2026, representing a growth of 22% (CAGR) as shown below in Figure 3.1.

Figure 3.1: Internet data traffic in APAC[6] [Source: Analysys Mason, 2022]



4 Google – e-Conomy SEA 2021 report, see: *economysea.withgoogle.com*

5 Sandvine – Mobile Internet Phenomena Report 2021, see: *sandvine.com/phenomena*

6 APAC excludes India and China throughout this report and the 2020 edition

Google announced investments in 6 new submarine cables systems, which brings the total number of submarine cable investments in APAC from 6 to 12

To handle this extraordinary surge in internet traffic, telecoms operators and content, application and service providers (CASPs) have continued to invest in network infrastructure, noticeably with more than ten international submarine cable systems launched across APAC in 2020 and 2021. Google continues to be a major investor with contributions to two of those submarine cable systems, in partnership with telecoms operators (Figure 3.2).

Figure 3.2: Google's APAC submarine cable investments that came online in 2020 and 2021 [Source: Submarine Cable Map, Analysys Mason, 2022]

Beyond 2021, Google has made further announcements of six more cables, which will bring the number of submarine cable investments in APAC to twelve, as shown in Figure 3.3.

- **MIST** is planned to connect India directly to Singapore and across South-East Asia, providing more than 216Tbit/s of potential capacity by 2022.[7]
- **Topaz,** mainly led by Google with local partners, connecting Japan to Canada in 2022
- **Echo**, due to be ready for service (RFS) in 2023, will be the first direct cable connection between Singapore and the USA.
- **IAX** is designed to connect South-East Asia and India, as a complement to and connecting with the IEX cable system that will connect Europe to the Middle East.[8]
- **Apricot** is expected to launch in 2024 and have more than 190Tbit/s of design capacity. This will enhance existing cable route resilience by offering multiple connection routes through Asia, connecting Singapore, Japan, Indonesia, the Philippines and Taiwan.[9]
- **Raman**, equipped with 16 fiber optic pairs, is expected to be ready for service in 2024 connecting Jordan, Saudi Arabia, Djibouti, Oman and India.[10]

Figure 3.3: Google's submarine cable investments in APAC [Source: Google, 2022]

Submarine cable system	Cable landing points	RFS year *(expected)*
Unity	Japan, USA	2010
SJC	Singapore, Hong Kong, Japan, China, the Philippines, Brunei, Thailand	2013
FASTER	Japan, Taiwan, USA	2016
Indigo	Singapore, Australia, Indonesia	2019
JGA-S	Australia, Guam	2020
PLCN	Taiwan, USA, the Philippines	2020
MIST	Singapore, Malaysia, Myanmar, Thailand, India	*2022*
Topaz	Japan, Canada	*2022*
Echo	Singapore, Indonesia, USA, Guam	*2023*
IAX	Singapore, Malaysia, Thailand, India	*2023*
Apricot	Singapore, Japan, Indonesia, the Philippines, Taiwan, Guam	*2024*

7 NEC – OLL and NEC Launch MIST Cable System Construction, see: nec.com/en/press/202008/global_20200821_02.html

8 Subcom – India at the Center of Two New Subsea Cable Systems to Support Exponential Data Growth, see: https://www.subcom.com/documents/2021/Media-Release-JIO-17052021.pdf

9 Facebook – Apricot subsea cable will boost internet capacity, speeds in the Asia-Pacific region, see: engineering.fb.com/2021/08/15/connectivity/apricot-subsea-cable/

10 See: https://cloud.google.com/blog/products/infrastructure/announcing-the-blue-and-raman-subsea-cable-systems

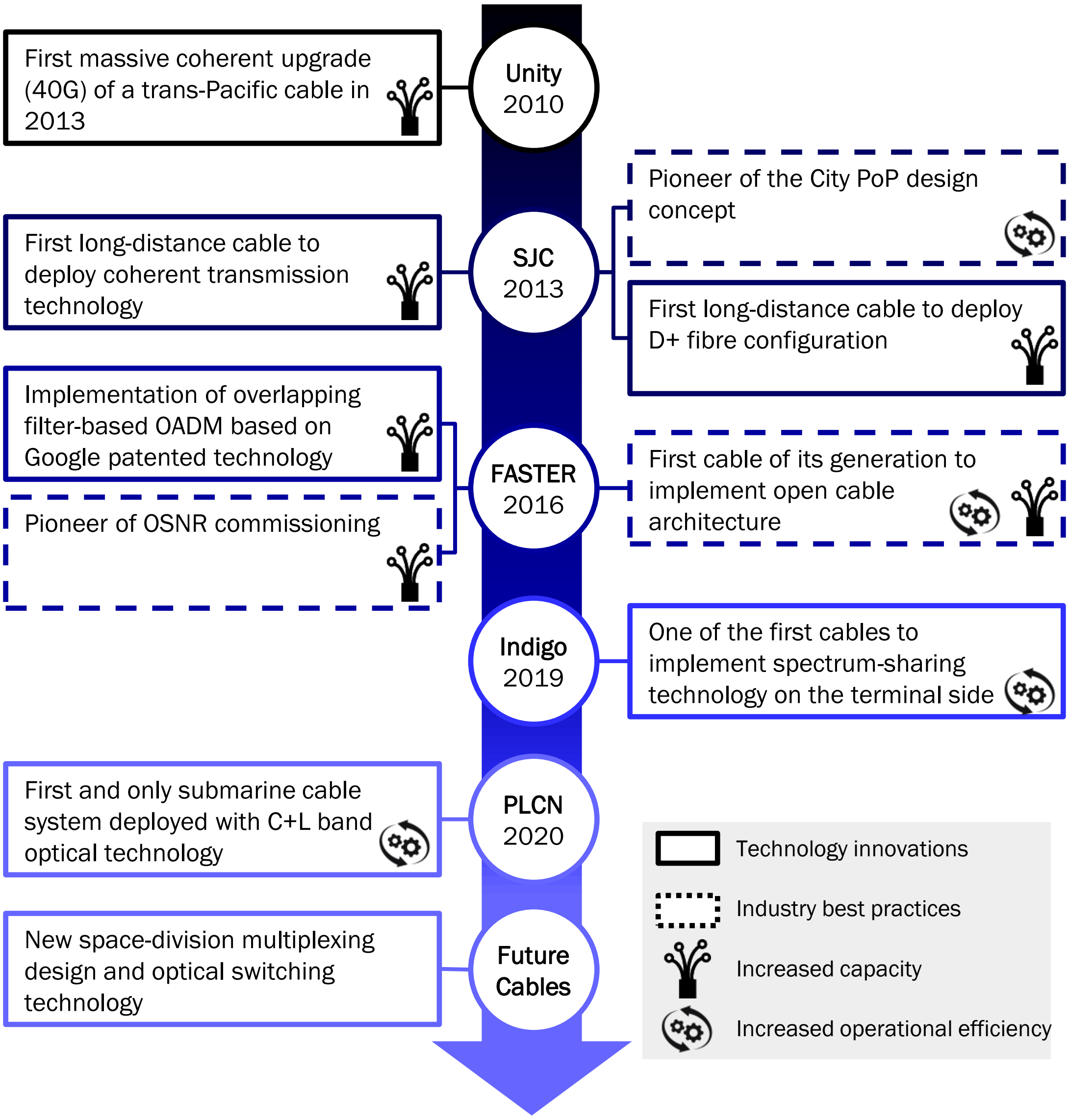
Submarine cable system	Cable landing points	RFS year *(expected)*
Raman	India, Jordan, Saudi Arabia, Djibouti, Oman	*2024*

These state-of-the-art submarine cables are expected to greatly increase the international capacity in the economies in which they land. This will enable sustained internet traffic growth which would have been challenging for many APAC economies to cater to without these new investments.

Submarine cables invested in by Google bring technology innovations and new best practices to the submarine cable industry

Since Google began investing in submarine cables in APAC in 2010, it has launched innovative technologies and driven new industry best practices in the submarine cable systems Unity, SJC, FASTER, Indigo, PLCN and JGA-S (See Figure 3.4).

Figure 3.4: Innovations enabled by Google cable investments in APAC [Source: Google, 2022]



These technology innovations not only improved the spectral efficiency and bandwidth capacity of submarine cables, they also enabled greater flexibility of traffic routing reconfiguration of cable branches. Google also led by example by driving industry best practices including:

- the City PoP design which resulted in more cost-effective backhaul and simplified traffic hand-off
- open cable architecture, which promotes competition and the development of more efficient and cost-effective equipment
- the introduction of optical signal-to-noise ratio (OSNR) as a contractual standard in open cables, which has resulted in a simpler design for transponder providers.

Google continues to innovate in the submarine cable space, as seen in the Dunant cable (2021) and upcoming Grace Hopper cable (expected RFS in 2022). Dunant is the first cable to use a space-division multiplexing (SDM) design[11] and delivers record-breaking capacity of 250Tbit/s across the Atlantic. This technology allows laser amplifiers to be shared across multiple fibre pairs, increasing the number of fibre pairs within the cable and improving system availability. Grace Hopper will be the first cable to incorporate optical fibre switching technology which will increase reliability by better enabling traffic to be moved around outages.[12] Future APAC cables could also benefit from these new technology innovations.

Google has continued its investments in new edge network locations across APAC

Google's investments in PoPs and cache nodes across APAC have also maintained momentum since the publication of the original report, 12 more PoPs have been rolled out (see Figure 3.5) and 50 metro areas have had GGC nodes installed (see Figure 3.6 below).

Figure 3.5: Number of Google PoPs in APAC [Source: Google, PeeringDB,[13] 2022]

APAC economy	APAC cities	Public peering 'fabrics[14]'	Private peering facilities
Japan	Tokyo, Osaka	11	9
Australia	Sydney	9	5
Singapore	Singapore	6	2
Hong Kong	Hong Kong	4	2
South Korea	Seoul, Anyang-si	2	4
Taiwan	Taipei, New Taipei City	2	3
Malaysia	Kuala Lumpur, Cyberjaya	2	3
Indonesia	Jakarta, Jakarta Selatan, Kabupaten Bekasi	4	3
Thailand	Bangkok	0	2

The PoPs deployed across APAC enable traffic to be exchanged between Google and internet service providers (ISPs) within their own territories. This results in an improved user experience due to lower latency and faster speeds. ISPs also benefit from cost savings as they do not have to incur overseas bandwidth costs in order to collect the content from the source country which may be

11 Google – The Dunant subsea cable, connecting the USA and mainland Europe, is ready for service, see: cloud.google.com/blog/products/infrastructure/googles-dunant-subsea-cable-is-now-ready-for-service

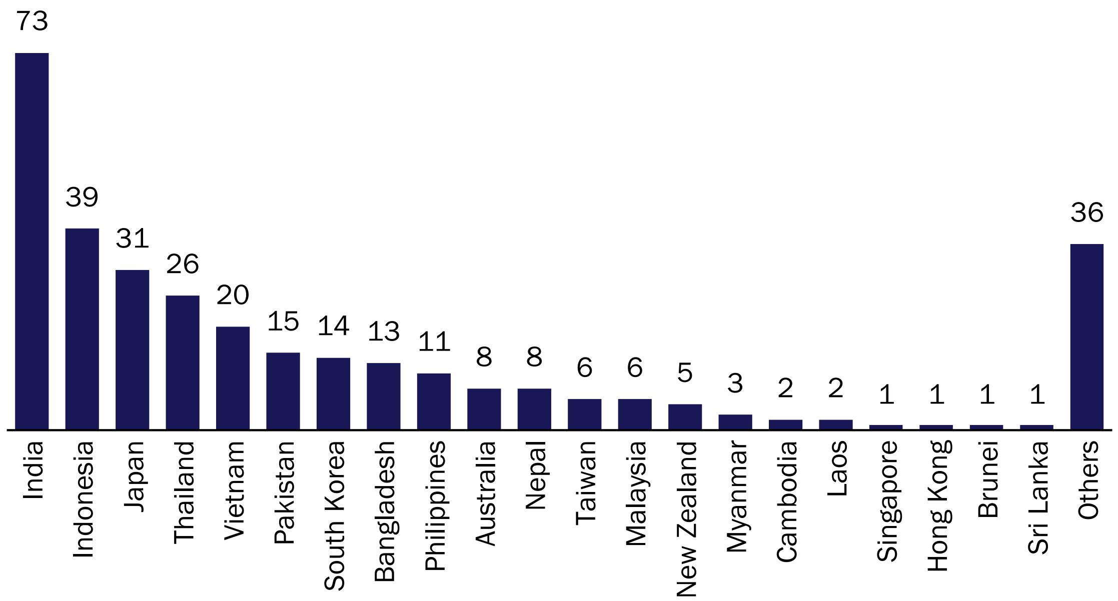
12 Google – Announcing the Grace Hopper subsea cable, linking the USA, the UK and Spain, see: cloud.google.com/blog/products/infrastructure/announcing-googles-grace-hopper-subsea-cable-system

13 The number of Google PoPs refers to the unique number of public and private peering facilities in which Google participates. Google also deploys on-net cache nodes within Google's network (e.g. in internet exchange points (IXPs))

14 Public peering is accomplished across layer 2 access technology, generally called a shared fabric, see: https://en.wikipedia.org/wiki/Peering

located outside of APAC, for example in Europe or the USA. Cloud adoption provides advantages ranging from security and performance to cost savings and scalability, and adoption has rocketed in recent years. Google has also invested in PoPs specifically to support new Google Cloud Regions, as can be seen in South Korea and Indonesia.

Figure 3.6: Number of cities with at least one GGC node in APAC[15] [Source: Google, 2022]



Google's GGC nodes store content in accessible locations within ISP networks; they primarily store static content that is popular with end users. The fact that content is stored in an accessible way in ISP networks is particularly important currently to serve video content, since video streaming occupied almost half of all downstream mobile internet traffic in 2021.[16] Alongside static video content, the popularity of live-streamed content has also boomed in recent years through the likes of video-game streamers on Twitch and live television streaming on YouTube TV. Modern caches, including Google's GGC, support these new live use cases and ensure that caching continues to deliver substantial benefits to users (through lower latency) and ISPs (through reduced long-distance/international costs).

15 The 'Others' category comprises 28 other APAC economies where Google has deployed GGC nodes, including Samoa and the Cook Islands

16 Sandvine – The Mobile Internet Phenomena Report 2021, see: *sandvine.com/phenomena*

4 Continued network infrastructure investments from Google are expected to support 3.5 million additional jobs by 2026 and drive additional economic benefits of approximately USD627 billion in GDP over the next five years

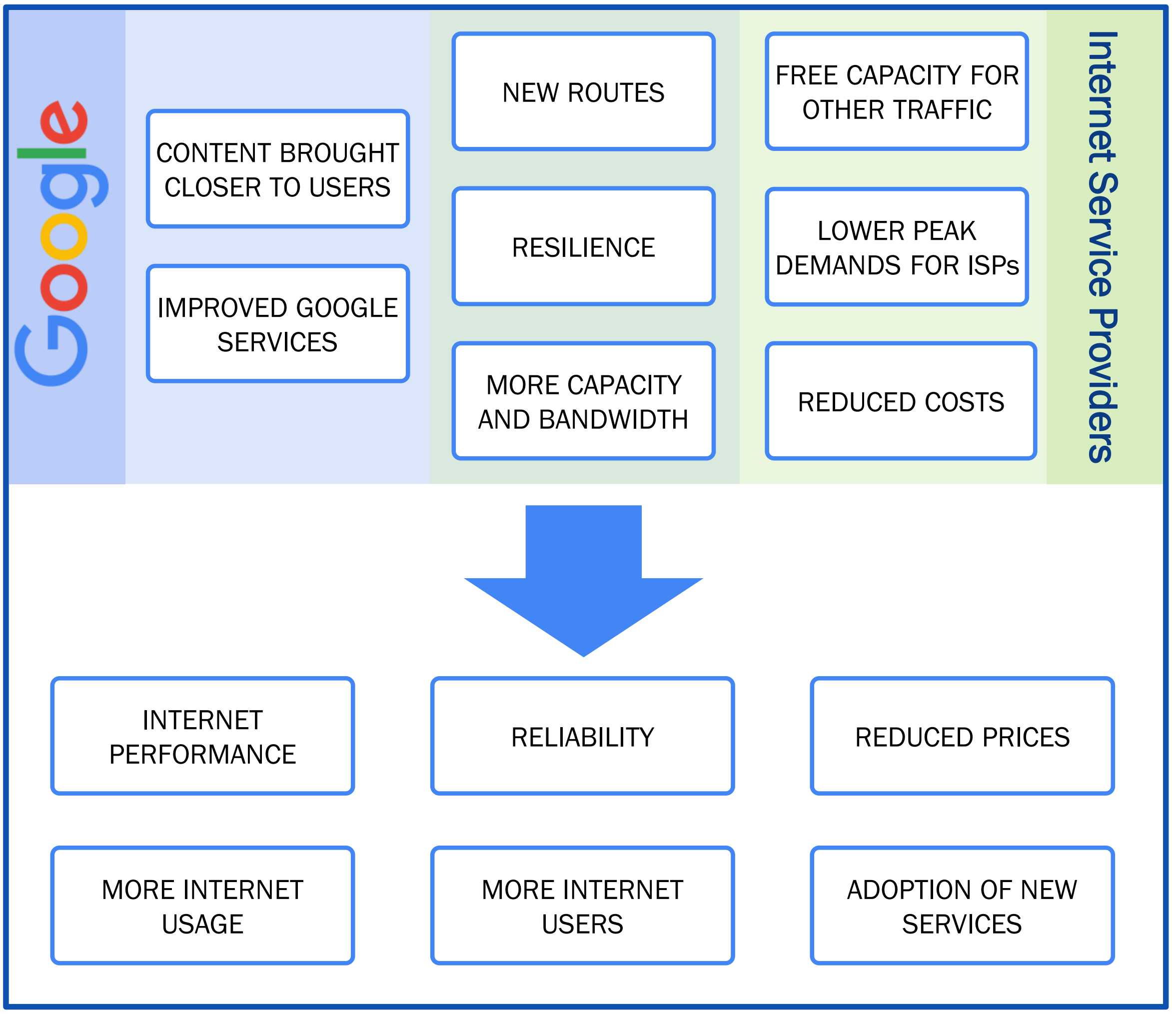
Google's network infrastructure investments contribute to the lower latency and improved reliability of Google's services. This is particularly important in the context of Google Cloud, as Google Cloud regions require multiple path connections in order to withstand failure events. The impact of Google's investments also benefit other players in the connectivity value chain, in particular the ISPs, and consequently also the end users, including consumers and businesses.

Google's network infrastructure investments improve the connectivity ecosystem across APAC economies

As discussed in the previous report, the internet infrastructure in APAC relies heavily on submarine cables. Most of the population in the APAC region live in coastal or island nations, and cities are positioned relatively close to the sea. By investing in submarine cables that cover new routes between countries, CASPs such as Google, and partner ISPs, can offer services with lower latency, and increased reliability. Shorter and more direct international cable routes between locations that host content and consumers lead to a reduction in end-user latency. This type of reduction has become especially important for the further growth of use cases such as two-way video calling, gaming and transactional services. The increase in the variety of submarine cable routes also enables CASPs and ISPs to diversify their international connectivity routes and offers increased resilience against cable failures.

The fact that Google is able to deliver international traffic directly to Google's APAC PoPs helps ISPs by significantly reducing international bandwidth traffic loads. The launch of new submarine cables has also brought about an increased supply of international bandwidth, which reduces IP transit and international bandwidth prices. ISPs are now able to carry more traffic through a greater variety of routes which translates to faster download speeds, and a better quality of internet experience for their end users. End users (both consumers and businesses) derive greater value from their internet usage when international connectivity is less constrained, more cost effective and of better quality. These positive impacts stimulate the adoption of digital services, drive an increase in internet users and ultimately an increase in internet traffic (see Figure 4.1).

Figure 4.1: Benefits of Google's network infrastructure investments [Source: Analysys Mason, 2022]



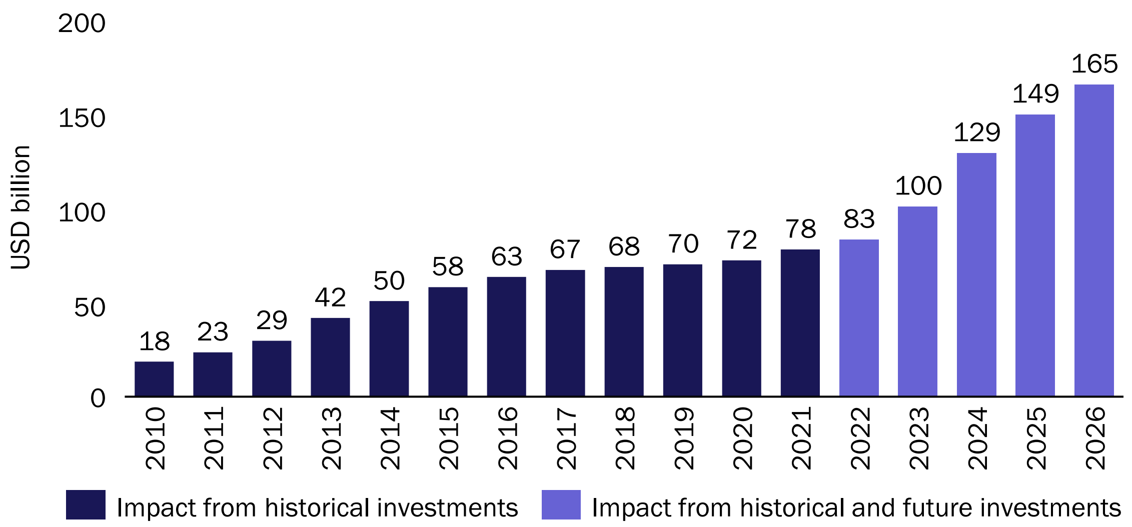
The positive impacts on internet penetration and data usage are estimated to support further economic growth in APAC of USD627 billion in GDP between 2022 and 2026

Since publishing the original report in 2020, we have refined our methodology to quantify the economic impact of Google's network infrastructure investments, the details of which can be found in Annex B of this report. Consequently, the correlations, regressions and overall statistical analyses are now more statistically significant, which strengthens the confidence in conclusions drawn in this version of the report. The expected economic impact in the form of job creation and GDP growth are detailed in the rest of this section.

Google's network infrastructure investments have supported the growing demand for internet traffic in APAC, starting with the Unity cable system connecting Japan to the USA in 2010. Submarine cable investments such as this improve the internet supply to the connected economies, primarily by lowering latency, increasing internet bandwidth, and reducing IP transit prices. Governments, enterprises and individual consumers of the internet experience these benefits across a range of economically beneficial areas, such as education and healthcare. We forecast the total GDP impact of Google's network infrastructure investments to be USD640 billion between 2010 and 2021 in

APAC. We forecast a further USD627 billion increase in GDP between 2022 and 2026, driven by both upcoming and historical investments made by Google in the region (see Figure 4.2).

Figure 4.2: Increase in real GDP[17] attributable to Google's network infrastructure investments [Source: Analysys Mason, 2022]



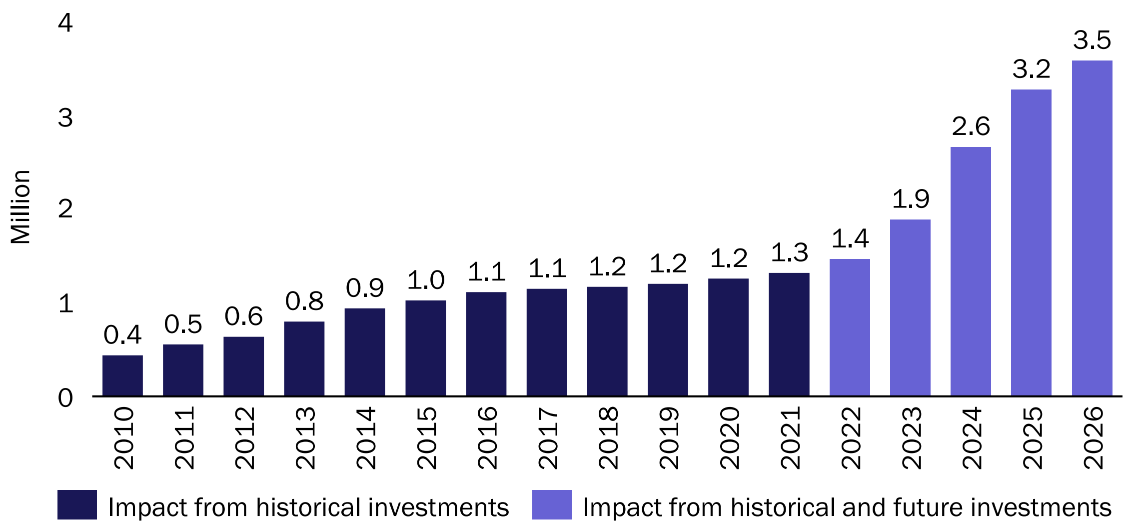
The expected economic growth will also enable up to 3.5 million jobs across APAC by 2026

This increase in economic activity resulting from Google's infrastructure investments leads to the enablement of new jobs – both directly and indirectly, and in an induced manner. Telecoms, construction and manufacturing jobs are created directly from network infrastructure investments. While these direct benefits are expected to be relatively small, they generate greater indirect and induced benefits. Improvements in internet quality and reduction in internet costs increase take-up and usage of the internet and lead to job creation largely in service-focused industries such as IT and finance, as well as internet-based industries such as e-commerce and social media.[18] We estimate that Google's network infrastructure investments in APAC have enabled up to 1.3 million additional jobs across APAC by 2021, with up to 3.5 million jobs supported by 2026 (see Figure 4.3).

17 GDP figures are in constant USD using 2020 as the base year and using a fixed exchange rate to USD in 2020; GDP statistics in USD are sourced from the World Bank and Euromonitor

18 ITU – Impact of Broadband on the Economy, see: itu.int/ITU-D/treg/broadband/ITU-BB-Reports_Impact-of-Broadband-on-the-Economy.pdf

Figure 4.3: Number of additional jobs supported through the increase in GDP attributable to Google's historical and upcoming submarine cable investments [Source: Analysys Mason, 2022]



5 Submarine cables are low-environmental impact infrastructure supporting more sustainable outcomes

Embracing sustainable development is vital in protecting the natural world and its inhabitants, preserving natural resources, and promoting forward-thinking values. In recent years, institutions and organisations across the world have started to place rapidly increasing emphasis on the critical importance of environmental sustainability. This has been demonstrated through international climate agreements as seen, for instance, at the UN Climate Change Conference (COP26), widespread activism across younger generations, and significant environmentally-focused pledges and initiatives from large companies including Amazon,[19] Apple[20] and Google.[21]

The deployment of submarine cables are proven to have only a minor impact on the marine ecosystem

Submarine cable deployment does not generally pose a risk to the environment, especially when following industry best practice during deployment and maintenance processes. The International Cable Protection Committee (ICPC) has consolidated international best practices and published guidelines for the deployment and landing of submarine cables. This is done to assist governments globally in developing laws, policies and practices to promote sustainable development and protection of submarine telecoms cables.[22] Some of the key topics covered in the guidelines include cable protection, permitting, route and landing optimisation, and inter-industry co-ordination. The guidelines also detail specifications in some of the categories such as spatial separation and charting for authorities to use as references.

Focused assessments of the environmental damage caused by the installation of submarine cables finds any damage to be *"low and spatially minor"* and caused by physical disturbance during cable placement.[23] Potential negative impacts stem from additional cable protection and deployment occurring in rare cases. These cases may include marine environment damage when rock armour or concrete mattresses are required, or when cables route through conservation areas or areas of high natural sensitivity, such as spawning grounds for important fish species. Effective regulation, such as the designation of maritime protection zones, means that the environmental impact of submarine cables can be managed, minimised or even removed entirely.

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19 Amazon Sustainability, see: *sustainability.aboutamazon.com*

20 Apple – Apple commits to be 100 percent carbon neutral for its supply chain and products by 2030, see: *apple.com/uk/newsroom/2020/07/apple-commits-to-be-100-percent-carbon-neutral-for-its-supply-chain-and-products-by-2030/*

21 Google Sustainability, see: *sustainability.google/commitments/*

22 International Cable Protection Committee, see: *https://www.iscpc.org/publications/icpc-best-practices/*

23 European Subsea Cables Association – An Introduction to Subsea Cables around the UK and North Western Europe, see: *escaeu.org/documents/*

To further diminish and manage the impact of submarine cables, governing bodies can mandate environmental impact assessments for all cable operations in the proposal stage.[24] A specific and successful example of such an assessment is the deployment of the JGA-South cable within the Marianas Trench Marine National Monument.[25] Environmental impacts were deemed to be either insignificant or not present at all across all related areas: biological resources, geology and topography, noise, endangered species, aesthetics, and so forth. Edge cases that may pose non-trivial risk to the natural environment can therefore be properly assessed using this process, with effective measures consequently required to reduce damage.

Examples of policies implemented in Australia and Singapore indicate that sustainable submarine cable policies are both realistically achievable and successful when legislated. Submarine cables may even serve to protect the environment, evidenced by Australia's three cable corridors that simultaneously act as maritime protection zones extending up to 60 miles offshore.[26] Beyond protection zones and environmental impact assessments, regulatory bodies can impose sustainable rulings on cable chemical composition, burial under the seabed, electromagnetic radiation, and routing where necessary, depending on the relevant geography.

Submarine internet cables are highly efficient and consume low levels of power

Submarine internet cables have been mistakenly understood to be harmful to the environment due to excessive energy use and as being a contributor to the destruction of the marine ecosystem. Unlike submarine power cables, however, the purpose of internet cables is simply to transmit long-wavelength (and therefore low-energy) light. This is done with tiny electric currents and highly efficient, optical repeaters that amplify the signal along the cables.[27] As a result, the electric power used by high-capacity, international submarine cables equates to that of a typical electric car,[28] which is miniscule compared to the level of electric power used by other telecoms network equipment and the last-mile power needed to connect homes to access networks.

Continued technological advancements further reduce submarine cable energy usage. For example, the Google-built Dunant cable utilises the first space-division multiplexing design to share its

24 L. Carter, D. Burnett and T. Davenport – The Relationship Between Submarine Cable and the Marine Environment, see: *sargassoseacommission.org/our-work/workshops/submarine-cables-workshop*

25 Duenas, Camacho & Associates, Inc. – Environmental Assessment for the Japan-Guam-Australia (JGA) South Telecommunications Cable Landing within the Marianas Trench Marine National Monument, see: *fws.gov/uploadedFiles/Region_1/NWRS/Zone_1/Marianas_Trench_Marine_National_Monument/Sections/News/News_Items/JGA-South_Draft_EA_June12_2019.pdf*

26 ACMA – Rules for operating around submarine cables, see: *acma.gov.au/rules-operating-around-submarine-cables*

27 Sub Optic – Pump Farming as Enabling Factor to Increase Subsea Cable Capacity, see: *web.asn.com/media/data/files_user/72/SDM1/liens/OP14-4-PECCI-ALCATEL-SUBMARINE-NETWORKS.pdf*

28 Electric Vehicle Database – Energy consumption of electric vehicles, see: ev-*database.uk/cheatsheet/energy-consumption-electric-car*

powered optical components between fibre pairs.[29] This means that there is lower power usage per fibre pair, and thus lower energy usage overall.

The deployment of submarine internet cables further promotes digitalisation of enterprises and supports sustainable outcomes

The downstream impacts of submarine internet cable deployment relating to digitalisation and cloud adoption support sustainable outcomes in enterprise operations and consumer lifestyles, and for governments. Cloud services are dependent on internet supply. Internet infrastructure, including submarine cable supply, can cause a bottleneck in the cloud integration process, especially when enterprises are in the process of being digitised. By migrating to the cloud, enterprises share computing resources and thus support the global transition towards carbon neutrality through economies of scale.[30] This is enabled by large-scale data centres that are powered by renewable energy and operate with high efficiency and utilisation, due to demand being aggregated across thousands of customers. Increases in energy of 2–3% from Google server use and network traffic are countered by an estimated 70–90% in energy savings across server use and cooling processes.[31] This is further reinforced by Google's accomplishment 100% renewable energy consumption, which has been in effect since 2017.[32] Building on this, Google aims to run on entirely 24/7 carbon-free energy, everywhere it operates by 2030 – an absolute-zero goal with zero carbon emissions. Digitalisation also enables businesses to centralise their services and logistical processes, while developing more advanced data analytics to improve operational and energy efficiency. In turn, consumer experiences can become more efficient and involve more sustainable purchasing journeys.

For governments, digitalisation and the use of cloud computing enables more effective monitoring and enforcement of environmental policies.[33] Remote sensors and artificial intelligence tools, supported by the connectivity ecosystem, can be used to monitor the progress of environmental sustainability initiatives and highlight incidents that could adversely impact the environment. These incidents can be rectified quickly before aggravation. Furthermore, with tracked data and metrics, environmental sustainability efforts can be measured and more effectively enforced to achieve governments' environmental sustainability goals.

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29 Google – The Dunant subsea cable, connecting the US and mainland Europe, is ready for service, see: *cloud.google.com/blog/products/infrastructure/googles-dunant-subsea-cable-is-now-ready-for-service*

30 Accenture – The green behind the cloud, see: *accenture.com/gb-en/insights/strategy/green-behind-cloud*

31 Google – Energy Efficiency in the Cloud, see: *static.googleusercontent.com/media/www.google.com/en//green/pdf/google-apps.pdf*

32 Google – Four consecutive years of 100% renewable energy—and what's next, see: *cloud.google.com/blog/topics/sustainability/google-achieves-four-consecutive-years-of-100-percent-renewable-energy*

33 Öko-Institut – Impacts of the digital transformation on the environment and sustainability, see: *https://ec.europa.eu/environment/enveco/resource_efficiency/pdf/studies/issue_paper_digital_transformation_20191220_final.pdf*

6 APAC economies should seize the current opportunity to promote more investments in network infrastructure and remove barriers to reap the benefits

Regulatory environments and investment regimes can act as enablers or obstacles to network infrastructure investments in a given region. It is therefore important for economies to implement and revise policies and/or regulations in a manner that attracts submarine cable investments, eases the associated processes with deployment, and protects the infrastructure thereafter. In doing so, economies can benefit from better internet quality and reliability, and as a result increase internet take-up, usage and ultimately enable accelerated digitalisation across industries.

APAC economies are elevating policies on submarine cables to form part of the national agenda and are making changes to enable more investments in new network infrastructure

In recent years, we have observed positive momentum to the regulatory and policy regimes across APAC that will promote further investments in new network infrastructure. As digital economies continue to grow, countries have begun to expand trade agreements to include digital trade as part of their national agendas. These digital trade agreements serve to lower barriers to digital trade, improve trade efficiencies, and enable a seamless flow of cross-border trade.

It is important to highlight that some of these digital trade agreements include submarine cables as a key module. This highlights that submarine cables are integral components of digital connectivity and emphasises that they play an important role in digital trade.

Case study: Singapore's digital economy agreements

In Singapore, the Ministry of Trade and Industry (MOTI) signed two digital economy agreements with Australia (SADEA)[34] and the UK (UKSDEA).[35] Both SADEA and UKSDEA encompassed regulatory guidelines for submarine cables, including terms on:

- flexibility to choose suppliers of installation, maintenance or repair services from either country
- licence or permit requirements to be made publicly available with criteria and application processes clearly stated
- timeline for approval of licences or permits to be provided within a reasonable timeframe

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34 Singapore Ministry of Trade and Industry, see *https://www.mti.gov.sg/Improving-Trade/Digital-Economy-Agreements/The-Singapore-Australia-Digital-Economy-Agreement*

35 Singapore Ministry of Trade and Industry, see *https://www.mti.gov.sg/Improving-Trade/Digital-Economy-Agreements/UKSDEA*

- public demarcation of areas where submarine cables are present with specific activities banned within that area to protect the submarine cable
- information sharing on the location of submarine cable to inform mapping and charting

These digital economy agreements reflect Singapore's continuous efforts to elevate its status as the leading digital hub in APAC, supported further by strong regulatory enforcement and a centralised, regulator-based cable application process.

The deployment, maintenance and repair of submarine cables typically involve international co-operation, as various licences and permits are required by regulatory authorities from each individual economy. Ensuring the importance of submarine cables are reflected in digital trade agreements will facilitate the expeditious and efficient installation, maintenance and repair of these systems, therefore enhancing digital connectivity between economies.

Submarine cables are capital-intensive investments. Removing foreign equity limitations on entities holding licences required for landing and operating submarine cables would enable the inflow of funds from external sources, thereby reducing reliance on the government and local companies to fund such large investments. The Philippines was the most recent APAC economy to take action in favour of foreign direct investment, having completely removed the 40% foreign ownership restrictions on all utilities outside of water, electricity and sewerage.[36] This is intended to attract foreign investment in critical infrastructure areas, including telecoms.

Finally, we note that APAC economies are acknowledging the importance of submarine cables as critical infrastructure that needs to be protected and, where damages have occurred, to enable quick repair of the cables. For example, the ASEAN regional bloc published the *ASEAN Guidelines for Strengthening Resilience and Repair of Submarine Cables* in October 2019. These guidelines aim to "provide guidance to relevant parties and facilitate the process for applying for the necessary permits from the various authorities in ASEAN Member States, with a view to expediting repairs of submarine cables by minimising permit requirements and cost, and benefiting businesses and consumers in the region".[37]

36 The Diplomat – The Philippines Readies Public Services for 100 Percent Foreign Ownership, see: thediplomat.com/2021/12/the-philippines-readies-public-services-for-100-percent-foreign-ownership/

37 See: https://asean.org/wp-content/uploads/2012/05/ASEAN-Guidelines-for-Strengthening-Resilience-and-Repair-of-Submarine-Ca....pdf

Case study: Australia's rapid repair of Australia Singapore Cable in 13 days[38]

On 1 August 2021, the Australia Singapore Cable was cut approximately 10 kilometres offshore from Perth by a cargo ship, with police claiming the damage was caused by the ships' anchor.

Field technicians and cable maintenance partners were able to be immediately deployed to assess and confirm the damage. IP services and traffic were rerouted overnight via an alternative cable system.

Permits and approvals were obtained within four days of the breakage, meaning repairs begun on 5 August 2021. Repair teams were able to work continuously, identifying the broken length of cable and laying down new cable alongside it. Due to bad weather the repair team, CS Reliance, slowed and temporarily ceased repaired efforts until 11 August in the interest of crew safety.

Finally, by the morning of 13 August, the 60Tbit/s Australia Singapore Cable was reconnected successfully. Normal services were fully restored by the thirteenth day, a record time repair as this would normally take months. The captain of the ship that caused damage faced criminal charges, as the damage was caused within a cable protection zone.

Besides streamlining processes for permit applications and shortening approval timelines, providing exemptions for foreign flagged vessels to conduct submarine cable repairs is also a critical enabler for fast and effective repairs on damaged submarine cables.

We also observed certain changes in the regulatory and policy landscape which may threaten future investments

While there have been positive changes to regulatory and investment regimes since the last report, we are also aware of specific changes implemented by some APAC economies that are seen negatively from a submarine cable investor's perspective and could deter future investments in network infrastructure. These changes may often be implemented without sufficient consultation with various industry players and therefore they could impact investor confidence in the stability of the regulatory regime in those economies.

One such example is the introduction of regulations, such as the Kepmen KP 14/2021 decree introduced in Indonesia, that restrict submarine cable deployment to specific corridors and restrict international landings to very few locations.[39] Cable corridors can be effective in supporting and protecting cable deployment, however it is important to ensure spatial separation and adequate protection of cables from maritime activities. The ICPC recommends that sea vessels should keep a distance of at least 500 metres or two times the depth of the water (if that is greater); maintain flexibility with the number and size of cable protection zones; adopt zones with consultation and

38 Vocus – Australia Singapore Cable repairs completed in record time of just 13 days, see: *vocus.com.au/news/australia-singapore-cable-repairs-completed-in-record-time-of-just-13-days*

39 See: https://thediplomat.com/2021/06/the-security-challenges-facing-indonesias-submarine-cable-communication-system/

support of cable operators; and include clear notices, directions, and damage warnings in relevant nautical publications. Creating wide cable corridors that avoid excessive clustering of submarine cables and are actively patrolled also provides adequate protection to submarine infrastructure, as seen in Australia.

Beyond spatial separation and protection of cable corridors, it is also important to provide flexibility and choice with respect to the use of corridors to further reduce risk of cable concentration. It is essential for governments to engage the community of submarine cable investors and builders when making decisions that have a critical impact on routes and resilience. This includes the definition of submarine cable corridors, which, if poorly designed, can have a detrimental impact on resilience, and on the rationale to invest in new cables.

Government mandated landing stations not in commercially attractive locations, reduces the attractiveness of cable deployment from investors' perspectives. If landing site designation is required, it is important to designate commercially attractive landing sites, such as being close to major cities and industrial hubs, and also sites that have sufficient physical space to support multiple cable landings.

Cabotage laws include restrictions such as the need to fly the national flag of a country, to have local crews, and to impose caps on foreign ownership for vessels, for these vessels to be allowed to engage in any form of economic activity within territorial waters, including repairing submarine cables. These laws are a key consideration for submarine cable investors, as they impact overall cable resilience and downtime through maintenance. In 2019, Malaysian cabotage law was relaxed, which allowed foreign-registered vessels to perform submarine cable maintenance in Malaysia's territorial waters. This move had been positive viewed by the submarine cable industry, however the change in cabotage law was subsequently revoked in November 2020.[40] As a result of the revocation and uncertainty this brought about in the regulatory landscape, industry observers have questioned the ability of Malaysia to attract new submarine cable investments. The Malaysian government has since provided more clarity on the use of foreign vessels for submarine cable maintenance by introducing the e-Domestic Shipping Licence (eDSL). eDSL maps out the licence approval process for the use of foreign-registered vessels in Malaysia's territorial waters and limits the approval process to ten working days.

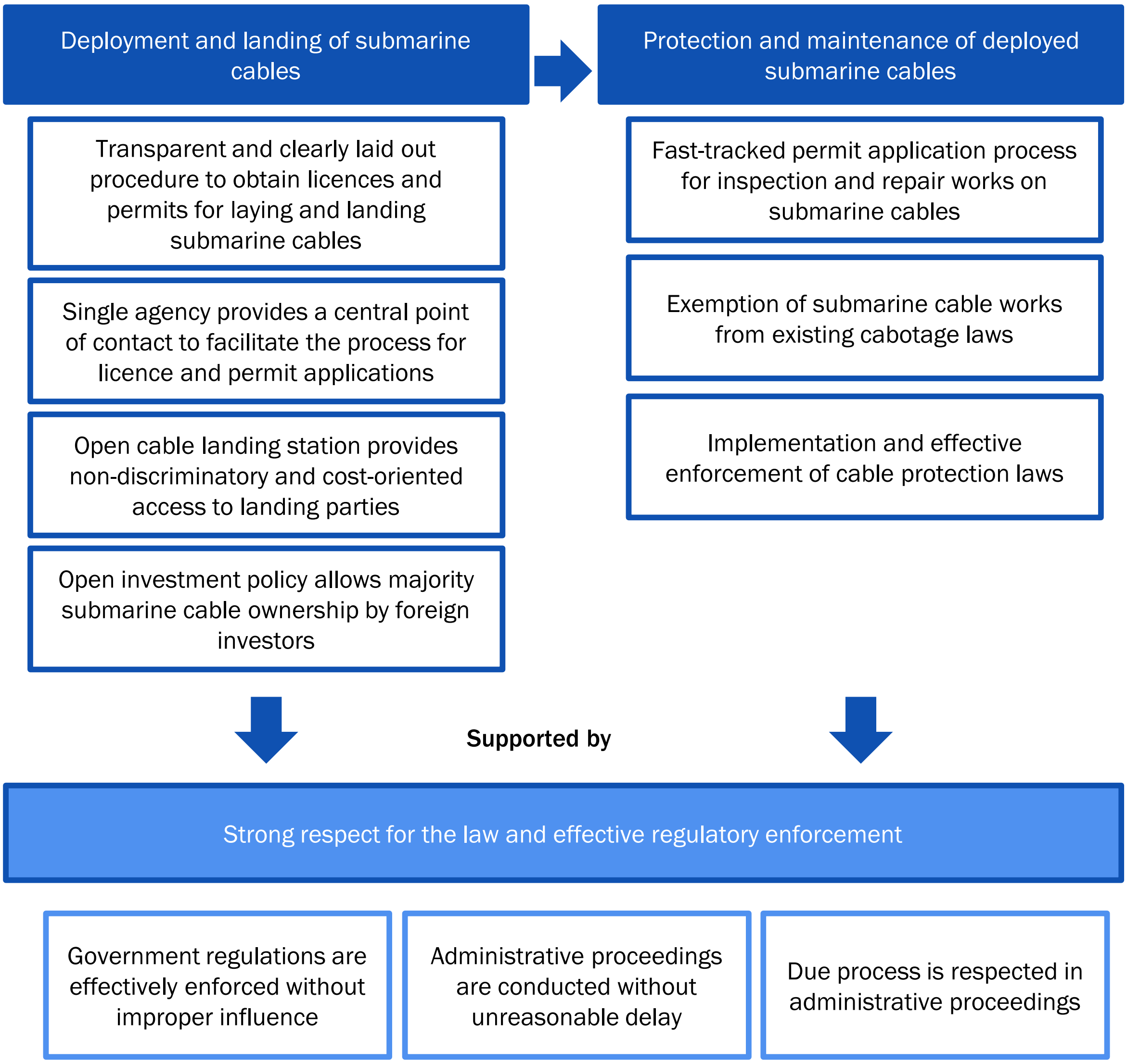
As submarine cables are capital intensive investments, cable owners will need to have confidence that the regulatory regimes are stable and supportive of investments in countries their cables land in. We would encourage regulators and policy makers to engage in dialogue with submarine cable owners to understand the technical and operational complexities related to network infrastructure investments before implementing new restrictions.

40 SoyaCincau – Malaysia govt's latest decision may delay undersea cable repairs and maintenance, see: *soyacincau.com/2020/11/18/undersea-cable-repair-maintenance-vessel-cabotage-exemption-revoked-malaysia/*

APAC economies are encouraged to continue to consider best practices

In our previous report, we encouraged the adoption of best practices as seen in leading economies, and noted that governments and policy makers could follow such types of practices to further stimulate submarine cable investment. These best practices span the deployment and landing of submarine cables, the protection and maintenance of the cables, and effective enforcement of regulation. A summary of the best practices in the APAC region is provided in Figure 6.1 below.

Figure 6.1: Best practices in regulatory and investment factors relating to submarine cable investments [Source: Analysys Mason, 2022]



Beyond considering best practices from leading economies that have a strong supply of submarine cables, authoritative bodies can also follow these guidelines outlined by the ICPC to further inspire confidence in investors and promote investments in their network infrastructure.

The principles in the ICPC guidelines include the promotion of commercial and regulatory environments that encourage numerous and diverse submarine cable landings within countries, as well as transparent regulatory regimes that support timely and efficient cable deployment and repair. This is broken down into clear categories such as domestic cable protection laws, permitting for installation and repair, and cabotage and crewing restrictions.

Although regulatory barriers still persist across some APAC economies which may impede or deter further network investments, the region on the whole has strengthened its regulation to be more conducive to the deployment, management, and licensing of network infrastructure and we are hopeful of future changes that would further promote this.

Annex A Economic impact assessment methodology

Key methodology changes since 2020 edition

We have updated the list of cables with additional "open-cable" effect to include not just Google cables but that of other CASP. We have also assessed the impact differently for each Google cable depending on a combination of factors including the number of international submarine cables landing in the country, the number of Google cables landing in the country, the consortium members participating in the cable, and Google's level of contribution to the consortium.

This annex details the quantitative, econometric approach Analysys Mason used to estimate the GDP and job impact resulting from Google's submarine cable and edge infrastructure investments in APAC. This work was supported by experts Dr Michael Kende (Senior Adviser to Analysys Mason, Senior Fellow and Visiting Lecturer at the Graduate Institute in Geneva, Digital Development Specialist at the IFC) and Professor Neil Gandal (see bio below).

Prof. Neil Gandal is the "Henry Kaufman Professor in International Capital Markets" in the Berglas School of Economics at Tel Aviv University. He received his B.A. and B.S. degrees from Miami University (Ohio) in 1979, his M.S. degree from the University of Wisconsin in 1981, and his Ph.D. from the University of California-Berkeley in 1989. He is also a research fellow at the Centre for Economic Policy Research (CEPR).

Prof. Gandal has published numerous empirical papers using econometrics in industrial organisation, the economics of information technology, the economics of the software and Internet industries, and the economics of cybersecurity and cryptocurrencies. His papers have received more than 6000 citations at Google Scholar.

In his capacity as managing editor at the International Journal of Industrial Organization (IJIO) from 2005 to 2012, he edited many empirical papers using a wide range of econometric techniques. Following his editorship at the IJIO, he was named "Honorary Editor" of the journal. He is the only honorary editor in the history of the IJIO.

A.1 Background

The core of our methodology rests on regressions – fitting a range of submarine cable-related and economic variables against the number of submarine cables – to build equations that can be used to model different scenarios of Google's involvement in APAC's submarine cable landscape.

In this edition of our report, our method employs two scenarios:

- **Scenario 1 (with Google investments)**: Google involvement in all past, present, and planned submarine cables

- **Scenario 2 (no Google investments)**: No Google involvement in all past, present and planned submarine cables

By simulating the difference between scenarios 1 and 2, we arrive at an estimate for the total impact of Google's submarine cable investments in APAC. As the fundamental difference between the two scenarios is the number and type of submarine cable systems in which Google has invested, we must carefully approach the difference in treatments of the cables in each scenario.

Firstly, we separate cables with Google investments under Scenario 1 into *standard* cables and *open* 'CASP-invested' cables. These cables in each country are generally classified as *open* CASP cables. We recognise that some countries (including for example Japan and Singapore) already have very significant supply of submarine cables, and that several of those cables have CASP investors. Where cables land in these markets, we have considered their impact (in these markets only) to be similar to *standard* cables, rather than the greater impact of *open* CASP cables. This is a conservative approach that leads to lower impacts of Google cables in markets such as Singapore and Japan.

Secondly, we determine what would have happened to these cables if Google did not invest in them. We have considered four possible outcomes:

- **No change**: cables in which Google is not the primary or anchor investor, and where other CASPs play a major role, could be deployed regardless of Google's involvement.
- **Deployment as *standard* submarine cables**: for systems where a consortium of telecom operators are involved, we have considered that Google's involvement would not be fundamental to the existence of the cable, but that without Google it would have been deployed as a *standard* cable.
- **No deployment**: in this case, the submarine cable system would not have been built at all without Google as an investor.

A.1.1 Choice of supply, demand, and endogenous growth model equations

Before we delve into each part of the estimation process, we first provide a brief background on why we modelled the process in the way we did and then briefly discuss the data employed in the analysis.

It is well known that consumer demand for the Internet is essentially a demand for speed, that is, how fast web pages load. Speed itself depends on both latency and bandwidth. The following quotes are representative.

"While bandwidth plays a big role in how fast webpages load, the journey from one machine to another takes time to traverse. No matter how much data you can send and receive at once, it can only travel as fast as latency allows."[41]

[41] Cody Arsenault – Understanding Network Bandwidth vs Latency, see: keycdn.com/blog/network-bandwidth

"True Internet speeds comes down to a combination of bandwidth and latency."[42]

Hence, on the supply side, we wanted to determine how investments in submarine cables affect latency and bandwidth by increasing the capacity for international connectivity.

Additionally, since demand also depends on retail prices to consumers and businesses, on the supply side, we estimate how investments in submarine cables affect IP transit prices. Despite the growing importance of direct peering relationships between ISPs and CASPs, IP transit remains an important component of retail Internet service, for which some price information is available, and where prices respond rapidly to the prevailing international connectivity environment. As a result, the price of IP transit is expected to impact retail prices to consumers and business. That is, a fall in IP transit prices typically leads to a fall in retail prices. We make this explicit in the model below.

On the demand side, we want to determine how (I) latency, (II) Internet bandwidth and (III) IP transit prices affect (IV) mobile data traffic[43]. This indicates how the impact of these variables affect Internet data traffic, including from those already using it. This enables us to determine how investments affect demand.

Finally, we then wanted to examine how changes in internet usage affect GDP. There are a number of existing models that have explored this relationship, which highlights the overall impact of Internet traffic on the economic performance of a country.

Thus we will estimate five equations: three supply equations, one demand equation, and an endogenous growth model equation.

A.1.2 Data

The data for this analysis consists of panel data from countries in the APAC region from the 2010-2019 period. Panel data involves repeated observations over time for the countries in the analysis. For some countries, we do not have complete observations on all of the variables. Hence, we have what is referred to as an "unbalanced panel". Fortunately, we have a fairly large data set, which enables relatively precise estimates of the key effects.

Having a panel rather than cross-sectional data is advantageous, since a cross-section cannot control for time-invariant 'country' effects; they are included in the error term in cross-sectional analysis.[44] If these unobserved effects are correlated with the right-hand-side variables, the estimates from the

42 Plug Things In – What is Latency – How is Latency Different from Bandwidth, see: plugthingsin.com/internet/speed/latency/

43 We do not have enough data observations to estimate fixed data traffic. This is not a problem because (I) mobile data traffic is increasing much faster than fixed data traffic and (ii) there is a high positive correlation between these variables.

44 Cross-sectional data are the result of a data collection, carried out at a single point in time on a statistical unit. See: https://www.statista.com/statistics-glossary/definition/357/coss_sectional_data/

cross-sectional analysis will be biased; however, we eliminate this problem by using "fixed-effect models."

A.1.3 Estimation

Our estimation covers three parts of the model.

- In section A.2, we estimate the supply-side impacts of an increase in submarine cable supply from investments in submarine cables on (I) latency, (II) Internet bandwidth and (III) IP transit prices.
- In section A.3, we then estimate the demand-side impact that latency, Internet bandwidth, and IP transit prices have on (IV) mobile data traffic.
- In section A.4, we estimate equation (V,) which measures the GDP per capita impact from an increase in mobile data traffic using an endogenous growth model.

A.1.4 Fixed Effects Models

We illustrate the importance of using a fixed-effect model by using as an example the demand model we employ for Internet data traffic:

$$\textbf{(IV)} \qquad \mathbf{R_{it} = \alpha_i + X_{it}\omega + \varepsilon_{it}.}$$

The variable R_{it} is annual Internet data traffic in country *i* in year *t* – i.e. the total internet usage of an entire country's population in a given year.

The vector $\alpha_i \equiv \alpha + A_i'\delta$ is such that α is a constant and A_i is a vector of unobserved time-invariant country factors. Given these unobserved time-invariant project factors, equation (IV) should be estimated using a fixed effects model in which $\alpha_i \equiv \alpha + A_i'\delta$ are parameters to be estimated.[45] The δ parameters are typically not of interest, but rather are controls.

The variables in X_{it} are observable time-varying country factors (like bandwidth and latency) and ω are parameters to be estimated. These parameters indicate the impact of the factors on Internet data traffic. Hence, the ω are parameters are the ones we are the interested in. Finally, ε_{it} is an error term.

We employ these fixed effect models for equations I-IV. In section A.4, we discuss the endogenous growth equations employed in equation (V).

45 As Angrist and Pischke note, treating α_i as parameters to be estimated is equivalent to estimating in deviations from the mean; see Angrist, J., and J. Pischke, 2009, 'Mostly Harmless Econometrics', Princeton University Press, Princeton, New Jersey.

A.2 Supply side estimation: How submarine cable supply affects (I) latency, (II) Internet bandwidth, and (III) IP transit prices

The goal in this section is to examine how submarine cable supply affect latency, Internet bandwidth, and IP transit prices.

We have three supply equations:

(I) Latency
(II) Internet bandwidth
(III) IP transit prices

A.2.1 Supply side: latency

We begin with equation I: latency. We use a log/log functional form which is typically employed in empirical work.[46]

$$\textbf{(I)} \qquad \mathbf{L_{it} = \alpha_i + \beta^* C_{it} + \delta^* P_{it} + \varepsilon_{it}.}$$

Where

- L_{it} is the natural logarithm of latency in milliseconds for round-trip time as of December of each year.
- C_{it} is the natural logarithm of the total number of international submarine cables (SMC in the country at a point in time: $Cit=\ln(SMC_{it} + 1)$
- P_{it} represents natural logarithm of the proportion of these cables that are 'CASP-invested cables'. To calculate this parameter, we first calculate the percentage of SMCs in country/territory i at time t in which a CASP is an investor, which we call $Q_{it.}$ If there are no cables with CASP investments at all in country/territory i at time t, this percentage is set equal to zero. G_{it} is the natural logarithm of "one plus Q_{it}:": $P_{it}=\ln(PSMC_{it} + 1)$

Recall that the "it" subscript means "in country i, in year t".

The results of estimating equation (I) are shown in the first regression in Figure A.1. The negative coefficient on the number of submarine cables makes sense. Latency (time) falls when the number of submarine cables increases. Further, latency additionally falls if the marginal cable is an open cable. The estimated coefficients in Figure A.1 are both statistically significant at the 99 percent level of confidence.

46 The coefficients (α β, δ etc.) in all of our equations are, of course, different. We use the same notation for simplification and clarity.

Since the variables are in (natural) logarithms, the coefficient is an elasticity and can easily be interpreted. For example, the –1.41 means that a one percent increase in the number of submarine cables reduces latency by 1.41 percent.

Further, even after controlling for the total number of cables, open cables provide additional benefits. In particular, a one percent increase in '1 + the percentage of "open" CASP-invested cables' reduces latency by an additional 3.73 percent.

A.2.2 Supply side: Internet bandwidth

We now estimate equation (II), the Internet bandwidth equation. We do this (A) using total Internet bandwidth (IBW) and (B) using Internet bandwidth per user (IBW_per). The results are qualitatively similar.

$$\textbf{(IIA)} \quad \mathbf{IBW_{it} = \alpha_i + \beta^*C_{it} + \delta^*P_{it} + \varepsilon_{it}.}$$

$$\textbf{(IIB)} \quad \mathbf{IBW\_per_{it} = \alpha_i + \beta^*C_{it} + \delta^*P_{it} + \varepsilon_{it}.}$$

Where

IBW_{it} = is the natural logarithm of the total used capacity of international Internet bandwidth as measured as the sum of capacity of all Internet exchanges offering international bandwidth.

IBW_per_{it} = is the natural logarithm of the total used capacity of international Internet bandwidth per user (as measured as the sum of capacity of all Internet exchanges offering international bandwidth divided by the number of users).

C_{it} and P_{it} are the same explanatory variables we used in equation (I).

The results of estimating equation (IIA) are shown in the second regression in Figure A.1. The positive coefficients on the number of submarine cables makes sense. Internet bandwidth increases when the number of submarine cables increases. Internet bandwidth further increases if the additional cable is an open cable. The estimated coefficients are statistically significant at the 99 percent level of confidence.

The results show that a one percent increase in the number of submarine cables increases Internet bandwidth by 4.11 percent. Further, even after controlling for the total number of cables, open cables provide additional benefits. In particular, a one percent increase in '1 + the percentage of "open" CASP-invested cables' increases Internet bandwidth by an additional 3.85 percent.

The results of estimating equation (IIB) are shown in the third regression in Figure A.1. The positive coefficients on the number of submarine cables makes sense. Internet bandwidth per user increases when the number of submarine cables increases. Internet bandwidth per user further increases if the additional cable is an open cable. The estimated coefficients are statistically significant at the 99 percent level of confidence.

The results show that a one percent increase in the number of submarine cables increases Internet bandwidth per user by 2.31 percent. Further, even after controlling for the total number of cables, open cables provide additional benefits. In particular, a one percent increase in the number of "open" submarine cables increases Internet Bandwidth by an additional 4.84 percent.

Adding the two coefficients together, a one percent increase in open cables increases Internet bandwidth per user by 7.15 (2.31+4.84) percent.

A.2.3 Supply side: IP transit price

We now estimate equation (III), the IP transit price equation.

$$\textbf{(IIIA)}\quad \mathbf{IP_{it} = \alpha_i + \beta{*}C_{it} + \delta{*}P_{it} + \varepsilon_{it}.}$$

Where

IP_{it} = is the natural logarithm of the IP transit price. This is the price for a data rate of 10Gbit/s averaged over all four quarters of each year.

C_{it} and P_{it} are the same explanatory variables we used in equation (I).

The results from equation (IIIA) are shown in the fourth regression in Figure A.1. The negative coefficient on the number of submarine cables make sense. IP transit prices fall when the number of submarine cables increases. The results show that a one percent increase in the number of submarine cables decreases IP transit prices by 2.66 percent.

Further, even after controlling for the total number of cables, open cables provide additional benefits. In particular, a one percent increase in in '1 + the percentage of "open" CASP-invested cables' reduces IP transit prices by an additional 2.41 percent.

We now repeat the estimation of the IP transit pricing equation (IIIB) using a log/linear functional form. This functional form is also common in empirical work. As we show below, the results using the two functional forms are very similar.

$$\textbf{(IIIB)}\quad \mathbf{IP_{it} = \alpha_i + \beta{*}SMC_{it} + \delta{*}PSMC_{it} + \varepsilon_{it}.}$$

Where

IP_{it} = is the natural logarithm of the IP transit price we used in equation (IIIA)

SMC_{it} is the total number of submarine cables in year t in country i.

$PSMC_{it}$ is the proportion of total cables that are open cables in year t in country i.

The results of estimating equation (IIIB) are shown in the second regression in Figure A.1. The negative coefficient on the number of submarine cables makes sense. IP Transit Price falls when the number of submarine cables increases. Further, IP Transit Price falls further if the additional cable is an open cable. As the Table shows, the estimated coefficients are both statistically significant at the 99 percent level of confidence.

Since the right-hand side variables are in totals, the coefficients are best interpreted at the means of the variables. For example, in the data, the average number of cables is approximately 10. Hence, an additional cable (which is approximately a ten percent increase) leads to a 20% percent decrease in IP transit prices.[47]

Note that the effect is fairly similar to the effect measured in the log/log equation (IIIA). From that equation a 10% increase in the number of cables leads to a 22 percent decrease in IP transit prices.

Further, even after controlling for the total number of cables, open cables provide additional benefits. Both of the estimated coefficients are statistically significant at the 99 percent level of confidence.

A table of the supply side regression results can be found below in Figure A.1. Note that all estimated coefficients are statistically significant at the 99% confidence interval

Figure A.1: Fixed effects supply side regressions: Explaining Latency, Internet bandwidth, and IP transit prices [Source: Analysys Mason, 2022]

	Regression I: Latency (log/log) Estimates (std. error)	Regression IIA: Internet bandwidth (log/log) Estimates (std. error)	Regression IIB: Internet bandwidth per user (log/log) Estimates (std. error)	Regression IIIA: IP transit prices (log/log) Estimates (std. error)	Regression IIIB: IP transit prices (log/linear) Estimates (std. error)
Standard SMC	-1.41 (0.15)	4.11 (0.33)	2.31 (0.31)	-2.66 (0.37)	-0.245 (0.029)
Open SMC	-3.73 (0.57)	3.85 (1.15)	4.84 (0.98)	-2.41 (1.03)	-2.48 (0.82)
Observations	179	167	159	118	118

A.3 Demand side estimation: How (I) latency, (II) Internet bandwidth, (III) IP transit prices affect, and (IV) mobile data traffic

In this section, we estimate the demand side equation for mobile data traffic that depends on the three variables modelled with the supply side equations: latency, Internet bandwidth, and IP transit prices.

47 This is calculated by exp(-0.22)=0.78 and 1-0.78=0.22

A.3.1 Demand side: mobile data traffic

We now estimate equation (IV), the demand side equation for mobile data traffic.

$$\textbf{(IV)} \qquad D_{it} = \alpha_i + \beta^* IBW_{it} + \gamma L_{it} + \delta IP_{it} + \varepsilon_{it}.$$

All variables are in natural logarithms.

Where

D_{it} is the total cellular data traffic (downstream and upstream) generated by all devices including fixed wireless devices in a given period. It includes both business and residential segments for country i at time t. We call this variable mobile Internet data traffic.

IBW_{it} is Internet bandwidth as defined above.

L_{it} is Latency as defined above.

IP_{it} is the price of IP transit, as defined above.

We make the following assumptions in order to be able to estimate equation (IV):

1. There is monopolistic competition in the provision of IP transit data. This means that the price (P_{it}) in country i at time t is a multiple (greater than one) of the marginal cost (MC) of the provision of IP transit data in country i at time t. While international services may have more market power in some countries, policy and regulatory pressures may take the place of competition in restraining the price.

2. The marginal cost (MC) of the provision of Internet service to business or residential segments is a constant (τ) multiplied by the price of IP transit data: $MC_{it} = \tau\ IP_{it}$,

3. We assume that there is also monopolistic competition in the provision of Internet service. Thus the price is a multiple of the marginal cost, where the multiple (ξ) is greater than one.

Taken together, these three assumptions mean that the price of the provision of internet service PIS_{it} is a multiple of the price of IP transit.

In other words, thus, $PIS_{it} = \xi * \tau * IP_{it}$ where the price of IP transit data itself is a function of its marginal cost.

We assume that the marginal costs are determined by technology, that is, marginal cost is exogenous to the equations we are estimating. This means that the retail price of the provision of internet service is exogenous. This is important because it means that we do not have simultaneous equations bias. Such bias occurs when the price is endogenous.

Now, of course we do not know ξ or τ. But since equation (IV) is in logarithms, note that $\ln(PIS_{it}) = \ln[\xi * \tau * IP_{it}] = \ln(\xi) + \ln(\tau) + \ln(IP_{it})$. Since $\ln(\xi)$ and $\ln(\tau)$ are constant, they become part of the coefficient of the constant and are not necessary for our estimation. Hence, we can estimate equation (IV) above without knowing ξ or τ.

The results of the estimation of equation (IV) are shown in Figure A.2. The coefficients on all of the explanatory variables make sense. Mobile internet data traffic increases when internet bandwidth increases. Controlling for this effect, mobile internet data traffic increases when latency decreases. Finally, mobile internet data traffic increases when the price falls.

The estimated 0.62 coefficient on internet bandwidth means that a one percent increase in Internet bandwidth per capita leads to a 0.62 percent increase in mobile internet data traffic. This estimated coefficient is significant at the 99 percent level of confidence.

Similarly, the estimated –0.57 coefficient on latency means that a one percent decrease in latency leads to a 0.57 percent increase in mobile Internet data traffic. This estimated coefficient is significant at the 99 percent level of confidence.

Further, the –0.58 coefficient on IP transit price means that a one percent decrease in IP transit price leads to a 0.58 percent increase mobile internet data traffic. This estimated coefficient is significant at the 99 percent level of confidence.

Figure A.2: Demand side regressions: Explaining (IV) Mobile Internet data traffic [Source: Analysys Mason, 2022]

	Regression IV: Mobile Internet data traffic Estimates (std. error)
Internet bandwidth	0.62 (0.11)
Internet bandwidth per user	
Latency	-0.57 (0.18)
IP transit price	-0.58 (0.15)
Observations	100

A.4 Approach to estimating traffic impact of Google's edge investments

In this section, we describe our approach and assumptions used to derive the economic impact of Google's investment in edge infrastructure in APAC.

Edge network investments affect Google traffic primarily. If Google had not invested in edge infrastructure, several scenarios are possible: a third-party may have done so and charged Google or ISPs for the caching service; ISPs may have had to carry the traffic at their own cost; or ISPs may have decided to constrain the amount of traffic they delivered to end users. In this last scenario, it is possible that ISPs would have chosen to pay to fetch Google's traffic from overseas PoPs, at the expense of other content. We have chosen to model a scenario whereby a proportion of mobile traffic, related to the proportion of Google traffic that is cached, would not be delivered by ISPs.

The model can be described in three parts:

- Part A: We first develop country/territory-level projections of traffic generated on mobile networks across APAC economies and estimate the share of Google traffic within mobile networks.
- Part B: Next, we estimate how Google mobile data traffic delivered in each country/territory is split into different traffic types that are served through (i) Google Global Cache nodes deployed in APAC (ii) Google PoPs deployed in APAC and (iii) Google PoPs deployed outside APAC.
- Part C: Lastly, we estimate the amount of mobile traffic that might be lost if the Google's network infrastructure were not present in APAC and run it through the endogenous growth model described in Annex NBED above.

A.4.1 Part A: Estimation of Google mobile date traffic in APAC

We first compiled the mobile data traffic across 20 APAC countries or territories, based on a variety of sources (Figure A.3), with a total estimate of 170EB generated across mobile networks in APAC for 2021 (Figure A.4).

Analysys Mason DataHub[48]	ITU[49]	Analysys Mason estimates[50]
Australia	Cambodia	Nepal
Bangladesh	Laos	Sri Lanka
Hong Kong	Myanmar	Brunei
Indonesia		Vietnam
Japan		
South Korea		
Malaysia		
New Zealand		
Pakistan		
The Philippines		
Singapore		
Taiwan		
Thailand		

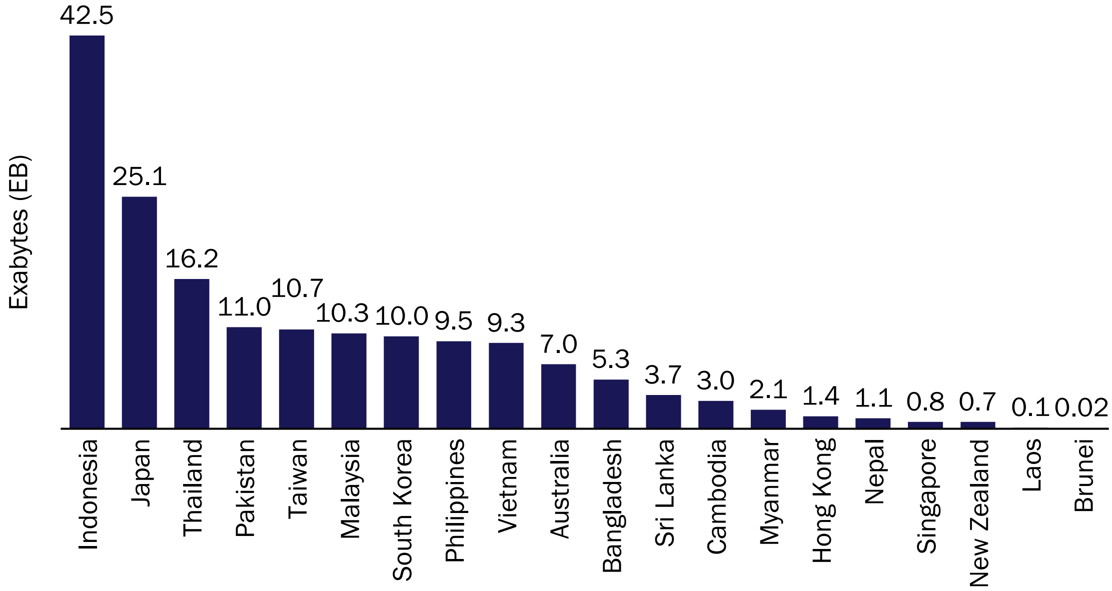
Figure A.3: Data sources on mobile data traffic in APAC [Source: Analysys Mason estimates, 2022]

48 From Analysys Mason DataHub; Definition: Total cellular data traffic (downstream and upstream) generated by all cellular devices (including fixed wireless devices). Excludes Wi-Fi offload. The sum of business and residential segments.

49 From ITU; Definition: Mobile-broadband Internet traffic refers to broadband traffic volumes originated within the country or territory from 3G networks or other more advanced mobile networks, including 3G upgrades, evolutions or equivalent standards in terms of data transmission speeds.

50 Analysys Mason bottom-up calculations based on subscriber and data usage estimates.

Figure A.4: Mobile data traffic in APAC countries in 2021 [Source: Analysys Mason DataHub, ITU, Analysys Mason estimates, 2022]



Based on research from Sandvine, around 40% of mobile network traffic is for Google services and we apply this percentage to the mobile data traffic shown above to derive the amount of Google mobile data traffic for each of the listed APAC markets.[51]

A.4.2 Part B: Estimation of Google mobile data traffic served through PoPs and caches

Once access to Google services is requested by a customer on the mobile network, the MNO will have to collect the content from Google through interconnecting with Google at the edge infrastructure. This can be in the form of cache nodes deployed by Google within the MNO's network or interconnection facilities in Google PoPs. If a Google PoP is available in the same country or territory, the MNO can readily collect the traffic from the in-country PoP with some costs incurred for domestic connectivity. However, if there are no Google PoPs available within the country or territory, the MNO will have to incur significantly higher international bandwidth costs to collect the traffic from a Google PoP in a nearby country or territory. Based on insights drawn from discussions with both MNOs as well as with the Google team, we applied the following assumptions on Google traffic for each APAC country or territory.

- Google Global Caches accounts for 65–75% of traffic, and countries/territories where content is primarily from a single-language other than English majority (e.g. Indonesia) typically have a higher cache rate.

[51] Sandvine - 2020 Mobile Internet Report; see: https://www.sandvine.com/phenomena

- In countries/territories where Google deployed PoPs, all of the remaining traffic not served through caches would be served through these PoPs.
- In countries/territories where Google does not currently have PoPs deployed, we assume that the majority of the remaining traffic is served through a PoP in a nearby APAC countries/territories with a small proportion (~2%) of traffic served through PoPs outside APAC (e.g. Pakistan collects traffic from the Middle East).

A.4.3 Part C: Mobile data traffic enabled by Google's edge infrastructure

Based on our discussions with MNOs, they typically have a fixed budget to manage bandwidth requirements, and the investments made by Google on caches and PoPs in APAC would therefore have enabled these operators to serve a greater volume of traffic that they would have been able to compared to the scenario where they had to collect the traffic from PoPs outside APAC. It is therefore reasonable to expect that a significant proportion of traffic would be lost if the investments had not been made by Google over the last ten years. We expect that, on a blended basis, around 45% of current Google mobile data traffic in APAC would be affected by these network infrastructure investments (this represents 18% of total data traffic based on Sandvine's estimates). The assumptions are listed below:

- ***Traffic served by APAC caches:*** Given that caches are deployed by Google within MNOs' networks, the expenses incurred by MNOs to serve this traffic are limited to the costs of supporting the operations and maintenance of the infrastructure. This is typically a trivial cost to the MNOs. In the absence of the cache infrastructure, MNOs would have to incur significantly higher costs to collect the traffic from a PoP and incur international bandwidth charges. We expect a significant proportion of traffic (~50%) to be affected.
- ***Traffic served by APAC PoPs:*** MNOs currently incur a mixture of domestic and international bandwidth costs to collect traffic from Google's APAC PoPs to serve traffic to end users. In the absence of the PoP infrastructure in APAC, MNOs would have to collect traffic from PoPs that are located further away, in Europe or the Americas. The additional costs incurred varies by the degree of connectivity of each market: MNOs in internet hubs (such as Singapore and Japan) would incur lower costs per unit of traffic to connect to markets outside APAC than an MNO in a less well-connected markets. Based on the varying cost of international connectivity for each APAC market, we expect 20–50% of traffic in each of the markets to be affected by Google's investments.

Finally, we pass the mobile data impact through the endogenous growth model discussed earlier in Annex A.3 in order to estimate the GDP impact from Google's edge network investments.

A.5 Endogenous growth model for estimating economic impact: GDP and job creation

A.5.1 Impact on GDP from change in mobile data traffic

Endogenous growth models became popular in the 1980s. Such models are different from traditional (classical) growth models because endogenous growth models assume that growth is an endogenous outcome, not the result of (say) external technological progress. Paul Romer provides a survey in the Journal of Economic Perspectives.[52]

In the telecommunications literature, endogenous growth models have been used to examine the relationship between changes in telecommunications use and economic growth.

The model we employ comes from an IMF paper by Andrianaivo and Kpodar (1994).[53] In that paper, they examined how ICT and financial inclusion affect economic growth in African countries. A modified version of the model used by Andrianaivo and Kpodar (2011) was also employed by in a Deloitte/GSMA study (2012)[54] in order to estimate the impact of mobile telephony on economic growth. Hence it seems natural to employ this model.

The model can be written

$$\textbf{(V)}\ \mathbf{Y_{it} = \alpha_i + \rho^* y_{i,t-1} + \beta D_{it} + \gamma X_{it} + \varepsilon_{it},}$$

Where

Y_{it} is the GDP per capita in country i at time t

$Y_{i,t-1}$ is the GDP per capita in country i at time t-1

D_{it} is the Internet data traffic from above.

For equation (V), total cellular data traffic (downstream and upstream) generated by all cellular

The variables we employ in X_{it} are:

Ratio_govt_gdp = the ratio of government expenses to GDP in country i at time t.

52 Paul Romer, 'The Origins of Endogenous Growth', 1994; see Journal of Economic Perspectives, Volume 8, Number 1, Winter 1994, pages 3–22.

53 Andrianaivo and Kpodar, 'ICT, Financial Inclusion, and Growth: Evidence from African Countries', 2011, see 'International Monetary Fund Working Paper'; https://www.imf.org/external/pubs/ft/wp/2011/wp1173.pdf

54 Deloitte/GSMA, 'What is the Impact of Mobile Telephony on Economic Growth', 2012; see: https://www.gsma.com/publicpolicy/wp-content/uploads/2012/11/gsma-deloitte-impact-mobile-telephony-economic-growth.pdf

Ratio_trade_gdp = the ratio of international trade to GDP in country i at time t

The unemployment rate = the number of people looking for work, divided by the sum of the number of people employed and the number of people looking for work.

These variables were also used in the Deloitte/GSMA (2012) model. Deloitte/GSMA (2012) use a six-year horizon for the estimation of the endogenous growth model. Hence, we include data from 2014-2019, which is also a six-year time horizon.

All of the variables are in natural logarithms. Hence, the coefficients can be interpreted as elasticities.

This is a dynamic panel data (DPD) model, since the lagged value of GDP ($Y_{i,t-1}$) appears on the right hand side. The empirical model we employ is due to Arellano and Bond (Rev. Ec. Stud., 1991)[55] and Holtz-Eakin, Newey and Rosen (Econometrica, 1988)[56]. It uses a Generalized Method of Moments (GMM) approach. It addresses the endogeneity problem of $y_{i,t-1}$.

By construction, the residuals of the differenced equation ($Y_{it} – Y_{i,t-1}$) should be auto-correlated of order one, i.e., an AR(1) process of serial correlation. But if the maintained assumption of serial independence in the original errors (ε_{it}) is true, the differenced residuals should not exhibit significant AR(2) behavior. If a significant AR(2) statistic is found, the second lags of the endogenous variable will not be appropriate instruments for their current values and we cannot use the model. This leads to a test, called the Arellano-Bond test, which we describe below.[57]

The results are shown in Figure A.5 below. For equation (V), since all of the variables are in (natural) logarithms, the coefficients have an elasticity interpretation. The estimate of our coefficient of interest is the one on mobile data traffic. The value of 0.015, which is significant at the 99% level of confidence, means that a ten percent increase in mobile data use leads to a 0.15% increase in GDP per capita. Controlling for data traffic, additional penetration does not lead to a significant increase in GDP per capita.

Figure A.5: Endogenous Growth Model: (V) coefficients for GDP per capita growth [Source: Analysys Mason, 2022]

	Regression V: GDP growth per capita Estimates (std. error)
GDP per capita (lagged)	0.70 (0.13)
Mobile data traffic	0.015 (0.0058)

55 Arellano and Bond, 'Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations', Apr 1991; see The Review of Economic Studies, Vol. 58, No. 2, pages 277–297.

56 Holtz-Eakin, Newey, and Rosen, 'Estimating Vector Autoregressions with Panel Data', 1988; see Econometrica, Vol. 56, Issue 6, pages 1371–95.

57 We employ the estimation procedure in Stata denoted "xtabond" to estimate the model and conduct the Arellano-Bond test. See https://blog.stata.com/2015/11/12/xtabond-cheat-sheet/

	Regression V: GDP growth per capita Estimates (std. error)
Ratio_Govt_GDP	−0.018 (0.030)
Ratio_Trade_GDP	0.021 (0.0092)
Employment rate	−0.055 (0.063)
Observations	72

For equation (V), the Arellano-Bond test for zero autocorrelation in first-differenced errors

Order	Z	Probability > Z
1	−1.89	0.059
2	−1.34	0.18

Figure 6.6: Equation (V) – Arellano-Bond test for zero autocorrelation in first-differenced errors [Source: Analysys Mason, 2022]

Since we cannot reject the null hypothesis that there is second order autocorrelation, the assumptions of the model hold.

A.5.2 Impact on jobs supported by the increase in GDP

Our approach to estimating the impact of Google's network infrastructure investments on jobs involves three key steps:

- Part A: We first translate the GDP impact into the gross-value-added (GVA) impact
- Part B: Next, we estimate the average GVA per job affected by Google's investments in network infrastructure
- Part C: Lastly, we estimate the job impact by dividing the GVA impact by GVA-per-job assumptions.

A.5.3 Part A: Estimation of GVA impact

We first estimate the GVA effect of the GDP impact calculated above, for each country/territory, using a GDP-to-GVA ratio.[58] This allows us to relate economic impact at national level to an industry-level metric which is more directly related to factors of production including labour and therefore jobs. For forecast years, we use the 2020 GDP-to-GVA ratio.

58 Gross value added (GVA) is a measure of contribution to GDP made by an individual industry; GDP-to-GVA ratio is derived from Euromonitor's database.

A.5.4 Part B: Estimation of GVA per job

Next, we estimate the GVA per job with weighting on industries likely to be most affected by developments in broadband connectivity, for each country/territory, in each year. Equinix's Global Interconnection Index[59] suggests that the primary beneficiaries of an increased consumption of Internet data traffic are likely to be the 'manufacturing', 'transport, storage and communications' and 'financial intermediation' industries.[60]

A.5.5 Part C: Estimation of job impact

Lastly, we divide the GVA impact by the calculated GVA per job for each country to estimate the number of new jobs that have been created with the higher GVA. The GVA per job estimates at a country level account for general growth in productivity, in-line with overall economic growth. These country-level job impact estimates are then aggregated to form the overall job impact of Google's submarine cable investments. We recognise that improving digital connectivity could result in a further increase workforce productivity and therefore additional increase in GVA per job. Without estimating the further increase in GVA per job caused by this productivity boost, we arrive at an upper bound of the number of jobs supported by the additional GDP enabled.

A.6 Range of impact scenarios on GDP and job creation

Given that the equations derived from the econometric modelling are based on historical data from 2010 to 2020, we have elected to choose a more conservative value of the coefficients within the 95% confidence interval range for the various supple-side and demand-side equations to simulate the impact of Google's submarine cable investments in future years. This is also driven by the fact that there will be other non-Google cables launching in the future in similar countries which have yet to be announced. For the avoidance of doubt, the coefficients that we have used in our modelling are provided in Figure A.7 below and the range of GDP and job impact between the scenario adopting the most conservative coefficients and the average coefficients are provided in Figure A.8 below.

Variables	Value of coefficients
Supple-side model	
Standard/open cable impact on Bandwidth	3.462839/1.585288
Standard/open cable impact on Latency	-1.105649/-2.60972
Standard/open cable impact on IP transit price	-0.1868731/-0.8565534
Demand-side model	
Bandwidth impact on mobile data traffic	0.624847
Latency impact on mobile data traffic	-0.2032615

Figure A.7: Coefficients of variables in base case [Source: Analysys Mason, 2022]

59 Equinix – "Global Interconnection Index"; see https://www.equinix.com/gxi-report/

60 Based on the list of industries available as part of Euromonitor's gross value-added dataset

IP transit price on mobile data traffic	–0.27969
Endogenous growth model	
Mobile data traffic impact on GDP	0.00979005

Scenario	2022-2026 GDP impact	Jobs supported in 2026
Most conservative value for coefficients	145 billion	0.81 million
Analysys Mason base case coefficients	627 billion	3.5 million
Average value for coefficients	2 229 billion	13 million

Figure A.8: Range of output on GDP and job impact [Source: Analysys Mason, 2022]