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Economic impacts of subsea cable deployment

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ABSTRACT

This paper provides a comprehensive empirical analysis of the economic impact of submarine cable (SMC) infrastructure, which is critical for global digital connectivity and carries almost all intercontinental data traffic. Despite their fundamental role in the digital economy, robust evidence on the economic returns of SMC investments is very scarce. To address this, we use a panel dataset of developed countries and causal identification strategies, such as two-way fixed effects models and instrumental variables exploiting exogenous variation from factors like a country's coastline length and legacy market competition. In our empirical analysis we first describe how international bandwidth (IBW) can be used as a proxy for SMC capacity and examine how it affects domestic broadband quality levels. We then quantify the impact on broadband demand, finding distinct yet robust demand elasticities for mobile and fixed services. We find that a 1% increase in IBW drives an increase in mobile broadband adoption between 0.049% and 0.081%, while the increase for fixed broadband adoption ranges between 0.056% and 0.061%. Finally, we translate these estimates into a simple cost-benefit framework using an illustrative transatlantic cable project connecting Ireland and the United States. This analysis shows that the substantial GDP spillovers overwhelmingly exceed the total private deployment costs. Our findings affirm that SMC deployments generate significant positive externalities and high social returns. While it has been argued in the previous literature that these effects are critical to developing nations lacking infrastructure, our findings indicate this effect is also applicable to advanced economies. Consequently, we argue that policymakers in coastal nations, regardless of their level of development, have a strong economic incentive to facilitate private investment by reducing regulatory barriers and transaction costs associated with, for example, cable permits and landing stations.

1. Introduction

Digitization has rapidly expanded across nearly all sectors of the economy and society, especially in the last twenty years. Global

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consumer IP data traffic, as an indicator of the digital economy, more than tripled between 2017 and 2022, growing from 100 to 333 exabytes[1] per month.[2] Projections suggest that data consumption will increase twentyfold by 2030 (Copenhagen Economics, 2021). This surge is largely fueled by popular online services, such as video streaming platforms (e.g., Netflix, Amazon Prime, YouTube), video conferencing tools (e.g., Zoom, Microsoft Teams, FaceTime), IPTV and mobile "apps", which have become central to the internet experience and the digital economy. With the continued expansion of 5G and fiber-optic networks and emerging bandwidth-intensive or real-time applications like augmented and virtual reality, artificial intelligence (AI), automation, the Internet of Things (IoT), cloud computing and online gaming, the demand for increased internet capacity is expected to grow even more.

The internet infrastructure is a complex system that connects content and services from data centers to billions of end-user devices, relying on access networks, backbone networks, and submarine cables to enable global communication and data transfer. All these infrastructure components are essential for maintaining the reliability, speed, and reach of the internet, thereby further enhancing the development of new digital services and applications worldwide. The critical role of resilient and adaptable digital infrastructures was particularly evident during the COVID-19 pandemic when large-scale shutdowns of traditional economies took place. Thanks to the broad-scale availability of modern internet infrastructures, a large part of the socio-economically important interactions could be continued online on the basis of digital services (such as teleworking, telemedicine, e-government, distance learning and schooling, but also entertainment services such as streaming or gaming).

Most online content is stored at data centers today,[3] and nearly all (99%) of intercontinental data traffic is transported via submarine cables (Brake, 2019; RTI International, 2021).[4] Submarine cables (SMC) are crucial components of internet infrastructure, linking continents, islands, countries, and regions across oceans. They form the core infrastructure for nearly all international data traffic, enabling the transfer of content stored in data centers worldwide. As such, SMC are integral to global internet connectivity, serving as its backbone and directly influencing the user's quality of experience (QoE). SMC have also gained geopolitical relevance. In a recent decision, the U.*S. regulator*, the Federal Communications Commission, ruled to boost SMC investments for faster AI infrastructure development, while at the same time protecting SMC from foreign threats.[5] Similarly, in order to increase submarine cable security, the European Commission recently provided €347 million for strategic submarine cable projects.[6]

SMC consist of bundled fiber optic connections, utilizing advanced transmission technologies and protective layers, and are laid along the seabed. Landing stations constitute complementary investments and connect SMC to terrestrial fiber-cable based backbone networks. Currently, there are 597 active or under-construction SMC systems globally with 1712 landing points.[7] To meet the growing demand for connectivity, major content providers ("Big Tech") like Amazon, Google, Microsoft, and Meta have invested heavily in private SMC in more recent years, securing crucial routes for delivering their own content services to data centers. In fact, these big tech operators are playing an increasingly important role as buyers and investors of international bandwidth. From 2005 to 2021, the global share of international bandwidth demanded by large content providers increased from around 5% to 69%, while the proportion of new SMCs deployed by content providers rose from 3.5% in 2010 to 24.4% in 2021 (Caoui & Steck, 2025).

Given the importance of SMC as the backbone of all global communication networks, it is relevant to raise the question of what the economic impact of additional SMCs is, in terms of GDP spillovers. To answer this research question, we propose testable hypotheses from the related research literature. We proxy SMC capacity through the international bandwidth (IBW) indicator reported by the ITU. In order to identify causal effects, we employ panel data estimation techniques such as two-way fixed effects estimation, Granger causality analysis and instrumental variables. Exogenous sources of variation are derived from legacy-based competition in broadband markets, benchmarking effects from neighboring countries as well as the length of a country's coastline. Our empirical analysis was conducted using 2005-2023 data for a group of developed countries. Our results confirm that IBW has a positive and significant impact on broadband speed, and we find that a 1% increase in IBW increases mobile broadband adoption by a range of 0.049% to 0.081%, while a 1% increase in IBW increases fixed broadband penetration by approximately 0.056% to 0.061%. Furthermore, we relate our estimation results to an illustrative real-world SMC deployment project connecting the US with Ireland. Using industry benchmarks and estimation results from the related literature and our own empirical analysis enables us to conduct a basic cost-benefit analysis, and based on this, to derive policy recommendations. These policies should consider measures to facilitate additional SMC deployment and site landings, as well as reducing regulatory transaction costs, while not overlooking important policy-relevant trade-offs associated with security and environmental impacts.

The study is structured as follows: Section 2 provides an overview of the key institutional background and the conclusions from related empirical literature on the extent to which additional capacity brought by a new SMC translates into economic benefits. Section

[1] One exabyte is a massive unit of digital storage, equivalent to 1,000,000,000,000,000,000 bytes.

[2] Information available at: https://www.cisco.com/c/dam/m/en_us/solutions/service-provider/vni-forecast-highlights/pdf/Global_Device_Growth_Traffic_Profiles.pdf.

[3] Information available at: https://www.statista.com/statistics/227268/global-data-center-ip-traffic-growth-by-data-center-type/.

[4] Information available at: https://www.iss.europa.eu/publications/briefs/changing-submarine-cables-landscape#:~:text=The%20rapid%20development%20of%20digital,communications%20and%20the%20internet%20economy. In principle, satellite-based communication is an alternative technology. However, SMC are significantly less expensive and at the same time offer higher transmission quality in terms of higher bandwidth and lower latency (Europe.connected, 2021). Satellite-based transmission paths should therefore be seen as complementary rather than substitutes for SMC, especially for connecting very remote regions.

[5] Information available at: https://docs.fcc.gov/public/attachments/DOC-413027A1.pdf.

[6] Information available at: https://digital-strategy.ec.europa.eu/en/news/commission-increases-submarine-cable-security-eu347-million-investment-and-new-toolbox.

[7] Information available at: https://submarine-cable-map-2025.telegeography.com/.

3 introduces the dataset to be used in the empirical analysis. Section 4 describes our research strategy. Section 5 presents our main estimation results concerning the impact of international bandwidth capacity on domestic broadband quality and adoption. Section 5 also contrasts the economic benefits generated with the costs of SMC deployment. These findings form the basis of our policy recommendations, which are presented alongside our main conclusions in Section 6.

2. Literature review, institutional background and hypotheses

In this section, we first review the relevant literature on the impact of broadband networks, with a particular focus on submarine cables in Section 2.1. Since the main expected economic impact of an SMC is through changes in the quality and adoption of domestic broadband, evidence on the economic impact of domestic broadband networks is relevant to this study. Next, in Section 2.2, we outline the institutional background and characteristics of the SMC industry. Based on this, we derive testable hypotheses at the end of the section.

2.1. Literature review

2.1.1. Research literature on broadband economic impact

Research on the economic contribution of SMC represents a subset of empirical research that examines the impact of broadband Internet adoption or quality on outcome variables such as gross domestic product (GDP), labor market effects (such as employment and labor productivity), and consumer surplus. Most research studies focus on broadband access network data, such as bandwidth or speed and the number of connections in broadband access networks (either deployed, which means coverage, or adopted by consumers), as they are relate to consumer adoption and usage decisions, which are, in turn, output-oriented and hence directly relevant to economic welfare.

The empirical literature on the economic impact of broadband networks is extensive and has been summarized in several articles reviewing the research. Bertschek et al. (2015) and Gómez-Barroso & Marbán-Flores (2020) examined the effects of basic or "older" broadband networks on various economic outcomes. Abrardi and Cambini (2019) provide a review of some of the earlier empirical studies using data on fiber-optic broadband networks. The most comprehensive and recent literature review, focusing on the economic impact of new wireline or wireless broadband networks, is provided by Briglauer et al. (2024). Studies on the economic effects of broadband networks typically concentrate on the following key variables: GDP, productivity, employment and consumer surplus. Most of these empirical studies use panel data from multiple countries, over varying time periods. While sharing a consensus about the economic contribution of broadband networks, it is important to note that the studies reviewed are not directly comparable due to differences in measurement units, broadband data used, and underlying quality levels of broadband technologies. For instance, studies based on broadband adoption data assess the GDP increase linked to new user adoption ("extensive margin"), while those using bandwidth data estimate the impacts of improvements in broadband quality on usage ("intensive margin"). In alignment with previous reviews, Briglauer et al. (2024) found that new broadband networks exert a positive and significant impact on GDP at the aggregate level, based on country-year panel data. Like the earlier studies on basic broadband, the authors also find strong evidence supporting the positive effects of new broadband networks on productivity. However, these effects can vary by industrial sector and may take time to materialize, often requiring complementary strategic and organizational investments. This finding aligns with broader research on ICT and productivity (Cardona et al., 2013; Jung & Gomez-Bengoechea, 2025), which indicates that the productivity impact of ICT grows over time and requires organizational investments, skills, and industry-specific adjustments.

2.1.2. Research literature on the economic impact of SMC

While research using data on broadband access networks estimates direct economic effects, studies of SMC quantify an indirect effect of a relevant input factor on the economic outcome variable. The indirect economic impact of SMC has been mostly assessed with regard to GDP.[8] A few studies also examine the impact of SMC on domestic broadband market indicators.

2.1.2.1. Impact on gross domestic product. Table 1 summarizes the main empirical contributions relating SMC deployment to GDP. All empirical contributions on the economic impact of SMC point to positive and significant effects on GDP or GDP per capita (p.c.).

As indicated in Table 1, the studies conducted by Analysys Mason (2021, 2022) provide the most explicit estimation of SMC economic effects and are the closest to our own methodological approach. According to their 2021 study, a 1% increase in SMC deployment drives a 4% increase in Internet bandwidth capacity in the backbone networks. This, in turn, yields an increase in the domestic mobile adoption rate and in mobile data usage between 0.15% and 0.62%, for a 1% increase in internet broadband capacity. These effects ultimately lead to an increase in GDP per capita (0.015% increase in GDP per capita for a 1% increase in usage).

While most studies of SMC economic impact use data from developing countries, RTI International (2021) is the only exception, where the authors rely on OECD data and find that a 1% increase in fixed broadband adoption, which is partly driven by internet bandwidth effect and reduced latency, increases GDP per capita by 0.023%. That said, the effect of broadband in advanced economies continues to be very significant as also evidenced in empirical studies using broadband access network data. The coefficient of OECD

[8] A few studies examine the impact of SMC deployment on trade flows, which are a key determinant of a country's GDP (Cariolle & da Piedade, 2023; El-Sahli, 2020; Imbruno et al., 2022).

Table 1
Studies of SMC impact on GDP.

Author(s)	Geography and time of dataset	Methodology	Outcome variables	Results
RTI International (2020a)	Africa (2023-2027)	• Expert interviews • External forecasts	**GDP p.c.** as a result of increase in broadband connections	Increase in GDP p.c. from 0.03% to 0.05% increase in fixed broadband connections, and 0.38%-0.54% for increase in mobile broadband connections.
RTI International (2020b)	Six Sub-Saharan African countries (2009-2017)	• Difference-in-differences • Synthetic Control Group	**GDP p.c.**	Impact varies widely, ranging from 6.1% increase in South Africa to 19% in Democratic Republic of Congo.
RTI International (2020c)	Malaysia (1992-2017)	• Structural model • Synthetic Control Group	**GDP p.c.** via international bandwidth consumption and broadband adoption	0.24% increase in GDP p.c. for every 10% increase in international bandwidth consumption and 0.19% increase in GDP p.c. for every 10% increase in broadband adoption.
Analysys Mason (2021)	Five Asia Pacific countries (2010-2019)	• Fixed effects • Generalized method of moments	**GDP p.c.** via increase in Internet bandwidth capacity, increase in mobile data use/adoption	Increase in SMC by 1% yields a 4% increase in Internet bandwidth capacity, 1% increase in Internet bandwidth per user leads to a 0.15% increase in broadband adoption, and 0.62% increase in the mobile data adoption rate, 1% increase in mobile data use leads to a 0.015% increase in GDP p.c.
Copenhagen Economics (2021)	Portugal (2022)	• Calculation based on Analysys Mason (2021)	**GDP**	Increase of 1% in the number of subsea cables increases GDP by 0.25%, disaggregated by internet bandwidth effect and reduced latency.
RTI International (2021)	22 OECD states (2018) projection (2024-2027)	• Structural model • Expert interviews	**GDP p.c.**	SMC leads to an increase in broadband adoption of 3.9%, resulting in GDP increase of 0.090% in GDP p.c.
Analysys Mason (2022)	Latin America & Caribbean countries (2010-2020)	• Fixed effects • Generalized method of moments	**GDP p.c.**	1% increase in mobile data use leads to 0.0075% increase in GDP p.c., while 1% increase in adoption rate leads to 0.016% increase in GDP p.c.
Simione and Yiruo (2021)	33 Sub-Saharan African countries (2005-2017)	• Fixed effects • Instrumental variables	**GDP p.c.**	Each percentage point increase in internet adoption induced by SMC capacity leads to 0.37 percentage point increase in real GDP p.c. growth.

Source: Own presentation

impact found in RTI International (2021) is very similar to the corresponding estimates in Briglauer and Gugler (2019), who also relied on OECD panel data on broadband access networks, which range from 0.024 to 0.026%. Katz and Jung (2022) also verified a rather high GDP contribution (0.139) using US states data. Finally, based on OECD panel data for the years 2002 to 2020, Briglauer et al. (2025) are the first to examine the causal impact of both broadband coverage and adoption on economic outcomes. Moreover, the authors are the first to simultaneously consider the impact of both new wireline broadband based on fiber-optic technologies and wireless (mobile) broadband based on 3G+/4G technologies. Coefficient estimates in Briglauer et al. (2025) range from 0.024 to 0.034% for fixed broadband adoption, and from 0.084 to 0.113% for mobile broadband adoption, respectively.

2.1.2.2. Broadband market effects. There are a few studies that focus on specific broadband market outcomes (such as quality and price): Hjort and Poulsen (2019) found that SMC increased measured speed in connected locations, relative to unconnected locations, by around 35% for a set of African countries. Cariolle (2021) employs data for 45 sub-Saharan African countries covering the period of 1990–2014. The author found that the rollout of SMC has yielded a 3–5 percentage point increase in Internet adoption rates in the treated region compared to non-treated countries. Cariolle et al. (2024) used panel data for 150 countries and found that doubling the international bandwidth resulting from SMC deployments leads to up to a 14% drop in fixed broadband price, and up to 21% drop in the mobile broadband price. The impact on fixed broadband price increases to 14%, 3 years post-expansion, before stabilizing around 7%-8% thereafter, while the impact on mobile broadband price drops to around 11%, 2 years post-expansion and continues dropping towards a non-significant impact 5 years post-expansion.

2.1.3. Conclusions from empirical literature

The review of the research literature shows that most studies focus on GDP and GDP per capita impact. A few studies also examine other broadband market effects such as pricing or service quality, suggesting that SMC lower prices and increase speed. Regarding GDP effects, most studies find positive and significant effects of SMC on GDP or GDP per capita. It appears that the deployment of SMC is highly relevant in developing countries, which exhibit much lower broadband adoption and usage rates and thus experience even higher incremental macroeconomic effects related to the initial or additional landing of SMC capacity. That said, the study of the contribution of SMC in advanced economies is still very limited. Moreover, the studies by Copenhagen Economics (2021) and RTI International (2021) are based on arithmetic inferences rather than causal analysis. We aim to fill this research gap using panel data from advanced economies. In light of this lack of rigorous econometric assessment work, the following study is the first one to consider the impact of SMC on both mobile and fixed broadband quality levels as well as mobile and fixed broadband demand using various panel estimation methods.

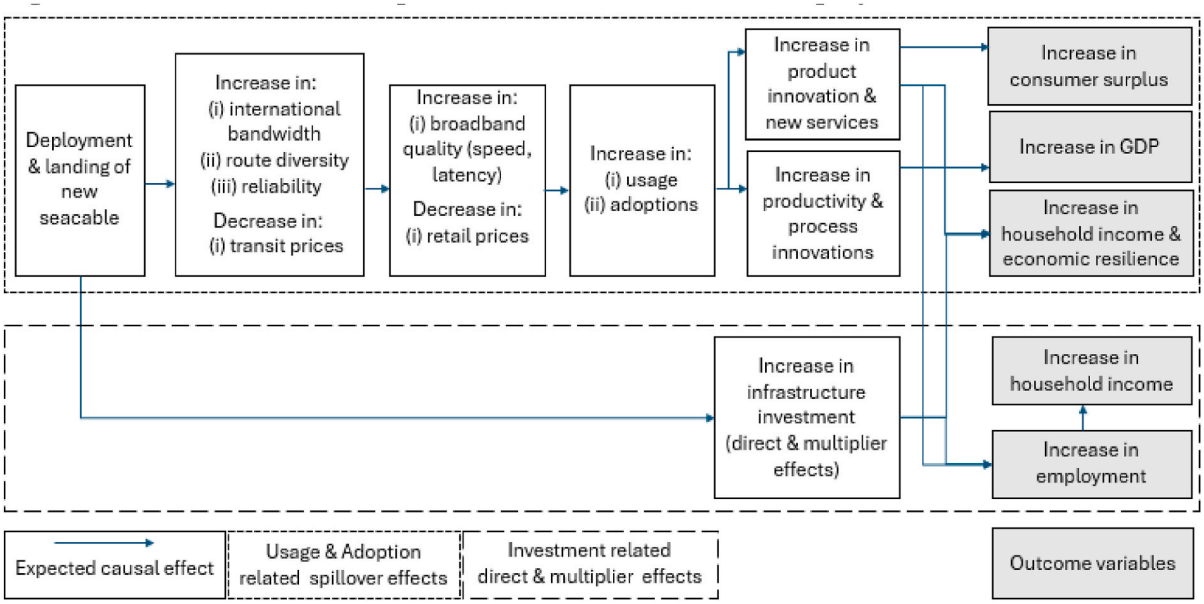


Fig. 1. Investment and adoption related effects of SMC deployment.
Source: Authors derived from Analysys Mason, 2021, 2022; Briglauer et al., 2024; Katz & Callorda, 2020.

Along these lines, Fig. 1 below summarizes the anticipated effects and mechanisms resulting from the deployment of additional SMC capacity and landing stations.

Next to the investment-related GDP effects (shown in the lower part of Fig. 1), there are indirect effects arising from an SMC-landing-induced increase in international bandwidth capacity (shown in the upper part of Fig. 1). The latter increases the quality of domestic broadband services via lower latency, higher bandwidth and higher reliability of services. These quality features are crucial to meet the increasing demand for data-heavy and real-time applications and services. At the same time, the increase in wholesale capacity should lower wholesale prices for IP transit which will also lower retail prices to some extent. These effects will jointly drive an increase in the adoption of broadband connections from consumers. New adoption of high-quality broadband connections enhances the use of various business and residential applications, which in turn increases consumer utility in terms of household income and leisure time, as well as product innovation, technological progress, and productivity improvements in firms, ultimately influencing GDP. Additionally, broadband Internet contributes to economic and societal resilience during major economic crises, influencing both GDP and consumer well-being. Finally, broadband service usage directly increases consumer surplus, a significant socio-economic benefit that is not captured by GDP measurements.

Summarizing, the broadband capacity made available by SMC serves as a fundamental infrastructure necessary for realizing welfare effects. Based on our literature review and the discussion of economic channels, we can derive the following testable hypotheses:

H1. An increase in IBW due to SMC deployment has a direct positive impact on domestic broadband quality levels.

H2. An increase in IBW has an indirect positive impact on domestic broadband adoption.

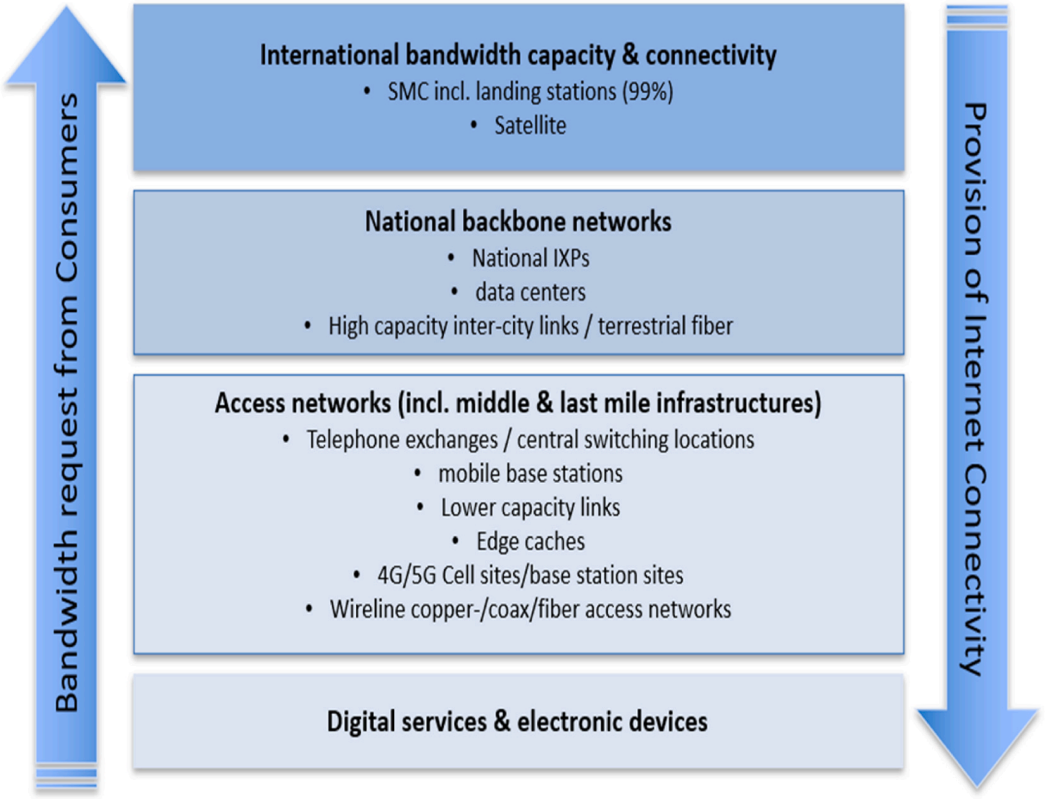


Fig. 2. Investment and adoption related effects of new SMC.
Source: Authors based on Cariolle (2021).

2.2. *Institutional background*

SMC are a core component of the internet infrastructure which is a complex and hierarchical system of complementary networks that includes access and backbone networks hosting large-scale core data centers and edge network elements such as points of presence (PoPs) and data exchange (IXP) and cache nodes for local storage of content close to end-users. Data traffic generated from various consumers' electronic devices travels through the access network[9] and typically through regional and national backbone networks[10] before entering international backbone networks via SMC for global connectivity.

Fig. 2 below illustrates the hierarchy of network infrastructure components of the Internet connectivity value chain, with international bandwidth capacity provided by SMC at the top and the bandwidth requirements generated by digital services and end-user electronic devices at the bottom of the value chain.

The deployment of SMC and coastal landing stations represents a significant investment within the internet infrastructure value chain. Average deployment costs vary widely, although standard communication SMC cost between $30,000 and $50,000 per km.[11] Due to these high deployment costs, SMC have been funded in the past by private-public partnerships or consortia of telecommunications network operators and other partners who then sell international bandwidth capacity. More recently, however, Internet

[9] Access networks refer to the portion of the internet infrastructure that connects end-users (households and businesses) to the local internet access service provider (ISP). These networks enable the delivery of broadband services such as video streaming, IPTV, online gaming, cloud computing or e-government and many other data services to homes, businesses, and institutions.

[10] Backbone networks constitute the central component of the terrestrial internet infrastructure, linking disparate regions and nations. They form the core of the terrestrial network infrastructure and are responsible for facilitating high-speed and reliable communication between various subnetworks. They facilitate high-speed, long-distance data transmission between numerous ISPs, data centers, and consumers. Internet backbone providers (IBPs) manage key network hubs and data centers, which are interconnected to form a network of networks. Data centers are strategically situated near end-users to minimize latency, ensuring efficient delivery of real-time critical or bandwidth demanding services and applications. IBPs predominantly employ modern high-capacity fiber optic cables and wireless technologies between towers to handle substantial data volumes over extensive distances.

[11] Information available at: https://www.thematica.com/the-under-the-surface-technology-thats-connecting-the-power-sector-to-a-cleaner-energy-future/#:~:text=Distance%3A%20AC%20submarine%20cables%20are,over%20%242.5%20million%20per%20km.

companies, such as Google, Meta, and Amazon Web Services have started deploying SMC. Although private players typically self-deploy SMC for serving their own data traffic, this also has a positive contribution to other operators (and consumers) demanding bandwidth capacity, as it increases overall capacity, lowers the potential for network congestion and reduces wholesale prices for IP transit services and ultimately also retail prices for end-users (Analysys Mason, 2022).[12] The ability to distribute capacity among various SMC enables operators to transfer capacity to different routes or cables efficiently, thereby optimizing bandwidth allocation.

The four largest companies building SMC are Alcatel Submarine Networks of Alcatel-Lucent, based in France, SubCom of Cerberus, a US based infrastructure fund, NEC Corporation of Japan and HMN Tech form China.[13] Despite the limited number of suppliers and network operators, the market appears to be competitive. In particular, there is a strong negative correlation between SMC capacity and international bandwidth prices. Based on past investment activities and efficiency gains in data transmission, unit costs have fallen 10-fold: compounded annually from 2016 to 2020, weighted median 10 Gbps and 100 Gbps prices fell an average of 14% and 23%, respectively, across critical global routes (Europe.connected, 2021). Competitive prices result from the specific cost structure with very low marginal costs and largely sunk fixed costs (Analysys Mason, 2022). Finally, the industry is also characterized by a high level of competition in terms of innovation, including ongoing improvements to increase capacity, reduce physical size and improve reliability of components (Copenhagen Economics, 2021).

3. Dataset

The main empirical models will be estimated based on country-level panel data covering years from 2005/2017 to 2023.[14] The focus of our analysis is the subgroup of a maximum number of 45 advanced countries within those with information available, given the limited evidence in literature on the contribution of SMC to high-income economies. We limit the set of advanced countries according to GDP per capita levels, for the case when this indicator is above the grand mean of the entire sample (GDP per capita in constant USD $>$ 19,120).

We combine several publicly available data sets (such as GSMA Intelligence, ITU Data Hub, OECD Stat, World Bank, Ookla/Speedtest, IMF, PWT, UNESCO) and proprietary data (such as calculations of Herfindahl–Hirschman Index based on market shares). Definitions, sources and descriptive statistics of all variables, including control variables, are provided in detail in Tables A.1 and A.2 in the Appendix.

3.1. Dependent variables

Our estimates will consist of identifying the effects of IBW on broadband quality and on adoption levels. The dependent variables for broadband quality models will consist of broadband download speed. These indicators measure the average of the median values of the fixed and mobile broadband speed (in bps) measured in the 12 months of the year.

The dependent variables measuring wireline and wireless broadband demand are defined as the log of the total number of fixed broadband and mobile broadband connections including all relevant basic and fast broadband access technologies, respectively.

3.2. Main independent variable

Our main explanatory variable, international Internet bandwidth, denoted with IBW, that has been employed in most empirical studies reviewed in Section 2.1.2, is provided by ITU and is defined as follows: "*total used capacity of international Internet bandwidth, in bits* per *second* per *Internet user. Used international Internet bandwidth refers to the average traffic load (expressed in Mbit/s) of international fiber-optic cables and radio links for carrying Internet traffic. The average should be calculated over the* 12-month *period of the reference year and should take into consideration the traffic of all international Internet links*."[15] Although most of the studies reviewed in Section 2.1.2 use this metric as a proxy for SMC capacity, there is no explicit reference to SMC in the ITU definition above. However, on p. 72 of the "Handbook for the collection of administrative data on telecommunications/ICT"[16] it is stated that (emphasis added by authors): "*Over the last few years international bandwidth capacity around the globe has increased significantly. Growth has been driven by the need to* support *ever growing data traffic much of it exchanged between data centers and end users from across the globe. The* ***vast majority of international Internet traffic flows over optical fiber SMC."***

Some authors (e.g., Cariolle, 2021) used the absolute number of SMCs as an alternative measure. While this measure does not account for technological upgrades or changes in capacity, IBW measures reflect capacity but miss other dimensions of SMC network connectivity. In fact, the number of SMC is a broader proxy for international connectivity. This variable not only reflects capacity, but

[12] These actors could de facto and de jure restrict access to the increased capacity, as there are no regulatory wholesale access obligations. This would allow them to limit access to their own services or customers. Nevertheless, private actors are still incentivized to monetize excess capacity by selling it to third parties.

[13] Information available at: Safeguarding Subsea Cables: Protecting Cyber Infrastructure amid Great Power Competition; 2025/21 "The Struggle for Subsea Cable Supremacy in Southeast Asia: ASEAN Relying on Diverse Suppliers" by Cha Hae Won – ISEAS – Yusof Ishak Institute.

[14] Note that we do not have balanced data, and we only have data for broadband quality indicators for the period 2017 to 2023.

[15] Long definition available at: https://databank.worldbank.org/metadataglossary/world-development-indicators/series/IT.NET.BNDW.PC-.

[16] Information available at: https://www.itu.int/en/ITU-D/Statistics/Documents/publications/handbook/2020/ITUHandbookTelecomAdminData2020_E_rev1.pdf.

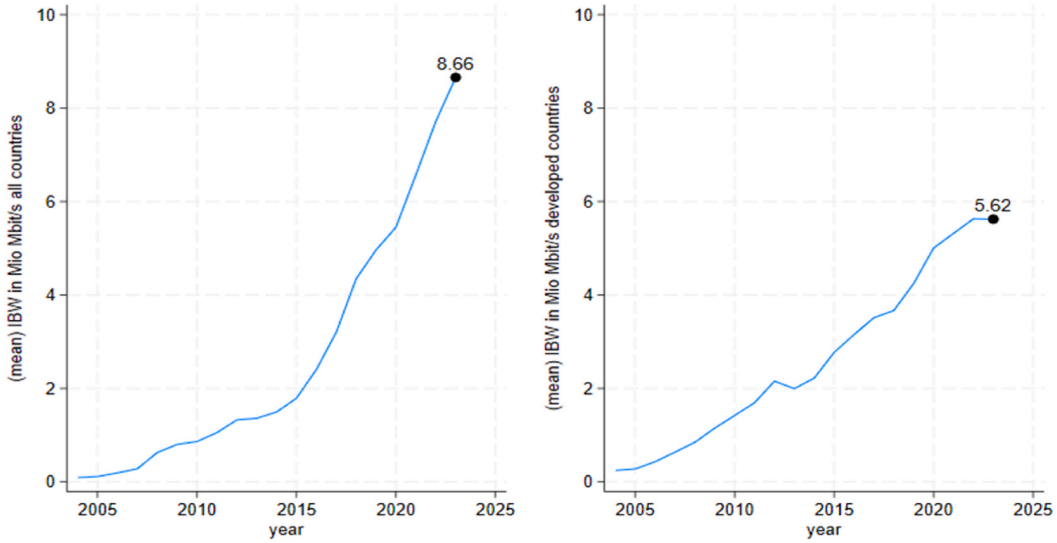


Fig. 3. IBW growth in the group of all countries (left panel) and developed countries (right panel).
Source: ITU, own calculations

also redundancy (more cables imply more rerouting options), market competition (more cables often imply more operators) and geographic diversity of partners. As our research focuses on the impact of increased Internet bandwidth wholesale capacity, IBW-based measures are an appropriate way of answering our key research question.[17]

Fig. 3 below illustrates the evolution of IBW for the total sample of countries (left panel) and for the group of developed countries with a GDP per capita exceeding USD 19,120 (right panel). Fig. 3 shows that the group of developed countries represents a large proportion of total IBW, and that IBW is subject to very high growth rates driven by data traffic, which, as mentioned earlier, has grown significantly in the last two decades. At the end of our observation period, for instance, the group of advanced countries accounted for almost two-thirds (65%) of international bandwidth capacity.

3.3. Instrumental and control variables

Table 2 below summarizes the instruments used to instrument the potentially endogenous regressors in our adoption equations: broadband price and IBW. Please note that we have also included squared terms for our competition-related instrumental variables because they may impact investment and market prices in a non-linear way (Sacco & Schmutzler, 2011; Schmutzler, 2013). More detailed explanations regarding the selection of the instruments can be found in Section 4.3.

All control variables are described in Table A.2.

4. Empirical research framework

4.1. Estimation of international bandwidth related broadband quality effects

According to the discussion in Section 2 (Fig. 1), an increase in IBW impacts broadband market outcomes such as service prices and quality levels experienced by consumers.[18] In examining this, we first estimate the impact of IBW in separate regression models with regard to the domestic broadband quality variable, BB_SPEED^{j}, where superscript $j = f, m$, denotes parameters specific to wireline (fixed, f) or wireless (mobile, m) broadband access technologies. We extend the previous contributions by explicitly modeling a representation of the dependence of domestic broadband quality on IBW in country i and in year t for broadband access technology j which reads as follows:

$$BB_SPEED^{j}_{it} = g\left(\text{IBW}_{it}, \text{IXP}_{it}, W_{it}, \text{GDP}_{\text{it}}, \text{BB_INVEST}^{j}_{it}, \mu_i^{j,SPEED}, \mu_t^{j,SPEED}\right) \quad (1)$$

[17] The authors would like to thank Joel Cariolle and an anonymous referee for providing these insights. Unfortunately, the lack of available data prevented us from further examining the robustness of our results through alternative SMC measures.

[18] Note that according to Fig. 1 there is – next to the direct quality impact – a direct impact on wholesale (transit) prices and thus an indirect impact on retail prices due to the increase in IBW. However, neither wholesale prices nor the pass-through rate are available for our analysis. According to Cariolle et al. (2024) the effect on retail price is substantial; doubling the international bandwidth because of SMC deployments leads to up to a 14% drop in fixed broadband price, and up to 21% drop in the mobile broadband price.

Table 2
Instrumental variables.

Endogenous regressor	Instruments
Log(BB_PRICE^{m})	Cellular HHI, Cellular HHI (lagged), mobile-fixed substitution, MFS (share of cellular voice subscriptions over all voice subscriptions) (lagged, in levels and squares)
Log(BB_PRICE^{f})	Log of average broadband price in similar neighboring (NB) country groups, BB_PRICE^{f,NB}(lagged), fixed-mobile substitution, FMS (share of fixed voice subscriptions over all voice subscriptions) in levels and squares
Log(IBW)	In mobile broadband demand model: Coastal length, interacted with mobile-fixed substitution, MFS, in levels and squares (in lags) In fixed broadband demand model: Coastal length, interacted with fixed-mobile substitution, FMS, in levels and squares (in lags)

Whereas IBW is an important determinant of domestic broadband quality variables, the latter also depend on the characteristics of domestic broadband market structures. Vector W contains information on the extent of competition in wireline and wireless broadband networks. According to basic economic theory, market quality variables such as broadband speed are driven by the competitive intensity in the market. Another crucial component of national broadband quality is the number of Internet Exchange Points (IXP), which serve as a physical hub where different ISPs interconnect to exchange traffic. The primary function of a national IXP is to enhance the performance of domestic internet traffic by improving speed and reducing latency. We control for broadband investment (BB_INVEST), as companies consistently invest to improve their product quality, which in turn helps them compete more effectively in the marketplace and ultimately increase consumer QoE. We also control for aggregate domestic income levels in terms of GDP, as high-quality broadband access will also depend on income effects. Finally, equation (1) includes country fixed effects, μ_iś, to capture any time-invariant heterogeneity at the country level, as well as year fixed effects, μ_tś, to cover common macroeconomic shocks, such as business cycles or the impact of the COVID-19 pandemic.

Estimating equation (1) for both fixed and mobile broadband speed allows us to test the hypothesis (H1) that an increase in IBW due to SMC deployment has an initial impact on domestic broadband quality levels. We can only expect an indirect impact on domestic broadband demand if IBW has a direct impact on domestic broadband quality. Therefore, testing this hypothesis is important, even if we cannot test a structural relationship between broadband quality and demand equations based on the available data.

4.2. Estimation of domestic broadband demand effects

In the next step we estimate the demand for broadband connections, which represents actual adoption decisions by consumers with sufficient willingness to pay to subscribe to a broadband connection under a commercial contract. The micro-founded determinants of demand for broadband connections (BB) are related to (i) retail prices (own price, BB_PRICE^{j}, and substitute fixed and mobile prices, denoted with BB_PRICE^{f} and BB_PRICE^{m}, respectively), (ii) income effects measured by GDP and household communications budgets (EXP), (iii) education level of consumers, EDUC, as higher educated users can utilize online services more comprehensively, and finally (iv) quality characteristics of the broadband connection measured by the variables IBW and IXP. Whereas the former measures the quality of international connectivity, the latter represents a measure of domestic broadband quality. Both metrics are crucial determinants of QoE of consumers and hence for willingness to pay and adopt a broadband connection. Including country and period fixed effects specific to the demand equation, the broadband demand function in country i and in year t for broadband access technology j reads as follows:

$$BB_{it}^{j} = l\left(IBW_{it}, IXP_{it}, BB_PRICE_{it}^{j}, BB_PRICE_{it}^{f,m}, EXP_{it}, \mathrm{GDP}_{it}, EDUC_{it}, \mu_i^{j,BB}, \mu_t^{j,BB}\right) \quad (2)$$

Note that we are not assessing the direct impact of domestic broadband quality in terms of speed in equation (2), but the indirect impact induced by an increase in IBW. This is because our data on broadband speed is only available for the years 2017 to 2023, and because IBW simultaneously captures the price effect due to lower wholesale prices.[19] The estimated coefficient of IBW in equation (2) should therefore be interpreted as the indirect, reduced-form effect of additional IBW on broadband adoption, operating through incomplete pass-through: an increase in wholesale capacity and a reduction in transit prices translate only partially into higher domestic broadband quality and lower retail prices, which in turn drive adoption; the analogy to imperfect compliance is that the "assignment" (higher wholesale capacity, lower transit prices) is not fully "received" at the retail level. Provided the effect is positive and pass-through is bounded between zero and one, the estimated reduced-form coefficient is smaller in magnitude than the underlying structural effect of domestic quality and retail prices on adoption that would obtain under full pass-through. Our IBW

[19] Under certain assumptions (such as linear demand, invertibility, inclusion of relevant control variables, etc.), the marginal price effect of the inverse demand function, ∂BB_PRICE/∂IBW,can be calculated from the corresponding coefficient estimates of the normal demand function shown in equation (2).

estimates can thus be read as a conservative, lower-bound characterization of this structural channel, conditional on the absence of an offsetting upward bias from potential endogeneity — which our identification tests (Section 4.3) do not indicate. In the limiting case of full pass-through, the reduced-form and structural effects coincide.[20] While from a welfare perspective the actual treatment effect of broadband adoption on socio-economic outcomes is an interesting question, from a policy perspective the effect of IBW availability may actually be more interesting, since availability is the parameter that can be primarily influenced by policy interventions (such as lower regulatory costs related to SMC deployment and landing stations).

In estimating equations (1) and (2), we use the logarithm for our dependent variables and for explanatory variables in levels that are positive and have skewed distributions. Furthermore, using the logarithm allows us to interpret the estimation results as percentage changes that can be directly compared across different model specifications. Another reason we use the log of the international bandwidth variable is that we assume there are diminishing marginal returns on additional SMC capacity. Taking the log implies that the economic impact of the first SMC connection is greater than that of later connections. This assumption is particularly relevant for the group of advanced economies, which typically already have had several landing stations or fiber-based terrestrial links across countries during our period of analysis.

We expect the coefficient estimates for the IBW variable to be positive and significant in equations (1) and (2) (H1 and H2).

4.3. Identification strategy

Compared with the reviewed empirical studies on SMC, we include a rather large number of covariates. This includes country and year fixed effects in all specifications ("selection on observables"). However, to obtain consistent estimates for the vector of estimation coefficients, this specification requires strict exogeneity which rules out any contemporaneous, past and future correlation of regressors and idiosyncratic errors. Strict exogeneity represents a strong identifying assumption in general.

The exogeneity of the variable IBW can perhaps best be argued with reference to the years it takes from the initial planning to the final completion of a certain SMC project: it typically takes three to five years to plan, design and obtain approval for new SMC projects (Analysys Mason, 2022). Because of this, and the long life of SMC (20+ years), rational investors will not base their decision to invest in an SMC on yearly fluctuating parameters, but rather on long-term stable market conditions, which are by and large captured by fixed effects.

However, two main concerns regarding endogeneity arise from the demand functions as specified in equation (2). The first relates to the respective fixed and mobile broadband prices, as these are determined simultaneously by market forces expressed through demand and supply. The second relates to our main variable of interest, IBW, as both broadband demand and international bandwidth capacity may be affected by omitted time-variant variables, such as innovations in digital products and services. As illustrated in Fig. 2, there may also be a reciprocal dependence underlying domestic broadband demand and demand for IBW.

First, to account for endogeneity concerns resulting from reverse causality, we consider lagging our main explanatory variable of interest (L_IBW) which mitigates simultaneity bias under certain conditions and has been common practice in applied empirical literature. Our main results are robust to the use of the first lags of the IBW variable in the broadband quality and demand equations. In addition, to further mitigate simultaneity concerns, we provide Granger causality tests, which suggest that IBW Granger causes broadband demand, while fixed and mobile broadband demand do not Granger cause IBW (results are reported in Table A.3 in the Appendix).

Second, to mitigate endogeneity in the IBW regressor due to omitted variables, we use external instruments based on the following sources of exogenous variation:

- For mobile broadband adoption, the instruments rely on the HHI, Cellular HHI, and on the share of mobile over all connections, MFS, in both cases for the legacy-based voice service. Market dynamics associated with narrowband voice services are on the one hand expected to represent adequately the forces that drive broadband prices, due to infrastructure-related path dependencies which are very strong in electronic communications markets (Czernich et al., 2011); for example, whether a country has copper- and coaxial cable-based fixed broadband infrastructure has been determined decades ago in many cases but still exerts a crucial impact on competition today, as these networks have been continuously upgraded via various copper (e.g., VDSL and G.fast) and coax (DOCSIS) acceleration technologies. On the other hand, as a "low-tech" variable this instrument should not have a direct impact on modern mobile broadband demand beyond its competition effect on prices. These indicators also interacted with a country's coastal length to instrument IBW. The longer a country's coastline, the greater the likelihood of SMC landing and the associated increase in IBW. The higher the level of competition, the greater the effect of IBW on broadband adoption. The level of competition in broadband markets is largely predetermined by the extent of legacy infrastructure. Hence, IV estimates rely on the assumption that, conditional on country and year fixed effects and the included controls, the coastline-based instruments affect broadband adoption only through IBW.

[20] In case of SMC deployment, the actual difference between these effects depends on the specific landing and interconnection scenarios. For example, if an SMC's landing station is directly connected to a data center owned by a content provider via terrestrial fiber connections, only the content provider's customers will receive a higher QoE for related services. Conversely, if the landing station is connected to a major national or international interconnection hub where all major ISPs within a certain region are interconnected, then all their customers can experience higher quality and lower prices. Therefore, the geographic and customer-related scope of the benefits brought by new SMC capacity depends on the underlying interconnection scenarios and network technologies.

Table 3
Regression results for the impact of IBW on domestic broadband quality.

Dep. var.:	Log(BB_SPEED^{f})	Log(BB_SPEED^{m})
Regr. nr.:	(1)	(2)
Log(IBW)	0.150***	0.358***
	[0.009]	[0.012]
INVEST^{f}	0.001**	
	[0.000]	
INVEST^{m}		0.001
		[0.001]
Log(IXP)	−0.021	0.029
	[0.023]	[0.035]
HHI_BB^{f}	0.000	
	[0.000]	
HHI_BB^{m}		−0.000*
		[0.000]
Log(GDP)	−0.182	0.225
	[0.230]	[0.188]
R2 within	0.925	0.929
#Countries	45	45
#Obs.	259	259

***Notes*:** All regressions control for country & year fixed effects. Robust standard errors in brackets are heteroscedasticity consistent, allow for autocorrelation up to lag two and are robust to very general forms of cross-country spatial dependence (Driscoll & Kraay, 1998). The timeframe for the estimations covers the period from 2017 to 2023.
*p < 0.10, **p < 0.05, ***p < 0.01.

- As for fixed broadband, we could not rely on data for HHI related to legacy infrastructures (fixed narrowband telephony) as data is not available. We use instead the share of fixed on all connections for legacy voice services, FMS, and a metric of cross-national spillovers, BB_PRICE^{f,NB}, that may affect market dynamics such as prices. The latter instrument measures the average price levels in neighboring (NB) countries that belong to the same region or supranational economic bloc as the "focal" country. This Hausman-type spatial instrument is expected to capture benchmarking effects among neighboring peers and was used as such in the most recent broadband related empirical literature (Briglauer et al., 2025; Duso et al., 2025). This institutional pressure of peers is reinforced in cases where supranational broadband targets exist, such as those set by the EU, or where detailed market monitoring reports are produced regularly, such as those by the OECD.[21]

We argue that peer-effects related to neighboring countries and competition related to legacy-based infrastructures that affect respective broadband market outcomes, interacted with the length of their coast in kilometers, represent relevant instruments: countries with adequate SMC landing conditions given exogenously by nature should experience higher international bandwidth capacity. This effect will translate into higher domestic bandwidth quality the higher the level of broadband-based competition or neighboring peer effects are.

Conducting instrumental variables estimations also allows us to conduct post-estimation analysis and test our assumption that our main explanatory variable, IBW, can be treated as exogenous.

5. Estimation results

According to the discussion in Section 4, we first present our estimation results on the impact of international bandwidth capacity on domestic broadband quality (Section 5.1), and then we report the results on fixed and mobile broadband demand (Section 5.2). While we use a two-way fixed effects estimator in Sections 5.1 and 5.2, we also employ a fixed effects instrumental variables estimator (FE-IV) in Section 5.2 to further strengthen the robustness of our main results.

5.1. Impact of international bandwidth on broadband quality

We first assess the impact of additional IBW on national broadband quality levels. The empirical specification is derived from equation (1) as follows:

$$Log\left(BB_SPEED_{it}^{j}\right) = \mu_i^{j,SPEED} + \mu_t^{j,SPEED} + \beta_0^j \text{Log}(\text{IBW}_{it}) + \beta_1^j \text{Log}(\text{IXP}_{it}) + \beta_2^j W_{it} + \beta_3^j \text{Log}(GDP_{it}) + \beta_4^j \text{BB_INVEST}_{it}^{j} + \varepsilon_{it}^{j,SPEED} \quad (1')$$

[21] While such peer benchmarking mechanisms are typically associated with price convergence, the direction of this effect is theoretically ambiguous: benchmarking can equally operate as a corrective mechanism, whereby high peer prices trigger regulatory or competitive responses that lower domestic prices, particularly where supranational targets or monitoring frameworks create pressure to converge toward regional peers.

Where variables, subscripts and superscripts in (1′) are defined as in equation (1) above. The model includes country-level ($\mu_i^{j,SPEED}$) and year ($\mu_t^{j,SPEED}$) fixed effects, while ε is a well-behaved error term. Table 3 presents in columns (1) and (2) the two-way fixed effects estimation results.

All regression models explain between ~92% and 93% of relevant within variation for BB_SPEED. All coefficient estimates exhibit expected signs when significant and reported standard errors are robust. IBW coefficients are elasticities and significant at the 1% level. All IBW coefficient estimates have the expected signs, with results suggesting that a 1% increase in IBW increases BB_SPEED^{f} by about 0.15% and BB_SPEED^{m} by 0.36%.

5.2. Impact of international bandwidth on mobile and fixed broadband demand

To measure the impact of IBW on mobile and fixed broadband adoption, the following empirical specification was derived from equation (2):

$$Log\left(BB_{it}^{j}\right) = \mu_i^{j,BB} + \mu_t^{j,BB} + \gamma_0^{j}\text{Log}(\text{IBW}_{it}) + \gamma_1^{j}\text{Log}(\text{IXP}_{it}) + \gamma_2^{j}Log\left(BB_PRICE_{it}^{j}\right) + \gamma_3^{j}Log\left(BB_PRICE_{it}^{f,m}\right) + \gamma_4^{j}\text{Log}(\text{GDP}_{\text{it}}) + \gamma_5^{j}\text{Log}(\text{EXP}_{\text{it}}) + \gamma_6^{j}\text{Log}(\text{EDUC}_{\text{it}}) + \varepsilon_{it}^{j,BB} \quad (2')$$

Where variables, subscripts and superscripts in (2′) are defined as in equation (2) above. The model includes country-level ($\mu_t^{j,BB}$) and year ($\mu_t^{j,BB}$) fixed effects, while ε is the error term.

Tables 4 and 5 report the estimation results for mobile and fixed broadband demand, respectively. Regression models explain between ~82% and 91% and between ~67% and 74% of relevant within variation, for the mobile and fixed demand models, respectively. This significantly lower proportion of the total variation explained by the fixed-line demand model compared to the mobile demand model is due, in particular, to the fact that significantly fewer observations were available in the fixed-line demand model. Importantly, however, all coefficient estimates have the expected sign when significant. The regression results for our main variable of interest (IBW) are by and large robust with respect to different selection of control variables, using lagged values of IBW

Table 4
Regression results for mobile broadband demand in advanced countries.

Dep. var.:	Log(BB^{m})						
Regr. nr.:	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log(IBW)	0.049*	0.081***	0.049***			0.045***	0.048**
	[0.024]	[0.016]	[0.011]			[0.016]	[0.022]
Lag: Log(IBW)				0.032*	0.041***		
				[0.018]	[0.012]		
Log(BB_PRICE^{m})	−0.283	−0.097	−0.117	−0.187	−0.113	−0.252**	−0.228*
	[0.173]	[0.144]	[0.085]	[0.140]	[0.084]	[0.113]	[0.133]
Log(EXP)	0.238*	0.193	0.164	0.130*	0.168	0.076	0.059
	[0.127]	[0.143]	[0.099]	[0.069]	[0.100]	[0.117]	[0.132]
Log(GDP)	1.246**	1.145**	0.820**	1.309**	0.829**	−0.044	−0.032
	[0.493]	[0.467]	[0.295]	[0.514]	[0.303]	[0.037]	[0.032]
Log(EDUC)	1.064***	1.182***	0.602**	0.947***	0.627***	−0.082	−0.083
	[0.296]	[0.315]	[0.209]	[0.242]	[0.204]	[0.092]	[0.107]
Log(BB_PRICE^{f})			−0.147**		−0.149**		−0.018
			[0.057]		[0.056]		[0.018]
Log(IXP)						0.004	0.004
						[0.007]	[0.007]
First stage F-test (log(IBW))						36.66	21.31
First stage F-test (log(BB_PRICE^{m}))						363.54	747.24
Weak-id test (Kleibergen-Paap Wald F-test)						27.031	30.312
Over-id test (Hansen J stat) P-value						0.379	0.315
Endogeneity test (log(IBW)) P-value						0.632	0.643
R2 within	0.905	0.905	0.855	0.892	0.854	0.825	0.824
#Countries	40	36	40	40	40	39	39
# Instruments						6	6
#Observations	502	445	431	488	431	230	230
Estimation method:	OLS	OLS	OLS	OLS	OLS	IV	IV

Notes: All regressions control for country & year fixed effects. Robust standard errors in brackets are heteroscedasticity consistent, allow for auto-correlation up to lag two and are robust to very general forms of cross-country spatial dependence (Driscoll & Kraay, 1998). The number of observations varies because some of the included control variables have missing values (Table A.4). In regression (2), the number of countries is 36 instead of 40 because we excluded four landlocked countries from our dataset of advanced economies: Austria, Czech Republic, Luxembourg and Switzerland. The timeframe for the estimations covers the period from 2017 to 2023.
*p < 0.10, **p < 0.05, ***p < 0.01.

Table 5
Regression results for fixed broadband demand in advanced countries.

Dep. var.:	Log(BB^f)						
Regr. nr.:	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log(IBW)	0.061**	0.060*	0.056**			0.115***	0.115***
	[0.024]	[0.027]	[0.022]			[0.043]	[0.044]
Lag: Log(IBW)				0.063**	0.059**		
				[0.021]	[0.019]		
Log(BB_PRICE^f)	−0.012**	−0.013**	−0.017**	−0.002	−0.008	−0.069**	−0.094**
	[0.004]	[0.004]	[0.005]	[0.006]	[0.006]	[0.032]	[0.039]
Log(EXP)	0.170*	0.169*	0.159*	0.153	0.142	0.100	0.071
	[0.078]	[0.076]	[0.070]	[0.084]	[0.076]	[0.093]	[0.091]
Log(GDP)	0.085	0.086	0.112**	0.049	0.075*	0.044	0.076
	[0.049]	[0.047]	[0.044]	[0.038]	[0.038]	[0.130]	[0.125]
Log(EDUC)	0.122	0.148	0.130	0.102	0.109	0.053	0.056
	[0.112]	[0.112]	[0.096]	[0.100]	[0.083]	[0.113]	[0.099]
Log(BB_PRICE^m)			0.150**		0.153**		0.140***
			[0.055]		[0.054]		[0.045]
Log(IXP)	0.045*	0.053*	0.043*	0.046*	0.044*	0.048**	0.047**
	[0.021]	[0.024]	[0.020]	[0.022]	[0.020]	[0.020]	[0.019]
First stage F-test (log(IBW))						59.36	39.66
First stage F-test (log(BB_PRICE^f))						92.15	92.53
Weak-id test (Kleibergen-Paap Wald F-test)						33.051	27.484
Over-id test (Hansen J stat) P-value						0.327	0.296
Endogeneity test (log(IBW)) P-value						0.919	0.672
R2 within	0.668	0.722	0.728	0.728	0.737	0.679	0.668
#Countries	39	35	39	39	39	39	39
# Instruments						5	5
#Observations	230	203	230	230	230	230	230
Estimation method:	OLS	OLS	OLS	OLS	OLS	IV	IV

Notes: All regressions control for country & year fixed effects. Robust standard errors in brackets are heteroscedasticity consistent, allow for autocorrelation up to lag two and are robust to very general forms of cross-country spatial dependence (Driscoll & Kraay, 1998). The number of observations varies because some of the included control variables have missing values (Table A.2). In regression (2), the number of countries is 35 instead of 39 because we excluded four landlocked countries from our dataset of advanced economies: Austria, Czech Republic, Luxembourg and Switzerland. Timeframe for the estimations cover the period 2013-2022.
*p < 0.10, **p < 0.05, ***p < 0.0.

instead of contemporaneous values in regressions (4) and (5) and number of countries. In regressions (3) and (5) we add further controls for cross-prices (BB_PRICE^f and BB_PRICE^m).

Estimating the broadband demand equation allows us to test the hypothesis that an increase in IBW increases QoE and decreases retail prices to some extent which ultimately results in higher demand of broadband connections. In Table 4 the IBW coefficient estimates for the mobile broadband regression are elasticities and significant across all estimates, both for contemporaneous (regressions (1) to (3)) and for one-period lagged effects (regressions (4) and (5)). All of the IBW coefficient estimates have the expected signs. A 1% increase in IBW increases mobile broadband demand by about 0.049% to 0.081% when considering the contemporaneous effect.

In columns (6) and (7) of Table 4 we examine whether the mobile broadband demand function is robust to instrumental variable estimation (IV). As highlighted above, both prices and IBW may be endogenous. We therefore consider both regressors as potentially endogenous in respective IV estimations with country and year fixed effects (FE-IV) and robust standard errors. The instruments used are those described in Table 2 above. As can be seen, in both cases the first stage statistics for both endogenous regressors are strong enough as evidenced by the respective F tests and the Kleibergen-Paap Wald weak identification test, suggesting a high explanatory power of the instruments. Also, the Hansen J statistics do not lead us to reject the null hypothesis of exogeneity of the underlying instrument sets. First-stage results are included in Table A.4 in the Appendix.

Most importantly, FE-IV estimation results exhibit a positive and strongly significant coefficient for the variable IBW across both specifications in regressions (6) and (7). It appears that the magnitude of the fixed effects (FE) coefficient estimates is very similar to the corresponding FE-IV coefficient estimates. Moreover, it is worth noting that the Durbin-Wu-Hausman endogeneity test conducted for IBW does not reject the null hypothesis that the suspect regressor is exogenous. The similarity between the FE and FE-IV estimates, together with the failure to reject the null hypothesis of exogeneity in the DWH test, provides reassuring evidence that the main results are not driven by endogeneity. Based on our identifying assumptions, this confirms our initial hypothesis that the variable IBW is presumably exogenous, which implies that we can rely on the more efficient estimated FE coefficients reported in regressions (1) to (5).

In Table 5 the IBW coefficients in the fixed broadband regressions are elasticities and significant at the 5%/10% levels, both for contemporaneous (regressions (1) to (3)) and for one-period lagged effects (regressions (4) and (5)). When controlling for endogeneity through FE-IV estimation in columns (6) and (7), the coefficients are significant at the 1% level. All of the IBW coefficient estimates have the expected signs. For example, a 1% increase in IBW increases fixed broadband demand by about 0.056% to 0.061% for the lowest lagged and highest contemporaneous effects when assuming IBW exogenous, respectively. As in the case of mobile broadband,

the IV estimates reported in regressions (6) and (7) also show a high explanatory power of the instruments, while the Hansen J statistics do not lead us to reject the null hypothesis of exogeneity of the underlying instrument sets. Also, the Durbin-Wu-Hausman endogeneity test conducted for IBW does not reject the null hypothesis that the suspect regressor is exogenous.

When comparing Tables 4 and 5, it is interesting to note first that for the cumulative coefficient estimates of IBW from mobile and fixed broadband demand, the sum of contemporaneous coefficient estimates is close to the corresponding estimates of Analysys Mason (2021) reported in Table 1, even though different data, measures and methods were used. In our view, this comparison with the most related empirical contribution further strengthens the credibility of our coefficient estimates for our main variable of interest.

Second, removing four landlocked countries has no effect on demand for fixed broadband: the IBW coefficient remains virtually unchanged. However, the effect of IBW on adoption seems to increase in the specification of mobile demand. One possible reason for the unchanged results in the case of fixed broadband is that the group of advanced countries also exhibits a high level of fiber-terrestrial cross-country interconnections, and that landlocked countries therefore benefit from SMC landing in neighboring coastal countries.

Third, when we compare cross-price elasticities, we can infer asymmetric substitution patterns. While mobile broadband appears to be a substitute for fixed broadband, fixed broadband appears to complement mobile broadband. Such consumer behavior is often typical of developed countries, where mobile broadband is often used to complement more complex internet ecosystems (e.g., Wi-Fi offloading and smart devices connected via fixed broadband), and where fixed broadband plans are usually unlimited. Developed countries typically have high-quality fixed broadband networks and high adoption levels, which fosters complementarity in view of heterogeneous needs (mobility versus heavy usage), data caps, and device ecosystems.

5.3. Cost benefit analysis: SMC connecting United States and Ireland

In this section, we compare the total benefits of deploying a SMC with the total costs using an illustrative example: a newly deployed SMC connection between the United States and Ireland. The related costs and benefits are detailed in Sections 5.3.1 and 5.3.2, respectively.

5.3.1. Cost analysis

Table 6 reports "Low" and "High" cost estimates for various CapEx components based on the following assumptions:

- Design capacity:$>$ 320 Tbps[22]
- Fiber pairs: 16; $>$ 20 Tbps/pair[23]
- Route length: $\approx$ 5500–6000 km[24]
- Unit-cost benchmarks:Cable US$6–20k/km; repeaters $\sim$ US$200k every 60–80 km
- Cable-ship day rate: $\sim$US$50–150k/day[25]

Summarizing, the cost components for the SMC deployment project are estimated in a total projected CapEx of roughly US $190–375 million.[26] Although our calculations are rudimentary and do not consider all cost components, we are confident that our range of estimates is sufficiently robust and aligns well with other industry studies. For example, scaling TeleGeography's (2025) baseline of $\sim$US$250 million for 7000 km to 5600 km would imply a cost of $\sim$US$200 million for a standard system. However, we estimate costs as being higher because it is a premium diversity build involving new landing stations, deep burial and drilling, and 16 fiber pairs.

Other costs that were not considered in this calculation relate to negative environmental externalities that should not be overlooked. For example, cable laying can disturb marine ecosystems, and the lifecycle of the associated infrastructure, including landing stations and maintenance activities, can incur additional ecological costs.

5.3.2. Benefit analysis

5.3.2.1. GDP effects. Our benefit calculations are based on the effects on GDP, as detailed in the most recent and related empirical literature (Briglauer et al., 2025). To simulate the GDP contribution of deploying a submarine cable linking Ireland and the United States, we first calculate the resulting increase of IBW from the current level. More specifically, our calculation is based on the following assumptions:

- The system's assumed design capacity is $\sim$320 Tbit/s (Section 6.1).
- The current international bandwidth ("legacy capacity") is 160 Tbit/s (including publicly available and private capacity).[27]

[22] Information available at: https://www.aboutamazon.com/news/aws/transatlantic-subsea-cable-us-ireland-fastnet-aws.
[23] Information available at: https://www.submarinenetworks.com/en/systems/trans-atlantic/fastnet/aws-to-build-its-first-private-subsea-cable-connecting-the-us-and-ireland-%E2%80%94-fastnet.
[24] Information available at: https://www.aboutamazon.com/news/aws/transatlantic-subsea-cable-us-ireland-fastnet-aws.
[25] https://www.powerandcables.com/subsea-cable-protection-part-2-of-5/.
[26] The formal derivation of these estimates can be found in Appendix Table B.1.
[27] Information based on correspondence with industry experts.

Table 6
Cost estimates by component.

Cost component	Basis/benchmark	Source	Low (US$ m)	High (US$ m)
Route survey & marine site investigation	Multi-year geophysical/geotechnical survey	Silicon Republic (2025); TeleGeography (2025)	8	16
Submarine cable — wet-plant supply	~5600 km × ~US$10–18k/km (16 FP, heavy armoring)	TeleGeography (2025); Amazon Web Services (2025)	56	101
Repeaters/optical amplification	~80 units × ~US$200k, every 60–80 km	TeleGeography (2025)	14	20
Marine installation & burial	Lay + deep burial (~1.5 m) + horizontal drilling both ends	Submarine Networks (2026a)	30	55
Optical-switching branching unit & spares	Distinctive SMC feature for future landing points	Authors' estimate	3	8
Dry plant — SLTE & power-feed equipment	Terminal transmission + power-feed equipment, both ends	TeleGeography (2025)	16	32
Cable landing stations (new build)	Purpose-built CLS (not co-located)	Submarine Networks (2026a, 2026b)	15	35
Terrestrial backhaul	Landing → Ashburn/NoVa; Castlefreke → Landing/Dublin	Authors' estimate	12	35
	MARA (IE) & FCC (US) consents; EIA; Community Benefit Funds	Silicon Republic (2025)	5	14
Project management, integration & testing	Owner's engineering, integration, commissioning	Authors' estimate	12	24
Contingency (~10%)	Applied to the components above	Authors' estimate	17	34
Total CapEx	Point-to-point 16-fiber pair diversity build		≈ **190**	≈ **375**

Source: Authors based on various sources

Table 7
GDP contribution in Ireland.

Year	Additional Lit Capacity (Tbit/s)	GDP (in US$ billion)	IBW impact on GDP (low) (in US$ billion)	IBW impact on GDP (high) (in US$ billion)	IBW impact as percent of GDP (Low)	IBW impact as percent of GDP (High)
2026	0	497.178	$0.00	$0.00	0.00	0.00
2027	60	508.613094	$1.43	$1.95	0.28	0.38
2028	88	520.311195	$2.15	$2.92	0.41	0.56
2029	125	532.278353	$3.13	$4.25	0.59	0.80
2030	150	544.520755	$3.84	$5.22	0.71	0.96
2031	196	557.044732	$5.13	$6.97	0.92	1.25
2032	224	569.856761	$6.00	$8.15	1.05	1.43
2033	240	582.963466	$6.58	$8.94	1.13	1.53
2034	240	596.371626	$6.73	$9.14	1.13	1.53
2035	240	610.088174	$6.88	$9.35	1.13	1.53
2036	240	624.120202	$7.04	$9.57	1.13	1.53
2037	240	638.474966	$7.20	$9.79	1.13	1.53
2038	240	653.15989	$7.37	$10.01	1.13	1.53
2039	240	668.182568	$7.54	$10.24	1.13	1.53
2040	240	683.550767	$7.71	$10.48	1.13	1.53
2041	240	699.272435	$7.89	$10.72	1.13	1.53
2042	240	715.355701	$8.07	$10.97	1.13	1.53
2043	240	731.808882	$8.26	$11.22	1.13	1.53
2044	240	748.640486	$8.45	$11.48	1.13	1.53
2045	240	765.859217	$8.64	$11.74	1.13	1.53
Total GDP spillovers			**$121.05**	**$163.09**		

Source: Own calculation

- The economic lifetime of the SMC plant is 20 to 25 years; a standard depreciation period used in subsea network financial modeling.[28]
- Capacity activation follows an aggressive, non-linear ramp-up profile. This reflects the high-demand profile of the US-Ireland route.[29]
- Effectively all relevant national and regional wireline ISPs as well as all mobile operators are interconnected at the Internet Neutral Exchange (INEX) in Dublin, the main IXP hub in Ireland. Consequently, all Irish ISP customers should benefit from higher international bandwidth capacity brought from the landing station to INEX.[30]

Table 7 reports the economic benefits in terms of the increase in Ireland's GDP induced by SMC. This analysis is based on lower and upper bound elasticity estimates from Briglauer et al. (2025), as well as our own coefficient estimates from the adoption equation. The GDP forecast is based on an annual real per capita income growth rate of 2.3%, as provided by the IMF. We then calculate the annual economic impact, if SMC deployment begins in 2026, will last for 20 years, and will increase gradually over time, while maintaining a constant legacy capacity of 160 Tbit/s. The total SMC-induced contribution to Irish GDP amounts to between US$121.05 billion (low estimate) and US$163.09 billion (high estimate).

To enable a comprehensive cost versus benefit comparison for both countries, the GDP effects induced in the US would also need to be considered. Using the same methodology, the SMC deployment project is expected to contribute between US$76.00 billion and US $89.23 billion to the GDP of Maryland and neighboring states.[31] Summarizing, total GDP benefits thus range between US$197.05 billion and US$252.32 billion.

It should be noted that our benefit analysis represents a scenario result under the stated assumptions (regarding capacity utilization, the legacy capacity, the time profile of capacity activation, the external GDP elasticity, GDP growth and the treatment of future benefits) rather than an actual estimate of the social return of a typical submarine cable project.

5.3.2.2. Other effects. As discussed in Section 2 (Fig. 1), the deployment of SMC also influences GDP related to infrastructure investment. However, investment effects on the supply side are expected to be of minor importance compared to adoption related broadband effects. Recent econometric estimates in Briglauer et al. (2025) confirm this hypothesis.

SMC deployment is anticipated to positively impact consumer welfare. This is measured by consumer surplus, representing the difference between what consumers would be willing to pay for a service or product, and what they actually pay. Better international bandwidth capacity improves the quality of domestic broadband services, as well as consumers' QoE and their willingness to pay for broadband services and connections.[32]

In addition to consumer surplus, another major benefit that is not captured in our GDP calculation is economic resilience. This is particularly relevant in times of socio-economic crisis, such as the global pandemic caused by COVID-19. The significant restrictions on economic and social life ("lockdowns") imposed during the pandemic emphasized the importance of digital infrastructure, including SMC as the backbone of the global internet. This "resilience effect", characterized by substantial mitigation of the decline in overall economic performance during crises, as well as subsequent faster economic recovery, is accompanied by an additional, potentially substantial positive externality of digital infrastructure and the digital services that are essential in times of crisis.

Another reason why we potentially underestimate the economic benefits of SMC deployment is that other countries along the SMC route may experience improved international connectivity indirectly, even if they do not have an SMC landing station. This indirect benefit stems from cross-border terrestrial fiber optic cables that facilitate traffic routing through a connected country (Cariolle et al., 2024). This effect is presumably stronger for advanced economies with high levels of network interconnection quality. Our empirical analysis provides some evidence for this.

Finally, note that our econometric analysis is based on a low economic lifetime estimate and historical data. The future effects of broadband, considering emerging technologies with high growth and productivity potential such as cloud computing and AI services, are only evident in the most recent years of the dataset. Therefore, taking all these effects into account we expect even stronger GDP spillover effects in the future.

6. Summary and conclusions

Submarine cables form the backbone of global internet connectivity, carrying the majority of international data traffic and linking

[28] Information available at: https://subtelforum.com/submarine-telecoms-industry-report/.
[29] Information based on correspondence with industry experts.
[30] Information based on correspondence with industry experts.
[31] Information available from the authors upon request.
[32] There is a considerably smaller body of research examining the impact of broadband on consumer surplus. Most studies on both basic and new broadband networks indicate significant welfare benefits for consumers. Some studies focus on consumers' willingness to pay for commonly used "free" online services such as Google Search, Wikipedia, and Facebook (Allcott et al., 2020; Bursztyn et al., 2023; Mosquera et al., 2020). Given the rapid technological progress and numerous product innovations in the ICT ecosystem, it is expected that consumer surplus will continue to grow, creating, for example, improvements in broadband quality, such as increased bandwidth and reduced latency, which will enhance consumer utility. This, in turn, will raise consumers' willingness to pay, as these enhancements allow access to a broader range of entertainment and information services (Nevo et al., 2016).

continents, countries and regions. They provide access to content from around the world and impact users' quality of experience (QoE). However, the empirical evidence relating to the economic impacts of SMCs is still very limited. In view of this research gap and the infrastructural importance of SMCs as the backbone of all global communication networks, this paper aims to examine the economic impacts, in terms of GDP spillovers, of additional SMC deployment. To answer this question, we first describe how international bandwidth capacity (IBW) can be used as a proxy for SMC capacity and examine how it affects domestic broadband quality levels. We then examine the indirect impact on domestic broadband demand. To identify causal effects, we employ panel data estimation techniques, including a large set of control variables, two-way fixed effects estimation, Granger causality analysis, and instrumental variables. Our empirical analysis was conducted using recent panel data for a group of developed countries.

First, our analysis reveals that, as anticipated, IBW has a positive and significant impact on broadband quality in terms of download speed. Second, with regard to international bandwidth, we find that a 1% increase in IBW increases mobile broadband adoption by approximately 0.049% to 0.081%. The impact on fixed broadband is similar: a 1% increase in IBW increases fixed broadband adoption by approximately 0.056% to 0.061%. These results are largely robust with respect to different regression specifications and estimators.

Furthermore, we conducted a basic cost-benefit analysis. In doing this we relate our estimation results to an illustrative SMC deployment project connecting the US with Ireland. Using various industry cost estimates and benchmarks, as well as our own econometric estimates and external estimates from a recent study, our findings clearly show that the GDP spillover effects generated outweigh the total costs of SMC deployment by far. Moreover, calculated GDP effects will most likely underestimate total welfare effects considerably since the gains in terms of higher socio-economic resilience and consumer surplus resulting from consumers adopting broadband connections are not included in the GDP effects. Therefore, this result holds true with respect to any reasonable changes in model assumptions and even if we omit certain cost components. These extraordinarily high welfare effects are related to the significant externalities generated by modern internet networks, which are a central, general-purpose technology (Bresnahan & Trajtenberg, 1995).

Given the significant economic spillovers generated by SMC capacity, it is in the interest of any government of a coastal country to facilitate additional SMC deployment and site landings, given that the domestic benefits are high and the costs are comparatively very low and external. Attracting SMC deployment can be achieved by reducing regulatory transaction costs. Next to the costs of laying SMC and connecting landing stations, SMC operators face high transaction costs relating to coordinating licenses and permits for construction activities, as well as paying annual permit fees and complying with extensive national and international SMC regulations (Morgan, 2023).

We acknowledge that the expansion of SMC raises important policy-relevant trade-offs that merit consideration. First, the strategic nature of submarine cables introduces security and geopolitical risks, as these assets are critical for data transmission and may be vulnerable to physical disruption, or influence by external actors, particularly in geopolitically contested regions. Second, environmental externalities should not be overlooked: cable laying can disturb marine ecosystems, and the lifecycle of associated infrastructure, including landing stations and maintenance activities, can entail additional ecological costs. These considerations suggest that, alongside the well-documented economic benefits, policymakers should design regulatory frameworks that promote competitive access, ensure resilience and security, and mitigate environmental impacts.

Our estimation results refer to the group of advanced economies. One avenue for future research is to examine whether there is heterogeneity in terms of the level of economic development. Given the global interconnectedness of the internet, future research should also examine the geographical scope of the economic impacts of a particular submarine cable project. Another important emerging area is digital sovereignty, and the role played by submarine cables or satellites in enabling independent and resilient ICT ecosystems. Future research should examine and quantify the resilience effect of SMCs, as well as their impact on QoE and the consumer surplus generated by high-quality, resilient SMC infrastructure.

CRediT authorship contribution statement

Wolfgang Briglauer: Writing – review & editing, Writing – original draft, Validation, Software, Methodology, Investigation, Data curation, Conceptualization. **Raúl Katz:** Writing – original draft, Validation, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization. **Monika Köppl-Turyna:** Validation, Supervision, Resources, Funding acquisition, Conceptualization. **Juan Jung:** Writing – original draft, Software, Methodology, Investigation, Formal analysis.

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Appendix A. Tables A.1 to A.5

Table A.1
Variable definitions

Variable	Definition	Source
Dependent variables		
BB_SPEED^{f}	Average of the median values of the fixed broadband speed (in kbps) measured in the 12 months of the year.	Ookla Speedtest
BB_SPEED^{m}	Average of the median values of the mobile broadband speed (in kbps) measured in the 12 months of the year.	Ookla Speedtest
BB^{m}	Number of mobile broadband connections based on 3G or higher mobile access technologies.	GSMAi
BB^{f}	Number of fixed broadband connections at downstream speeds equal to, or greater than, 256 kbit/s.	Statista ITU
Main explanatory variable		
IBW	Amount of international bandwidth available measured in bits per second (bit/s). Average usage of all international links including fiber-optic cables, radio links and traffic processed by satellite ground stations and teleports to orbital satellites.	ITU
Broadband market and other control variables		
BB_PRICE^{m}	Average revenue per mobile subscriber (ARPU) in USD.	GSMAi
BB_PRICE^{f}	Price of a monthly subscription to an entry-level fixed broadband plan in USD.	ITU
HHI_BB^{f}	Herfindahl-Hirschman Index (HHI) for the fixed broadband market. It measures the level of market concentration, with values ranging from 0 to 10,000. Higher values indicate greater market concentration.	OVUM TAS
HHI_BB^{m}	Herfindahl-Hirschman Index (HHI) for 3G and 4G mobile broadband market. It measures the level of market concentration, with values ranging from 0 to 10,000. Higher values indicate greater market concentration.	GSMA TAS
INVEST^{m}	Mobile telecommunication investment (at 2022 prices) in USD divided by the annual population.	ITU GSMA
INVEST	Telecommunication investment (at 2022 prices) in USD divided by the annual population.	ITU GSMA
IXP	Number of IXPs in each country (per 1,000,000 inhabitants).	Packet Clearing House
EDUC	Tertiary education enrollment rate (% of population in the relevant age range).	UNESCO
EXP	Per capita expenditure on fixed and mobile telecommunications (USD per capita).	ITU GSMAi
GDP	Constant GDP at 2017 prices.	WDB
Instrumental variables		
Cellular HHI	Herfindahl-Hirschman Index (HHI) for mobile voice market. It measures the level of market concentration, with values ranging from 0 to 10,000. Higher values indicate greater market concentration.	GSMAi
MFS	Share of mobile cellular subscriptions on all voice connections (fixed and mobile).	Calculated from ITU/ GSMAi
FMS	Share of fixed telephone subscriptions on all voice connections (fixed and mobile).	Calculated from ITU/ GSMAi
BB_PRICE^{f,NB}	Average fixed broadband price in similar neighboring countries (as distinguished by group of region, OECD membership, European Union membership and year)	Calculated from ITU
Coastal length	km of coastline of the country	TAS

Table A.2
Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Broadband variables					
BB_SPEED^{f}	745	73.340	69.259	3.522	330.308
BB_SPEED^{m}	722	49.765	48.704	5.122	403.562
BB^{m}	725	22575422	49963399	0	3.954e+08
BB^{f}	648	82718.332	169508.25	19.5	1260000
IBW	727	2.771e+12	7.320e+12	−3.563e+10	6.214e+13
BB_PRICE^{m}	747	25.653	11.443	1.07	80.24
BB_PRICE^{f}	620	31.408	21.365	2.23	176.42
HHI BB^{f}	502	3608.205	2273.913	0	10000
HHI BB^{m}	722	4055.515	1581.331	2079.637	10000
Telecom variables					
INVEST^{m}	747	65.006	33.733	0.22	295.363
INVEST	747	202.29	118.101	7.946	1006.22
IXP	351	0.637	0.702	0	3.724
Macro. variables					
EDUC	549	68.16	21.725	9.643	150.202
EXP	640	73.686	32.213	8.063	281.12
GDP	746	1.238e+12	3.073e+12	5.479e+09	2.267e+13
Instrumental variables					
Cellular HHI	2180	3956.964	1287.833	1150	10000
MFS	2170	0.835	0.130	0.090	1
FMS	2170	0.165	0.130	0	0.910
BB_PRICE^{f,NB}	1728	32.550	13.114	10.99	176.42
Coastal length	2180	6610.174	21894.800	0	202080

Our analysis covers a maximum of 45 developed countries: Australia; Austria; Bahrain; Belgium; Canada; Croatia; Cyprus; Czech Republic; Denmark; Estonia; Finland; France; Germany; Greece; Hungary; Iceland; Ireland; Israel; Italy; Japan; Korea; Kuwait; Latvia; Lithuania; Luxembourg; Malta; Netherlands; New Zealand; Norway; Oman; Poland; Portugal; Qatar; Saudi Arabia; Singapore; Slovak Republic; Slovenia; Spain; Sri Lanka; Sweden; Switzerland; Trinidad and Tobago; United Arab Emirates; United Kingdom; United States.

Table A.3
Granger non-causality tests

Test log(BB^f) ↔ log(IBW)
Number of units = 30
Obs. per unit (T) = 6
Number of lags = 2
JKS non-causality test
H0: log(BB^f) does not Granger-cause log(IBW).
H1: log(BB^f) does Granger-cause log(IBW) for at least one panelvar.
HPJ Wald test: 1.8471
p-value: 0.3971
JKS non-causality test
H0: log(IBW) does not Granger-cause log(BB^f).
H1: log(IBW) does Granger-cause log(BB^f) for at least one panelvar
HPJ Wald test: 10.2730
p-value: 0.0059
Test log(BB^m) ↔ log(IBW)
Number of units = 30
Obs. per unit (T) = 18
JKS non-causality test
H0: log(BB^m) does not Granger-cause log(IBW).
H1: log(BB^m) does Granger-cause log(IBW) for at least one panelvar.
HPJ Wald test: 0.3995
p-value: 0.8189
JKS non-causality test
H0: log(IBW) does not Granger-cause log(BB^m).
H1: log(IBW) does Granger-cause log(BB^m) for at least one panelvar.
HPJ Wald test: 7.4373
p-value: 0.0243

Notes: The Granger noncausality tests were developed by Juodis et al. (2021) and Xiao et al. (2023) and implemented by Stata command "xtgrangert" that performs the half-panel jackknife (HPJ) Wald-type test for Granger noncausality. All tests reported allow for cross-sectional dependence and cross-sectional heteroskedasticity and are obtained by bootstrapping based on 500 repetitions. As the estimated equation includes log-transformed variables, all variables in the Granger causality test are also in logs for consistency. As Granger noncausality tests require stationarity, we also conducted unit root tests. While most tests assume that either T and/or N tends to infinity, the Im–Pesaran–Shin tests are also valid in unbalanced and finite samples (where N and T are fixed). All Im-Pesaran-Shin unit root tests strongly reject the null hypothesis that "All panels contain unit roots" (not reported).

Table A.4
First-stage IV regression results from mobile broadband demand

Dep. Var.:	Log(IBW)	Log(BB_PRICE^m)
Regr. nr.:	(1)	(2)
Cellular HHI	0.0006***	0.0001***
	(0.0001)	(0.0000)
L.Cellular HHI	−0.0009***	0.0001***

(*continued on next page*)

Table A.4 (*continued*)

Dep. Var.:	Log(IBW)	Log(BB_PRICE^{m})
	(0.0002)	(0.0000)
L.MFS	19.376***	−9.2198***
	(4.6958)	(2.2563)
L.MFS^2	−11.356***	5.4099***
	(3.2085)	(1.4810)
L.MFS * Coastal length	−0.0002***	−0.0000
	(0.0001)	(0.0000)
L.MFS^2 * Coastal length	0.0002***	0.0000
	(0.0001)	(0.0000)
Exogenous covariates included in column (5) of Table 4	YES	YES

Notes: All regressions control for country & year fixed effects. Robust standard errors in brackets are heteroscedasticity consistent, allow for autocorrelation up to lag two and are robust to very general forms of cross-country spatial dependence (Driscoll & Kraay, 1998). *p < 0.10, **p < 0.05, ***p < 0.01.

Table A.5
First-stage IV regression results from fixed broadband demand

Dep. Var.:	Log(IBW)	Log(BB_PRICE^{f})
Regr. nr.:	(1)	(2)
Log(BB_PRICE^{f,NB})	−0.5854	−0.4429**
	(0.4483)	(0.1903)
FMS	4.5265**	−3.0261
	(2.1476)	(2.1310)
FMS^2	−13.8452***	3.6399
	(3.8902)	(6.6681)
L.FMS * Coastal length	−0.0001***	−0.0000
	(0.0000)	(0.0000)
L.FMS^2 * Coastal length	0.0002***	0.0001
	(0.0000)	(0.0001)
Exogenous covariates included in column (5) of Table 5	YES	YES

Notes: All regressions control for country & year fixed effects. Robust standard errors in brackets are heteroscedasticity consistent, allow for autocorrelation up to lag two and are robust to very general forms of cross-country spatial dependence (Driscoll & Kraay, 1998). *p < 0.10, **p < 0.05, ***p < 0.01.

Appendix B. Evaluation of the CapEx bounds

This appendix documents the calculation underlying the capital-expenditure (CapEx) interval reported in Section 5.3.1 (Table 6). The point estimate is built bottom-up as the sum of ten cost components, each specified as a low–high range. Evaluating the sum at the component-wise lower and upper bounds yields the reported interval of US$190–375 million.

Model specification

Let C_i denote the i-th cost component ($i = 1, \ldots, 10$) and δ the contingency rate. Total projected CapEx is given by equation (B.1):

$$CapEx = (1+\delta)\sum_{i=1}^{10} C_i \tag{B.1}$$

Two components are length-driven. With route length L, unit cable cost u (US$ per km), repeater spacing s (km) and repeater unit cost p, the wet-plant cable term (B.2) and repeater term (B.3) are:

$$C_2 = L \cdot u \tag{B.2}$$

$$C_3 = \frac{L}{s} \cdot p \tag{B.3}$$

The remaining eight components are treated as fixed with respect to L over the relevant range. The model adopts the following parameter values:

- $\delta = 0.10$ - contingency rate.
- $L \approx 5600$ km - as-laid route length.
- $u \in [10, 18]$ US$k/km - unit cable cost (16 fiber pairs, heavy nearshore armoring).
- $s \in [60, 80]$ km; $p \approx 0.2$ US$m - repeater spacing and unit cost.

Component vector

Table B.1 lists the ten components at their lower and upper bounds (US$ million). Rows 2 and 3 follow (B.2)–(B.3); the remainder are the fixed-cost items.

Table B.1
Component vector for the CapEx model (values in US$ million)

i	Cost component	C_i low (US$ m)	C_i high (US$ m)
1	Route survey & marine site investigation	8	16
2	Submarine cable — wet-plant supply	56	101
3	Repeaters/optical amplification	14	20
4	Marine installation & burial	30	55
5	Optical-switching branching unit & spares	3	8
6	Dry plant — SLTE & power-feed equipment	16	32
7	Cable landing stations (new build)	15	35
8	Terrestrial backhaul	12	35
9	Permitting, licensing, environmental & community	5	14
10	Project management, integration & testing	12	24
	Σ C_i (subtotal before contingency)	**171**	**340**

Evaluation of the bounds

Summing the ten components at their lower and upper bounds gives $\Sigma C_i = 171$ (low) and $\Sigma C_i = 340$ (high). Applying the contingency uplift of equation (B.1) yields the two bounds:

$$CapEx_{low} = 1.10 \times 171 = 188.1 \approx 190 \tag{B.4}$$

$$CapEx_{high} = 1.10 \times 340 = 374.0 \approx 375 \tag{B.5}$$

The contingency line equals $\delta \cdot \Sigma C_i$ and is therefore not an eleventh independent component but the uplift itself. Rounding 188.1 and 374.0 to the nearest US$5 million gives the bounds of US$190 million and US$375 million.

Data availability

The data that has been used is confidential.

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