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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. First, our analysis establishes that increased international bandwidth (IBW) capacity resulting from submarine cable deployment significantly improves broadband quality by increasing speeds and reducing latency. 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 capacity drives mobile broadband demand up between 0.044% and 0.088%, while the increase for fixed broadband demand is slightly lower at between 0.041% and 0.062%. 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 — quantified at between US$121.05 billion and US$163.09 billion for the Irish landing site alone — overwhelmingly exceed the total private deployment costs of $180–$260 million. Our findings affirm that SMC deployments generate significant positive externalities and high social returns. While it has been argued that these effects are critical to developing nations lacking infrastructure, our findings indicate this to also be applicable to advanced economies. Consequently, we argue that policymakers in coastal nations 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.

Keywords

Submarine cables; economic impact; costs and benefits; panel econometrics

JEL

L50, L52, L86, L96,

1 Introduction

Digitization has rapidly expanded across nearly all sectors of the economy and society, especially in the last twenty years. Global 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. Each of these infrastructure components is 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 (RTI, 2021; Brake, 2019).[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 the global internet connectivity, serving as their 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 such as China.[5]

SMC consists of bundled fiber optic connections, utilizing advanced transmission technologies and protective layers, and are laid along the seabed. Landing stations constitute complementary

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[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.

investments and connect SMC to terrestrial fiber-cable based backbone networks. Currently, there are 597 active or under-construction SMC systems globally with 1,712 landing points.[6] To meet the growing demand for connectivity and ensure high quality of experience, 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 and Steck, 2025).

Given the importance of SMC as the backbone of all global communication networks, it is relevant to inquire about the economic impact of additional SMC infrastructure. To answer this research question, we derive testable hypotheses from the related literature. 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 recent panel data for a group of developed countries. Furthermore, we relate our estimation results to an illustrative SMC deployment project connecting the US with Ireland. Using industry benchmarks and our estimation results enables us to conduct a basic cost-benefit analysis, and, based on this, to derive policy recommendations.

The study is structured as follows: Chapter 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 3 describes our research strategy and the panel dataset employed. Section 4 presents our main estimation results concerning the impact of international bandwidth capacity on domestic broadband quality and adoption. Section 5 contrasts the economic benefits generated with the costs of SMC deployment. These findings form the basis for 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. Evidence on the economic impact of domestic broadband (access) networks is relevant to this study, since it is expected that the main economic impact of a SMC is via induced changes in domestic broadband quality and adoption. Next, we outline the institutional background and characteristics of the SMC industry, before reviewing the available empirical literature related to SMC. Finally, we describe the main economic impacts of the additional international bandwidth capacity induced by the deployment of new SMC. Based on this and the empirical literature, we derive testable hypotheses at the end of this Section.

2.1 Research literature on broadband economic impact

Research on the economic contribution of SMC represents a subset of empirical contributions that examine 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 related to consumer

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

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 Gomez-Barroso and Marban-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 find also 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 and Gomez-Bengoechea, 2025), which indicates that the productivity impact of ICT grows over time and requires organizational investments, skills, and industry-specific adjustments.

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 interconnection (PoPs) and data exchange (IXP) and cache nodes for local storage of content close to end-users. Data traffic generated from various consumer´s electronic devices travel through the access network[7] and typically through regional and national backbone networks[8] before entering international backbone networks via SMC for global connectivity.

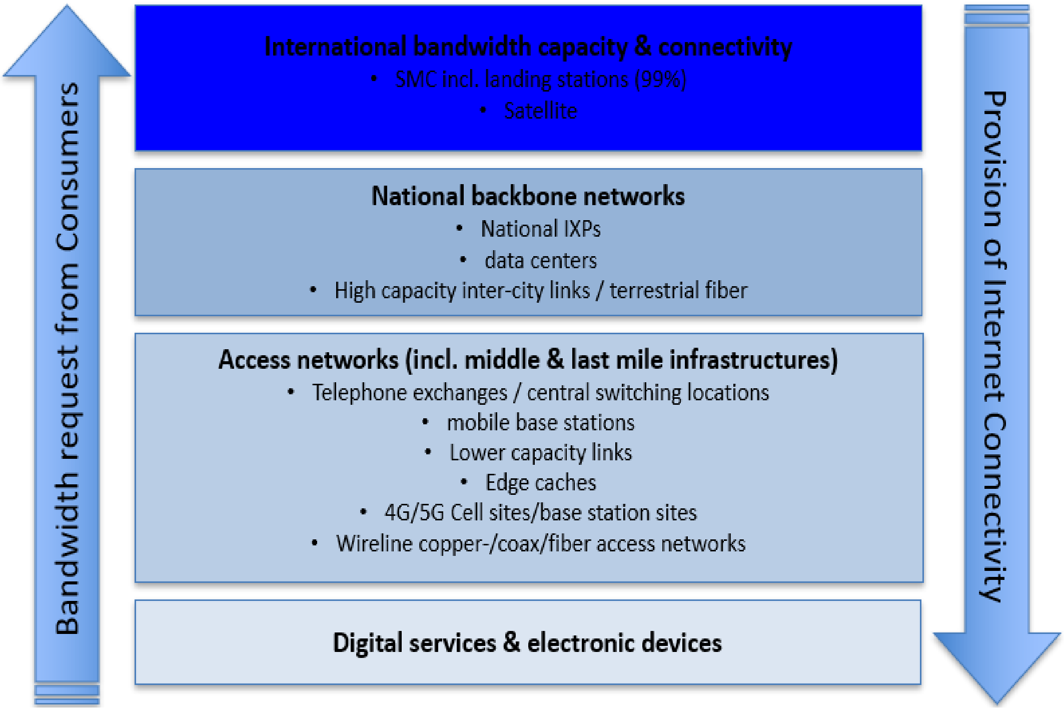
Figure 1 below illustrates the hierarchy of network infrastructure components of the Internet connectivity value chain, with international bandwidth capacity provided by SMC at the top and

[7] 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.

[8] 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.

the bandwidth requirements generated by digital services and end-user electronic devices at the bottom of the value chain.

Figure 1: Investment and adoption related effects of new SMC



Sources: Own presentation (based on Cariolle, 2021)

The deployment of SMC and costal 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.[9] Due to these high deployment costs, SMC have traditionally been funded by private-public partnerships or consortia of telecommunications network operators and other partners who then sell international bandwidth capacity. More recently, Internet companies, such as Google, Meta, and Amazon Web Services have started deploying SMC. Although private players typically self-deploy SMC capacity 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).[10] The ability to distribute capacity among various SMC enables operators to transfer capacity to different routes or cables efficiently, thereby optimizing bandwidth allocation.

The three largest companies building SMC are Alcatel Submarine Networks of Alcatel-Lucent, based in France, SubCom of Cerberus, a US based infrastructure fund, and NEC Corporation of Japan (Brake, 2019). 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

[9] 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.

[10] These actors could de facto and de iure 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.

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, 2022). 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 reliability of components (Copenhagen Economics, 2021).

2.3 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 regards to GDP.[11] A few studies also examine the impact on domestic broadband market indicators.

2.3.1 Impact on Gross Domestic Product

Table 1 summarizes all available 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 0.62% and 0.15%, 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% in usage increase).

While most studies of SMC economic impact use data from developing countries, RTI (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 impact found in RTI (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 (0.1387) using US states data. 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.

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

Table 1: Studies of impact of SMC 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%-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 methods 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 (2020)	**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) and 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 and Caribbean countries (2010-2020)	Fixed effects Generalized methods 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 effect 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: Compiled by authors

2.3.2 Broadband market effects

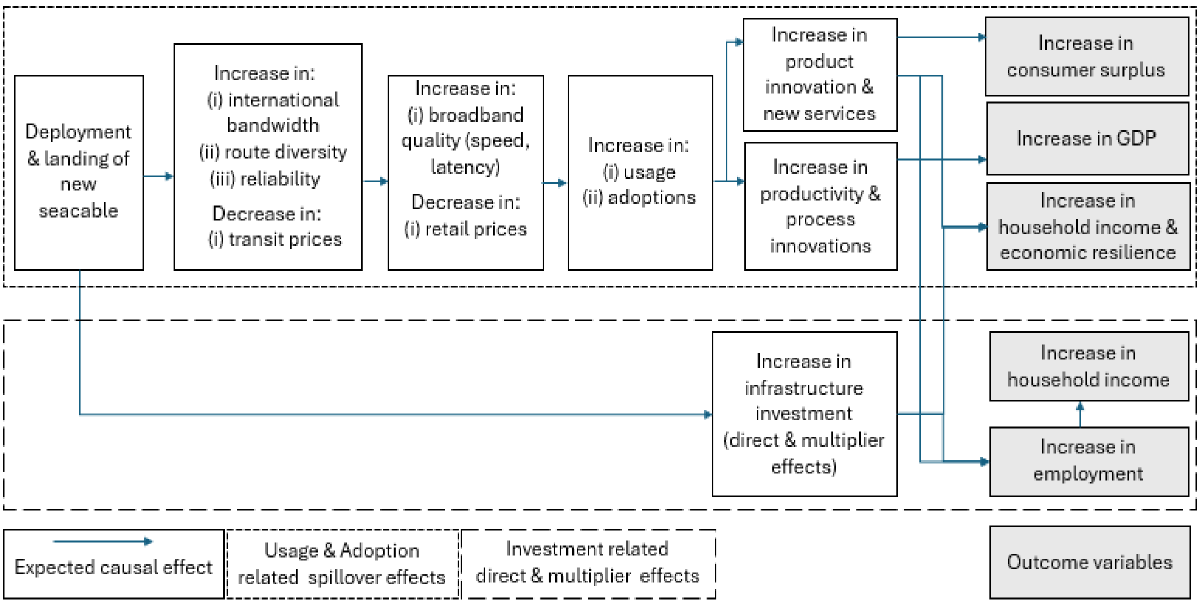
Finally, there are a few studies that focus on specific broadband market outcomes (such as quality and price): Hjort and Poulsen (2019) found that SMC increased measured speed in connected locations, relative to unconnected locations, by around 35 % for a set of African countries. Cariolle (2021) employs 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.

2.3.3 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 conclude on 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 analysis by Copenhagen Economics (2021) and RTI International (2021) is based on arithmetic inferences instead of actual causal analysis. We aim to fill this research gap using panel data from advanced economies. Our study is also 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.

Along these lines, Figure 2 below summarizes the anticipated effects and mechanisms resulting from the deployment of new internet infrastructures (additional SMC capacity and landing stations).

Figure 2: Investment and adoption related effects of SMC deployment



Sources: Own presentation (based on Briglauer et al. (2024); Analysys Mason (2021, 2022); Katz and Callorda (2020))

Next to the investment-related GDP effects (shown in the lower part of Figure 2), there are indirect effects arising from a SMC landing induced increase in international bandwidth capacity (shown in the upper part of Figure 2). 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 induce an increase in the demand of broadband connections from consumers. New adoptions of high-quality broadband connections enhance the use of various business and residential applications, which in turn increase consumer utility in terms 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 the review of the related empirical research literature 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 (H1a) and hence an indirect positive impact on domestic broadband adoption (H1b).
- H2: The adoption and usage related contribution of SMC is expected to be much larger than the investment effects.
- H3: The gains in GPD derived from SMC are positive and substantial.
- H4: Given the large externalities generated by Internet networks as general-purpose technologies,[12] we expect total benefits for society to exceed total private costs.

3 Empirical research framework

3.1 Estimation of international bandwidth related broadband quality effects

According to the discussion in Section 2 (Figure 2), an increase in international bandwidth capacity (IBW) impacts broadband market outcomes such as prices and quality levels experienced by consumers.[13] In doing this, we first estimate the impact of IBW in separate regression models with regard to domestic broadband quality variables, BB^j, where superscript j = f, m, denotes parameters specific to wireline (fixed, f) or wireless (mobile, m) broadband access technologies. We extend the previous empirical contributions by explicitly modeling a representation of the dependence of domestic broadband quality variables on IBW in country i and in year t for broadband access technology j which read as follows:

$$BB\_SPEED_{it}^{j} = g(\mathrm{IBW}_{it}, \mathrm{IXP}_{it}, W_{it}, \mathrm{GDP}_{\mathrm{it}}, \mathrm{BB\_INVEST}_{it}^{j}, \mu_i^{j,SPEED}, \mu_t^{j,SPEED}) \quad (1)$$

$$BB\_LATENCY_{it}^{j} = h(\mathrm{IBW}_{it}, \mathrm{IXP}_{it}, W_{it}, \mathrm{GDP}_{\mathrm{it}}, \mathrm{BB\_INVEST}_{it}^{j}, \mu_i^{j,LATENCY}, \mu_t^{j,LATENCY}) \quad (2)$$

Whereas international bandwidth (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 outcome variables such as

[12] For the theoretical foundations of general-purpose technologies, the reader is referred to the seminal work of Bresnahan and Trajtenberg (1995).

[13] Note that according to Figure 2 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 passthrough 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.

broadband quality 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, equations (1) to (2) include country fixed effects, μ_i´s, to capture any time-invariant heterogeneity at the country level, as well as year fixed effects, μ_t´s, to cover common macroeconomic shocks, such as business cycles or the impact of the COVID-19 pandemic.

Estimating equations (1) and (2) allows us to test our auxiliary hypothesis (H1a) 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 auxiliary hypothesis is important, even if we cannot test a structural relationship between these equations based on the available data.

3.2 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^{fixed} and BB_PRICE^{mobile}, 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, (iv) potential market size (M) and finally (v) 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:

$$BB_{it}^{j} = l\left(IBW_{it}, IXP_{it}, BB\_PRICE_{it}^{j}, BB\_PRICE_{it}^{fixed,mobile}, EXP_{it}, \mathrm{GDP}_{it}, EDUC_{it}, \mathrm{M}_{it}, \mu_{i}^{j,BB}, \mu_{t}^{j,BB}\right) \tag{3}$$

Note that we are not assessing the direct impact of domestic broadband quality in terms of speed and latency in equation (3), but the indirect impact induced by an increase in IBW. This is because our data on broadband speed and latency are only available for the years 2021 to 2023, but also because IBW simultaneously captures the price effect due to lower wholesale prices.[14] The estimated coefficient of IBW in equation (3) should therefore be interpreted as the indirect effect of additional IBW capacity on broadband adoption which measures the "intention-to-treat effect" (ITT) rather than the treatment effect itself. The ITT effect is typically smaller than both the average treatment effect (ATE) and the average treatment effect on the treated (ATT). ITT captures the impact of being assigned to treatment (higher wholesale capacity and lower transit prices) rather than actually receiving it (higher domestic broadband quality and lower retail prices). Because some individuals do not comply to their assignment (i.e., they do not receive the treatment,

[14] 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 (3).

same QoE as before the SMC deployment), the ITT estimate is weakened by the presence of non-compliers. The extent of this difference is determined by the level of non-compliance. In cases of full compliance, ITT, ATE, and ATT are identical.[15]

In fact, since the marginal effect of IBW is expected to be less than one in equations (1) to (3), the estimated IBW coefficient is a proportional effect that is likely to be smaller than the (unobserved) effect of the BB_SPEED and BB_LATENCY variables (if included in the respective adoption equation). 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)-(3), we intend to 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 of the ratio 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 (3), and negative and significant in equation (2) (H1b).[16]

3.3 Calculations of domestic GDP effects

In a final step we calculate the impact of the IBW induced changes on broadband adoption, $\Delta BB\_ADOP_{it}^{j}$(from equation (3)), and on aggregate economic outcome (GDP). The latter is a key factor in our cost-benefit analysis in Section 5. In doing this, we refer to the broadband related empirical literature that employs panel data on advanced economies and similar model versions based on an augmented production function framework for aggregate country level data (Koutroumpis, 2009 and 2019; Briglauer and Gugler, 2019; Katz and Jung, 2022; Briglauer et al., 2025). The estimation results provided by Briglauer et al. (2025) represent the most recent and comprehensive analysis of the impact of both wired and wireless broadband adoption and coverage on GDP. The results contained therein are also largely consistent with the estimation results from previous work for both the effect of mobile broadband (Edquist, 2018) and fixed broadband (Briglauer and Gugler, 2019; Koutroumpis, 2009 and 2019). Therefore, we are confident that these

[15] 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 rcenter 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.

[16] Broadband latency refers to the time it takes for data to travel from a device to a destination server and back, typically measured in milliseconds (ms). Lower latency implies quicker reply from destination servers, which increases QoE for a certain range of popular online services, such as online gaming or video calls, which require (low-latency) real-time performance.

estimation results not only provide a very up to date but also reliable basis for calculating GDP effects. Relevant 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 (Table A.1 in the Appendix reports their main estimations results). The comparatively high impact of mobile broadband is in line with the findings in Edquist et al. (2018) who are the first to examine the impact of 3G/4G mobile broadband. Using country-level panel data for the years 2002-2014 the authors find that 1% increase in mobile adoption increases GDP by 0.08%. Based on these coefficient estimates, the total change in GDP due to increased IBW capacity can finally be evaluated for coefficient estimates β_j´s as follows:

$$\Delta GDP = \beta_{adop}^{mobile} * \Delta BB\_ADOP^{mobile} + \beta_{adop}^{fixed} * \Delta BB\_ADOP^{fixed} + \beta_{cov}^{mobile} * \Delta BB\_COV^{mobile} + \beta_{cov}^{fixed} * \Delta BB\_COV^{fixed} \quad (4)$$

where (from equation (3))

$$\Delta BB\_ADOP^{mobile} = \beta_{IBW}^{mobile} * \Delta IBW$$
$$\Delta BB\_ADOP^{fixed} = \beta_{IBW}^{fixed} * \Delta IBW \quad (5)$$

where β_{IBW}^{mobile} and β_{IBW}^{fixed} denoted the coefficient estimates for the variable IBW in the demand equations. Since the coefficient estimates β_{cov}^{mobile} and β_{cov}^{fixed} reported in Briglauer et al. (2025) are either insignificant or low (with a maximum elasticity value of 0.003), we infer that coverage-related GDP effects will be close to zero and much smaller than adoption-related GDP effects. When discussing the total benefits of deploying SMC in Section 5, we will refer to our own input-output analysis of the effects of infrastructure construction and contrast these effects with the total adoption-related GDP spillovers from equation (5).[17] Contrasting these numbers allows us to test hypothesis H2. Calculating GDP effects and contrasting them with total costs of SMC deployment allows us to answer hypotheses H3 and H4.

3.4 Identification strategy

When comparing 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 another SMC on yearly fluctuating parameters, but rather on long-term stable market conditions, which are by and large captured by fixed effects.

[17] Note that broadband connections are expressed as levels in equation (3), but as adoption rates ("ADOP") in equations (4) and (5). The elasticity of broadband connections in levels corresponds to the elasticity of broadband adoption only if the reference value, i.e. households, remains (roughly) constant. In our data set, the average growth rate of households is less than 1 per cent, which is why we can ignore any bias in this regard.

However, two main concerns regarding endogeneity arise from the demand functions as specified in equation (3). 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 sector-specific regulations or innovations in digital products and services. As illustrated in Figure 1, there may also be a reciprocal dependence underlying domestic broadband demand and demand for IBW.

First, to account for endogeneity concerns resulting from reversed 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.2 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 index and on the share of mobile over all connections, 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 (Briglauer et al., 2018). These indicators will also be 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.

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, and a metric of cross-national spillovers that may affect market dynamics such as prices. The latter instrument measures the average price levels in neighboring countries that belong to the same region or supranational economic block 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.

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 and valid 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 postestimation analysis and test our assumption that our main explanatory variable, IBW, can be treated as exogenous.

3.5 Data

The baseline estimating models (1), (2) and (3) outlined in Section 3.2 are estimated based on panel data for a maximum number of 90 and 40 countries, respectively, and for a maximum number of years from 2005/2021 to 2023. Note that we do not have balanced data (Table A.1), and we only have data for the years from 2021 to 2023 for estimating equations (1) and (2). Since our example SMC project aims to evaluate the economic effects in developed countries, we have limited the data set to observations whose GDP per capita 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 Hirschan Index based on market shares). Definitions, sources and descriptive statistics of all variables, including control variables, are provided in detail in Tables A.3 and A.4 in the Appendix.

3.5.1 Dependent variables

The dependent variables in equations (1) and (2) measure broadband quality in terms of speed and latency. The speed indicator, BB_SPEED, measures the average of the median values of the fixed and mobile broadband speed (in bps) measured in the 12 months of the year. The latency indicator, BB_LATENCY measures the median latency (in ms) of fixed and mobile broadband as the average of the measurements of all 12 months of the year.

The dependent variables measuring wireline and wireless broadband demand, BB^f and BB^m, in equation (3) 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.

3.5.2 Main independent variable

Our main explanatory variable, international Internet bandwidth, denoted with IBW, that has been employed in most empirical studies reviewed in Section 2.3.1, 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."[18] Although most of the studies reviewed in Sections 2.1 and 2.2 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"[19] it is stated that "*[o]ver 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 rcenters 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 SMC count does not account for technological upgrades or changes in capacity, IBW

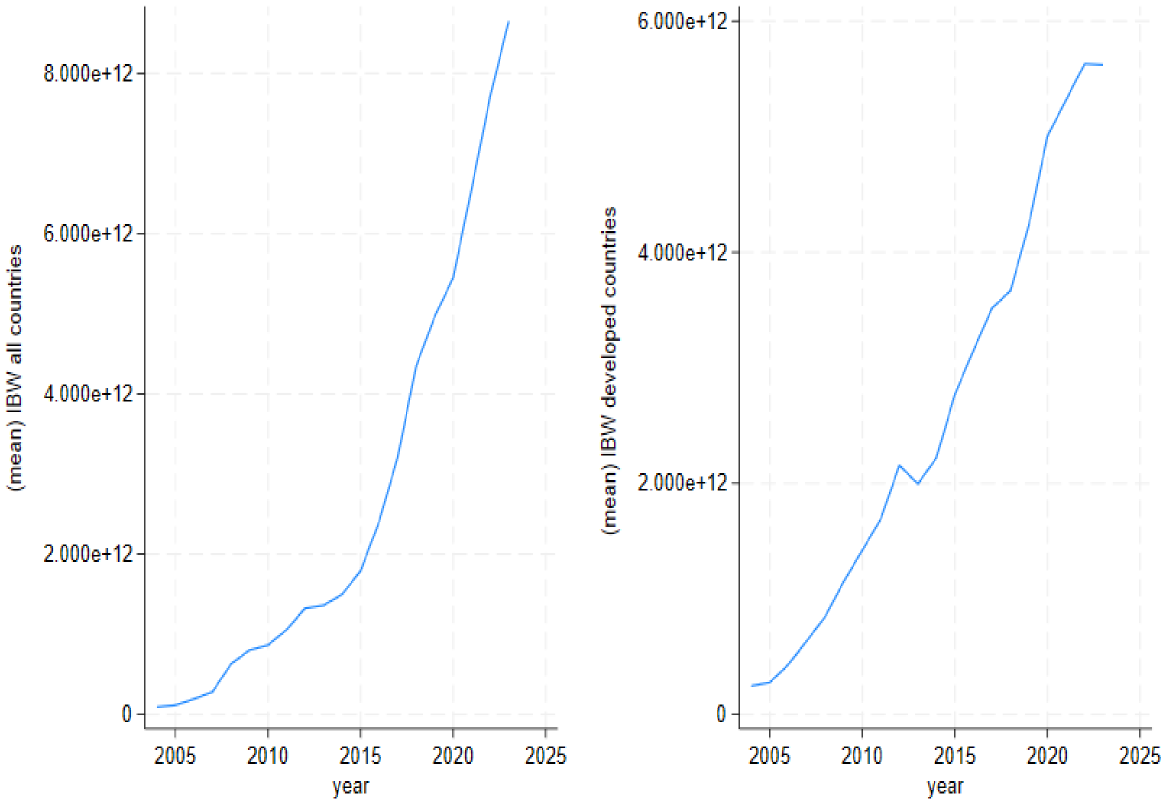
[18] Long definition available at: https://databank.worldbank.org/metadataglossary/world-development-indicators/series/IT.NET.BNDW.PC-

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

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 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 wholesale capacity, IBW-based measures are the most appropriate way of answering our research questions.[20]

Figure 3 below illustrates the evolution of IBW for the total sample of 108 countries (left panel) and for the group of developed countries with a GDP per capita exceeding USD 19,120. Figure 3 shows that the group of developed countries represents a large proportion of total IBW capacity, 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. In 2022, for instance, 36 countries with above-average GDP per capita accounted for around 73% of international bandwidth capacity.

Figure 3: IBW growth in the group of all countries (left panel) and developed countries (right panel)



Source: ITU, own calculations

3.5.3 Instrumental variables

In accordance with the rationale outlined in Section 3.4, Table 2 below summarizes the instruments used to endogenize both types of potentially endogenous regressors. 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 and Schmutzler, 2011, Schmutzler, 2013).

[20] The authors would like to thank Joel Cariolle for providing these insights.

Table 2: Instruments used in FE-IV regressions

Endogenous regressor	Instruments
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 BB price in similar 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, Coastal, interacted with mobile-fixed substitution, MFS, in levels and squares (in lags) In fixed broadband demand model: Coastal length, Coastal, interacted with fixed-mobile substitution, FMS, in levels and squares (in lags)

4 Estimation results

According to the discussion in Sections 2 and 3, we first present our estimation results on the impact of international bandwidth capacity on domestic broadband quality (Section 4.1), and then we report the results on fixed and mobile broadband demand (Section 4.2). While we use a two-way fixed effects estimator in Sections 4.1 and 4.2, in Section 4.3 we also employ a fixed effects instrumental variables estimator (FE-IV) to further strengthen the robustness of our main results.

4.1 Impact of international bandwidth on broadband quality

We first assess the impact of additional IBW on national broadband quality levels. Table 3 presents the estimation results based on the entire data set including 98 or 99 countries.[21] All regression models explain between ~ 63% and 84% of relevant within variation for BB_SPEED, but only between 14 and 18% for BB_LATENCY regression models. All coefficient estimates exhibit expected sign when significant and all standard errors are robust. IBW coefficients are elasticities and significant at the 5 and 10% level, except for the variable $BB\_LATENCY^f$ in regression (3). All IBW coefficient estimates have the expected signs (positive in BB_SPEED regressions and negative in BB_LATENCY regressions). For example, from regressions (2) and (4) a 1% increase in IBW capacity increases BB_SPEED^m by about 0.08% and decreases $BB\_LATENCY^m$ by 0.016%, respectively.

[21] We included data from all countries because information on broadband latency and speed is only available for the last three years of our analysis period (Table A.4). This somewhat limits the comparability of the results with the rest of the analysis conducted. However, we estimate equations (1) and (2) separately, which only serves to examine our auxiliary hypothesis H1 as a first step.

Table 3: Regression results for the IBW equation impact on domestic broadband quality

Dep. var.:	$Log(BB\_SPEED^{f})$	$Log(BB\_SPEED^{m})$	$Log(BB\_LATENCY^{f})$	$Log(BB\_LATENCY^{m})$
Regr. nr.:	(1)	(2)	(3)	(4)
Log(IBW)	0.0567**	0.0803*	0.0441	-0.0160**
	(9.29)	(3.96)	(2.58)	(-4.39)
$INVEST^{f}$	-0.0002		-0.0003	
	(-2.32)		(-1.52)	
$INVEST^{m}$		-0.0002		-0.0003**
		(-0.45)		(-6.16)
Log(IXP)	0.0906***	-0.1194	-0.1250*	0.0150
	(13.98)	(-2.74)	(-3.46)	(2.28)
HHI_BB^{f}	-0.0000**		-0.0000	
	(-6.00)		(-0.61)	
HHI_BB^{m}		-0.0000		-0.0000
		(-1.49)		(-2.57)
Log(GDP)	0.7126***	1.1219**	-0.3726***	-0.0127
	(11.21)	(4.90)	(-10.29)	(-0.44)
Constant	0.0000	-27.9118*	10.5210***	4.0541**
	.	(-4.20)	(10.22)	(5.62)
R2 within	0.840	0.626	0.180	0.140
F-Test	104.824	21.126	53.187	10.704
#Countries	98	99	99	99
#Obs.	288	290	291	290

Notes: All regressions control for country & year fixed effects. Robust standard errors are heteroscedasticity consistent, allow for autocorrelation up to lag two and are robust to very general forms of cross-country spatial dependence (Driscoll and Kraay, 1998). The number of observations varies because of a few missing values. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4.2 Impact of international bandwidth on mobile and fixed broadband demand

Tables 4 and 5 report the estimation results for mobile and fixed broadband demand, respectively. Regression models explain between ~ 87% and 91% and between ~ 73% and 69% of relevant within variation, for the mobile and fixed demand models, respectively. Importantly, 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 (including lagged values of IBW instead of contemporaneous values in regressions (3) and (4)) and number of countries (excluding landlocked countries in regressions (2), see table notes). In regressions (4) we add further controls for cross-prices (BB_PRICE^{fixed} and BB_PRICE^{mobile}) and market size (MOB_TEL and COMP).

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 at the 1% level, both for contemporaneous (regressions (1) and (2)) and for one-period lagged effects (regressions (3) to (4)). All of the IBW coefficient estimates have the expected signs. A 1% increase in IBW capacity increases mobile broadband demand by about 0.044% to 0.088% for the lowest lagged and highest contemporaneous effects, respectively.

Table 4: Two-way FE regression results for mobile broadband demand

Dep. var.:	**Log(BB^m)**			
Regr. nr.:	(1)	(2)	(3)	(4)
Log(IBW)	0.0693***	0.0881***		
	(3.59)	(4.95)		
Lag: Log(IBW)			0.0437***	0.0480***
			(3.52)	(5.23)
BB_PRICE^m	-0.0247**	-0.0183*	-0.0159*	0.0043
	(-2.16)	(-1.82)	(-1.80)	(1.13)
Log(EXP)	0.2589**	0.2897*	0.1450**	-0.0204
	(2.14)	(2.00)	(2.31)	(-0.32)
Log(GDP)	1.0332**	0.9607**	1.1745**	0.8688***
	(2.29)	(2.17)	(2.50)	(3.36)
Log(EDUC)	0.9955***	1.1262***	0.9200***	0.7251***
	(4.01)	(4.00)	(4.05)	(3.78)
Log(BB_PRICE^{fixed})				-0.1446**
				(-2.66)
MOB_TEL				0.0079***
				(4.19)
Constant	-23.0637*	-22.4249*	0.0000	-12.0561
	(-1.96)	(-1.88)	.	(-1.59)
R2 within	0.908	0.907	0.894	0.872
#Countries	40	36	40	40
#Observations	502	445	488	431

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

In Table 5 the IBW coefficients in the fixed broadband regressions are elasticities and significant at the 5 and 10% level, both for contemporaneous (regressions (1) to (2)) and for one-period lagged effects (regressions (3) to (4)). All of the IBW coefficient estimates have the expected signs. For example, a 1% increase in IBW capacity increases fixed broadband demand by about 0.0410% to 0.0615% for the lowest lagged and highest contemporaneous effects, respectively.

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 ranges from 0.115 to 0.15. This matches 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 landlocked countries has no effect on demand for fixed broadband: the IBW coefficient remains virtually unchanged. However, there is a statistically insignificant effect on the specification of mobile demand. One possible reason for these weak effects is that the group of advanced countries also exhibits a high level of fiber-terrestrial cross-country interconnections. Hence, landlocked countries also 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.

Table 5: Two-way FE regression results for fixed broadband demand

Dep. var.:	**Log(BB^f)**			
Regr. nr.:	(1)	(2)	(4)	(5)
Log(IBW)	0.0615**	0.0600*		
	(2.51)	(2.19)		
Lag: Log(IBW)			0.0632**	0.0410*
			(3.41)	(2.24)
Log(BB_PRICE^f)	-0.0121**	-0.0130**	-0.0024	-0.0098**
	(-3.27)	(-2.97)	(-0.46)	(-2.50)
BB_PRICE^{mobile}				0.0052**
				(3.41)
Log(EXP)	0.1702*	0.1693*	0.1530*	0.2543
	(2.19)	(2.22)	(2.13)	(1.85)
Log(GDP)	0.0854	0.0861	0.0487	0.0149
	(1.73)	(1.83)	(1.71)	(0.34)
Log(EDUC)	0.1219	0.1478	0.1020	0.2613*
	(1.09)	(1.32)	(1.03)	(2.01)
COMP				0.0015
				(1.47)
Log(IXP)	0.0448*	0.0533*	0.0459*	0.0453
	(2.09)	(2.26)	(2.31)	(1.31)
Constant	5.3949**	5.3984**	6.4589***	0.0000
	(2.49)	(2.47)	(4.57)	.
R2 within	0.719	0.722	0.728	0.692
F-Test	2857.158	2029.443	28708.110	964.356
#Countries	39	35	39	37
#Observations	230	203	230	148

Notes: All regressions control for country & year fixed effects. Robust standard errors are heteroscedasticity consistent, allow for autocorrelation up to lag two and are robust to very general forms of cross-country spatial dependence (Driscoll and 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 35 instead of 39 because we excluded four landlocked countries from our dataset of advanced economies: Austria, Czech Republic, Luxembourg and Switzerland. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4.3 Results for fixed effects instrumental variables

In this subsection we examine whether the demand functions estimated above are 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.

In Table 6 we present the estimation results for fixed and mobile broadband demand which are based on the respective FE specifications in Tables 4 and 5. As can be seen, in all cases the first stage statistics for both endogenous regressors are strong enough as evidenced by the respective F tests, suggesting a high explanatory power of the instruments. Also, the Hansen J statistics allow us not to reject the null hypothesis of exogeneity of the underlying instrument sets in regressions (1) and (2). Therefore, all post-estimation tests show that the instruments are strong, and the exclusion restrictions are valid. First-stage results are included in Table A.5 in the Appendix.

Table 6: FE-IV regression results for fixed and mobile broadband demand

Dep. var.:	**Log(BB^f)**		**Log(BB^m)**	
Regr. nr.:	(1)	(2)	(1)	(2)
Log(IBW)	0.1146***	0.1175***	0.0492***	0.0517***
	(2.69)	(2.86)	(3.55)	(3.37)
Log($BB\_PRICE^{f,fixed}$)	-0.0695**	-0.1032**		-0.0186
	(-2.20)	(-2.50)		(-1.15)
$BB\_PRICE^{m,mobile}$		0.0075***	-0.0117***	-0.0108**
		(4.27)	(-3.19)	(-2.36)
Log(EXP)	0.0997	0.0763	0.0507	0.0358
	(1.07)	(0.86)	(0.47)	(0.30)
Log(GDP)	0.0440	0.0832	-0.0547***	-0.0415***
	(0.34)	(0.64)	(-3.01)	(-2.76)
Log(EDUC)	0.0527	0.0556	-0.0919	-0.0914
	(0.47)	(0.62)	(-1.22)	(-1.04)
Log(IXP)	0.0484**	0.0467**		
	(2.43)	(2.50)		
First stage F-test (log(IBW)	59.36	35.93	36.66	21.31
First stage F-test (log(BB_PRICE^f))	92.15	58.11	915.70	3309.84
P-value Hansen J stat	0.327	0.260	0.300	0.310
P-value endog test (log(IBW))	0.919	0.628	0.875	0.796
R2 within	0.680	0.661	0.818	0.819
#Countries	39	39	39	39
#Observations	230	230	230	230

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

Most importantly, FE-IV estimation results exhibit a positive and strongly significant coefficient for the variable IBW across all the different specifications in regressions (1) and (2). It appears that the magnitude of the fixed effects (FE) coefficient estimates are included in the interval of 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 suspicious regressor is exogenous. This confirms our initial hypothesis that the variable IBW is presumably exogenous, which implies that we can rely on the more narrowly estimated FE coefficients reported in Tables 4 and 5. The latter serve as a point of departure for our cost-benefits simulation analysis and for deriving policy recommendations in final Sections 5 and 6, respectively.

5 Cost benefit analysis: SMC connecting United States and Ireland

In this section, we compare the total benefits of an SMC deployment with the total costs of an illustrative example: a newly deployed SMC connection between the United States and Ireland. Our numerical benefit calculations are limited to the effects on GDP, derived from our own estimates and econometric estimates from the literature (Briglauer et al., 2025). The costs and benefits are detailed in Sections 5.1 and 5.2, respectively.

5.1 Cost analysis

This section outlines the capital expenditure required for deploying a new transatlantic submarine cable system on the high-demand route between New Jersey in the United States, and Cork in Ireland. This route is a strategic infrastructure corridor for financial and cloud services, with precedents set by systems such as Hibernia Express (GTT, 2015) and Havfrue/AEC-2 (Aqua Comms, 2020).

The cost model operates under four core assumptions:

(i) The route length is about 4,600 km.[22]
(ii) The system design incorporates 8 fiber pairs, representing the contemporary industry standard for new long-haul cables.[23]
(iii) Landing stations are co-located within established cable hubs in both the United States and Ireland, mitigating costs associated with greenfield construction and permitting (FCC, 2020; ComReg, 2019).
(iv) The largest cost drivers are the wet plant (cable manufacturing & marine deployment) and terrestrial backhaul, the latter being highly variable based on local geography and existing infrastructure.[24]

Cost estimates are derived from a synthesis of industry benchmarks. Wet plant manufacturing costs are estimated at $18k-$26k per km, based on analysis of publicly disclosed SMC project budgets (TeleGeography, 2023). Marine deployment costs for modern cable ships are reported to amount to $150,000 per day (SubCableWorld, 2021), and the project timeline corresponds to the similar Hibernia Express system. The **total projected budget of $180-$260 million** is consistent with, yet lower than, the reported $300 million cost of Hibernia Express (GTT, 2015), after adjusting for the shorter route length.

5.2 Benefit analysis

5.2.1 GDP effects

To simulate the GDP contribution of deploying a submarine cable linking Ireland and the United States, we first calculate the resulting increase of international broadband capacity from current level. More specifically, the capacity forecast model is based on five core assumptions:

(i) The system's assumed design capacity is ~240 Tbit/s, calculated from 8 fiber pairs each supporting ~30 Tbit/s (Fontaine et al., 2022). The per-fiber-pair capacity of 30 Tbit/s is grounded in the demonstrated performance of recent state-of-the-art systems, including the Dunant cable (Fontaine et al., 2022) and the Grace Hopper cable (Google, 2021).
(ii) We estimate that the current international bandwidth ("legacy capacity") is currently 160 Tbit/s (including publicly available and private capacity).
(iii) The economic lifetime of the SMC plant is 20 to 25 years; a standard depreciation period used in subsea network financial modeling.[25]
(iv) Capacity activation follows an aggressive, non-linear ramp-up profile. This reflects the high-demand profile of the US-Ireland route.

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[22] Information available at: https://cnetworks.info/wp-content/uploads/2021/11/Submarine-Telecoms-Industry-Report-Issue-10.pdf.
[23] Information available at: https://submarine-cable-map-2023.telegeography.com/-
[24] Information available at: https://subtelforum.com/submarine-telecoms-industry-report/.
[25] Information abrufbar unter: https://subtelforum.com/submarine-telecoms-industry-report/.

(v) We assume that 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.

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 ($\beta_{IBW}^{mobile}$and β_{IBW}^{fixed}). 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, assuming that SMC deployment will begin 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 GDP contribution to Irish GDP will increase by between US$121.05 billion (low estimate) and US$163.09 billion (high estimate).

Ignoring the other effects and benefits of SMC deployment, as described in the next section, it appears that the total benefits reported in Table 7 far outweigh the total private costs reported in Section 5.1. Therefore, this result holds true with respect to any reasonable changes in model assumptions.

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			**$121,05**	**$163,09**		

Source: International Monetary Fund; Authors

5.2.2 Other effects

As discussed in Section 2 (Figure 2), the deployment of SMC also has an effect on GDP related to investment. Using the OECD published input-output analysis, the authors calculated the total construction effect, consisting of direct, indirect and induced effects relating to construction work at the U.S. landing site. The investment required to build the subsea equipment and landing site, and to deploy the backhaul/fronthaul facility, will generate a one-time total GDP contribution of US$21,098. As expected, this one-time contribution is rather small compared to the adoption-related GDP effects reported in Table 7. This finding based on input-output analysis is also consistent with the econometric estimates of coverage and adoption in Briglauer et al. (2025, Table A.1) and confirms our hypothesis H4.

Additionally, 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.[26]

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 the COVID virus. 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 probably 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, please 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, we expect even stronger GDP spillover effects in the future. Taking all these effects into account, we did not discount the expected future GDP gains in Table 7.

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[26] 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 (Poquiz, 2022; Alcott et al., 2020; Mosquera et al., 2020; Burstyn et al., 2023). 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, 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).

6 Summary and Conclusions

Submarine cables form the backbone of global internet connectivity, carrying the majority of international data traffic and linking continents, countries and regions. They provide access to content from around the world and directly 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 answer the following research question: what are the actual economic impacts, in terms of GDP spillovers, of additional SMCs? To answer this question, we first examine how SMC deployment increases international bandwidth capacity (IBW) and 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.

Our analysis reveals that, as anticipated, IBW has a positive and significant impact on broadband speed and a negative impact on latency. With regard to international bandwidth, we find that a 1% increase in IBW capacity increases mobile broadband demand by approximately 0.044% to 0.088%. The impact on fixed broadband is similar: a 1% increase in IBW capacity increases fixed broadband demand by approximately 0.0410% to 0.0615%. These results are largely robust with respect to different regression specifications and estimators.

Furthermore, 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 estimates of the impact of broadband adoption on GDP from recent empirical studies, we conducted a basic cost-benefit analysis. Our findings show that the spill-over profits generated substantially outweigh the total costs of SMC deployment. Deploying the submarine cable from the point it reaches the Irish coast to the main interconnection hub in Dublin, for example, will contribute between US$121.05 billion and US$163.09 billion for the Irish GDP alone; this overwhelmingly exceeds the total private deployment costs of $180–$260 million. Notably, substantial GDP effects will also be generated at the other end in neighboring states, far exceeding the corresponding costs. Related research based on broadband data suggests that the economic effects of the submarine cable will be felt not only in the region where it lands, but also in neighboring states through the interconnected nature of the internet. Additionally, 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. By contrast, the multiplier effects of SMC investment appear to make a minor contribution to GDP.

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 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 Lewis, 2023).

Given the global interconnectedness of the internet, future research should examine the geographical scope of the economic impacts of submarine cables. 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.

Appendix

Tables A.1 to A.6

Table A.1: Two-way FE regression results for the production function equation

	Log of real GDP per capita					
Dependent variable:			*log(GDP_pc)*			
Estimation method:	FE	FE	FE	FE-IV	FE-IV	FE-IV
Regression #:	(1)	(2)	(3)	(4)	(5)	(6)
log(CAPITAL)	0.237***	0.243***	0.214***	0.241***	0.273***	0.170***
	(0.030)	(0.025)	(0.029)	(0.020)	(0.028)	(0.050)
log(LABOR)	0.334***	0.362***	0.356***	0.237***	0.201***	0.314***
	(0.040)	(0.038)	(0.033)	(0.051)	(0.049)	(0.066)
$log(BB\_COV^{fiber})$		-0.002	0.002**		-0.001	0.003***
		(0.002)	(0.001)		(0.002)	(0.001)
$log(BB\_ADOP^{fixed})$		0.025**	0.034***		0.024***	0.032***
		(0.009)	(0.011)		(0.008)	(0.010)
log(COV_3G+)	-0.002***	-0.002***	-0.000	-0.002**	-0.002***	0.000
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
$log(BB\_ADOP^{mobile})$	0.092***	0.084***	0.100***	0.102***	0.098***	0.113***
	(0.020)	(0.020)	(0.014)	(0.023)	(0.025)	(0.015)
$years\_since\_adop^{fiber}$			0.014***			0.015***
			(0.003)			(0.004)
$years\_since\_adop^{mobile}$			0.011***			0.012***
			(0.003)			(0.003)
$log(EDUC^{secondary})$	0.282***	0.229***	0.322***	0.296***	0.257***	0.328***
	(0.046)	(0.045)	(0.053)	(0.044)	(0.046)	(0.061)
$log(EDUC^{high})$	0.217***	0.181***	0.184***	0.217***	0.189***	0.171***
	(0.027)	(0.023)	(0.025)	(0.029)	(0.025)	(0.021)
First Stage F-test				11.72	12.08	11.11
p-value Hansen J stat				0.884	0.659	0.125
Within R-squared	0.437	0.455	0.525	0.433	0.448	0.518
Observations	608	608	608	608	608	608

Source: Table taken from Briglauer et al. (2025), p. 14

Table A.2: Granger non-causality tests

Test log(BB_ADOPf) ↔ log(IBW)

Number of units= 30
Obs. per unit (T) = 6
Number of lags = 2

JKS non-causality test
H0: log(BB_ADOP^f) does not Granger-cause log(IBW).
H1: log(BB_ADOP^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_ADOP^f.
H1: log(IBW) does Granger-cause log(BB_ADOP^f for at least one panelvar

HPJ Wald test: 10.2730
p-value: 0.0059

Test log(BB_ADOP^m) ↔ log(IBW)

Number of units= 30
Obs. per unit (T) = 18

JKS non-causality test
H0: log(BB_ADOP^m) does not Granger-cause log(IBW).
H1: log(BB_ADOP^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_ADOP^m).
H1: log(IBW)does Granger-cause log(BB_ADOP^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 roots tests. While most tests assume that either T and / or N tends to infinity, the Im-Pesaran-Shin tests that 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.3: 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
$BB\_LATENCY^f$	Median latency of fixed broadband (in ms) as the average of measurements of all 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
$BB\_LATENCY^m$	Median latency of mobile broadband (in ms) as the average of the measurements of all 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
MOB_TEL	Number of mobile telephony connections.	GSMAi
COMP	Percentage of the households that have a computer (fixed or mobile devices).	ITU
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

Table A.3 (cont.)

Variable	Definition	Source
	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
MBS	Share of mobile cellular subscriptions on all voice connections (fixed and mobile).	Calculated from ITU and GSMAi
FMS	Share of fixed cellular subscriptions on all voice connections (fixed and mobile).	Calculated from ITU and 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	km of coastline of the country	TAS

Table A.4: Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Broadband variables					
BB_SPEED^{f}	131	91.984	46.057	1.727	249.769
$BB\_LATENCY^{f}$	134	11.797	16.585	3	125
BB_SPEED^{m}	130	65.366	33.845	4.129	216.893
$BB\_LATENCY^{m}$	130	26.79	15.37	15.917	131.667
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	.22	295.363
INVEST	747	202.29	118.101	7.946	1006.22
IXP	351	.637	.702	0	3.724
MOB_TEL	747	125.977	33.922	.655	264.049
COMP	595	75.37	17.638	0	99.5
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	.835	.130	.090	1
FMS	2170	.165	.130	0	.910
$BB\_PRICE^{f,NB}$	1728	32.550	13.114	10.99	176.42
Coastal length	2180	6610.174	21894.800	0	202080

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

Dep. Var.:	Log(IBW)	BB_PRICE^m
Regr. nr.:	(1)	(2)
Cellular HHI	0.0006***	0.0032***
	(4.55)	(5.60)
L.Cellular HHI	-0.0009***	0.0005
	(-4.21)	(1.42)
L.MFS	19.376***	-199.9685***
	(4.13)	(-2.98)
$L.MFS^2$	-11.356***	114.1347***
	(-3.54)	(2.78)
L.MFS * Coastal length	-0.0002***	-0.0008
	(-2.79)	(-0.96)
$L.MFS^2$ * Coastal length	0.0002***	0.0007
	(2.63)	(1.36)
Exogenous covariates included in column (1) of Table 6	YES	YES

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

Table A.6: 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**
	(-1.31)	(-2.33)
FMS	4.5265**	-3.0261
	(2.11)	(-1.42)
FMS^2	-13.8452***	3.6399
	(-3.56)	(0.55)
L.FMS * Coastal length	-0.0001***	-0.0000
	(-4.39)	(-0.65)
$L.FMS^2$ * Coastal length	0.0002***	0.0001
	(5.77)	(1.24)
Exogenous covariates included in column (1) of Table 7	YES	YES

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

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