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The Impact of Submarine Cables on Internet Access Price, and the Role of Competition and Regulation

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Abstract

Submarine cables enable international connectivity and are essential for high-speed internet access. This paper examines their impact on internet access price, focusing on price reductions driven by cost savings and competition intensity. Using a dataset of submarine cable capacity and internet access prices across 150 countries over 12 years, and following an instrumental variable approach, the analysis finds that a doubling of submarine cable capacity reduces internet prices by 30–50 percent, with regional disparities. .../...

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.../... In fixed broadband markets, market concentration initially lowers prices, reflecting economies of scale, but raises them in the long term, a dynamic less evident in mobile broadband markets. Telecom market regulations, particularly those empowering regulators to oversee competition, infrastructure sharing, and consumer protection, amplify these effects. The findings are robust to adopting a staggered difference-in-differences framework.

Keywords: Telecommunications, Submarine Cable, Price, Competition, Regulation.
JEL Codes: E31, L51, L96, O33.

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1 Introduction

Submarine cables (SMCs) are part of a global network of fiber optic cables that run through oceans to connect countries,[1] and therefore individuals and businesses, to the Internet. They form a crucial component of Internet access and are often considered the 'first mile' as all telecom operators need access to submarine cables to connect their customers to the global Internet. On average, 15 to 20 new submarine cables have been deployed across the globe annually over the past 30 years and a similar trend is expected to continue over the next decade.[2] Each new submarine cable typically requires several million dollars of investment and often involves additional investments in terrestrial digital infrastructure such as fiber optic cables, towers, and data centers, as well as digital innovation, entrepreneurship, and skills to benefit end-users. As such, they can support market and broader economic development in the landing countries and beyond.

Studies such as Hjort and Poulsen (2019), Simione and Li (2021), Houngbonon et al. (2022), Imbruno et al. (2022), and Cariolle and da Piedade (2023) have investigated the economy wide effects of SMCs, especially their impact on economic growth, employment, innovation, entrepreneurship, and trade. Other studies, such as Cariolle (2021), investigated the market outcomes of SMCs but focused on access to connectivity. Empirical evidence on the market outcomes of SMCs, especially the impact on price, and the role of competition and regulation is still not available. Yet, such evidence remains crucial to understanding the channels through which SMCs affect access to connectivity and generate the economy wide effects quantified in previous studies.

Anecdotal evidence abounds on how Internet access prices evolved following the arrival of major submarine cables (Appendix A). For instance, Nigeria experienced the arrival of five SMCs between 2010 and 2015.[3] These new SMCs have accelerated the growth of international Internet bandwidth used in the country, from an annual rate of 48 percent between 2010 and 2014 to 70 percent between 2015 and 2020.[4] Such an expansion in bandwidth was accompanied by a 5 percentage point drop in the price of mobile broadband (BB) over the same period.[5] Cameroon also experienced the arrival of three major SMCs during the same period, among the five which arrived in Nigeria: ACE, WACS and NCSCS. These arrivals were also associated with an expansion of international bandwidth and a similar drop in mobile BB price. In Tunisia, the arrival of a submarine cable in 2014 (Didon) was associated with a percentage drop in the price of mobile BB.

Telecom sector research and industrial organization theories suggest two main channels through which SMCs can affect Internet access prices in the short run. First, the deployment of SMCs can result in cost savings on international connectivity for telecom operators through (i) economies of scale brought by increased international Internet bandwidth; (ii) a drop in data (re)routing cost supported by greater connectedness enabled by new SMCs; and (iii) a drop in network maintenance cost due to stronger resilience induced by the duplication of SMCs routes. Second, deploying SMCs can reduce barriers to entry into BB markets and result in a price drop and improved quality through competition, especially when the new infrastructure is shared under an open and non-discriminatory basis among retail BB operators. In both cases, regulation can enhance these effects. Cost-saving effects pertain to the short term, i.e., assuming no change in the availability and quality of connectivity for end-users. In the long run, increased demand for connectivity may spur changes in availability and quality of connectivity stemming

[1] Some submarine cables may have some terrestrial segments.
[2] Telegeography, 2022.
[3] Glo-1 and MainOne in 2010; Africa Coast to Europe (ACE) and West Africa Cable System (WACS) in 2012, and the Nigeria Cameroon Submarine Cable System (NCSCS) in 2015.
[4] Based on bandwidth data from Telegeography.
[5] Price of 2GB of mobile BB data in percentage of monthly income per capita - based on data from the ITU.

from investment in middle and last-mile infrastructure which may exert upward pressure on price.

In this paper, we assembled a dataset on SMCs to investigate their impact on internet price and the role of competition and regulation, controlling for several confounding factors, including the availability and quality of connectivity and market size. Specifically, our analysis seeks to understand how SMCs influence pricing dynamics, assess regional heterogeneities, and identify the primary drivers of price impacts—particularly evaluating the relative contributions of cost savings and competition under different regulatory frameworks.

Our dataset covers about 150 countries across all regions over 12 years (2008-2020) and includes detailed information on the capacity of SMCs, measured by the amount of international Internet bandwidth. We complement this information with data on the price of a basket of fixed and mobile BB Internet package, as well as market concentration indexes and 50 indicators measuring various aspects of ICT regulation. We employ an instrumental variable (IV) estimator, complemented by a staggered difference-in-differences estimation strategy.

Our estimates lend support to the hypothesis that SMC deployment results in a drop in the price of Internet access: doubling the international bandwidth leads to an immediate 32% drop in fixed BB price, and up to a 50% drop in the mobile BB price. However, fixed BB prices return to their initial levels four years post-expansion, while mobile BB prices stabilize around a 15% decline. These effects exhibit regional variation, with significant price reductions observed in emerging markets such as Africa, Asia, and the Middle East. Europe shows the largest price decline in both markets, likely due to a more competitive and stronger regulatory environment.

Our findings suggest that cost savings primarily drive the observed price effects in the short term, with market concentration playing an ambivalent role over time. In the short run, greater market concentration tends to lower prices, likely due to economies of scale, whereas in the long run, it pushes prices upward. This dynamic is particularly pronounced in fixed BB markets, where higher infrastructure costs amplify these effects. In fact, high fixed costs of infrastructure deployment are associated with greater economies of scale, which can lead to lower prices due to cost efficiencies. However, these high costs also create significant entry barriers, deterring new competitors from entering the market. This lack of competition can result in higher prices over time, as incumbent providers face less pressure to maintain competitive pricing. This mechanism is supported by our findings.

Moreover, our findings also suggest that regulation can be a powerful tool to increase the pass-through rate of cost savings and limit further concentration of retail BB markets. In particular, an independent regulator, with a strong mandate to enforce competition through (i) reduced barriers to entry for domestic and foreign operators, (ii) shared infrastructure, including radio spectrum, (iii) regulation of interconnection and market dominance, as well as (iv) universal service provisions, and (v) consumer protection can all contribute to boost the impact of SMCs on price and alleviate the adverse effects of market concentration over time.

This paper relates to the literature on digital development and the industrial organization of the telecom sector. Studies on digital development have investigated the economy-wide effects of digital infrastructure, especially on GDP, jobs, productivity, innovation, entrepreneurship, and trade, but did not analyze the market outcomes of this infrastructure. A notable study is Hjort and Poulsen (2019) which exploits the gradual arrival of SMCs in Africa between 2000 and 2010 and found that changes in access to high-speed Internet post arrival of the cables led to job creation across all levels of education. A recent study conducted by Simione and Li (2021) exploited the arrival of SMCs in Africa after 2009 and found that a percentage point (pp) increase in Internet penetration induced a 0.37 pp increase in real per capita

GDP growth, with increased labor productivity in the utilities, trade, and transportation sectors. These findings were supported by country case studies in Sub-Saharan Africa (SSA) (O'Connor and Anderson, 2020) which found a positive impact on GDP per capita, and an increased likelihood of being employed in fiber-connected areas. SMC connectivity can also affect trade in developing countries as suggested by findings from Imbruno et al. (2022) and Cariolle and da Piedade (2023).

Studies on the industrial organization of the telecom sector have looked, among others, at the drivers of price, especially the role of competition and regulation, but did not consider these effects in the context of infrastructure deployment. To our knowledge, the market effects of SMCs have until now been confined to the impact on Internet penetration and delimited to the SSA context (Cariolle, 2021). Cariolle (2021) considered the deployment of two SMCs[6] along the Eastern and Southern African coasts in 2009-2010 as quasi-natural experiments and found that they resulted in a 3 to 5 percentage points increase in internet penetration in recipient countries. Other studies have also investigated drivers of the digital divide, especially in SSA, and identified the digital infrastructure as an important determinant (Schumann and Kende, 2013; Akue-Kpakpo, 2013; Bates, 2014), and a regulatory and competition environment that until recently was not conducive to Internet affordability and quality (Wentrup et al., 2016; Gallegos et al., 2020).

This study complements these two strands of the literature by connecting infrastructure investment with market outcomes, taking into consideration the role of competition and regulation. The remaining of the paper is organized as follows: Section 2 presents the conceptual framework; Section 3 provides some background on SMCs; Section 4 presents the data and descriptive statistics, Section 5 presents the empirical framework and identification strategy; Section 6 reports the main results on the impact of SMCs on price and analyzes the role of competition; Section 7 investigates the heterogeneous effects of regulations; Section 8 presents some robustness checks; and Section 9 concludes.

2 Conceptual framework

Determinants of Internet access prices, i.e., the price charged to individuals and businesses seeking to connect to the Internet, can be grouped into (i) supply-side factors related to the cost of international and domestic connectivity, (ii) demand-side factors related to the size of the telecommunication market, and (iii) institutional factors related to competition, which determine margin over cost, and regulations. This study focuses on supply-side factors, in relation to submarine cables (SMCs) which primarily affect the cost of international connectivity,[7] taking into consideration the heterogeneous effects of institutional factors, and controlling for demand-side ones.

The channels through which SMCs affect Internet access prices reflect the structure of Internet infrastructure. This structure can be represented by three segments, each supported by a variety of technologies, as depicted in Figure 1: a 'first-mile' that involves international connectivity (i.e., connecting countries to the Internet), a 'middle-mile' which involves domestic connectivity (i.e., connecting large cities and communities to the Internet), and a 'last-mile' which involves end-users access to the Internet (i.e., connecting individuals, households and businesses to the Internet).

[6] EASSy and SEACOM.

[7] Other international connectivity infrastructure such satellites could be considered, but they carry less than 5 percent of international Internet traffic according to D'Andrea and Limodio (2019), based on the testimony of D. Burnett before the Senate Foreign Relations Committee on the United Nations Law of the Sea Convention. This number has been later confirmed by Mauldin, A. "Do Submarine Cables Account For Over 99% of Intercontinental Data Traffic?", Telegeography, May 2023.

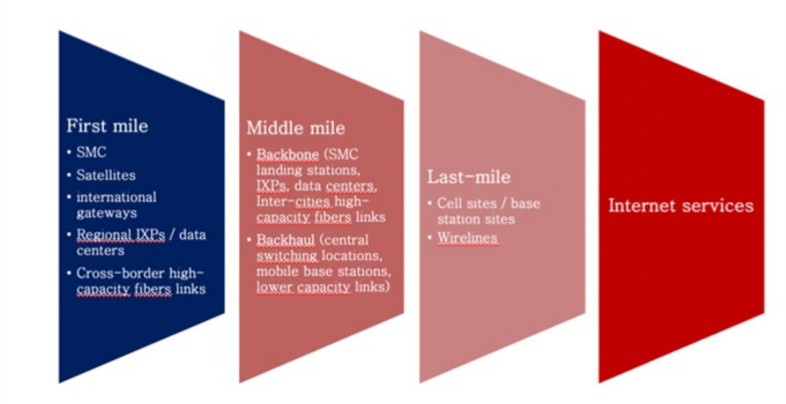

Fig. 1. A representation of the internet infrastructure

Source: Adapted from Schumann and Kende (2013)

That structure of Internet infrastructure means that SMCs can affect Internet access prices both in the short term and in the medium term. In the short term, the arrival of SMCs does not affect investment in middle and last-mile Internet infrastructure,[8] but rather reduces the cost of access to international connectivity for national telecom operators through the following three channels (Figure 2):

- **Scale economies** in international connectivity as new SMCs come with high capacity and, therefore, enable network operators to carry higher Internet traffic at the same cost.
- **Savings on (re)routing costs** as new SMCs increase international connectedness and enable network operators to bypass third countries and, therefore, save the associated routing cost. For instance, an operator in country A may have to pay a routing cost to a carrier in country B to reach country C. A new SMC connecting country A to C would allow the operator to save on that routing cost.
- **Savings on maintenance costs** as new SMCs can provide redundancy and, therefore, strengthen network resilience (Weller and Woodcock (2013), Cariolle (2018, 2021))[9] and avert disruptions in international connectivity that would require maintenance by network operators.

There are two ways in which these cost reductions can affect Internet access prices:

- **Direct pass-through**, i.e., telecom operators would pass through part of the cost savings to end-users. However, the pass-through rate would depend on the regulation of bottleneck infrastructure in the middle and last mile, and the intensity of competition in the market for Internet access services. Middle and last-mile Internet infrastructure typically entail bottleneck infrastructure called backbone and backhaul or metro network that are owned by a single operator which may also be active in the retail market and, as a result, have an incentive to discriminate against competitors in the retail markets. Regulations on infrastructure sharing are crucial to enable open access to this infrastructure on a non-discriminatory basis.

[8] On some occasions, companies may undertake investments in middle and last-mile infrastructure once the arrival of an SMC is announced. However, the roll out of this infrastructure takes time and there is limited evidence on whether they are completed before the SMCs.

[9] Resilience is reflected by three particular aspects of the telecommunications network functioning: fault-tolerance permitted by greater network redundancy, survivability permitted by a greater network diversity, and disruption tolerance permitted by a greater network connectivity (Sterbenz et al. (2014).

- **Indirect pass-through** via increased competition in the retail connectivity market as reduced cost of access to international connectivity lowers barriers to entry for retail network operators,[10] thereby inducing a price drop. However, regulation is here again key to support such an outcome. For instance, a new SMC which is exclusively used by a vertically integrated dominant telecom operator would not reduce the barrier to entry. Regulation can mandate access to the SMC and, therefore, enable the expansion of competitors.

In the medium term, the arrival of SMCs would result in improved quality of Internet access by inducing investment in middle and last-mile infrastructure. For instance, in a competitive environment, network operators would upgrade the capacity of middle and last-mile infrastructure such as data centers, towers, and domestic fiber optic networks to respond to the demand for Internet traffic induced by the short-term drop in price. These investments can improve internet quality and availability and exert upward pressure on prices in the medium term.

In sum, SMCs are expected to exert a direct downward pressure on BB price by reducing the costs of internet provision, and an indirect one by fostering competition. In the longer run, an upward price pressure, reflecting a greater internet quality and resulting from greater investment and innovation processes, might be exerted and also promoted through greater competition. While the former mechanism is termed a "cost-reduction effect", the latter one is termed the "quality effect" of SMC rollout. These mechanisms should be affected by regulations, preventing excessive market power, protecting internet users' rights, and ensuring internet coverage.

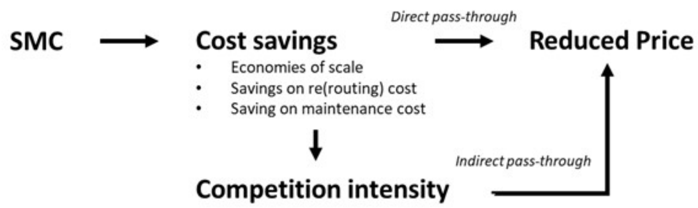

Fig. 2. The short-term impact of SMCs on price

3 Institutional Context

This section outlines the planning and ownership structures of SMCs, their relationship with last-mile providers, and the extent to which the installation of new cables affects international bandwidth availability. These details inform key empirical considerations, particularly with respect to potential sources of endogeneity in estimating the effects of SMC deployment.

3.1 Planning, Ownership, and the Role of Last-Mile Internet Service Providers

Building submarine cable systems demands significant financial investment, often amounting to several hundred million dollars. The ownership of these systems can take various forms, typically either consortia-based models or privately owned cables. In the traditional consortium model, multiple telecommunications operators collaborate to finance and own the cable, with each member securing a portion of the bandwidth capacity. Examples of such operators include NTT, Orange, Arelion, and China Telecom. Recently, technology giants like Google, Meta, and Microsoft have started funding privately owned cables, which allows them to have more control over data transmission and reduces their dependence on

[10] Entry refers to the establishment of a new network operator serving end-users, or the expansion of an existing operator in new geographical markets (cities) or new product lines.

third-party transit providers. These content providers have become the primary users of international bandwidth, making up 73 percent of the total used capacity worldwide in 2023.[11]

The interaction between SMC operators and last-mile providers takes place at landing stations, where international bandwidth is transferred to domestic networks. Although regulatory frameworks often require open-access provisions, market structures can differ significantly. In some regions, vertically integrated telecommunications companies manage both SMC access and domestic broadband markets. In contrast, in other areas, independent ISPs lease capacity from various SMCs operators. These differences in market structure affect how SMC investments impact consumer internet prices and quality.

Several factors drive the decision to construct new cables, including the limited availability of potential capacity and fiber pairs. The demand for bandwidth continues to grow rapidly, which could lead to capacity shortages without new investments. Content providers, in particular, prefer owning fiber pairs rather than buying capacity from other providers. As the largest users of bandwidth, these content providers with substantial demand opt to invest in new cables to acquire capacity at cost. They aim to secure large blocks of capacity in the form of fiber pairs or spectrum, which can be challenging to obtain on existing systems.

3.2 Timeline of SMCs Deployment

The deployment of a new SMC follows a multi-year planning cycle, involving regulatory approvals, consortium formation, and infrastructure deployment. Most cables are announced well in advance due to the significant investment and permitting requirements. However, the degree of transparency can vary. In markets with state-regulated telecommunications infrastructure, government involvement often makes project timelines publicly observable. In contrast, in more competitive environments, certain details—such as specific routing and activation dates—may be strategically withheld by private investors to maintain a competitive edge.

Despite the involvement of various stakeholders, the extensive regulatory and permitting processes required for SMC deployment introduce significant delays and uncertainties beyond the control of any single stakeholder, including last-mile providers. These processes often involve multiple government agencies and international bodies, making the timing and approval of new cables less predictable.

Additionally, the selection of cable routes is influenced by technological and environmental factors, such as seabed topography, tectonic activity, and marine ecosystems, which limit the flexibility of stakeholders in determining the exact routing and timing of new cables. The decision to invest in new SMCs is also driven by global demand for bandwidth and market forces influenced by macroeconomic trends, technological advancements, and international trade. These factors create pressures for new investments that are not directly related to the actions of last-mile providers in specific regions.

Furthermore, in consortium-based models, the involvement of multiple international telecommunications operators dilutes the influence of any single participant, including domestic ISPs. The collective decision-making process within consortia introduces additional layers of complexity and reduces the likelihood of any one stakeholder dictating the timing and location of new cables.

3.3 SMCs and access to connectivity

The introduction of a new submarine cable significantly alters the global distribution of bandwidth, affecting both directly connected countries and those that are not directly connected. The magnitude of these effects depends on network topology and domestic infrastructure capacity.

[11] TeleGeography. (2025). Transport Networks, formerly Global Bandwidth Research Service

For countries where an SMC lands, international bandwidth availability increases substantially. This often leads to lower wholesale transit costs for ISPs, reduced latency, and improved reliability of international data transfers. Additionally, the increased bandwidth can potentially lower retail broadband prices, depending on the level of market competition within the country. These direct benefits are a result of the enhanced connectivity and the ability to handle larger volumes of data traffic more efficiently.

Regarding countries without direct SMC landing points, they may still benefit from increased regional bandwidth availability through terrestrial fiber networks and peering agreements. The extent of these benefits depends on several factors. Network topology plays a crucial role; countries with existing cross-border fiber links can more easily absorb additional bandwidth. This means that the physical layout and interconnections of the network infrastructure are critical in determining how effectively the increased bandwidth can be utilized.

Market structure is another important factor. In competitive ISP markets, the reduced transit costs are more likely to be passed through to consumers, leading to lower prices and improved services. Conversely, in markets dominated by monopoly providers, the gains from increased bandwidth may be captured by the providers themselves, with less benefit passed on to consumers. The competitive dynamics within the ISP market thus influence the degree to which the benefits of increased bandwidth are realized.

Geographic constraints also affect the extent of the benefits for unconnected countries. Landlocked countries or those with limited terrestrial infrastructure may experience weaker benefits due to the higher transit costs imposed by intermediary nations. The geographical conditions, such as the presence of natural barriers and the distance from the SMC landing points, can impact the efficiency of data routing and the overall benefit derived from the increased bandwidth.

4 Data and descriptive statistics

We built a country-level panel dataset covering 150 countries for which price data was available over the following period: 2008-2021 for fixed BB, and 2012-2021 for mobile BB. Our dataset includes data on price, SMCs, competition, and regulation, as well as several variables used as controls in the econometric modeling. Definitions and sources of variables are described in Table B.1. Summary statistics are reported in Table 1 below, while correlation matrices are presented in Tables C.1 and C.2 in the Appendix. The descriptive statistics in Table 1 highlight significant variation in key variables across countries, such as fixed broadband prices, which range from 0.06 USD to 1,760.45 USD, and the number of submarine cables, which varies from 0 to 64. The Herfindahl-Hirschman Index (HHI) for market concentration also shows a wide range, indicating differing levels of competition intensity. These variations underscore the diversity of our sample and the necessity of controlling for country-specific factors in our empirical analysis to ensure robust results. Additional information on variables' definitions, sources, and distribution is provided in Appendix Tables B.1 and 1.

Table. 1. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
	Fixed BB market analysis				
Fixed BB price (USD)	1,548	48.24835	128.082	0.06	1760.45
Fixed BB price (USD, log)	1,548	3.352292	0.8333747	0.0582689	7.473893
Cable #	1,548	5.564599	7.856278	0	64
Cable # (log)	1,548	1.45987	0.8675313	0	4.174387
Bandwidth (Kbps)	1,159	10428.04	44920.89	0.0870534	618921.8
Bandwidth (Kbps, log)	1,159	19.28478	3.183365	11.37428	27.15125
HHI fixed BB market	1,369	4919.819	2671.243	2000	10000
HHI fixed BB market (log)	1,369	8.360146	0.5273283	7.601402	9.210441
ICT Regul. Tracker	1,548	68.32805	19.689	2.5	99
GDP per cap (USD, log)	1,548	8.733258	1.3972	5.62835	12.11016
Population size (log)	1,548	15.9286	2.024634	9.291828	21.06751
Electricity access (% pop)	1,548	81.18987	27.48085	6	100
IXP #	1,548	3.531008	8.930874	0	126
Fixed-tel. subscript. #/100 inhab.	1,548	17.63871	18.03847	0	135.6037
1st-order connection #	1,440	17.54306	15.66487	0	62
% world GDP cabled	1,440	23.4261	24.5477	0	81.67836
Cable owner #	1,435	21.21882	19.64776	0	122
Internet disrupt. # [t;t-5]	941	1.167906	1.749611	0	11
Cable disrupt. # [t;t-5]	941	0.8150903	1.354985	0	10
	Mobile BB market analysis				
Variable	Obs	Mean	Std. Dev.	Min	Max
Mobile data-only price (USD)	864	15.06295	11.62074	0.48	149.92
Fixed BB price (USD, log)	864	2.561058	0.6738659	0.3920421	5.01675
Cable #	864	6.421296	8.549674	0	64
Cable # (log)	836	1.349159	1.008265	0	4.158883
Bandwidth (Kbps)	864	1.19E+10	4.66E+10	271040	6.19E+11
Bandwidth (Kbps, log)	864	19.77619	2.98788	12.51002	27.15125
HHI fixed BB market	864	4038.844	1354.842	1453	10000
HHI fixed BB market (log)	864	8.257281	0.2969905	7.282073	9.210441
ICT Regul. Tracker	864	73.7278	17.35198	2.5	99
GDP per cap (USD, log)	864	8.756964	1.41555	5.600855	11.27381
Population size (log)	864	16.15473	1.806391	11.407	21.06751
Electricity access (% pop)	864	82.24459	27.16472	7	100
IXP #	864	4.357639	10.66451	0	126
3G coverage (% pop)	864	83.29258	23.21129	0	100
1st-order connection #	781	19.72599	16.12338	0	62
% world GDP cabled	778	24.65296	21.08499	0	122
Cable owner #	781	25.70794	24.86616	0	81.67836
Internet disrupt. # [t;t-5]	529	1.514178	2.029211	0	11
Cable disrupt. # [t;t-5]	529	1.020794	1.548931	0	10

4.1 Data

4.1.1 Internet prices

Telecom markets host a variety of packages with different levels of usage allowance and attributes, and this can make the measurement of price challenging in this sector. Several approaches are considered in the literature to address this challenge. Studies like Nicolle et al. (2018) use a hedonic price model, whereby price is estimated as a function of the attributes of packages. As such, a focus can be set on the price of a particular attribute, for instance, data allowance or quality, and be used in the analysis.

Such modeling requires comprehensive data on all packages offered by operators and the results can be dependent on the functional form of the model. Other studies like Genakos et al. (2018) rely on the price of a particular basket of usage. As part of this approach, baskets of usage are defined, and the price of the least expensive offer is tracked for each basket. In this paper, we use the basket approach which does not require the availability of comprehensive data on packages – a task that would have been challenging to complete for a study that involves more than 150 countries/markets.

Interestingly, the ITU has defined several baskets of BB packages and tracked their price since 2008.[12]

[12] https://www.itu.int/en/ITU-D/Statistics/Dashboards/Pages/IPB.aspx.

We focused on two baskets that are the most representative of recent trends in data usage: (i) a basket of fixed BB packages enabling at least 5 Gigabytes of data usage per month; and (ii) a basket of mobile BB packages enabling at least 2 Gigabytes of data usage per month. These baskets have evolved over time to reflect growing data usage by the average consumer. For instance, in 2017, the allowance of the fixed BB basket increased from 1 GB to 5 GB, and the allowance of the mobile BB basket increased from 1 GB to 1.5 GB. In 2020, the allowance of the mobile BB basket further increased to 2 GB. Figure 3 below reports the trends in fixed and mobile BB prices in our dataset, with a faster drop in prices in countries starting from a high level.

To address the issue of changing basket definitions, we have ensured that our analysis accounts for these updates. Specifically, we have focused on the most recent definitions that reflect current market realities. The ITU has mapped historical ICT price baskets to current baskets to facilitate historical comparison. For example, fixed-broadband basket figures between 2008 and 2017 refer to the fixed-broadband basket (1GB, $\geq$ 256Kbit/s), and data-only mobile-broadband basket figures from 2013 to 2017 refer to the mobile-broadband postpaid, computer-based basket (1GB, 3G and above). Although by 2017, the actual allowance in most countries was close to those used from the following year, a minor break in trend may be observed between 2017 and 2018. By using the updated baskets and accounting for these historical mappings, we ensure that the price data are consistent and comparable across different periods.

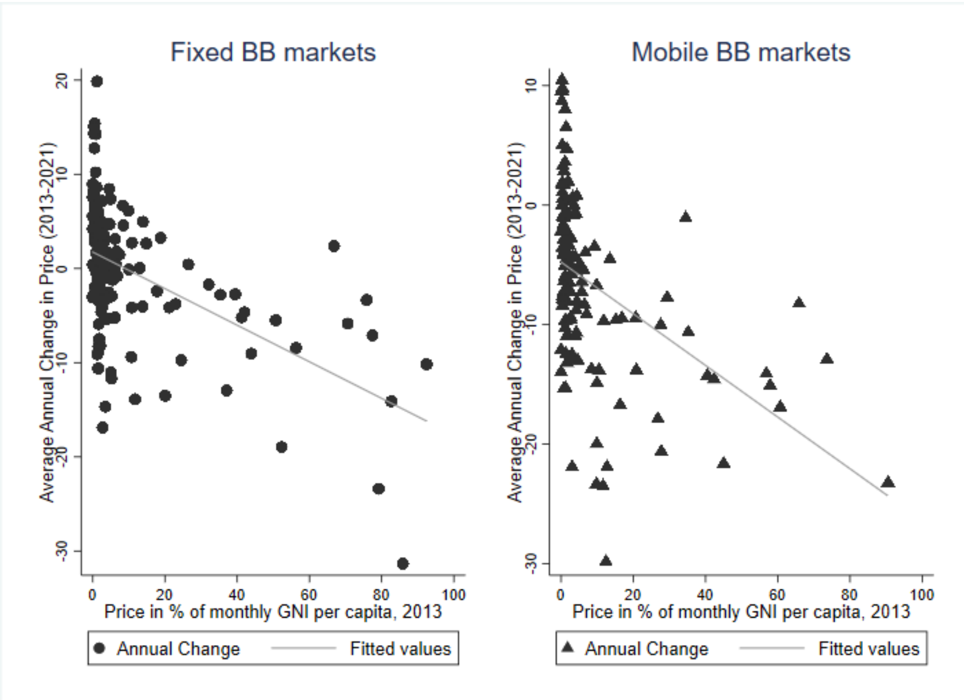

Fig. 3. Country-level trends in prices

Source: Authors. Countries with baseline prices equivalent to more than 100 percent of monthly Gross National Income (GNI) per capita have been dropped from the dataset.

4.1.2 Interest variables

The analysis focused on three variables of interest: international connectivity, competition intensity, and regulation in the telecom sector.

International connectivity. International connectivity is measured by the international Internet bandwidth (Kbit/sec, log) activated by Internet backbone providers, content providers, research and education networks, and enterprises in a country during a given year, SMC_band_{it}. Activated bandwidth differs from traffic, which reflects the actual bandwidth usage by end-users. It also contrasts with the bandwidth of an SMC, which specifically indicates the capacity available to coastal countries and excludes capacity accessible via neighboring countries. For landlocked countries, this measure is particularly relevant, as their connectivity depends on terrestrial cables that connect to SMCs in coastal regions. Thus, the focus is on the capacity available for a country's use, rather than the total capacity of the SMCs themselves or the user-generated traffic.

We collected data on international Internet bandwidth used by country and year from Telegeography, a proprietary but widely used industry database. The capacity of an SMC available for a particular country is directly observed in the Telegeography data, which provides detailed information on the activated international bandwidth for each country. This data includes the bandwidth capacity that is specifically allocated and utilized by each country, taking into account both direct connections to SMCs and connections via terrestrial cables for landlocked countries. Figure 4 presents the amount of international internet bandwidth per user in 2020, showing wide variation across countries.

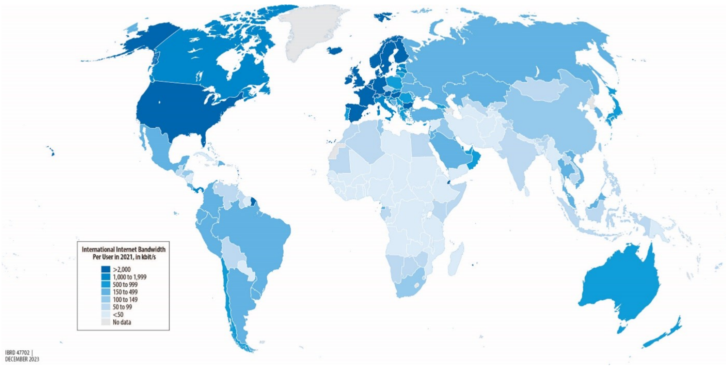

Fig. 4. International Internet bandwidth per user, 2020

Source: Authors, based on data from Telegeography.

Competition intensity. Competition intensity can be measured in various segments of the BB value chain. However, due to data constraints, the analysis focuses on competition in the fixed and mobile BB retail markets, recognizing that competition in these markets mirrors the intensity in upstream segments such as IP transit and international gateways. We measured competition intensity using the Hirschman-Herfindahl Index (HHI) of subscribers in the fixed or mobile BB market depending on the technology. Data on the HHI in the mobile BB market is sourced from the GSMA Intelligence database, a proprietary dataset, and encompasses all active mobile BB network operators.[13] Data on the HHI of the fixed BB market comes from Telegeography and covers the 5 largest players, acknowledging that those markets often host a long tail of small retail operators focused on specific geographies or customer segments. In our analysis, we examine competition not only as a result of international connectivity but also as a mediator that influences internet pricing patterns.

The regulatory framework. The regulatory framework is measured by the ITU's ICT Regulatory Tracker, a composite index of 50 indicators covering four dimensions, namely 'Regulatory Authority' (the functioning of the telecom sector regulator, its independence and autonomy in decision-making), 'Regulatory Mandates' (the possible areas of intervention of the regulator), 'Regulatory Regime' (available

[13] Virtual network operators are not included in the calculation.

types of regulations) and 'Competition Framework' (subjective assessment of competition intensity across market segments).[14] We use the aggregate index score as a control variable, but also further investigate the heterogeneous effects of regulatory sub-indexes or regulation indicators in the analysis.

4.1.3 Control variables

Control variables are grouped into two broad categories: variables related to the quality of connectivity and those related to the market size.

We measure the quality of connectivity by the amount of middle and last-mile infrastructure. Middle-mile infrastructure access is measured by the number of Internet exchange points (IXPs), which are crucial for the storage and processing of digital traffic across various networks. Last-mile infrastructure availability is measured by the following indicators:

- The number of fixed telephony subscriptions per inhabitant, reflecting the potential availability of fixed BB which generally rely on or follow existing fixed telephony networks. That variable serves as a control when investigating internet prices in fixed BB markets.
- Percentage of population covered by a mobile BB network (3G or above). That variable serves as a control when investigating mobile BB prices.

Potential market size is proxied by several indicators:

- Population, expressed in logarithm.
- The average income per inhabitant, proxied by the logarithm of GDP per capita.
- Electricity access, proxied by the share of the population with access to electricity.

4.2 Descriptive evidence

A simple cross-country binned correlation plot between international Internet bandwidth capacity and Internet prices is presented in Figure 5. The graph shows that as bandwidth capacity increases from low to moderate levels, the prices of fixed broadband decrease, achieving a minimum at a certain capacity threshold before rising again at higher capacities. This U-shaped pattern could indicate that up to a certain point, increases in bandwidth capacity drive down prices due to for instance cost-saving mechanisms. However, beyond this point, the costs associated with expanding and maintaining such high levels of bandwidth, possibly in less competitive environments with higher market concentration, could drive prices up. A similar U-shaped relationship is observed in mobile BB markets, although the curve is less pronounced than in fixed BB markets. This suggests that mobile markets might be somewhat less sensitive to changes in bandwidth capacity, possibly due to differing cost structures or competitive dynamics in mobile telecom markets.

Thus, the U-shaped relationship captured in the graphs can be understood as a preliminary and descriptive evidence of competing mechanisms at different levels of bandwidth capacity—cost savings and efficiency gains at moderate levels versus high infrastructure and maintenance costs, along with possible monopolistic behaviors, at higher levels.

The next correlation graphs in Figures 6 and 7 display the relationships between market concentration (HHI), regulatory environment (ICT Regulatory Tracker Index), and internet prices in fixed and mobile

[14] See the Methodology note of the ICT regulatory tracker: https://app.gen5.digital/tracker/about.

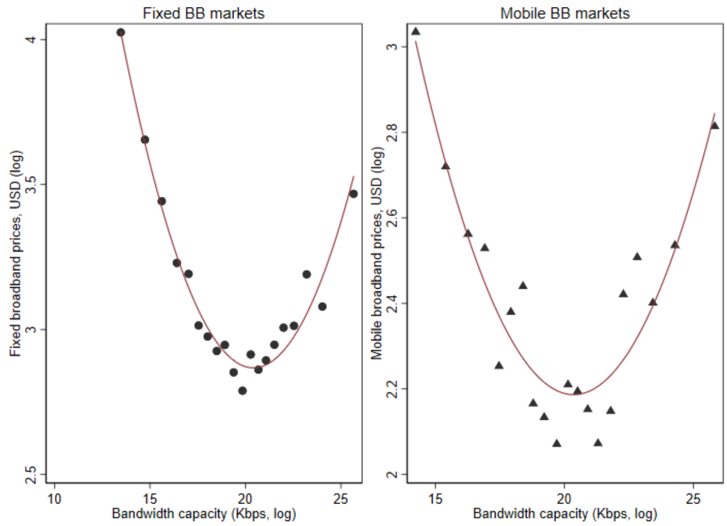

Fig. 5. International connectivity and broadband prices, binned scatter plot, 2008-2021

Sources: ITU ICT Internet basket prices and Telegeography.

broadband markets. The first figure depicts a positive correlation between the Hirschman-Herfindahl Index (HHI) and broadband prices in both markets, indicating that higher market concentration (i.e., less competition) is associated with higher internet prices. The second figure plots the ICT Regulatory Tracker Index scores against fixed and mobile broadband prices, showing that stronger regulatory frameworks (higher scores on the ICT index) are associated with lower broadband prices.

Having observed these initial patterns and correlations, we further examine these relationships through instrumental variable estimations in the next section.

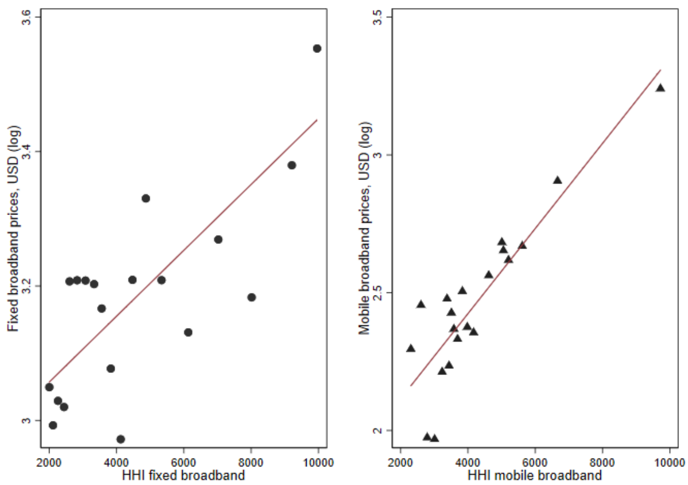

Fig. 6. Market concentration and broadband prices, binned scatter plot, 2008-2021

Sources: ITU ICT Internet basket prices, GSMA and Telegeography.

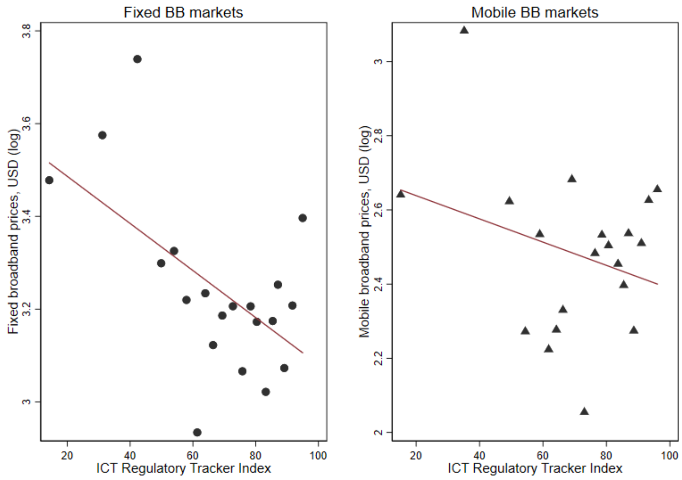

Fig. 7. Regulatory quality and broadband prices, binned scatter plot, 2008-2021

Sources: ITU ICT Internet basket prices, ICT Regulatory Tracker.

5 Empirical framework

To estimate the impact of SMCs on market outcomes, we develop an econometric model that links the arrival of SMCs to changes in internet prices, market structure, and competition intensity. The arrival of SMCs increases international connectivity capacity, which can lead to cost savings for ISPs and potentially lower prices for consumers. Additionally, increased capacity can alter market dynamics by affecting competition intensity and market concentration.

5.1 Reduced form equation

To test the expected outcomes from our conceptual framework, we estimate the following general two-way fixed-effect (TWFE) econometric model that captures the relationship between the market outcome and the capacity of international connectivity, the regulatory framework, and a set of control variables:

$$Y_{i,t} = \beta_0 \cdot CAP_{i,t} + \gamma_0 \cdot REG_{i,t} + \Delta_0 \cdot X_{i,t} + \alpha_i + \lambda_t + \epsilon_{0,i,t} \tag{1}$$

Available bandwidth is denoted by $CAP_{i,t}$, regulatory framework by $REG_{i,t}$, and other control variables by $X_{i,t}$. Subscripts i and t reflect country and year, respectively. α_i is a country-fixed effect, which controls for geographical determinants of connectivity and other time-invariant unobserved country characteristics, and λ_t is a time-fixed effect, which allows controlling for changes in SMC technology and other unobserved common shocks, such as the COVID-19 pandemic or the 2008 financial crisis. $\epsilon_{i,t}$ is an error term. Driscoll-Kraay standard errors are computed, correcting for heteroscedasticity, contemporaneous spatial (cross-country) correlation, and autocorrelated disturbances[15].

5.2 Identification strategy

To limit omitted variable bias, we control for supply- and demand-side factors, in addition to country- and year-fixed effects. Indeed, the country-fixed effects control for unobserved supply and demand side factors that are country-specific, especially given that price is measured at the market level and not at the level of a particular operator. The year-fixed effects are expected to capture unobserved time-specific

[15] Autocorrelation order is determined using the Inoue-Solon test for autocorrelation with panel data, reported in Appendix Tables C.1 and C.2

shocks or trends, common across countries, such as technological changes (e.g., transition from 2G to 3G or 4G; or transition from cooper to fiber optic cables).

However, the expansion of SMCs may still be endogenous as, for instance, telecom operators in less competitive markets may purposely expand the capacity for international connectivity to reduce costs. To avoid such a potential reverse causality, we employ an instrumental variable (IV) approach. This approach rests on incidental changes in international connectivity due to the changing architecture of the SMC network. Indeed, SMCs typically connect two or more countries following a particular route. The decision to follow a route is generally made by an international company (e.g., a global digital platform like Google or Meta/Facebook) or a consortium of telecom operators, and shaped by geographical and geopolililtical constraints (Eichengreen et al., 2023). As such, the specific route and network structure followed by an SMC is unrelated to the performance of a cable-recipient country. Building on this feature, our IV setup consists in taking parts of the variation in a country's *indirect bandwidth capacity*, i.e. exploiting changes in the total bandwidth that stem from changes in the bandwidth of countries they are connected to. For landlocked countries, we considered the indirect bandwidth of the coastal country hosting the closest SMC to their capital city.[16] Since the impact of the indirect bandwidth may be heterogeneous according to the geography of connected partners, we group connected partners' bandwidth by region, considering the resulting indirect regional bandwidth variables in our instrument set.

Therefore, we add to our baseline model the below first stage equation, instrumenting total bandwidth capacity by a set of indirect regional bandwidth variables ($INDCAP^r_{i,t}$) :

$$\text{CAP}_{i,t} = \Gamma_1 \cdot \text{INDCAP}^r_{i,t} + \Delta_1 X_{i,t} + \alpha_i + \lambda_t + \epsilon_{1,i,t} \tag{2}$$

With $INDCAP^r_{i,t}$ is the set of indirect bandwidth variables for region r, used as instruments. This set encompasses bandwidths from connected partners in Sub-Saharan Africa (SSA), East Asia and Pacific (EAP), South Asia (SA), Europe and Central Asia (ECA), North America (NA), and Latin America and the Caribbean (LAC).[17] IV estimations using different combinations of indirect regional bandwidths are conducted in robustness analysis (Section 8).

Further in the analysis, we also investigate the mediating effect of competition, stemming from the theory of change depicted earlier in Figure 2, by adding the BB market concentration (HHI) as additional right-hand side variable in the price Equation (1), and instrumenting it together with indirect bandwidth variables:

$$\text{HHI}_{i,t} = \Gamma_2 \cdot \text{INDCAP}^r_{i,t} + \Delta_2 X_{i,t} + \alpha_i + \lambda_t + \epsilon_{2,i,t} \tag{3}$$

6 Empirical analysis

6.1 Main results

Baseline estimations are reported in Table 2. First-stage statistics support the validity of the instrument set, while first-stage estimates highlight the positive and strongest contribution of the indirect sub-Saharan African bandwidth, but also of those originating from European, North-American, and South Asian regions.[18]

[16] results are robust to excluding landlocked countries. See the robustness section.

[17] Indirect bandwidth from MENA countries is not considered because strongly correlated with South Asian (95% correlation) and EAP (70% correlation) bandwidth capacity.)

[18] SSA's contribution reflects the recent surge in digital markets and its strategic geographical location along key undersea cable routes, which has made the region a connective bridge between the Americas, Europe, the Middle East, and Asia, offering alternative paths to traditional congested routes. In fact, the continent experienced one of the highest growth in

Second-stage estimates stress a negative and significant effect of bandwidth capacity on internet prices, stronger than OLS estimates. This difference between OLS and IV estimates can be explained by the possible reverse causality between prices and the SMC infrastructure, making more mature markets with lower internet prices more likely to host SMCs, hence leading to an attenuation bias. Second-stage estimates suggest that a doubling in bandwidth capacity leads to a 50% and 32% drop in fixed and mobile BB prices, respectively.

Next, we explore regional heterogeneity in Internet price responses to SMC capacity, by separately adding to our baseline model 1 the interaction between the bandwidth capacity and regional dummies. Marginal effects, reported in Figure 8, indicate that the negative price effects of bandwidth capacity are close across regions in both mobile and fixed BB markets, except for LAC countries where the drop in fixed BB price is non-significant.

Further, we consider the dynamic or longer-term price effects by introducing the lagged value of capacity into Equation (1), i.e., CAP_{it-1}, CAP_{it-2} , CAP_{it-3}, CAP_{it-4} or CAP_{it-5}, with and without control variables to maximize country and time coverage. Results, reported in Figure 9, highlight a decreasing negative marginal effect of bandwidth capacity on both mobile and fixed BB prices through time. In fixed BB markets, the marginal effect becomes non-significant four years post-expansion, even turning positive thereafter.

Table. 2. Broadband Prices: OLS and IV estimations.

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS		**2SLS**			
Dep. Var: BB prices (log)	**Mobile**	**Fixed**	**Mobile**		**Fixed**	
			2nd stage	**1st stage**	**2nd stage**	**1st stage**
Bandwidth_log	-0.206***	-0.062**	-0.505***		-0.316**	
	(0.026)	(0.021)	(0.088)		(0.138)	
Instrument set:						
EAP_BW_log				0.010		-0.033
				(0.012)		(0.028)
ECA_BW_log				0.037***		0.042***
				(0.012)		(0.015)
LAC_BW_log				0.023		-0.029**
				(0.014)		(0.013)
NA_BW_log				0.020***		0.017***
				(0.003)		(0.006)
SA_BW_log				0.027		0.063***
				(0.020)		(0.014)
SSA_BW_log				0.073***		0.074***
				(0.010)		(0.007)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Country & Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	989	1,318	958	958	1,268	1,268
AR F-stat			8.66e-05		2.97e-10	
KP Wald F-stat			705.8		3319	
LM-weak			1.866		1.973	
Hansen-J pval			0.852		0.860	

Driscoll-Kraay standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. EAP: East-Asia and Pacific. ECA: Europe and Central ASia. LAC: Latin America and the Caribean. NA: North America. SA: South America. SSA: sub-Saharan Africa.

The observed reversion of prices to their initial levels can be attributed to two key mechanisms discussed in Section 2: the infrastructure quality upgrades and the competition environment, which is pivotal for passing on wholesale cost savings. First, the reversal of impact in both mobile and fixed broadband markets may reflect the medium-term improvements in infrastructure quality and coverage needed to meet rising demand for connectivity, driven by increased telecommunications capacity and lower prices. Second, the less pronounced and shorter-lived negative effect on fixed broadband prices can be explained by higher entry barriers, stemming from the high costs of last-mile infrastructure, and the pivotal role of

international bandwidth capacity over 2011-2021 (CAGR +52%). Results are robust to the use of different instrument subsets, including at least the indirect SSA bandwidth capacity. But to avoid arbitrary choice in the instrument set composition, to maximize its strength, and to conduct regional heterogeneity analysis, we consider all regional bandwidths together.

market concentration in the fixed broadband market for translating wholesale cost savings into end-user benefits.

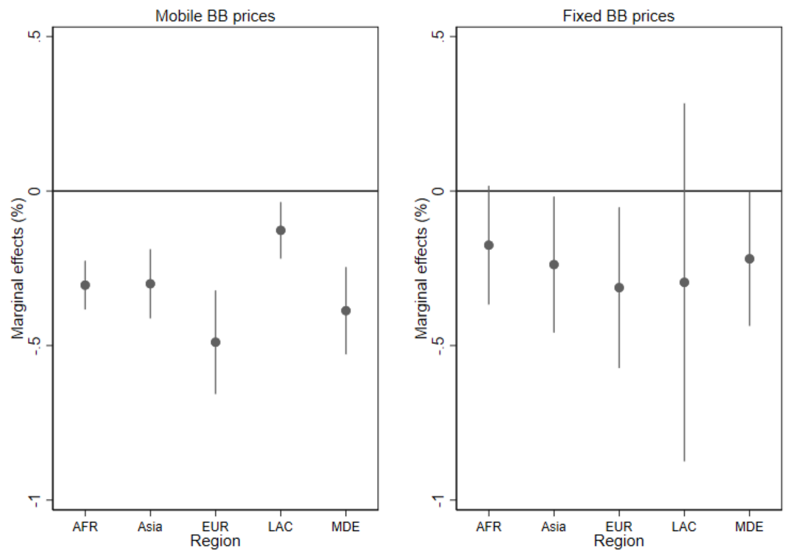

Fig. 8. Internet prices in the mobile and fixed BB markets, regional effects.

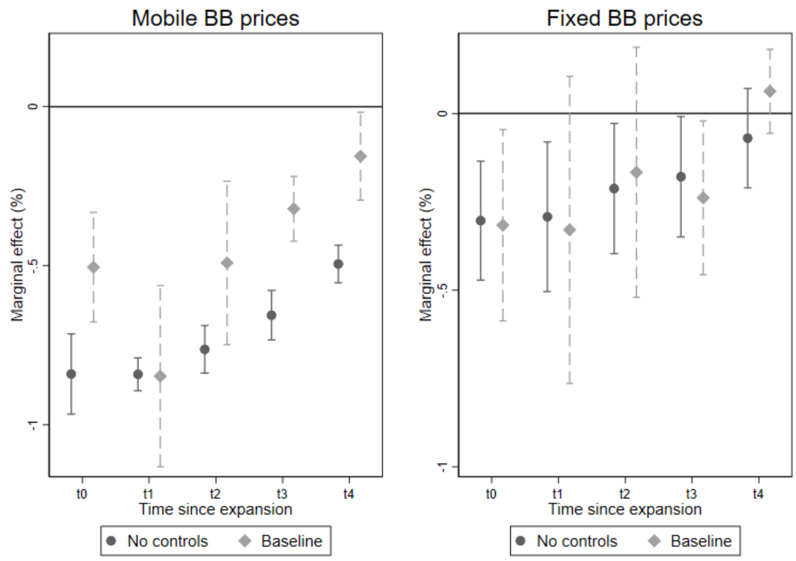

Fig. 9. Internet prices in the mobile and fixed BB markets, dynamic effects.

6.2 The mediating effect of competition intensity

Thence, previous findings lead us to investigate the mediating effect of market concentration on fixed and mobile BB prices. Since SMCs may directly affect internet price, through cost-saving mechanisms, or indirectly by affecting competition intensity, we jointly instrument bandwidth capacity and market concentration. Results are reported in Table 3.

First-stage statistics and estimates confirm that IVs strongly predict bandwidth capacity and market concentration, while satisfying over-identification conditions. Second-stage results reveal a negative impact of market concentration on both mobile and fixed broadband prices. According to our estimates, a 1000 index-point increase in the HHI leads to a 3% and 2% decrease in mobile and fixed BB prices. Importantly, market concentration is found to mediate the negative effect of bandwidth capacity in fixed BB markets, as including the HHI variable in the model reverses the sign of the bandwidth coefficient and cancels its significance. By contrast, the negative price effect of bandwidth capacity in mobile BB market is marginally affected by this inclusion. This evidence suggests that high infrastructure costs may act as an entry barrier to competitors while driving cost saving through scale economies, especially in fixed BB markets where the infrastructure is costlier and its last mile segments are often dedicated.

Table. 3. Broadband Prices and the mediating effect of competition, IV est.

	(1)	(2)	(3)	(4)	(5)	(6)
	Mobile BB market			Fixed BB market		
	2nd stage	1st stage		2nd stage	1st stage	
Var:	Price (log)	Bandwidth (log)	HHI	Price (log)	Bandwidth (log) (ln)	HHI
Bandwidth_log	-0.4378***			0.2111		
	(0.073)			(0.1282)		
HHI	-0.0003**			-0.0002***		
	(0.0001)			(0.0000)		
SSA_BW_log		0.0712***	10.6854		0.0479***	228.6073***
		(0.0097)	(7.8694)		(0.0059)	(21.6246)
SA_BW_log		0.0279	90.2837***		0.0245*	39.0566***
		(0.0200)	(8.9952)		(0.0126)	(11.1221)
EAP_BW_log		0.0063	-126.5352***		-0.0050	-260.1287***
		(0.0124)	(14.2691)		(0.0154)	(27.8171)
LAC_BW_log		0.0224	-13.7020*		-0.0294**	8.8099
		(0.0141)	(6.9888)		(0.0147)	(16.5254)
ECA_BW_log		0.0410***	114.1979***		0.0312***	288.0836***
		(0.0122)	(20.2644)		(0.0105)	(17.8073)
NA_BW_log		0.0190***	-5.0225***		0.0169***	68.1396***
		(0.0027)	(1.1645)		(0.0064)	(20.8483)
Observations	950	950	950	1,140	1,140	1,140
AR F-stat	3.54e-05			0		
KP Wald F-stat	1379			52.73		
LM-weak	1.771			1.959		
Hansen p-val	0.740			0.762		

Driscoll-Kraay standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Next, we investigate the dynamic effect of bandwidth capacity on market concentration, using the HHI as dependent variable and including the lagged value of capacity on the right-hand side of Equation (1). In fact, changes in bandwidth capacity may last to influence the competition environment, particularly in fixed BB markets where fixed-costs and scale economies are larger. IV estimates reported in Figure 10 support this hypothesis. While the estimations show a persistent but somewhat modest positive effect of capacity on mobile BB market concentration[19], they reveal a much stronger but decreasing effect in fixed BB markets. Our results show that a doubling in bandwidth capacity leads to an immediate 1122 index-point increase in the fixed BB market concentration, corresponding to approximately 50% of the HHI sample standard deviation, shrinking to a 314 index-point increase four years later.

Finally, we re-estimate Equation (1), jointly instrumenting lagged values of bandwidth capacity and HHI variables. The results, presented in Figures 11 and 12, offer insights that reinforce our previous interpretation. Specifically, estimates in Figure 11 confirm the mediating role of fixed BB market concentration, as highlighted earlier in Table 3, while providing a dynamic perspective on its impact. The right-hand graph reveals that a 1,000 index-point increase in the HHI initially reduces fixed broadband prices by approximately 2%. However, this effect diminishes over time, eventually reversing to become positive and symmetric after four years, closely mirroring the price dynamics of bandwidth capacity previously illustrated in Figure 9. Interestingly, once market concentration is accounted for in the IV framework, the dynamic effect of bandwidth capacity (left-hand graph) exhibits a distinct pattern: posi-

[19] an approximate 500 increase in the HHI following a doubling in bandwidth capacity, which represents 20% of the HHI's sample standard deviation.

tive in the short term, it turns negative and significant three years later. By contrast, this dynamic does not apply to mobile BB markets (Figure 12), where the negative effect of bandwidth capacity remains persistent but decreasing over time, while the influence of market concentration dissipates within a year.

Therefore, these findings suggest that increased market concentration facilitates an initial drop in fixed BB prices in the years following SMC deployment, likely due to the higher infrastructure costs and greater economies of scale in this market. However, persistent concentration ultimately drives prices upward in the long run. This underscores the critical role of regulatory measures in promoting and sustaining competition, especially once the fixed costs of infrastructure deployment are absorbed.

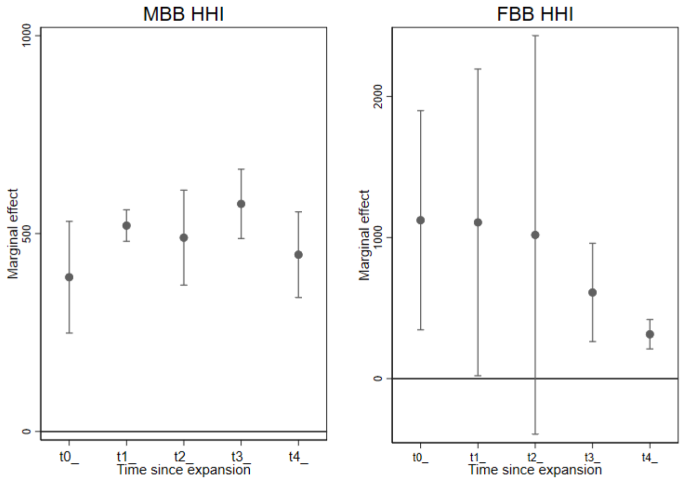

Fig. 10. Mobile and fixed BB markets concentration, dynamic effects.

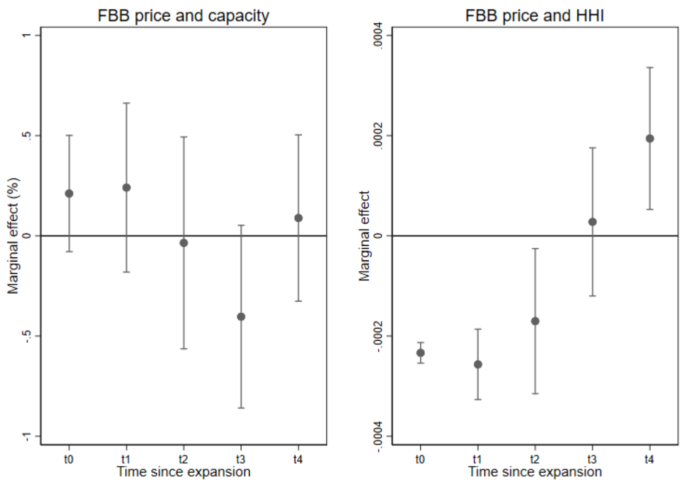

Fig. 11. Fixed BB market prices - Combined dynamic effects of capacity and competition

7 The moderating effects of regulations

In this section, we investigate whether the impact of SMCs on price and competition depends on the regulatory framework. In particular, our focus is set on those regulations that would (i) boost the price drop induced by international connectivity, or (ii) attenuate the rise in market concentration associated

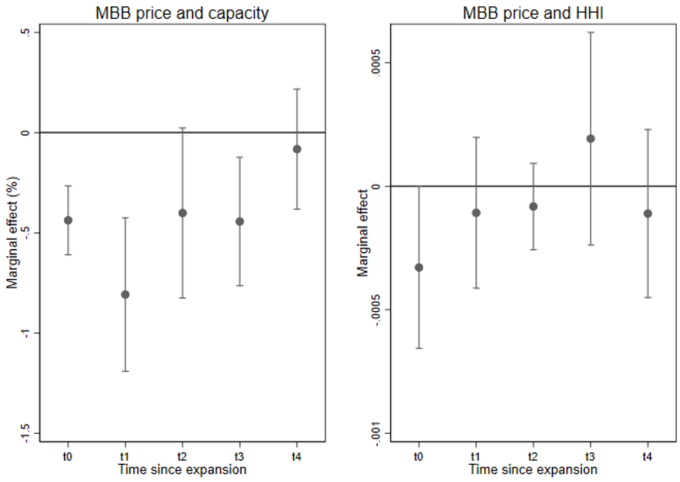

Fig. 12. Mobile BB market prices - Combined dynamic effects of capacity and competition

with international connectivity. This approach recognizes that some regulations may incentivize greater pass-through of wholesale cost savings or support open and non-discriminatory access to international connectivity, while others may have the reverse effects.

We test these hypotheses by estimating the below econometric model (4) which includes an interaction term between the change in each of the 50 regulatory indicator j ($\Delta Reg^j_{i,t}$) and international Internet bandwidth $CAP_{i,t}$. Table B.3 in the Appendix presents the list of regulatory indicators. We select regulations relevant for each type of BB technology (fixed or mobile)[20], which leads us to keep 37 regulations for the fixed BB market and 39 for the mobile BB market. We also focus on regulatory change from one year to another, rather than regulatory level. This choice also enables us to exploit greater between and within-country variability in regulatory quality, as well as the discrete nature of changes in regulatory scores – taking the values 0, 1, or 2 depending on the effectiveness of the target regulatory areas measured by the indicator. Last, since regulations may take time to be implemented and yield their expected benefits, we consider possible dynamic effects and interact contemporaneous bandwidth capacity with lagged values of the four regulatory sub-indexes: regulatory authority, mandate, and regime, and the competition framework

We therefore estimate the following equation:

$$Y_{i,t} = \beta_3 \cdot CAP_{i,t} + \gamma_3 \cdot CAP_{i,t} \times Reg^j_{i,t(-k)} + \Lambda_3 \cdot Reg_{i,t(-k)} + \Delta_3 \cdot X_{i,t} + \alpha_i + \lambda_t + \epsilon_{3i,t} \tag{4}$$

The variable $Y_{i,t}$ is the price of fixed or mobile BB, or the HHI in the fixed or mobile market, and $Reg_{i,t(-k)}$ the set of lagged first-differenced regulatory indicators, or regulatory sub-index scores.[21]

7.1 Regulations and Internet prices

We report in Figures 13 and 14 significant marginal effects of individual regulation exceeding, i.e. amplifying, the marginal effect of standalone bandwidth capacity ($\Delta Reg^j_{i,t} = 0$) on internet prices. Empirical results allow identifying 15 and 16 regulatory boosters, in the fixed and mobile BB markets respectively,

[20] For instance, regulation of radio spectrum does not apply to fixed BB; and likewise, licensing to Internet service providers does not apply to mobile BB.

[21] To avoid the proliferation of instruments, when interacting them with regulatory changes, we restrict our instrument set to i) the indirect SSA capacity, identified as the regional bandwidth with the strongest effect on capacity; and ii) indirect capacities of regions where fixed and mobile broadband technologies are most widespread, respectively, Europe and North America for the fixed BB market, and East-Asia and North America for the mobile BB market.

whose effect exceeds standalone bandwidth capacity's.

In fixed BB markets, regulations have a modest amplifying price effects (not significantly different from the baseline marginal effect). In this market, top 5 regulatory boosters include regulations that i) reinforce the level of competition in cable modem, DSL, fixed wireless broadband, ii) that permit individuals to use Voice over Internet Protocol (VoIP) services, iii) that give mandate to entities in charge of interconnection rates and price regulation, iv) that compel incumbent telecommunications operators to provide competing service providers access to the local loop, and v) that govern whether and how foreign entities can own or invest in companies that build, operate, and maintain the physical telecommunications infrastructure.

In mobile BB markets, regulations are found to have stronger amplifying price effects. Top five boosters are entities i) in charge of radio frequency allocation and assignment, and ii) in charge of quality of service obligations measures and service quality monitoring, iii) dispute resolution mechanisms, iv) infrastructure sharing requirements, v) and entities in charge of licensing.

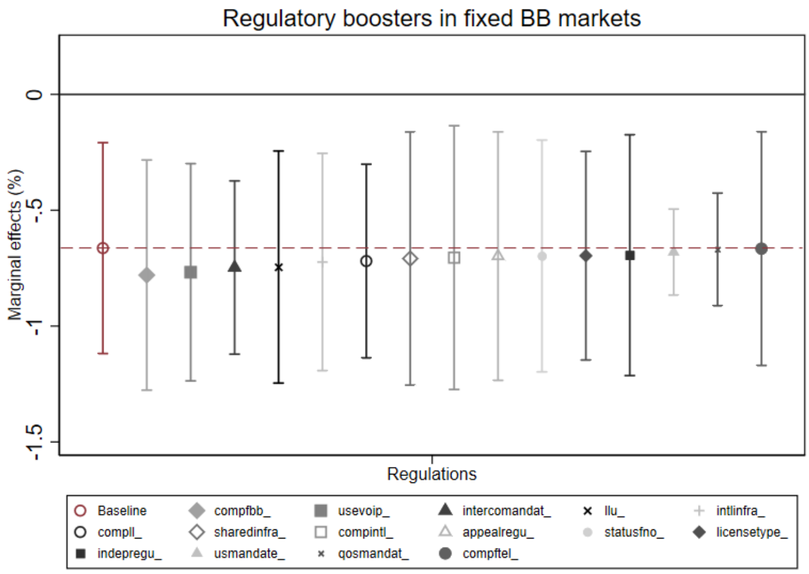

Fig. 13. Identified regulatory boosters in fixed BB markets

7.2 Regulations and market concentration

Investigating the moderating effect of regulations on fixed BB market concentration, we identified 35 regulations over 37 that attenuate the positive effect of capacity on market concentration. Among the top five regulatory boosters, reported in Figure 15, we identified i) the availability of a national broadband plan, ii) the sanctions or penalties imposed by regulators, mandates on iii) universal service/access, iv) and licensing, and v) requirement for operators to publish Reference Interconnection Offer. These regulations are found to strongly and significantly dampen the positive effect of bandwidth capacity on market concentration.

In mobile BB markets, 23 regulations over 39 display significant marginal effects below the marginal effect of standalone bandwidth capacity. Top five regulations, reported in Figure 16, are i) the control of market dominance, regulatory bodies in charge of ii) interconnection rates and price regulation, of iii) radio frequency allocation and assignment, and iv) spectrum monitoring and enforcement, and finally v)

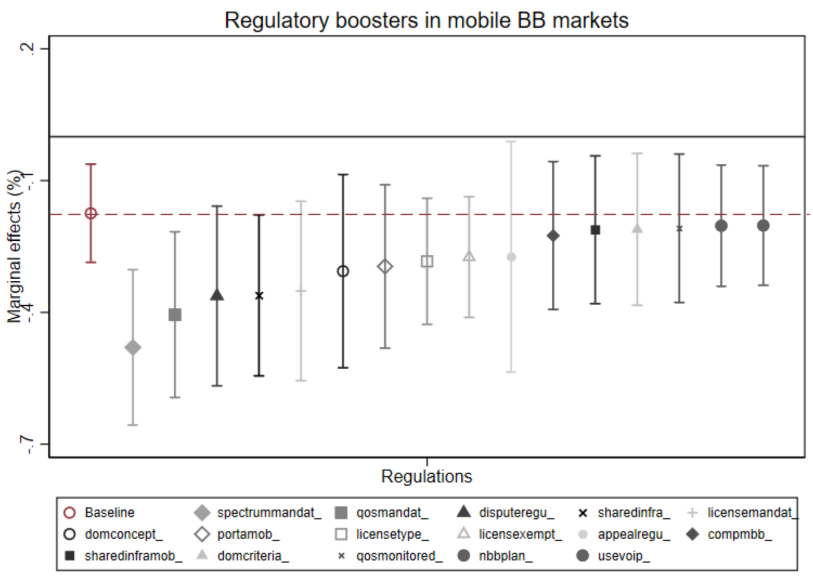

Fig. 14. Identified regulatory boosters in mobile BB markets

a regulatory authority with enforcement power.

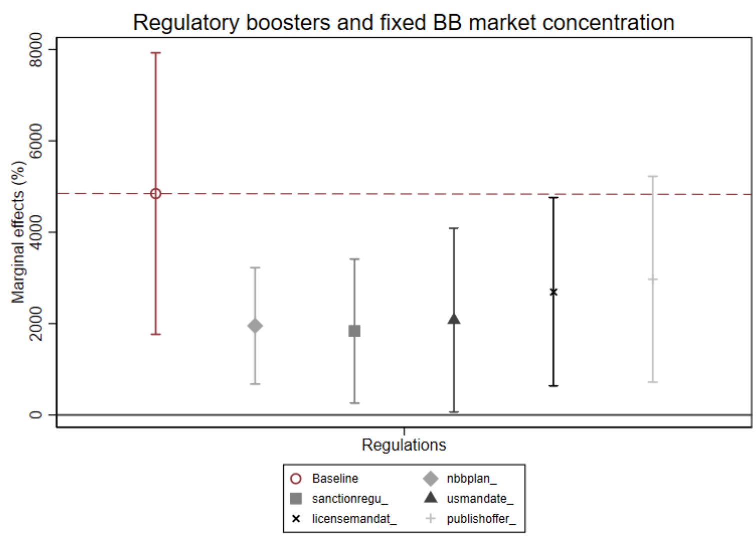

Fig. 15. Identified regulatory boosters and fixed BB market concentration (HHI)

Therefore, the regulator's mandates and its provision to enforce competition across segments of the broadband value chain are crucial to boost the impact of international connectivity on prices both for fixed and mobile BB. However, attenuating the effect of international connectivity on market concentration, particularly in fixed broad markets, requires more regulatory changes beyond those that support price effects. In addition to binding regulator's enforcement powers, the existence of a national road-map for broadband deployment, the effective control of market dominance, the promotion of interconnection and infrastructure sharing – including spectrum – are additional regulatory reforms needed to lessen the impact of international connectivity on market concentration.

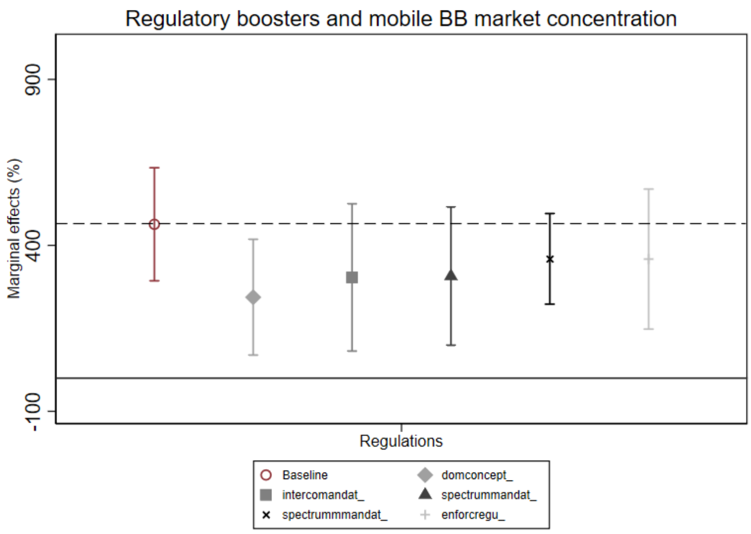

Fig. 16. Identified regulatory boosters in mobile BB market concentration (HHI)

7.3 Dynamic moderating effects of regulations

The effectiveness of regulatory interventions in mobile and fixed broadband (BB) markets varies over time and across regulatory dimensions. Therefore, we re-estimate Equation 4 and compare the dynamic marginal effects of four key dimensions of regulatory policies measured by the ICT Regulatory Tracker - i.e. the Regulatory Authority, Regulatory Mandate, Regulatory Regime, and Competition Framework sub-indexes — to the dynamic effects of bandwidth capacity evidenced in Section 6 (Figure 9). Results are reported in Tables 4 and 5.

In mobile broadband markets, estimations reveal that the competition framework exerts a lagging but persistent boosting effect on prices.Therefore, fostering competition in mobile BB markets leads to stronger market effects over time compared to merely increasing bandwidth availability. This suggests that policies promoting fair market entry, consumer protection, and competitive pricing are essential for long-term mobile broadband growth.

The fixed broadband market exhibits a different pattern of regulatory effectiveness. Unlike mobile BB markets, interventions across multiple regulatory dimensions have immediate and sustained effects in fixed BB markets. However, in the same way as mobile BB, regulations shaping the competition framework drives long-term improvements.

Table. 4. Regulatory boosters in fixed BB markets, marginal dynamic effects

Time	Bandwidth	× Reg authority	× Reg mandate	× Reg regime	× Competition frame.
t	-0.316**	-0.905***	-0.886***	-0.724***	-0.816***
	(0.138)	(0.181)	(0.180)	(0.161)	(0.168)
t+1	-0.329	-0.987***	-1.020***	-0.789***	-1.047***
	(0.222)	(0.104)	(0.155)	(0.120)	(0.0951)
t+2	-0.166	-0.906***	-1.040***	-0.742***	-0.957***
	(0.181)	(0.090)	(0.160)	(0.101)	(0.0860)
t+3	-0.238**	-0.640***	-0.975***	-0.583***	-0.715***
	(0.111)	(0.145)	(0.259)	(0.219)	(0.134)
t+4	0.063	-0.158**	-0.677***	-0.0574	-0.235***
	(0.061)	(0.062)	(0.225)	(0.162)	(0.0594)

Driscoll-Kraay standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Marginal effects of regulations significantly stronger than baseline effects of capacity are highlighted in blue.

Table. 5. Regulatory boosters in mobile BB markets, marginal dynamic effects

Time	Bandwidth	× Reg authority	× Reg mandate	× Reg regime	× Competition frame.
t	-0.505***	-0.731***	-0.760***	-0.312	-0.712***
	(0.088)	(0.146)	(0.113)	(0.233)	(0.167)
t+1	-0.847***	-0.903***	-0.888***	-0.343*	-0.955***
	(0.145)	(0.118)	(0.122)	(0.200)	(0.219)
t+2	-0.491***	-0.603***	-0.575***	-0.509***	-0.877***
	(0.131)	(0.116)	(0.139)	(0.132)	(0.088)
t+3	-0.321***	-0.621***	-0.527***	-0.552***	-0.830***
	(0.0519)	(0.114)	(0.138)	(0.131)	(0.109)
t+4	-0.156**	-0.482***	-0.466***	-0.499***	-0.593***
	(0.0705)	(0.097)	(0.091)	(0.155)	(0.120)

Driscoll-Kraay standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Marginal effects of regulations significantly stronger than baseline effects of capacity are highlighted in blue.

8 Robustness Checks

In this section, we check the robustness of IV estimations and address possible heterogeneous and dynamic effects which could bias estimated relationships.

8.1 IV estimations: additional checks

Fist, we ensure that baseline IV estimations are not sensitive to the high number of instruments. We therefore re-estimate our IV framework combining the indirect SSA bandwidth with each indirect regional bandwidth. Figure 17 below plots the resulted estimates and Appendix Table D.1 reports the detailed results, including first-stage statistics and estimates. Results remain robust to these alternative calibrations.

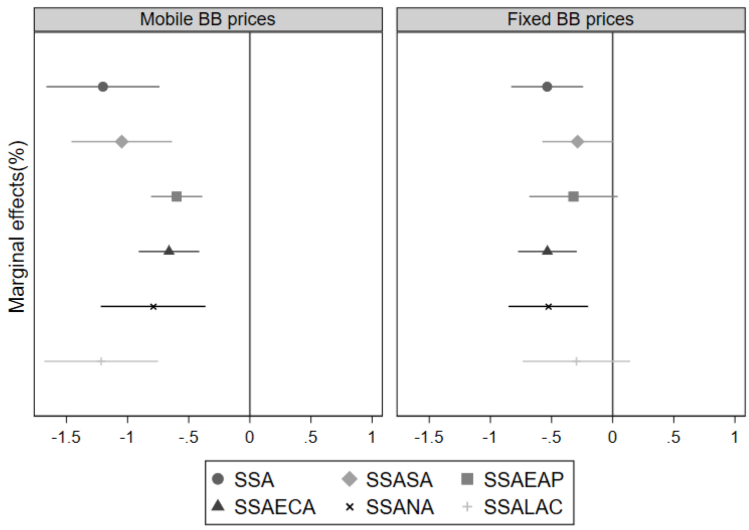

Fig. 17. Bandwidth capacity and internet prices, alternative IV calibrations.

Next, we check whether our estimates are sensitive to control variable inclusion and and/or the resulting sample attrition. Results reported in Figure 18 and Appendix Table D.2. show that sample attrition poorly affects estimates, but control variable inclusion is found to lower the negative effect of capacity, on mobile BB prices. Fixed BB prices elasticities are consistent and robust to sample attrition and control variable inclusion.

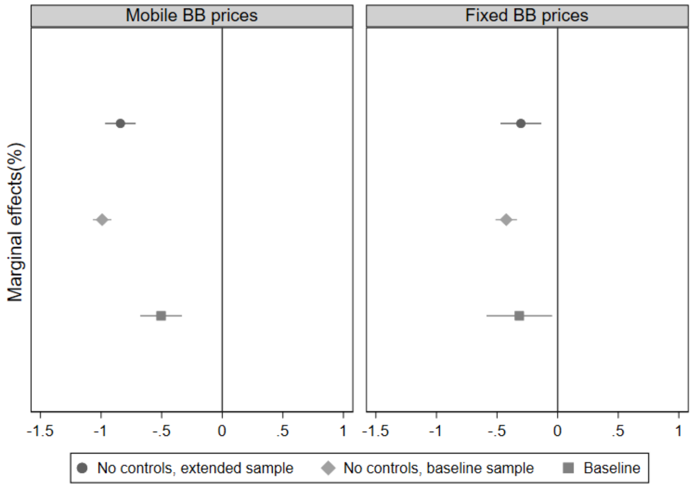

Fig. 18. Bandwidth capacity and BB prices, sensitivity analysis

8.2 Addressing the heterogeneous and dynamic effects of SMC arrivals

The TWFE estimation strategy applied above faces two important inference challenges. The first challenge is related to the existence of possible heterogeneous treatment effects which, if not considered, may be biased, and may even lead to produce estimates of opposite sign of the true Average Treatment on Treated (ATT). The second challenge is related to the existence of dynamic treatment effects, which reinforces the bias arising from the static framework, due to contamination effect of early treated groups on lately treated groups (De Chaisemartin and d'Haultfoeuille (2020); Baker et al. (2022); Liu et al. (2022)).[22] A third challenge is related to the nature of our baseline interest variable, the international bandwidth capacity, which is continuous and non-staggered, and therefore not appropriate for available Diff-in-Diff (DiD) frameworks designed to deal with the first two estimation challenges. We attempt to address these three challenges in the following sub-sections.

We replaced our interest variable, i.e., the international bandwidth capacity, with the number of SMCs that landed in a given country over the estimation period.[23] This variable consists in transforming the raw number of SMCs in (strictly increasing) cumulative difference, starting from 0 at the beginning of the estimation period to K at the end when the SMC number increased by K units over the estimation period. While this variable does not comprehensively reflect a country' international broadband capacity, it has the merit of better identifying the treatment since SMCs deployment in recipient countries is a critical source of increased international connectivity, and since this variable is of staggered and ordered nature.

Then, we address the issues of heterogenous and dynamic treatment effects by implementing the extended DiD estimator with multiple groups (DID_M), periods and non-binary treatments of de Chaisemartin and d'Haultfoeuille (De Chaisemartin and d'Haultfoeuille (2022); De Chaisemartin and d'Haultfoeuille

[22] In a TWFE setting, the treatment effect is a weighted sum of the average treatment effect on different treated groups g (early treated, later treated), at different points of time t. The weights for some groups are not related to the size of the group, which means that some groups are over-weighed, and others are under-weighted. More importantly, some weights may be negative, which may lead to type 1 and 2 errors, and this problem increases as the group has been treated for a long time, and many groups are treated in period t. Therefore, the problem stems mainly from the inclusion in the control group of units already treated as controls, which leads to the "forbidden comparison" (Goodman-Bacon (2021)).

[23] We prefer using exploiting the variation in the number of SMCs over the estimations period rather than the stock of SMCs, cumulated before our estimations period. The raw number is a stock variable that takes many values, from 0 to 64 with very few observations or countries for high values the SMC number variable, which challenges the analysis by reducing the number of counterfactuals (switchers-in and- out) for these values. On the other hand, using a simple first-differenced, and therefore non-staggered, SMC variable would improperly reflect the staggered arrival of cables.

(2023); de Chaisemartin et al. (2022)).[24] We then estimate the following model, considering the effect of the cumulative difference in SMCs (CD_{it}) on the logarithm of fixed or mobile broadband prices ($Y_{i,t}$), controlling for the lagged number of SMCs (SMC_L_{it}), and additional control variables (X'_{it}):

$$Y_{it} = \delta_0 + \delta_{\mathbf{1}}.\mathbf{CD_{it}} + \delta_{\mathbf{2}}.\mathbf{SMC\_L_{it}} + \delta_{\mathbf{3}}.\mathbf{X'_{it}} + \theta_i + \lambda_t + \epsilon_{i,t} \tag{5}$$

In addition to the baseline control variables (including the regulatory quality), we added the lagged number of SMCs to account for nonlinearities in the effect of SMC variation on BB price depending on their number, as there may be for instance return to scale in their deployment (cost-saving hypothesis).

Last, since the mobile broadband price variable has a shorter time dimension, we had no option but to balance the sample between treated and untreated observation units by binning together the highest values of the variable, associated with few observations (using the *recat_treatment* option, as recommended by CDH), and to reduce the number of lags and placebos when using this price variable. We used a binning threshold of 15, based on the variable's treatment distribution represented on Figure E.1 in the Appendix.

DID_M estimates of ($\hat{\delta}_1$) are reported in Figure 19 below and detailed in Tables E.1 to E.3 in the Appendix. Graph (A) on Figure 19 reports estimates using the fixed BB variable and points to a 1% significant negative and dynamic effect of SMC arrivals, starting one year after the treatment onset, persisting and intensifying afterward. However, these estimates point to an eventual parallel trend violation, with a 10% significant pre-trend identified one year before the treatment occurrence. This pre-trend could be the result of specific regional trends in fixed BB prices, resulting from the unequal coverage of the last-mile fixed-line infrastructure prior to the treatment. To account for this possibility, we re-run estimation adding a non-parametric regional trend, consisting in comparing switching and non-switching countries belonging to the same region. Results, reported on panel (C) of Figure 19, show that the parallel trend hypothesis is respected, and confirms previous relationships. Moreover, controlling for these regional trends, results support a stronger effect of SMC rollout, with a 38% decrease in fixed BB price one year after the treatment, to 79% decrease five years later.

Regarding the impact of SMC on mobile BB prices, our results point to a same-magnitude but less significant effect on mobile BB prices. Estimates indicate, in a 10% confidence level, that mobile BB prices decrease by 41% one year after SMC arrival, and by 81% four years later. No violation of the parallel trend hypothesis is observed.

[24] Using the *did_multiplegt* Stata package. Other methodologies like Butts (2021) deal with spatial spillovers in difference-in-differences.

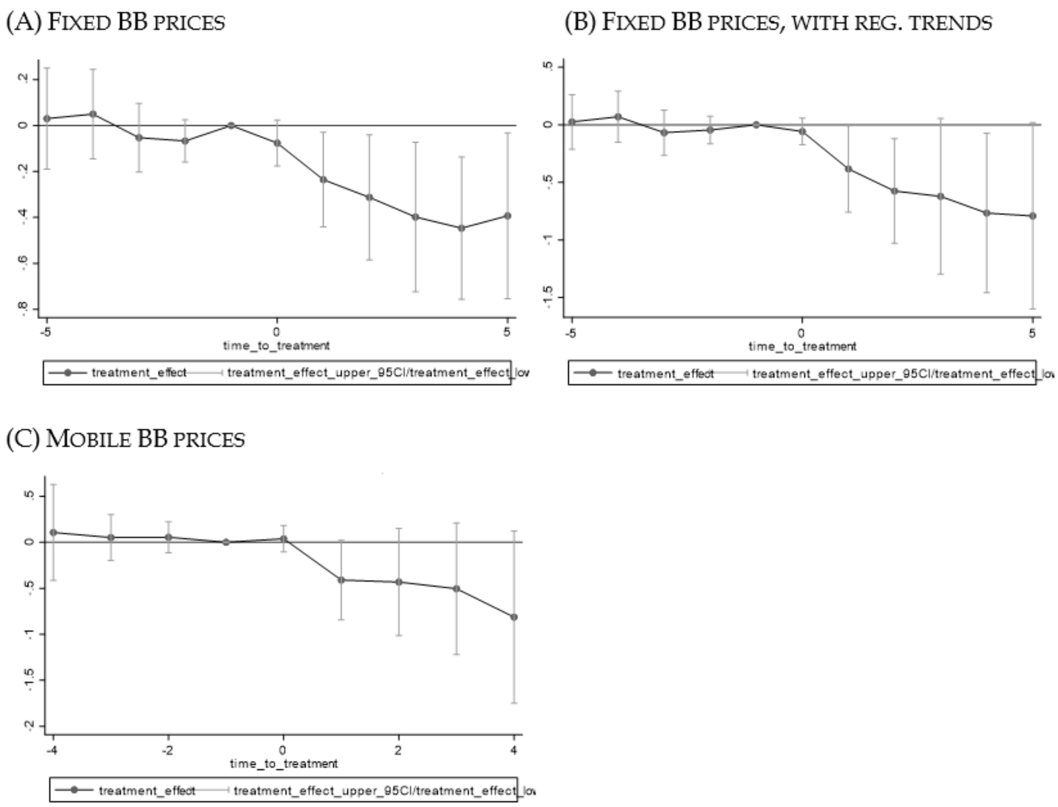

Fig. 19. Impact of SMCs on broadband prices: Staggered DiD estimates

Source: Authors. Standard errors are clustered by country, robust to dynamic effects, and bootstrapped (200 replications).

Next, we studied the impact of SMC arrival on competition intensity, measured by the concentration in fixed and mobile BB markets. We estimated the following model:

$$HHI_{i,t} = \mu_0 + \mu_{\mathbf{1}}.\mathbf{CD_{it}} + \mu_{\mathbf{2}}.\mathbf{X'_{it}} + \theta_i + \lambda_t + \epsilon_{i,t} \tag{6}$$

Where $HHI_{i,t}$ is the Herfindhal index in the BB markets. The model is estimated with baseline control variables set ($\mathbf{X'_{it}}$), and the SMC variable ($CD_{i,t}$)'s values are again binned above 15. DID_M estimates of ($\hat{\mu}_{\mathbf{1}}$) are reported in Figure 20 below and detailed in Tables E.4 and E.5 in the Appendix. No violation of the parallel trend hypothesis is observed. The estimates confirm the positive effect of SMCs on the concentration of fixed and mobile BB markets (panels A) and (B)), increasing over time, but not at the usual confidence level - estimates in the Appendix are significant at the 10% level.

(A) Fixed BB market, all controls

(B) Mobile BB market, all controls

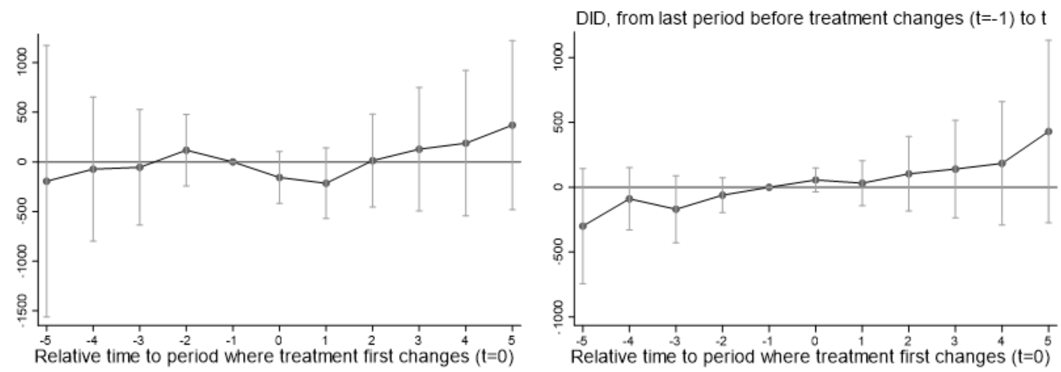

Fig. 20. Impact of SMCs on market concentration: staggered DiD estimates

Source: Authors. Standard errors are clustered by country, robust to dynamic effects, and bootstrapped (200 replications).

Overall, although the nature of the treatment emphasized in the section slightly differs from the initial focus of this study, the price impacts of the international bandwidth, analyzing the heterogenous and dynamic effects of the staggered arrival of SMCs on BB prices lead us to confirm our baseline results. Improvements in international connectivity have resulted in lower fixed and mobile broadband prices and are associated with a greater BB market concentration. The cost-saving effects of SMC infrastructure deployment therefore appear as a plausible channel for the reduction in Internet price observed.

9 Conclusion

This paper has sought to investigate how SMCs affect telecom market outcomes, especially the price of Internet access. Our analysis supports the hypothesis that the arrival of SMCs is associated with a drop in the price of fixed and mobile Internet access. These price effects decline with the available capacity of international connectivity and tend to dwindle over time.The price drop is also significant in developing countries, though in a lesser extent than in more developed European markets.

Our findings suggest that cost savings are the main drivers of the price effects with some indicative role of higher market concentration in the short term, and competition and quality improvement in the medium term. They also suggest that regulation can be a powerful tool to increase the pass-through rate of cost savings and limit further concentration of retail broadband markets. In particular, a regulator with strong mandates to enforce competition through (i) reduced barriers to entry for domestic and foreign operators, (ii) shared infrastructure, including radio spectrum, (iii) regulation of interconnection and market dominance, as well as (iv) universal service provisions, and (v) consumer protection can contribute to boost the impact of SMCs on internet affordability and alleviate the adverse price effects of market concentration on long term.

This study has focused on the impact of SMCs on nationwide Internet access prices. Future studies could explore the impact of SMCs on sub-national prices, especially those of fixed broadband Internet, as well as wholesale prices. Further, telecom regulation was deemed exogenous in this study. Future work could endogenize regulations and investigate the impact of SMCs on telecom regulatory reforms.

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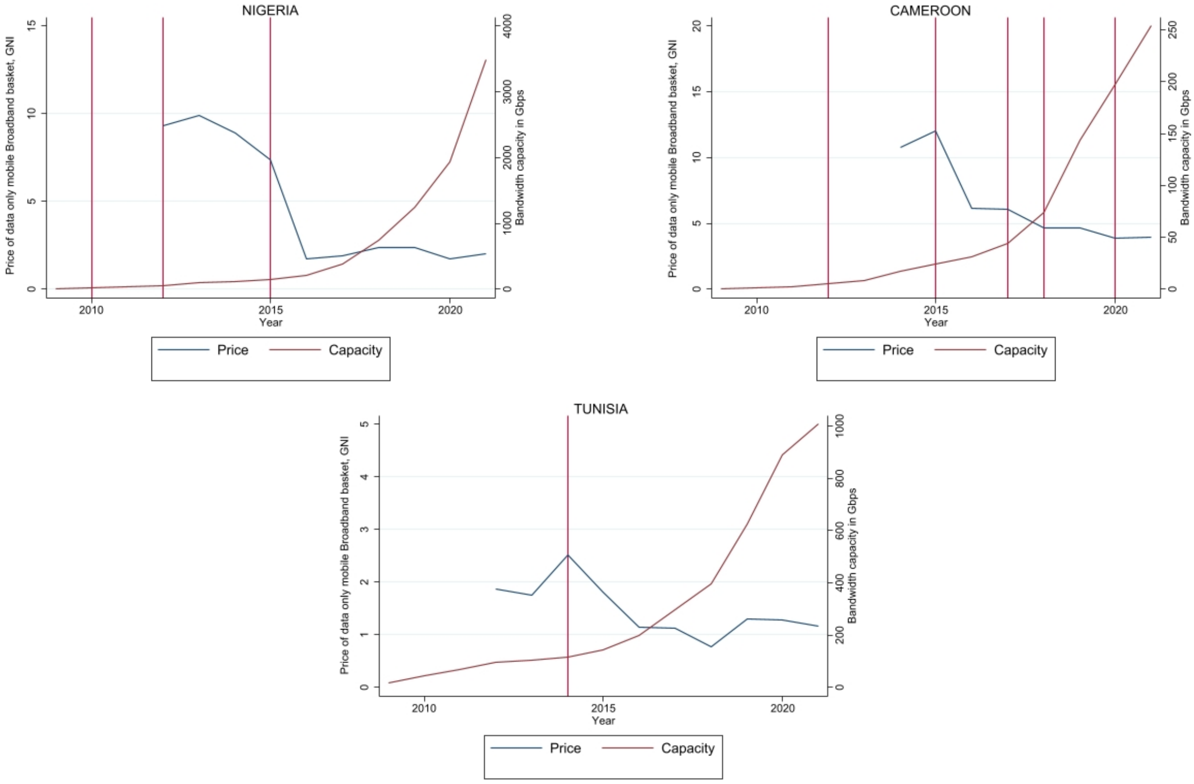
Appendix

A Mobile Broadband Price and the Arrival of SMCs

Fig. A.1. Impact of Major Submarine Cable Arrivals on Internet Access Prices



Source: Authors, based on data from Telegeography and ITU's ICT Price Basket.

B Data, sources, and descriptive statistics

Table. B.1. Sources and definition of the main variables

Variable	Source	Definition
Fixed_broadband_USD_log	ITU's ICT Price Basket	Price of the fixed broadband basket is the least expensive offer with a minimum monthly usage of 5 Gigabytes (GB) and an advertised download speed above 256 Kilobits per second (Kbps). Price is expressed in USD PPP and used in logarithm form.
Data_only_mobile_bdb_USD_log	ITU's ICT Price Basket	Price of data-only mobile broadband basket is the least expensive offer with a minimum monthly usage of 2 GB based on 3G or newer technologies. Price is expressed in USD PPP and used in logarithm form.
n_cables /n_cables_log	Telegeography	Number of Submarine cables laid in a given country.
Bandwidth / Bandwidth_log	Telegeography	International used Internet bandwidth corresponding to the inventory of capacity used by four categories of users: Internet backbone providers, content providers, research-educational networks, and enterprises and others. The capacity is measured in Gbps.
RegulationScore	ITU	ICT regulatory tracker is an index pinpointing the changes taking place in the ICT regulatory environment based on 4 sub-indexes (regulatory authority, regulatory mandate, regulatory regime, and competition framework) and 50 indicators.
HHI_fixedBdb / HHI_fixedBdb_log	Telegeography	Herfindahl-Hirschman Index (HHI) of the top 5 retail fixed-broadband operators.
HHI_mobileBdb / HHI_mobileBdb_log	GSMA Intelligence	Herfindahl-Hirschman Index (HHI) in the retail mobile broadband markets.
GDP_log	WDI	GDP in 2015 constant USD
GDPpC_log	WDI	GDP per capita in 2015 constant USD
Population_log	WDI	Total Population size, proxied by the size of the 15+ population.
Population_electricity	WDI	Share of population with electricity access
IXP	PCH	Number of Internet exchange points built in a given country.
Penetration_rate_FixedTel	ITU	Fixed-telephone subscriptions per 100 inhabitants.
Coverage_3G	ITU	Percentage of the population covered by at least a 3G mobile network.
nb_relation	Telegeography	The number of partner countries directly (first-order) reached by SMC.

Table. B.2. List of countries by region

Africa		Asia	Europe		Latin America		Middle East
Algeria	Libya	Armenia	Albania	Moldova	Antigua and Barbuda	Peru	Afghanistan
Angola	Madagascar	Azerbaijan	Andorra	Monaco	Argentina	Puerto Rico	Bahrain
Benin	Malawi	Bangladesh	Austria	Netherlands	Aruba	St Kitts and Nevis	Iraq
Botswana	Mali	Bhutan	Belarus	North Macedonia	Bahamas, The	St Lucia	Israel
Burkina Faso	Mauritania	Cambodia	Belgium	Norway	Barbados	St Vincent and the Grenadines	Jordan
Burundi	Mauritius	China	Bulgaria	Poland	Belize	Suriname	Kuwait
Cabo Verde	Morocco	Georgia	Croatia	Portugal	Brazil	Trinidad and Tobago	Lebanon
Cameroon	Mozambique	Hong Kong SAR, China	Cyprus	Russian Federation	Cayman Islands	Uruguay	Oman
Central African Republic	Namibia	India	Czechia	San Marino	Chile	Venezuela, RB	Qatar
Chad	Niger	Indonesia	Denmark	Slovak Republic	Colombia		Saudi Arabia
Comoros	Nigeria	Japan	Estonia	Slovenia	Costa Rica		Türkiye
Congo, Rep.	Rwanda	Kazakhstan	Finland	Spain	Cuba		United Arab Emirates
Côte d'Ivoire	São Tomé and Príncipe	Kyrgyz Republic	France	Sweden	Dominica		
Djibouti	Senegal	Malaysia	Germany	Switzerland	Ecuador		
Egypt, Arab Rep.	Seychelles	Maldives	Greece	Ukraine	El Salvador		
Equatorial Guinea	Sierra Leone	Mongolia	Greenland	United Kingdom	Grenada		
Eritrea	Somalia	Myanmar	Hungary		Guatemala		
Eswatini	South Africa	Pakistan	Iceland		Guyana		
Gabon	Sudan	Philippines	Ireland		Haiti		
Gambia, The	Tanzania	Singapore	Italy		Honduras		
Ghana	Togo	Sri Lanka	Latvia		Jamaica		
Guinea	Tunisia	Tajikistan	Liechtenstein		Mexico		
Guinea-Bissau	Uganda	Thailand	Lithuania		Nicaragua		
Kenya	Zambia	Turkmenistan	Luxembourg		Panama		
Lesotho	Zimbabwe	Uzbekistan	Malta		Paraguay		
Liberia							

Table. B.3. Regulatory indicators and notations

Category	Regulatory items	notation
Regulatory authority	Separate telecom/ICT regulator	indepregu
	Autonomy in decision making	autonregu
	Accountability	accountregu
	Percentage of diversified funding	fundregu
	Public consultations mandatory before decisions	publiconsultregu
	Enforcement power	enforcregu
	Sanctions or penalties imposed by regulator	sanctionregu
	Dispute resolution mechanism	disputeregu
	Appeals to decisions	appealregu
	Existence of Competition authority	compauth
Regulatory mandate	Traditional mandate: entity in charge of quality of service obligations measures and service quality monitoring	qosmandat
	Traditional mandate: entity in charge of licensing	licensemandat
	Traditional mandate: entity in charge of interconnection rates and price regulation	intercomandat
	Spectrum: Entity in charge of radio frequency allocation and assignment	spectrummandat
	Entity in charge of Spectrum Monitoring and Enforcement	spectrummmandat
	Entity in charge of universal service/access	usmandate
	New mandate: entity in charge of broadcasting (radio and TV transmission)	not used
	New mandate: entity in charge of broadcasting content	not used
	New mandate: entity in charge of Internet content	not used
	New mandate: entity in charge of IT	not used
	Consumer issues: entity responsible for comparative tariff information, consumer education and handling consumer complaints	consumandat
Regulatory regime	Types of licences provided	licensetype
	License exempt	licensexempt
	Operators required to publish Reference Interconnection Offer (RIO)	publishoffer
	Interconnection prices made public	publishinterco
	Quality of service monitoring required	qosmonitored
	Infrastructure sharing for mobile operators permitted	sharedinframob
	Infrastructure sharing mandated	sharedinfra
	Co-location/site sharing mandated	sitecolo
	Unbundled access to the local loop required	llu
	Secondary trading allowed	tradespectrum
	Band migration allowed	refarming
	Number portability available to consumers and required from fixed-line operators	portafixed
	Number portability available to consumers and required from mobile operators	portamob
	Individual users allowed to use VoIP	usevoip
	National plan that involves broadband	nbbplan
Competition framework	Level of competition in local and long distance (domestic and international) fixed line services	compftel
	Level of competition in IMT (3G, 4G, etc.) services	compmbb
	Level of competition in cable modem, DSL, fixed wireless broadband	compfbb
	Level of competition in leased lines	compll
	Level of competition in International Gateways	compintl
	Status of the main fixed line operator	statusfno
	Legal concept of dominance or SMP	domconcept
	Criteria used in determining dominance or SMP	domcriteria
	Foreign participation/ownership in facilities-based operators	intlinfra
	Foreign participation/ownership in spectrum-based operators	intlmob
	Foreign participation/ownership in local service operators/long-distance service operators	intlfixed
	Foreign participation/ownership in international service operators	intlintl
	Foreign participation/ownership in Internet Service Providers (ISPs)	intlisp
	Foreign participation/ownership in value-added service providers	intlvas

C Additional tests and estimations

Table. C.1. Inoue-Solon Autocorrelation tests: Fixed Broadband

	H0: No auto-correlation of any order			
	IS-stat	p-value	N	Max T
Ha: Auto-correlation up to order 1	43.88	0	96	14
Ha: Auto-correlation up to order 2	54.09	0.001	96	14
Ha: Auto-correlation up to order 3	59.27	0.009	96	14
Ha: Auto-correlation up to order 4	67.26	0.022	96	14
Ha: Auto-correlation up to order 5	74.08	0.044	96	14
Ha: Auto-correlation up to order 6	80.34	0.069	96	14
Ha: Auto-correlation up to order 7	82.24	0.15	96	14
Ha: Auto-correlation up to order 8	84.21	0.243	96	14
Ha: Auto-correlation up to order 9	84.9	0.362	96	14

Table. C.2. Inoue-Solon Autocorrelation tests: Mobile Broadband

	H0: No auto-correlation of any order			
	IS-stat	p-value	N	Max T
Ha: Auto-correlation up to order 1	38.74	0	104	9
Ha: Auto-correlation up to order 2	60.09	0	104	9
Ha: Auto-correlation up to order 3	66.99	0	104	9
Ha: Auto-correlation up to order 4	68.83	0	104	9
Ha: Auto-correlation up to order 5	70.33	0	104	9
Ha: Auto-correlation up to order 6	72.59	0	104	9
Ha: Auto-correlation up to order 7	73.32	0	104	9
Ha: Auto-correlation up to order 8	73.32	0	104	9
Ha: Auto-correlation up to order 9	68.98	0	104	9

D Instrumental Variable Estimations: Additional evidence

Table. D.1. Bandwidth capacity and broadband prices, alternative IV calibrations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES				**Mobile BB prices**			
Bandwidth_log	-1.201***	-1.048***	-0.598***	-0.661***	-0.791***	-1.216***	-0.399***
	(0.236)	(0.210)	(0.107)	(0.126)	(0.218)	(0.237)	(0.090)
				First-stage estimates			
SSA_BW_log	0.079***	0.075***	0.079***	0.073***	0.083***	0.078***	0.080***
	(0.009)	(0.010)	(0.010)	(0.009)	(0.009)	(0.009)	(0.009)
SA_BW_log		0.035***					
		(0.011)					
EAP_BW_log			0.049***				0.031***
			(0.005)				(0.009)
ECA_BW_log				0.045***			0.023***
				(0.004)			(0.008)
NA_BW_log					0.020***		0.020***
					(0.003)		(0.003)
LAC_BW_log						0.015	
						(0.012)	
Observations	958	958	958	958	958	958	958
AR F-stat	0.000276	6.86e-05	4.81e-05	0.000322	0.00101	0.000660	0.000122
KP Wald F-stat	76.03	32.41	75.78	105.1	63.62	42.66	52.86
LM-weak	1.676	1.682	1.695	1.676	1.679	1.680	1.861
Hansen-J pval		0.213	0.180	0.183	0.170	0.792	0.590
	(9)	(10)	(11)	(12)	(13)	(14)	(15)
VARIABLES				**Fixed BB prices**			
Bandwidth_log	-0.536***	-0.287*	-0.321*	-0.534***	-0.526***	-0.296	-0.358**
	(0.150)	(0.147)	(0.185)	(0.122)	(0.166)	(0.224)	(0.177)
				First-stage estimates			
SSA_BW_log	0.084***	0.080***	0.085***	0.078***	0.086***	0.085***	0.085***
	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.005)
SA_BW_log		0.057***					
		(0.010)					
EAP_BW_log			0.037***				0.030
			(0.013)				(0.021)
ECA_BW_log				0.028***			0.010
				(0.003)			(0.014)
NA_BW_log					0.012		0.012
					(0.009)		(0.008)
LAC_BW_log						-0.044***	
						(0.013)	
Observations	1,268	1,268	1,268	1,268	1,268	1,268	1,268
AR F-stat	-0.032	0.00464	9.75e-05	0.000878	0.0478	2.03e-06	3.36e-08
KP Wald F-stat	0.0167	505.8	384.1	602.6	517	503.8	414.3
LM-weak	690.8	1.826	1.813	1.822	1.853	1.830	1.959
Hansen-J pval	1.792	0.195	0.191	0.962	0.641	0.199	0.630

Driscoll-Kraay standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

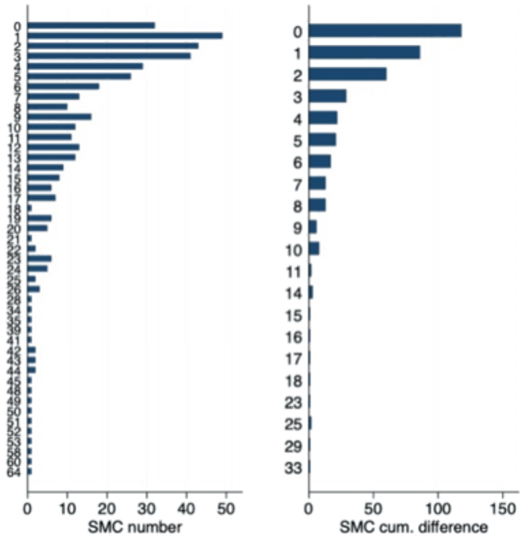
Table. D.2. Bandwidth capacity and broadband prices: sensitivity analysis.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Dep. Var (log):	**MBB prices**		**FBB prices**		**MBB prices**		**FBB prices**		**MBB prices**		**FBB prices**	
	2nd stage	**1st stage**	**2nd stage**	**1st stage**	**2nd stage**	**1st stage**	**2nd stage**	**1st stage**	**2nd stage**	**1st stage**	**2nd stage**	**1st stage**
Bandwidth_log	-0.505***		-0.316**		-0.991***		-0.424***		-0.840***		-0.303***	
	(0.088)		(0.138)		(0.039)		(0.045)		(0.064)		(0.086)	
EAP_BW_log		0.010		-0.033		0.011		-0.037		0.120***		0.077*
		(0.012)		(0.028)		(0.014)		(0.032)		(0.019)		(0.040)
ECA_BW_log		0.037***		0.042***		0.017		0.021		-0.053***		-0.054***
		(0.012)		(0.015)		(0.014)		(0.015)		(0.007)		(0.019)
LAC_BW_log		0.023		-0.029**		0.018		-0.031**		0.003		-0.044***
		(0.014)		(0.013)		(0.017)		(0.014)		(0.013)		(0.015)
NA_BW_log		0.020***		0.017***		0.010**		0.005		0.002		-0.007
		(0.003)		(0.006)		(0.004)		(0.008)		(0.002)		(0.005)
SA_BW_log		0.027		0.063***		0.052***		0.092***		-0.009		0.015
		(0.020)		(0.014)		(0.015)		(0.019)		(0.011)		(0.020)
SSA_BW_log		0.073***		0.074***		0.154***		0.151***		0.149***		0.157***
		(0.010)		(0.007)		(0.010)		(0.009)		(0.016)		(0.009)
Baseline sample	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
Controls	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No
Observations	958	958	1,268	1,268	958	958	1,268	1,268	1,266	1,266	1,505	1,505
AR F-stat	8.66e-05		2.97e-10		0		1.91e-09		0		0	
KP Wald F-stat	705.8		3319		291.2		1374		1275		324.9	
LM-weak	1.866		1.973		1.992		1.994		2.098		2.071	
Hansen-J pval	0.852		0.860		0.853		0.858		0.850		0.852	

Driscoll-Kraay standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

E DiD estimation with staggered, inter-temporal, and multi-groups treatment

Fig. E.1. Number of treated countries across values of SMC treatment variables, fixed BB sample



Note: using the baseline sample with fixed BB price variable, 1548 observations.

Table. E.1. Staggered DiD estimations - Fixed BB price (log)

	$\hat{\delta}_1$ (Eq. (6))	SE	LB CI	UB CI	N	Switchers
Effect_0	-0.076598	0.0510601	-0.1766757	0.0234798	595	87
Effect_1	-0.2359241	0.1049975	-0.4417192	-0.0301291	494	84
Effect_2	-0.312826	0.1390746	-0.5854122	-0.0402399	401	80
Effect_3	-0.3982151	0.165979	-0.7235339	-0.0728964	308	75
Effect_4	-0.4467955	0.1580523	-0.7565781	-0.137013	269	73
Effect_5	-0.3930371	0.1837987	-0.7532825	-0.0327918	218	66
Placebo_1	-0.0672882	0.0467337	-0.1588862	0.0243098	470	60
Placebo_2	-0.053178	0.0762482	-0.2026245	0.0962685	302	48
Placebo_3	0.0496256	0.0992731	-0.1449497	0.2442009	178	24
Placebo_4	0.0298259	0.1123375	-0.1903555	0.2500073	83	18

Note: Standard errors were clustered by country, robust to dynamic effects, and bootstrapped (200 replications). Sample (1315 observations) covers up to 126 countries over 2009-2020.

Table. E.2. Staggered DiD estimations - Fixed BB price (log), With regional non-parametric trends.

	$\hat{\delta}_1$ (Eq. (6))	SE	LB CI	UB CI	N	Switchers
Effect_0	-0.0584586	0.0590066	-0.1741116	0.0571944	595	87
Effect_1	-0.3835344	0.1911315	-0.7581521	-0.0089167	494	84
Effect_2	-0.5750701	0.2317062	-1.029214	-0.1209259	401	80
Effect_3	-0.6219049	0.3445298	-1.297183	0.0533735	308	75
Effect_4	-0.7666985	0.3530775	-1.45873	-0.0746666	269	73
Effect_5	-0.7915211	0.4129981	-1.600997	0.0179551	218	66
Placebo_1	-0.0453231	0.061217	-0.1653084	0.0746623	470	60
Placebo_2	-0.0684512	0.1003749	-0.2651861	0.1282836	302	48
Placebo_3	0.06959	0.1128454	-0.151587	0.290767	178	24
Placebo_4	0.0249611	0.1209993	-0.2121976	0.2621198	83	18

Note: Standard errors are clustered by country, robust to dynamic effects, and bootstrapped (200 replications). Sample (1315 observations) covers up to 126 countries over 2009-2020.

Table. E.3. Staggered DiD estimations - Mobile BB price (log)

	$\hat{\delta}_1$ (Eq. (6))	SE	LB CI	UB CI	N	Switchers
Effect_0	0.0386585	0.0726331	-0.1037024	0.1810194	318	36
Effect_1	-0.4104876	0.2204825	-0.8426334	0.0216581	248	33
Effect_2	-0.4318357	0.296242	-1.01247	0.1487986	183	28
Effect_3	-0.5046333	0.365068	-1.220167	0.2108999	104	22
Effect_4	-0.8134535	0.477762	-1.749867	0.1229601	92	22
Placebo_1	0.0548473	0.0859506	-0.1136159	0.2233104	236	21
Placebo_2	0.051269	0.1275094	-0.1986494	0.3011874	121	13
Placebo_3	0.1066206	0.2652556	-0.4132804	0.6265217	25	3

Note: Standard errors are clustered by country, robust to dynamic effects, and bootstrapped (200 replications). Sample (802 observations) covers up to 121 countries over 2013-2020.

Table. E.4. Staggered DiD estimations - Fixed BB market's HHI

	$\hat{\mu}_1$ (Eq. (7))	SE	LB CI	UB CI	N	Switchers
Effect_0	-157.2049	125.8189	-403.8099	89.40014	521	80
Effect_1	-215.2798	173.3022	-554.952	124.3925	453	80
Effect_2	12.64539	242.0587	-461.7897	487.0805	379	77
Effect_3	128.0447	317.4106	-494.0799	750.1694	292	72
Effect_4	188.3019	370.7242	-538.3174	914.9213	265	72
Effect_5	370.42	448.3701	-508.3853	1249.225	218	66
Placebo_1	117.6856	165.0637	-205.8393	441.2105	412	58
Placebo_2	-54.64949	290.0099	-623.069	513.77	282	42
Placebo_3	-73.00301	377.3501	-812.6093	666.6033	184	31
Placebo_4	-194.9506	638.0484	-1445.526	1055.624	86	13

Note: Standard errors are clustered by country, robust to dynamic effects, and bootstrapped (200 replications). Sample (1,010 observations) covers up to 112 countries over 2008-2020.

Table. E.5. Staggered DiD estimations - Mobile BB market's HHI

	$\hat{\mu}_1$ (Eq. (7))	SE	LB CI	UB CI	N	Switchers
Effect_0	56.38095	47.26526	-36.25895	149.0209	495	70
Effect_1	31.33538	87.98025	-141.1059	203.7767	386	62
Effect_2	103.8924	146.7287	-183.6957	391.4806	297	56
Effect_3	140.2361	191.5464	-235.1948	515.6671	198	48
Effect_4	184.4044	242.808	-291.4992	660.308	172	45
Effect_5	430.2074	358.9707	-273.3752	1133.79	125	34
Placebo_1	-60.61023	68.63356	-195.132	73.91155	371	47
Placebo_2	-169.6476	131.8776	-428.1276	88.83236	210	28
Placebo_3	-89.16347	122.5719	-329.4044	151.0775	95	14
Placebo_4	-299.914	226.456	-743.7678	143.9398	38	5

Note: Standard errors are clustered by country, robust to dynamic effects, and bootstrapped (200 replications). Sample (1,082 observations) covers up to 126 countries over 2009-2020.

“ Sur quoi la fondera-t-il l’économie du monde qu’il veut gouverner ? Sera-ce sur le caprice de chaque particulier ? Quelle confusion ! Sera-ce sur la justice ? Il l’ignore. ”

Pascal

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